

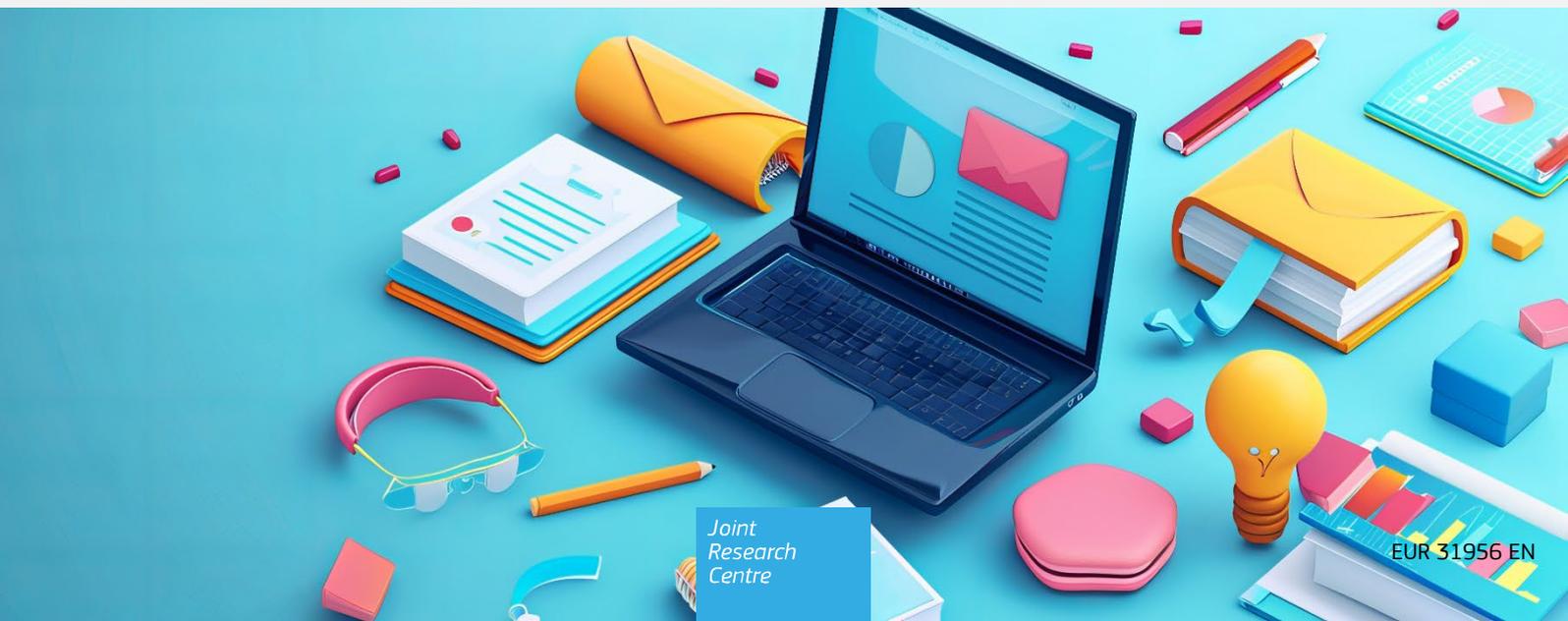


JRC TECHNICAL REPORT

The effect of online learning on students' academic performance in Italy

Josep Amer Mestre
Sara Flisi

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Abstract

This study identifies the academic effects of online learning mandates on high-school students separately from the overall effect of the pandemic. We exploit exogenous variation in 2020/2021 Italian schooling mandates that imposed online learning on upper secondary school students while preserving in-person teaching for lower grades. Relying on students' performance on standardised tests, we implemented a matched difference-in-difference strategy comparing grade 13 and grade 8 students before and after the introduction of the online learning mandates. We find that, on average, students who were subject to online learning in the 2020/2021 school year (i.e. grade 13 students) performed 0.25 and 0.15 standard deviations worse in reading and mathematics, respectively, than those who were taught in person (i.e. grade 8 students). The learning loss associated with online learning in 2021 is equivalent to around 75 % of the expected yearly learning gain in reading, and around 45 % in mathematics. The losses registered by the subsequent cohorts are very similar to those of 2021. This suggests that, even 1 or 2 years after being exposed to online learning, students are still suffering from the associated learning losses.

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1. Introduction

Following the outbreak of the COVID-19 pandemic in early 2020, more than 60 million students in the EU were temporarily kept at home when schools were fully closed as part of the policy response to limit the spread of the disease. The share of students affected by full school closures varied over time, in line with the cyclical pattern of the pandemic, with more than 90 % of students sent home during the first wave in spring 2020. Subsequent waves saw lower shares of students affected, peaking at around 35 % in January 2021. While full school closures became less frequent during the subsequent waves, many schools still operated at limited capacity. In April 2021, for example, around two thirds of students were attending schools that were only partially open. These disruptions in education activities are very likely to have had consequences for students, in terms of both overall well-being and academic performance.

Comparable international evidence on the evolution of students' achievement after the outbreak of the pandemic became available only very recently. The Organisation for Economic Co-operation and Development (OECD) 2022 Programme for International Student Assessment (PISA), the first results of which were released in December 2023, is the first large-scale study providing descriptive evidence on student performance in both reading and mathematics after the pandemic. PISA data show unprecedented drops in performance across the OECD. As reported in [OECD \(2023\)](#), compared with 2018, mean performance fell by 10 score points in reading and by almost 15 score points in mathematics, which is equivalent to three quarters of a year's worth of learning. The decline in mathematics performance is three times greater than any previous change between consecutive PISA studies. While these drops in mathematics and reading point to a strong effect of COVID-19 in most countries, no clear causal relationship can be inferred from these data.

Another interesting source of cross-country information is the Progress in International Reading Literacy Study (PIRLS), an international assessment programme of students' reading achievement in their fourth year of schooling, carried out by the International Association for the Evaluation of Educational Achievement (IEA). According to this assessment of educational achievement, based on data collected in 2021, when COVID-19 led to the disruption of students' schooling, around two thirds of countries experienced a decline in average reading achievement between 2016 and 2021, suggesting a widespread negative impact of the pandemic on students' academic performance in the fourth grade ([Mullis et al., 2023](#)).

Moving beyond descriptive evidence, a range of national studies have attempted to estimate the impacts of the pandemic, including school closures, on academic outcomes. These studies show large variation in the estimated impact, which reflects considerable cross-country variation in the intensity of the pandemic, the duration and extent of school closures imposed, the different modes of distance or hybrid learning adopted, the readiness to move towards online learning, the efficiency of online learning and the type, scope and timing of measures adopted to mitigate learning loss.

This report investigates the impacts of online learning mandates implemented in the 2020/2021 school year due to the pandemic on the academic performance of high-school students in Italy. We explore the effect on students' performance of regulations, implemented between November 2020 and June 2021, mandating that upper secondary school students attend lessons online or in hybrid mode most of the year, while preserving in-person teaching for younger pupils⁽¹⁾. We estimate the effect of online learning on the performance in standardised tests of two groups of coexisting students, one (those in grade 13) exposed to online learning and another (those in grade 8) that attended mostly in-person lessons. Our empirical strategy relies on repeated cross-sections of student-level data for both grades and a matched difference-in-difference (DiD) specification.

We consider that the contribution of our study to the literature analysing the effect of the pandemic on academic performance is twofold. First, while a range of studies have attempted to estimate the impacts of pandemic-induced school closures on academic outcomes, to the best of our knowledge, none has been able to separate the potential confounding effect of online learning from that of the overall COVID-19 pandemic. In their review of the literature, [Mazrekaj and De Witte \(2023\)](#) reach the same conclusion and advocate for research that disentangles the two effects. This is indeed the aim of this study. To do this, we follow an approach that goes beyond the empirical strategy adopted in all previous studies evaluating the impact of the pandemic on students' academic performance, that is, using a pre-pandemic cohort of students to construct the counterfactual outcomes of a COVID-19-affected one. This methodology, known as shift difference-in-differences (or shift-DiD), builds on a different estimand and requires stronger assumptions for causal identification. Because the outcomes of treated and control groups are measured at different points in time,

⁽¹⁾ This decision was based on the premise that, among students of all school grades, those in upper secondary would be better able to follow lessons online, and therefore suffer less from distance learning, and the fact that parental presence at home would be less important ([Contini et al., 2023](#)).

this methodology 'shifts' one of the two groups across the timeline of events by normalising the time dimension. Thus, the period at which each unit is observed defines its treatment status, with the result that the estimated effect of a DiD or event study specification compounds the common time effects with the rest of the differences across the two groups.

The estimated effect on academic outcomes obtained using such a strategy ought to be interpreted as the composite effect of several factors that changed between the points in time at which subsequent cohorts were observed – what can be considered the 'overall impact of the pandemic'. In the particular case of COVID-19-induced school closures, several relevant factors that go beyond online learning changed between the periods in which the treatment group's and the control group's outcomes were measured, such as economic insecurity due to parental job loss, health risks and limited social interactions outside school. By comparing coexisting treated and control groups, we can isolate the effect of online learning from the overall impact of the pandemic. The second contribution of our study is that it provides estimates of the effect of online learning not only in the short term, that is, in 2020/2021 (as in [Contini et al. \(2022, 2023\)](#) and [Borgonovi and Ferrara \(2023\)](#)), but also for a longer period, covering up to the 2022/2023 school year; this allows us to measure the impact of online learning on cohorts who were exposed to it 1 and 2 years before being tested.

To measure students' academic performance, we rely on data from national standardised tests in mathematics and the Italian language. We find that, on average, in the 2020/2021 school year students who were subject to online learning (i.e. grade 13 students) performed 0.25 and 0.15 standard deviations (SD) worse in reading and mathematics, respectively, than those who were taught in person (i.e. grade 8 students). These effects represent roughly three fifths and one third of the overall effect of the pandemic on students' academic performance identified in that year by the rest of the literature so far. Similar drops in test performance are found for the cohorts tested in the 2021/2022 and 2022/2023 school years, who were subject to the online mandates 1 and 2 years, respectively, before being tested. While both genders were affected by the online learning mandates, boys show worse results than girls in both subjects. No significant difference in performance in either subject is detected between students of native origin and those of foreign origin.

One of the possible main mechanisms through which exposure to online learning might have had a greater effect on the performance of grade 13 students than on that of grade 8 students is lower motivation levels due to changes in the learning environment. Motivation to study, which is widely recognised to play a critical role in successful online learning, can deteriorate quickly without a school routine and easy access to teacher and peer support. Nearly half of the grade 13 teachers surveyed in spring 2021 by the Italian National Institute for the Educational Evaluation of Instruction and Training (INVALSI) reported that one of their biggest challenges during the pandemic was motivating students; this might indeed confirm that, without the extrinsic drivers of school routine and regular interaction with teachers and classmates, many students struggled to find the intrinsic motivation to study.

Another potential channel is through teachers. Effective, high-quality remote teaching requires specific training and careful planning. The need to move quickly to online learning most likely resulted in less effective instruction. Indeed, this seems to be the case; in the teachers' survey mentioned above, around 55 % of teachers reported the increased workload in preparing lessons as one of the main challenges. Around 40 % of them stated that they would need further support from the school in terms of training to make their online teaching more effective. This suggests that another way in which online learning impacted students was the difficulty of ensuring high-quality remote teaching from teachers.

The remainder of the report is organised as follows. Section 2 goes over the relevant strands of the literature, and Section 3 explains the institutional setting and the data used for the analysis. Section 4 goes over all the details of the empirical strategy, while Section 5 presents the results of the analysis. Finally, Section 6 concludes.

2. Literature review

Since the outbreak of the pandemic, several studies have tried to quantify its impact on students' performance. The literature has focused on what can be called 'learning deficit', which comprises both a delay in expected learning progress and a loss of skills and knowledge already gained (Betthäuser, Bach-Mortensen and Engzell, 2023; Mazrekaj and De Witte, 2023).

Over the last few years, several systematic reviews have been conducted to take stock of existing studies and to understand to what extent students' learning has been impacted by the pandemic. Hammerstein et al. (2021) provide a first overview of evidence-based studies (carried out up to April 2021) on the impact of COVID-19-related school closures in spring 2020 on student achievement in primary and secondary education; they find a median negative effect of school closures on student achievement of -0.10 and -0.09 SD for mathematics and reading, respectively, but also a stronger impact among younger students and students from families with low socioeconomic status. This first overview covered 11 studies in seven countries (Australia, Belgium, China, Germany, the Netherlands, Switzerland and the United States); only one study was considered to have a low risk of bias.

Other studies find an even stronger learning loss. Betthäuser, Bach-Mortensen and Engzell (2023) carried out a systematic review, quality appraisal and meta-analysis of evidence on the COVID-19-related learning deficits 2.5 years into the pandemic, that is, covering studies identified by a literature search carried out in August 2022. They also find an overall high risk of bias, with 15 % of studies considered to be at 'low' risk of bias, 30 % at 'moderate' risk of bias, 25 % at 'serious' risk of bias and 30 % at 'critical' risk of bias. After excluding studies rated to be at critical risk of bias, they carried out a meta-analysis of 42 studies across 15 countries, finding a pooled effect size of around -0.14 SD. Based on the rule of thumb that students normally improve their performance by around 0.4 SD per school year, they estimate that students lost around 35 % of a school year's worth of learning. Most estimates show an increase in educational inequality by socioeconomic background, regardless of subject or education level. The authors also highlight that learning deficits arose early in the pandemic, and appear to be persisting over time.

Di Pietro (2023) provides a meta-analysis of 38 observational studies carried out up to early 2022 in 19 countries. He also finds a relatively high overall risk of bias, with only 16 % of the studies classified as being at low risk, more than 40 % as at moderate risk and 42 % as at serious risk of bias. On average, based on the results of the study, the pandemic generated a learning deficit of around 0.19 SD of student achievement. The results also show that, in 2021, students were not able to recover from the learning deficits caused by the 2020 school closures. De Witte and François (2023) provide an overview of the influence of COVID-19 on educational attainment based on 24 observational studies in 13 EU Member States, the United Kingdom (England) and Switzerland. Without carrying out any risk assessment, they report an average learning deficit equal to 0.11 SD, corresponding to a learning deficit of roughly between 1 and 3 months.

Mazrekaj and De Witte (2023) also provide a review of the existing literature on the impact of school closures during the COVID-19 pandemic on children's learning and mental health. After taking stock of the overall results, they point out an important limitation of most studies found in the literature, namely the inability to distinguish between the effect of school closures per se and the effects of the COVID-19 pandemic in general. This is exactly what our study aims to do.

A few studies have attempted to measure potential learning losses arising from school closures during the pandemic in Italy. Contini et al. (2022) focus on the impact of the national lockdown in spring 2020, combining data from the standardised national tests administered by INVALSI at grade 2 with the results of an ad hoc standardised assessment administered by the research team at the end of grade 3 in the province of Turin. By comparing the pre-COVID-19 and the COVID-19 cohorts (sitting the grade 3 tests in April 2019 and October 2020, respectively), they find a large mean negative impact on pupils' performance in mathematics. Borgonovi and Ferrara (2023) use INVALSI data for the whole country to provide a comprehensive assessment of the medium-term effects of pandemic-related disruptions on the mathematics and reading achievement of students who completed primary school and lower secondary school in the summer of 2021. By comparing this cohort with the pre-COVID-19 one, which completed the cycle in 2018/2019, they find drops in mathematics achievement at both levels, but a more mixed picture for reading. Bazoli et al. (2022) also study the impact of school closures in Italy, focusing on grades 5, 8 and 13, by comparing the performance in such grades before and after the pandemic using a matching approach. Contini et al. (2023) studied the impact of a full year of the COVID-19 pandemic on school performance, focusing on students at the end of upper secondary school, who are therefore about to enter the labour market or start university without having had the opportunity to recover; they find that the pandemic had a huge negative impact on students' performance in mathematics and

reading.

Overall, these studies on Italy report substantial reductions in performance for both reading and mathematics in secondary school, and for mathematics in primary school. With different methods, all these studies rely on a comparison between pre- and post-COVID-19 cohorts. Moreover, none of these studies exploited the heterogeneity in containment measures implemented in the country across school grades. This heterogeneity represents the basis for the identification strategy adopted in our study, which will be explained below. By focusing on the online learning mandates imposed on higher school grades during the second half of the pandemic, our approach contributes to the literature in two ways. First, we are able to disentangle the effect of online learning mandates from the overall effect of the pandemic, increasing our understanding of the impact of such a specific measure ⁽²⁾. Second, we provide estimates of the effect of online learning for up to 2 years after its introduction, to understand how persistent the associated learning losses can be.

⁽²⁾ Another strand of relevant literature worth mentioning is the one investigating the impact of online learning at university level. This research used the closure of universities during the pandemic as a natural experiment to obtain causal estimates of the effect of online learning on academic performance (Altindag et al., 2021; Kofoed et al., 2021; Orlov et al., 2021; De Paola et al., 2023), relying on a two-by-two DiD strategy using a pre- and a post-COVID-19 student cohort and the within-cohort difference in academic assessment between two dates. This literature also has to deal with the already described main issue of using a shifted DiD strategy, that is, identifying the effects of online learning separately from other confounders. In the particular case of a university setting, an additional confounder normally not accounted for is the potential change in the exam difficulty for the online learning cohort.

3. Institutional setting and data

3.1. Institutional setting

Due to the rapid spread of the COVID-19 pandemic across the globe, in March 2020 most countries implemented sudden school closures to limit the spread of the virus. While initially intended to be temporary, these closures often lasted for several weeks, or even months. The duration of school closures during the 2019/2020 school year varied considerably across countries, depending on the severity of the outbreak, the effectiveness of containment measures and government decisions.

In response to subsequent waves of the pandemic and local outbreaks during the 2020/2021 school year, some countries imposed repeated school closures or introduced regional variations in the implementation of remote or hybrid learning, with frequent shifts between learning modalities. This was particularly the case in Italy, the country we investigate in this study. Italy was the first EU country to be hit by the COVID-19 pandemic, and the first one to impose a national lockdown, at the beginning of March 2020. This included the closure of commercial establishments, the prohibition of events and exhibitions, the limitation of individual mobility, the closure of schools at all levels and the large-scale implementation of home-based working ⁽³⁾. During the 2019/2020 school year, the country registered one of the longest periods of school closures in Europe.

Extensive limitations were also implemented in the 2020/2021 school year; these are the focus of our study. In November 2020, to address the second wave of the COVID-19 pandemic, the Italian government introduced a new policy whereby different restrictions were applied depending on the local epidemiological situation and risk level. Based on a set of indicators, Italian regions (and autonomous provinces) were classified into four colour zones (red, orange, yellow and white) corresponding to different risk scenarios, for each of which specific restrictive measures were set out. The indicators were updated weekly, and risk zones were declared automatically in each region depending on those indicators. As a result, the time that each region spent in each risk zone could vary greatly. This emerges clearly in Figure 1, which shows the share of days on which each colour zone was mandated in each Italian region between 6 November 2020 and 8 June 2021 (i.e. around the end of the school year). The figure also shows that red-zone mandates were imposed in all Italian macro-regions; the strictest measures were therefore not concentrated in a specific part of the country.

Importantly for our analysis, each colour zone entailed a different combination of in-person and online learning depending on the education level; Table A1 in Appendix A presents an overview of the modalities implemented over the school year, depending on the grade and the risk level of the region. This heterogeneity represents the basis for the identification strategy of our analysis, as explained in more detail in Section 4.

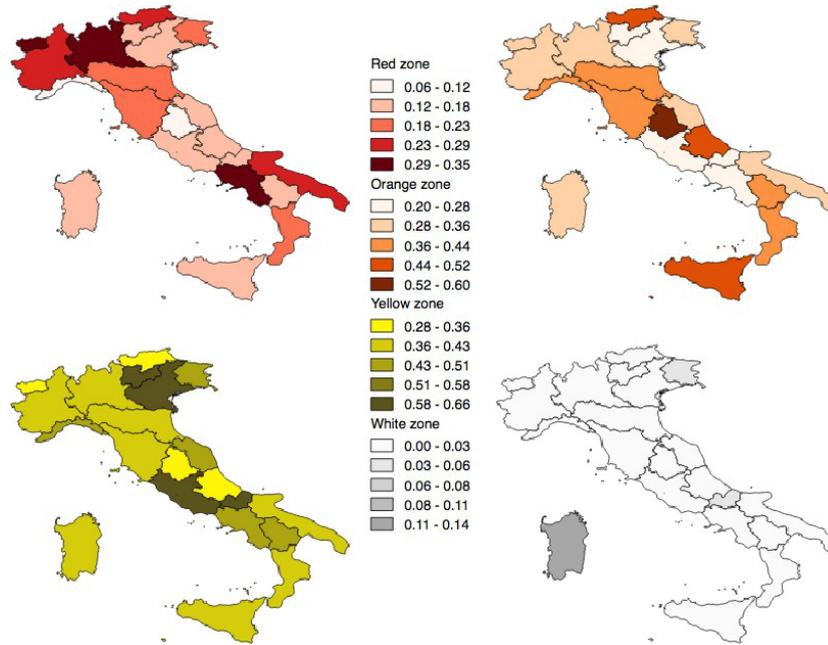
3.2. Data

To measure students' academic performance, we rely on data from national standardised tests administered by INVALSI to the student population of certain grades ⁽⁴⁾. These standardised tests are designed to measure the knowledge and skills of all students in grades 2, 5 (primary school), 8 (lower secondary school), 10 and 13 (higher secondary school) in mathematics, Italian (reading) and English (reading and listening). Testing for grade 13 was introduced only in 2018/2019. Since tests are administered between March and May each year, no examination was administered in the 2019/2020 school year due to the strict lockdown measures in place in the spring of that year. The test was not administered to grade 10 students in the 2020/2021 school year either; it was reintroduced in the 2021/2022 school year.

⁽³⁾ See the document from the Health Ministry '[Prevention and response to COVID-19: Evolution of strategy and planning in the transition phase for the autumn–winter season](#)'.

⁽⁴⁾ INVALSI is entrusted with administering periodic tests to evaluate students' academic achievement at different levels of education.

Figure 1: Intensity of risk levels in Italian regions



Note: Share of days that each colour zone was mandated in each Italian region from 6 November 2020 to 8 June 2021.

Overall, the questions included in the standardised test are aimed at measuring the level of preparation of students in specific skills that are deemed to be fundamental for school, work and everyday life. Some specific aspects in these domains are tested in specific grades. The assessment for Italian, or reading, is normally divided into two parts: reading comprehension and reflection on the language. Both measure linguistic proficiency, one of the basic skills that schools must develop in students. The mathematics test assesses basic knowledge, problem-solving and reasoning skills in selected areas that differ across grades ⁽⁵⁾. Of the three tests, it is the one that depends the most on disciplinary knowledge, but the questions often start from real-life problems and require students to reflect on the reasons for their choices. The assessment of English measures listening and reading skills.

Computer-based testing (CBT) was introduced in the 2017/2018 school year for grades 8 and 10; for grade 13, this was adopted from the first year of assessment, that is, 2018/2019. Primary school pupils still take paper-based tests. Each secondary school student has a computer and is normally required to take the tests in a computer lab. Under CBT, each student takes a different test with different items, but with the same overall difficulty, measurement equivalence and mode of composition (domains, text types, number of questions, question formats, etc.). The different test administration formats generate some minor additional differences between primary and secondary school students, such as the need for secondary school students to change classrooms. For both primary and secondary school students, test scores are calculated taking into account the difficulty of different items through psychometric methods and are reported, after being standardised, to have a mean of 200 and an SD of 40, which we further standardised to be 0 and 1, respectively.

To allow within-grade over-time test score comparisons, the overall difficulty of each test was fixed from a certain year onwards. This horizontal anchoring starts at two different points in time: in the 2017/2018 school year for grades 8 and 10, and in 2018/2019 for grades 2, 5 and 13. Thus, starting from each of those years, test scores are comparable over time within each grade. As explained in Section 4, the analysis presented in this study uses data available for students in grades 13 and 8 who took part in the reading and mathematics tests in the 2018/2019 (henceforth 2019) to 2022/2023 (henceforth 2023) school years.

The datasets also include relevant demographic information about students, their parents and their school. Examples of the information provided are the student's gender and month and year of birth, whether the student is Italian or a first- or second-generation migrant, the student's parents' economic, social and cultural status

⁽⁵⁾ For primary school children, the areas are numbers, relationships, data and predictions, and space and figures; for secondary school students, the areas are probability and statistics, arithmetic or algebra, geometry, relations and functions.

(ESCS) ⁽⁶⁾ and an anonymised identification of the school attended and the province in which it is located. Moreover, INVALSI administers surveys to a representative sample of schoolteachers and principals to, among other things, obtain further information on their teaching methods and the resources they use.

Thanks to longitudinal identifiers, it is possible to follow students over time and to retrieve past information. This allows us to recover information on variables that, for some reason, is not available in a specific year, but was at some point in the past; this is particularly useful for variables that are known to be time invariant (e.g. parental level of education) or that normally change very little over time (e.g. socioeconomic and cultural status) ⁽⁷⁾. The longitudinal dimension of the dataset also, theoretically, allows us to retrieve each student's past scores in the standardised tests taken in lower grades; for example, for grade 13 students, one could recover the test scores in grades 10, 8, 5 and 2.

Table 1 contains the descriptive statistics for grade 8 and grade 13 students across different samples, showing mean test scores and mean values of selected covariates that will be used in the analysis, for the period 2019–2023. Descriptives and number of observations are shown for all students in the student population who took the tests (columns 1 and 2), and for samples resulting from removing the observations with missing information in some of the covariates; in particular, columns 3 and 4 show figures for the sample without missing information on gender, foreign origin, ever retained (i.e. ever kept back a year), month of birth, class size decile and province, while columns 5 and 6 show figures for a further restricted sample of students with available information on ESCS. The last two columns refer to the sample used in the analysis, which, as explained in more detail in Section 4, is derived from a matching DiD strategy excluding ESCS. The use of these variables in the analysis (together with others that will be further explained in Section 4) implies some degree of selection in the working sample we use in the analysis, due to information on these variables potentially being missing not at random; the comparison between samples in Table 1 allows us to check to what extent this might be affecting our estimates.

Table A3 in Appendix A shows the proportion of missing information for the variables used as controls for each grade, year and subject. The table shows a substantial share of missing information in the ESCS variable ⁽⁸⁾, reaching 30 % of the grade 13 population in 2019 (i.e. the first year in which INVALSI tests at this grade took place) and 11 % of the grade 8 population in 2023. A comparison across samples in Table 1 reveals that the inclusion of gender and country of origin (i.e. dropping students for whom the relevant information is not available) does not change the mean scores observed; in the sample for which information on ESCS is available ⁽⁹⁾, on the other hand, the mean test score of both groups increases, suggesting a positive selection of the sample.

⁽⁶⁾ The index of ESCS is built by INVALSI in line with the international definition adopted, for example, in PISA surveys. It is derived from three main components related to family background: parents' level of education, parents' occupational status and home possessions. It is built to have a mean of 0 and an SD of 1.

⁽⁷⁾ This solution allows us to reduce the share of missing information from 11 % to 8 %, on average, for ESCS, and from 5 % to 2 % for country of origin.

⁽⁸⁾ There is basically no missing information for gender, retention, province and class decile, while for country of origin the share of missing information is always below 5 %.

⁽⁹⁾ As the ESCS index is computed by INVALSI as a standardised indicator on the part of the population for which information on parental educational attainment, parental occupational status and 'household possessions' is available, by construction this indicator would appear to be correctly distributed even in a positively selected sample.

Table 1: Student characteristics across samples

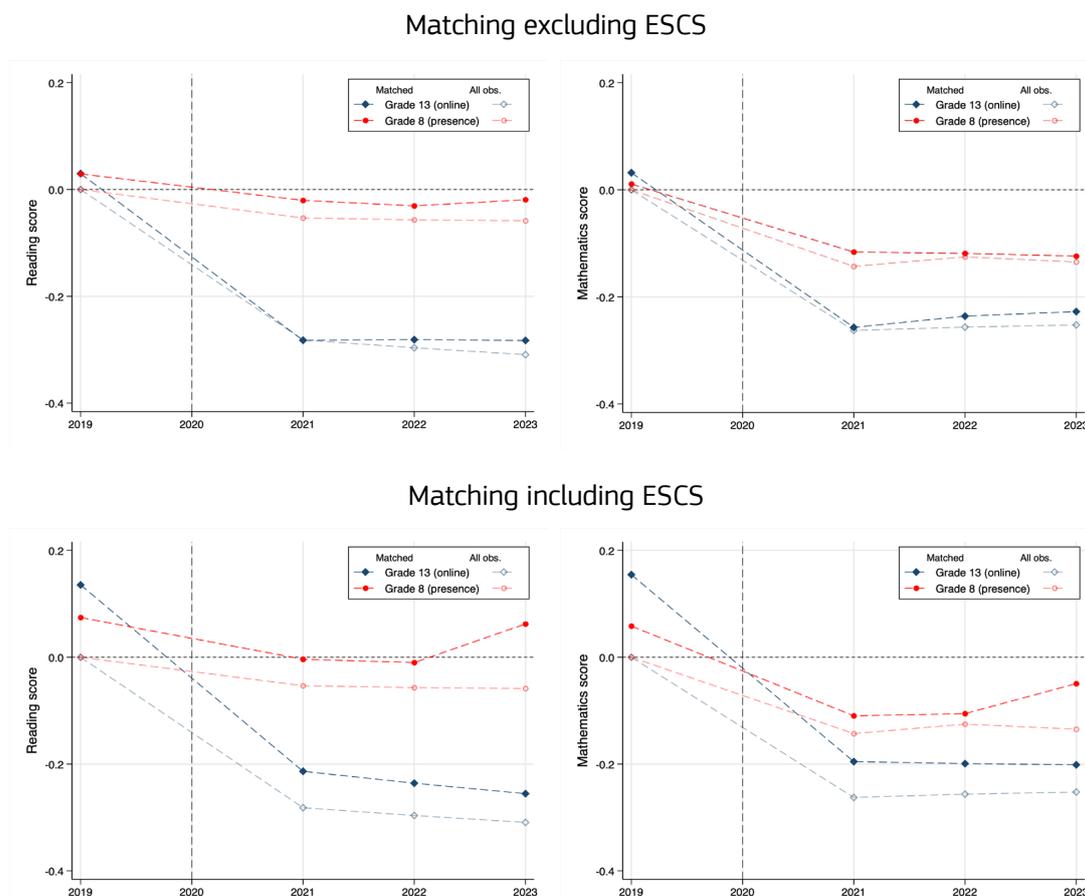
	All		No missing information		No missing information + ESCS		Matched	
	Grade 13	Grade 8	Grade 13	Grade 8	Grade13	Grade 8	Grade 13	Grade 8
(A) Reading								
Test score	-0.22	-0.04	-0.21	-0.03	-0.17	-0.00	-0.20	-0.01
Ever retained	0.19	0.06	0.18	0.06	0.16	0.05	0.18	0.05
Female	0.50	0.49	0.50	0.49	0.51	0.49	0.50	0.50
Native	—	—	0.92	0.88	0.92	0.88	0.91	0.92
ESCS quartile	—	—	—	—	2.49	2.50	—	—
Birth month	—	—	6.60	6.61	6.59	6.60	6.60	6.60
Class size decile	5.22	5.12	5.20	5.12	5.25	5.12	5.09	5.09
Number of students	1 811 106	2 133 402	1 772 906	2 092 870	1 568 265	2 007 800	1 611 771	1 614 103
(B) Mathematics								
Test score	-0.19	-0.10	-0.18	-0.09	-0.14	-0.06	-0.17	-0.09
Ever retained	0.19	0.06	0.18	0.06	0.16	0.05	0.18	0.05
Female	0.50	0.49	0.50	0.49	0.51	0.49	0.50	0.50
Native	—	—	0.92	0.88	0.92	0.88	0.91	0.92
ESCS quartile	—	—	—	—	2.48	2.50	—	—
Birth month	—	—	6.60	6.61	6.59	6.60	6.62	6.60
Class size decile	5.22	5.11	5.21	5.11	5.26	5.11	5.12	5.10
Number of students	1 813 104	2 145 559	1 774 762	2 104 363	1 564 591	2 015 444	1 586 849	1 589 703

Notes: Mean values of selected variables from INVALSI microdata files for the years 2019, 2021, 2022 and 2023 for reading and mathematics. Test scores are standardised to have a mean of 0 and an SD of 1 in the overall population in 2019, i.e. the baseline year. The 'All' sample comprises all observations for which information on the test score is available. The 'no missing information' sample excludes students if information is missing for any of the following variables: ever retained, gender, foreign origin, month of birth, class size and province. The 'no missing information + ESCS' sample further omits those observations also missing information on ESCS. The 'matched' sample is restricted to students matched using a first-nearest-neighbour matching strategy without replacement.

The same positive sample selection driven by the non-random missing pattern can be seen by plotting the evolution of the mean test scores of grade 13 and grade 8 students computed with three different samples. The benchmark sample common to all plots in Figure 2 (labelled 'All obs.') is the same as columns 1 and 2 of Table 1 and contains all students in the population. The other two samples contain the observations resulting from two different matching exercises that differ in the inclusion of the ESCS indicator to match treated and control students.

Figure 2 serves two purposes: the first is to show how mean test scores for our treated and control groups evolved in the period studied, and the second is to understand how selected the matched observations are in terms of test performance. Starting from the top row, the figure shows that mean test scores for grade 13 students registered a significant drop between the 2019 and 2021 cohorts in both subjects, but then remained rather stable for the 2022 and 2023 cohorts. Grade 8 also registered an initial decline in both subjects in 2021, much larger in mathematics than in reading, which remained similar for subsequent cohorts.

Figure 2: Mean standardised test scores in grades 13 and 8



Notes: Mean standardised test scores for reading (left) and mathematics (right) between 2019 and 2023 for grade 13 (online) and grade 8 (presence) students in three different samples: the overall population of students in all graphs, the sample obtained from a matching exercise excluding ESCS (top row) and the sample obtained from a matching exercise including ESCS (bottom row). Test scores are standardised within grade and subject to have a mean of 0 and an SD of 1 in 2019 using the overall population of students. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

The top row of Figure 2 also shows how the mean test scores of the students in the matched sample (without using ESCS as a matching characteristic) follow a very similar pattern to the one computed with all grade 13 and grade 8 students in both reading and mathematics. Mean scores for students in the matched sample are a bit higher than those of the overall population ⁽¹⁰⁾; however, given the empirical strategy adopted in the analysis (which will be described in Section 4), this would not impact the DiD estimates. The graphs in the bottom row plot the mean test scores obtained using the observations matched when including ESCS as a matching characteristic (and therefore reducing the sample size to those for whom the relative information is available). Clearly, these follow a different trend from the overall student population. To avoid this substantial reduction in sample size, and the consequent issues of representativeness of the sample, we choose not to use ESCS as a matching characteristic or as a control in our analysis ⁽¹¹⁾.

⁽¹⁰⁾ Scores in the reference year (i.e. 2019) are standardised to have a mean of 0 for the overall population, so the mean for the selected sample can be different due to sample selection.

⁽¹¹⁾ Moreover, the composition of students in the different ESCS quartiles can vary greatly across grades; this variation can impact the suitability of grade 8 as a good counterfactual for grade 13, when carrying out the analysis within quartiles.

4. Empirical strategy

4.1. Treatment and comparison groups' selection

As explained in Section 3.1, the 2020/2021 school year in Italy was characterised by combining in-person and online teaching; which of the two teaching methods was in place in each school grade depended on the local risk level assigned to the region. The risk level classification of Italian regions was based on a four-category colour system meant to indicate the level of contagion risk and the measures that needed to be in place ⁽¹²⁾. To reduce the spread of the COVID-19 virus in schools, in November 2020, the authorities decided that teaching at grades 9–13 would be moved online, while students in all other grades would continue their lessons in person. There were two reasons for this decision. First, upper secondary students would be better able than those in more junior grades to handle online and hybrid learning; therefore, their academic progress would not be as hindered by these learning modalities. The second was that senior students would be more autonomous and therefore, when studying at home, would not require as much parental supervision as their junior counterparts (Contini et al., 2023).

As shown in Table A1 in Appendix A, from November 2020 until the end of the 2020/2021 school year, upper secondary students participated in either online or hybrid learning, but were never attending school fully in person. From the beginning of November until the end of December, education for all upper secondary students was fully online. After the Christmas holidays, the same modality continued for students under red-zone mandates. In regions where the risk level was deemed lower (i.e. under yellow- and orange-zone mandates), students were allowed to go back to in-person schooling, but with presence capped at 50–75 % of the classroom's usual capacity to ensure a certain level of social distancing ⁽¹³⁾. In practice, this meant that, from January until the end of April, in low-risk zones, upper secondary students followed a biweekly rotation scheme, alternating between in-person and online learning. By contrast, students in lower grades (primary and lower secondary school) were normally allowed to attend school in person ⁽¹⁴⁾. The only exception was for seventh and eighth graders, who, during red-zone mandates, also had to attend lessons online.

Such differentiated implementation of online teaching across school grades motivates our decision to use students in upper and lower grades as our treated and comparison groups, respectively. As shown in Table A2 of Appendix A, not all grades participate in the national tests, which poses a challenge to the selection of our treated and comparison groups. Given the institutional setting, our choice for the treated group would be between grades 13 and 10, as these students had to attend online lessons for most of the 2020/2021 school year. Grade 13 students started to be tested only in the 2018/2019 school year, and grade 10 students were not tested in 2020/2021. Given data availability, we opted for grade 13 students as the treatment group. This group is also especially relevant because grade 13 is the year of graduation from high school; as a consequence, any negative impact on students at this level deserves special attention since they are about to enter the labour market or start university, without having had the opportunity to recover (Contini et al., 2023).

Regarding which grade to use as our comparison group, the choice is between students of two lower grades with available testing information but who were not subject to online learning: grades 5 and 8. Grade 5 students are not deemed a suitable comparison group for 13th graders: the fact that they differ in relevant factors for test scores, such as age, schooling institutions and testing methodology (paper v computer-based), could lead to a heterogeneous impact of online learning on test scores. Moreover, the parents of primary school students are more likely to help them to do their homework, which might counterbalance the lack of regular instruction during the pandemic. Since more technical skills are needed to help students at higher grades, children in grade 8 might be less likely to benefit from parental involvement and support in their learning activities. Although eighth graders attend a different type of school from 13th graders, we consider them a suitable comparison group given the smaller age difference and common contextual factors, such as the teaching methods they are exposed to, parental time devoted to them and exam-taking methodology (i.e. CBT, as explained above).

We use questionnaires administered to teachers of our treated and control students in spring 2021 to verify that lessons were taught online or in person as mandated during that school year. Only 9% of grade 13 teachers

⁽¹²⁾ In practice, however, the same restriction measures were put in place in regions with the two lowest risk levels, the white and yellow zones, making the distinction between these two colour zones irrelevant to our analysis.

⁽¹³⁾ The percentage of students allowed to attend in-person lessons in yellow and orange zones was increased to between 70 % and 100 % at the end of April 2021.

⁽¹⁴⁾ It should also be noted that, even though students were technically allowed to have in-person schooling, over the 2020/2021 school year, class-level closures were also implemented, depending on the number of COVID-19 cases in the class and/or school. No detailed data on classrooms or school closures are available.

reported having taught mainly in person, as opposed to online or hybrid, in that year, while 70% of grade 8 teachers did so. We take these figures as evidence that schools and teachers in both groups complied with the regulations, with grade 13 students having their lessons moved online while most lessons for grade 8 continued in person.

Nevertheless, and given that grade 8 students were also subject to some level of online learning during red-zone mandates (see Table A1), we first validate their suitability as a comparison group for grade 13 students. We do so by exploiting the geographical variation in the introduction of online learning mandates caused by red-zone declarations across different regions of the country, thereby identifying grade 8 students who were subject to relatively more online learning and those who were never exposed to it. The highest share of online schooling days due to red zone mandates (between 21 % and 24 %) was found in Lombardia, Campania and Valle d'Aosta; on the other hand, Liguria and Umbria had no days under red zone mandates, with grade 8 students therefore normally allowed to have all their lessons in person ⁽¹⁵⁾. With the two groups of grade 8 student identified, we estimate a DiD model to evaluate whether a certain degree of online learning impacted grade 8 students' performance in the standardised test. We find a precisely estimated null effect of online learning on the test scores of grade 8 students in both subjects. This suggests that, for these students, being taught online for between 20 and 25 % of the school year had no impact on their test score performance, possibly because they were able to benefit from in-person learning in the rest of the school year. Such a null effect of a small part of online learning on grade 8 students supports our choice of this group as a valid comparison group for grade 13 students. Appendix B contains all the relevant details of this analysis.

In our main analysis, we estimate the causal effect of online learning on students' standardised test scores by a matching DiD estimation of grade 13 and grade 8 students. We start by matching students subject to online learning (i.e. those in grade 13) with those enjoying in-person learning (i.e. those in grade 8) based on students' gender, origin (foreign or native), month of birth, class size decile, province and year. For the matching strategy, we use a first-nearest-neighbour matching strategy without replacement ⁽¹⁶⁾. We then estimate the following event study specification using the matched sample of grade students:

$$Y_i = \sum_{s \neq 2019} (1[s = t] \beta_s \times Grade13_{g(i)}) + \lambda_{t(i)} + \alpha \times Grade13_{g(i)} + X'_i \delta + \phi_{j(i)t(i)} + \epsilon_i \quad (1)$$

where Y stands for the standardised test score of student i , which has been standardised to have a mean of 0 and an SD of 1 in the baseline year (i.e. 2019). Grade 13 takes value 1 for 13th graders and 0 for 8th graders. λ represents year fixed effects, and X represents the following set of controls for individual characteristics: gender, if ever retained in a grade, country of origin, month of birth and decile in the national distribution of class size ⁽¹⁷⁾. ϕ represents province-by-year fixed effects, which allow us to account for unobserved province characteristics that might change over time. We are interested in the β coefficients capturing the difference in test performance between grade 13 students, who followed their lessons online, and grade 8 students, who had in-person lessons. Standard errors are clustered at the region by school grade level since this is the relevant level for the implementation of the online learning mandates. The period covered in the analysis spans from 2019 (i.e. test performed at the end of the 2018/2019 school year) to 2023 (end of the 2022/2023 school year), excluding the 2019/2020 school year due to lack of testing.

To increase the plausibility of the parallel-trends assumption, we match grade 13 students to grade 8 ones using first-nearest-neighbour propensity score matching without replacement. Within each year, grade 13 students were matched to grade 8 students using their gender, origin, month of birth, decile in the national distribution of class size and school province. Figure A1 in Appendix A plots the density function of the estimated propensity score for the unmatched and matched samples, providing evidence of the high quality of the match and the support covered. The number of observations used in this matched sample and mean values for most of the controls used in the regression analysis are presented in Table 1.

In the second part of the analysis, we evaluate the intensive margin of attending online schooling using the duration of red-zone mandates in each region. As discussed in the previous sections, between November 2020 and June 2021, Italy saw a great variability between regions in the amount of time spent in a red zone, where the containment measures were the strictest. In particular, between January and April 2021, 100 % of classes

⁽¹⁵⁾ Table A4 in Appendix A shows the number of weeks in online learning across regions for grade 8 and grade 13 students. For grade 8, the number goes from 0 to 8.2, while for grade 13 it ranges from 6.7 to 11.8. Apart from the number of online weeks strictly speaking, it should also be noted that non-online weeks were in person for grade 8, but hybrid for grade 13.

⁽¹⁶⁾ Additional matching strategies, such as those using a kernel or a radius, were also implemented and yielded the same results.

⁽¹⁷⁾ Quartile of the parental socioeconomic and cultural level was also used in an alternative specification, but was dropped from the core of the analysis because of the sample selection issue described in Section 3.2.

for grade 13 students in a red zone were online; in contrast, their peers in yellow and orange zones were taught using the hybrid modality (alternating between in-person and online classes). This part of the analysis, therefore, tries to quantify the additional impact of being exposed to the stricter learning modality. For this exercise, we construct an indicator variable, taking a value of 1 for those regions for which the share of days in online learning for grade 13 students was above the median, and 0 otherwise, and implement a triple difference estimator (TD) or difference-in-difference-in-difference (DiDiD).

4.2. Assumptions for identification

The DiD estimator we implement relies on comparing the difference in standardised test scores of students who were exposed to online learning mandates (i.e. those in grade 13) with the test scores of those whose exposure was negligible (grade 8), before and after such mandates were introduced in the 2020/2021 academic year. Four assumptions ought to be fulfilled for the DiD estimator to identify the average treatment effect on the treated (ATT). The first two have to do with the absence of spillover effects of the treatment or the stable unit treatment value assumption (SUTVA), and no anticipation effects. Provided that each group of students was subject to different mandates regulating online learning and that school attendance is mandatory in grade 8, we can rule out relevant spillover effects from the treatment to the control group, as grade 8 students could not independently choose to attend lessons online rather than in person. Furthermore, given the extraordinary nature of the online schooling mandates and the particular context in which these took place, there is no reason to believe that grade 13 students and teachers could have anticipated them ⁽¹⁸⁾.

The third assumption, known as the stationarity assumption, requires the student composition to remain stable across its repeated cross sections. Using coexisting groups of students improves the plausibility of the stationarity assumption, compared with relying on a previous cohort's outcomes to construct a counterfactual, as commonly done in other studies. However, the decision of the Ministry of Education to suspend grade retention at the end of the 2019/2020 school year could have implications in the fulfilment of the stationarity assumption. Since grade retention is significantly more common in upper secondary than in lower secondary grades ⁽¹⁹⁾, its suspension might have had stronger implications for the student composition of grades that would be attending more lessons online.

In reality, however, the suspension of grade retention entailed two counteracting compositional changes. Grade 7 and grade 12 students who otherwise would have been retained in 2020 were allowed to continue to grades 8 and 13, respectively, in the next school year ⁽²⁰⁾. Similarly, grade 8 and grade 13 students who otherwise would have been retained were allowed to continue to grade 9 or to finish their studies ⁽²¹⁾. Therefore, while the inflow of the former group of students potentially decreased the mean test scores of grades 8 and 13 in the 2020/2021 school year, the outflow of the latter groups increased them. Which of the two counteracting compositional changes prevails is an empirical question that cannot be answered, as doing so would require observing the test performance of both groups of students, something that is not possible for the group that is allowed to continue or leave school at the end of the 2019/2020 school year. In the light of these two counteracting compositional changes, and of the very similar standard retention rates in grades 7 and 8 and in grades 12 and 13, we argue that the suspension of retention had a quite limited impact on the mean test scores of grade 8 and grade 13 students in 2020/2021 and subsequent school years ⁽²²⁾.

Nevertheless, to provide evidence in favour of the plausibility of the stationarity assumption, we estimate Equation 1 using a series of covariates as the dependent variable. This exercise allows us to analyse whether the student composition has significantly changed across the two groups over the period studied in terms of the observed characteristics. The results are reported in [Appendix C](#) and show how student composition was unchanged in terms of the relevant characteristics that we observe across the two groups. Notably, there was

⁽¹⁸⁾ Importantly, the same assumptions hold in 2020/2021 also for grades 6-7 and 11-12, i.e. those that students tested in grade 8 and 13 in 2022 and 2023 were attending.

⁽¹⁹⁾ In the 2019 student population, 17 % of those in grade 13 had been retained in the past; in grade 8, the share was 7 %.

⁽²⁰⁾ According to data from the Ministry of Education, 98.7 % of students in grade 12 in 2020 were promoted to grade 13; in 2019, the share was 94.6 %. For grade 7, promotion rates were 98 % in 2019 and 99.7 % in 2020.

⁽²¹⁾ According to data from the Ministry of Education, the retention rate at the final exam at grade 13 was 4.2 % in 2019, but only 1.2 % in 2020. For the final exam at grade 8, the retention rate was 2 % and 0.2 %, respectively.

⁽²²⁾ Existing studies investigating the impact of the pandemic in Italy and relying on the outcomes of a previous cohort to construct counterfactuals of the academic performance also need to deal with the fact that such policy change produces differential retention rates across the cohorts used as treatment and control. While [Contini et al. \(2022\)](#) discuss the implications only of the inflow of students, [Borgonovi and Ferrara \(2023\)](#) acknowledge the existence of both flows. However, in both cases, the authors perform additional analysis taking account only of the inflow of students, without addressing the outflow of those who actually moved to the next grade and are therefore not included in the data. Such exercises potentially yield a more biased student sample than the original one.

no change in the proportion of retained students between the two groups, implying that grade 8 teachers were as lenient as grade 13 teachers in letting their students pass the grade.

The fourth and key assumption of DiD, known as the parallel-trends assumption, in our setting is the idea that, were it not for the introduction of online schooling mandates, the outcomes of the treated and control groups would have evolved in the same way. In our case, the parallel-trends assumption implies that the average performance of the two grades did not evolve differently pre-exposure, and therefore would have continued to evolve similarly in the absence of the online learning mandates. At least three specific requirements follow from the parallel trends assumption. First, it assumes that the pre-trends of both grades evolved in parallel up to the start of the 2020/2021 school year. This also implies that students' academic performance in both school grades was affected in the same way by the national lockdown imposed at the end of the 2019/2020 school year. The second implication is that the effect of online learning on grade 8 would have been the same as that on grade 13, had grade 8 been treated. The third requirement is that the relative level of difficulty of the tests between the treated and comparison groups remains constant over the period analysed.

The plausibility of the parallel trends assumption is commonly assessed by showing that there are no pre-treatment differences in the trends (pre-trends) of standardized test scores among the two groups of students. Unfortunately, testing of grade 13 students began only in the 2018/2019 school year, leaving us without the possibility of analysing differences in the pre-trends of standardised test scores between grade 13 and grade 8 students. Moreover, INVALSI standardized tests were not designed to maintain the same difficulty level over time before the implementation of horizontal anchoring in 2018 and 2019, making it impossible to analyse pre-trends even when comparing school grades that were already tested.

Given the impossibility of using INVALSI for this purpose, in line with the attempt by [Borgonovi and Ferrara \(2023\)](#), we rely on similar data from international standardised assessments in mathematics for grades 10 and 8⁽²³⁾ to provide evidence of how grade 13 pre-trends might have looked in comparison with those of grade 8. Figure A2 in [Appendix A](#) plots the means of the standardised test scores for grade 10 students (or 15-year-olds) in PISA, as a close substitute for grade 13 students, and those obtained by grade 8 students in the Trends in International Mathematics and Science Study (TIMSS). None of the changes taking place over the 10 years before 2019 is statistically significant, reassuring on the plausibility of the parallel-trends assumption⁽²⁴⁾.

Finally, concerning the third requirement mentioned above, our empirical strategy exploiting coexisting cohorts tested from 2019 onwards allows us to rely on data which is comparable over time, thanks to the anchoring introduced in 2018 and 2019, which ensures the difficulty level is kept constant over time. This represents an advantage when compared to other studies using the same data but relying on previous cohorts' academic performance to construct counterfactual outcomes; these studies cannot rule out the possibility that their estimated effect is potentially compounded over time by changes in the difficulty of the tests⁽²⁵⁾.

⁽²³⁾ International assessment tests for reading are performed for grades 10 (PISA) and 4 (PIRLS) only, leaving us without a good alternative group for grade 8 students.

⁽²⁴⁾ Note that we show the unconditional test score means; thus, one should expect the differences in the pre-trends across the two grades to be smaller in an event study regression specification, as in Equation 1, with matched observations using relevant covariates.

⁽²⁵⁾ Indeed, [Contini et al. \(2023\)](#) and [Borgonovi and Ferrara \(2023\)](#), both of whom compare the test scores of a post-COVID-19 cohort with those of a previous one, acknowledge this possibility. They both argue that, for their estimates to be interpreted as causal effects, it is required to assume a lack of structural trends in students' performance across cohorts.

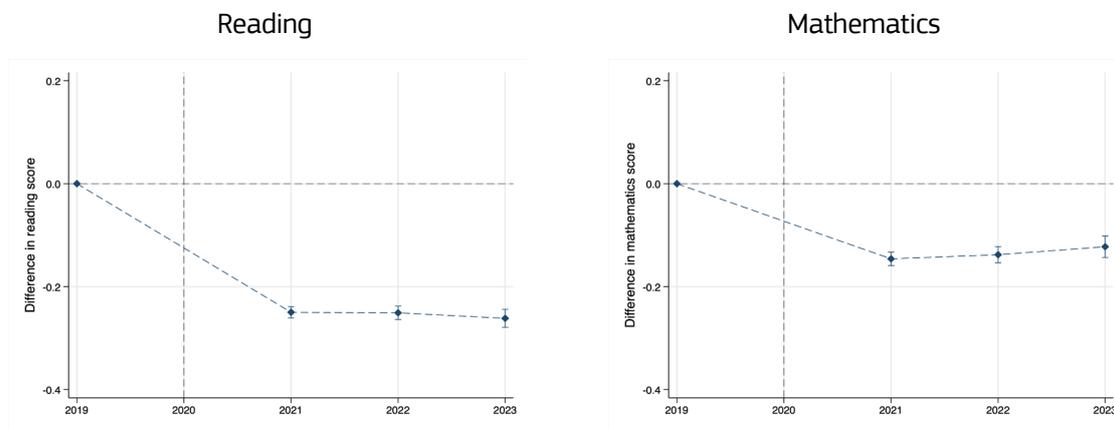
5. Results

5.1. Learning losses induced by online learning

Figure 3 presents estimates from the matched DiD model described in Section 4. The estimates measure the additional learning loss associated with the online learning modality, which was imposed on grade 13 students in the 2020/2021 school year, compared with in-person learning, to which grade 8 students continued to be exposed. Thus, our estimates ought to be interpreted as the additional impact that online learning in the 2020/2021 school year had on test scores on top of the effects produced by other policy measures, including the lockdown measures imposed in the preceding year. Online learning produced considerable learning losses in 2021 in both reading and mathematics, with grade 13 students scoring 0.25 and 0.15 SD lower, respectively, than their counterparts who attended in-person lessons. Overall, the additional learning losses due to online or hybrid learning appear to be greater in reading than in mathematics. To ease interpretation, the literature often tries to translate SD differences into the normal learning progress of students over time, thereby presenting gaps in terms of ‘school-year equivalents’⁽²⁶⁾. In line with Hanushek and Woessmann (2020) and Patrinos, Vegas and Carter-Rau (2022), we consider, as a rule of thumb, that the expected yearly learning gain per school year is around 0.33 SD. The learning loss associated with online learning in 2021 is therefore equivalent to around 75 % of the expected yearly learning gain in reading, and around 45 % in mathematics.

Our estimated learning losses due to online learning represent, for reading, roughly three fifths and, for mathematics, one third of the overall effect of the pandemic on students’ academic performance identified in Contini et al. (2023) for high-school students in Italy. The learning losses we identify are considerably lower because those estimated by Contini et al. (2023) can be attributed to the pandemic overall, including the initial lockdown in spring 2020, rather than solely the online learning modality implemented during the 2020/2021 school year.

Figure 3: Learning losses due to online learning mandates



Notes: Estimates of the DiD specification detailed in Equation 1 comparing the performance of grade 13 (online) and grade 8 (presence) students in reading (left) and mathematics (right) standardised tests. Differences are expressed in SDs. Years on the x axis represent years in which students took the test. Control variables are gender, origin, month of birth, if ever retained in a grade, decile in the national distribution of class size and province-by-year fixed effects. Vertical bars represent 95 % confidence intervals. Standard errors are clustered at the region by school grade level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

The loss remained quite stable for the next two cohorts of students, tested in 2022 and 2023. These students were exposed to online learning in grades 12 and 11 and returned to the standard in-person form of instruction

⁽²⁶⁾ As explained by Azevedo et al. (2021), this is linked to expected school productivity, or how much students are expected to learn as they move from one grade to the next, and calculations are based on the literature on school productivity, unexpected school closures and summer learning loss. There is currently no consensus on one single measure, as this varies depending on the data used, grade, position in the test distribution and other factors. However, a few studies estimated that, over a school year, students, on average, learn between 0.2 SD (Azevedo et al., 2021) and 0.4 SD (Betthäuser et al., 2023). According to Woessmann (2016), as a rule of thumb, learning gains on most national and international tests during 1 year are equal to between one quarter and one third of an SD.

in the following years ⁽²⁷⁾. These results suggest that the learning losses due to online learning continue for 1 or 2 years after being exposed to it, even after a return to in-person learning, with no clear sign of catching up in terms of performance in reading, and only a small improvement in mathematics.

These results are in line with the evidence provided by the literature; recent meta-analyses (Betthäuser, Bach-Mortensen and Engzell, 2023; Di Pietro, 2023) suggest that the negative impact of the pandemic on students' achievement in the first months of the pandemic typically persisted in the following year. As highlighted by Betthäuser, Bach-Mortensen and Engzell (2023), previous research on the effects of teacher strikes and other education disruptions on students' attainment has suggested that learning deficits are difficult to overcome and tend to persist in the long run; this is exactly what the evidence from the 2022 and 2023 cohorts seems to suggest. Therefore, students appear to need support to recover from the learning deficit generated by online learning, to avoid the long-term consequences of these disruptions in education activities.

The findings are also coherent with the evidence provided by the non-pandemic literature analysing the effect of online learning on students' academic performance; most of the literature studies the effect of online versus face-to-face teaching on tertiary education students, relying either on small-scale randomized trials in institutions of tertiary or vocational education (Coates et al., 2004; Figlio, Rush and Yin, 2013; Joyce et al., 2015; Alpert, Couch and Harmon, 2016; Cacaault et al., 2021), or on instrumental variable approaches with larger populations (Xu and Jaggars, 2013; Bettinger et al., 2017). All these studies find negative effects of online learning in comparison to in-person learning.

5.2. Robustness tests

Before going further into the analysis, we report the results of three robustness tests that we carry out on our data.

First, we check whether our results are affected by the preferred specification we adopt in the analysis, and subsequent sample selection, as described in Section 3.2. As mentioned above, to control for the main demographic characteristics in the regression, we are forced to exclude some members of the student population available in INVALSI data because information in some variables is missing (in particular, gender and country of origin). Second, due to the choice of our matched DiD specification, we run the analysis on a matched sample, which is therefore further restricted compared with the full student population.

To check how much this affects our estimates, in Table D1 in Appendix D we present the results of estimating Equation 1 on three different samples: the full student population ('All', columns 1 and 2), the sample of students for whom information on relevant covariates is available ('No missing information', columns 3 and 4) and the matched sample ('Matched', columns 5 and 6, which is the sample used in our matched DiD specification; the results in column 6 were presented in Figure 3). For all three, we present estimates for two specifications, one without any control and one with all controls available. For the student population, this means including province-by-year fixed effects; for the other samples, this specification also includes all the controls in Equation 1. The results from columns 2 and 6 are also presented in Figure D1, which clearly shows how estimates are pretty much consistent across different samples. This confirms the conclusions we drew from Figure 2 in Section 3.2, further reassuring us about the representativeness of the sample used in our analysis and the reliability of our results.

The second robustness exercise aims to check whether the results change when controlling for students' previous achievement, as is often done in the literature (Borgonovi and Ferrara, 2023; Contini et al., 2023). Given the longitudinal component of INVALSI data, it is possible to retrieve prior achievement for students in grades 13 and 8 by using their scores from 3 years before, when students were in grades 10 and 5, respectively (only for those not retained in between) ⁽²⁸⁾. This would, however, exclude the use of the 2022/2023 school year in the study, as no test was carried out 3 years before (i.e. in 2020). For this reason, our preferred specification does not control for students' prior achievement. In Appendix D we repeat our analysis for the period up to 2021/2022, introducing this additional control in our regression specification. We do so by computing each school grade's deciles of performance in the standardised test sat 3 years before, and assigning each student to their decile ⁽²⁹⁾. Figure D2 plots the results of this estimation, showing that they are very similar

⁽²⁷⁾ A certain degree of online learning might have occurred also in the school year 2021/2022 when students tested positive for COVID-19. No data are available on these cases, but they were highly likely to have been more sporadic than the structural hybrid learning that was in place in 2020/2021.

⁽²⁸⁾ As explained in Section 3.2, INVALSI tests are carried out at grades 2, 5, 8, 10 and 13 only.

⁽²⁹⁾ Since scores are not directly comparable across different school grades, we cannot use the actual score that each student obtained in their past tests.

to those found with our main specification, but with slightly bigger learning gaps.

The last robustness test involves the use of a different dataset to estimate the impact of online learning. INVALSI provides two different types of dataset, the population one (*popolazione*), which is the one used in this study and in other studies on Italy (Borgonovi and Ferrara, 2023; Contini et al., 2023), and the sample one (*campione*), which comprises the test results of a statistically representative sample of schools and students at the regional level. The sample data come from students who are subjected to external monitoring when sitting tests, rather than being supervised by their teacher, which reduces the potential for cheating, and, in general, reduces the potential for different behaviour across grades by both students and teachers during INVALSI test sessions. Importantly, high-school students take the tests using a computer (i.e. CBT). While CBT is likely to eliminate cheating, it might still be useful to ascertain if the patterns found in the population data are the same as in the sample data. Indeed, Figure D3 in Appendix D shows the same patterns found in Figure 3, once again confirming the reliability of our main results.

5.3. Learning loss among different population subgroups

The previous analysis measured the extent of the average learning loss suffered by grade 13 students due to online learning implemented in the 2020/2021 school year. Such average results could hide heterogeneous effects across different population subgroups; this section presents the same analysis on a few of these subgroups.

As shown in Table 2, there are indeed clear gender differences in the impact of online learning on student performance. On average, girls appear to do better than boys. The gender gap, in favour of girls, was around 0.05 SD in reading in 2021, but almost doubled in 2023. A similar pattern is found for mathematics (though with smaller learning losses overall): the loss in 2021 is 0.04 SD lower among girls than among boys. The gap in the loss increases in subsequent cohorts, more than doubling to 0.1 SD in 2023. Based on the rule of thumb mentioned above, this gender gap is therefore equivalent to between 15 % and 30 % of a year's worth of learning. These gender gaps in favour of girls might be explained by higher levels of intrinsic motivation and self-discipline among girls than among boys, which applies equally to both subjects (Duckworth et al., 2021).

Results by origin do not show significant differences between native and foreign students. While this might seem surprising, it should be noted that for foreign students, even among those who were not exposed to online learning that much, i.e. those in grade 8, standardised scores are consistently and considerably lower than the population average (on average, around 0.6 SD lower); based on performance-equivalence scales defined by INVALSI, this level would already correspond to a very weak performance, with competences not in line with the learning targets for lower secondary education. This might explain why losses cannot increase further, despite the additional issues imposed by online learning. Table 2 shows that a significant difference by origin is found only for mathematics in 2023, when foreign students are found to have slightly smaller learning losses than their native peers.

5.4. Learning loss by economic, social and cultural status

Despite choosing not to control for the students' ESCS in the main analysis (because of the sample selection issues that would result from the inclusion of this variable, especially in 2023; see Figure 2 in Section 3.2), this section exploits relatively better availability of ESCS information up to 2020/2021 to look into different learning losses associated with online learning for students from different types of socioeconomic background in the year when online learning was implemented.

Previous studies on Italy (Borgonovi and Ferrara, 2023; Contini et al., 2023), comparing pre- and post-COVID cohorts, found no differences in the impact of the pandemic across levels of socio-economic background. Our results, presented in Table 3, show something different. In the 2020/2021 school year, the ESCS quartile that showed the greatest relative loss due to online and hybrid learning was the top one, and this was true for both reading (0.36 SD) and mathematics (0.23 SD), while the lowest quartile registered the smallest gaps (0.17 and 0.06 SD in reading and mathematics, respectively)⁽³⁰⁾. The relatively smaller impact among more disadvantaged students could be explained by some sort of floor effect. Even among those students who were less exposed to online learning (i.e. those in grade 8), standardised scores are considerably lower than the population average (on average, around 0.2 SD lower, and around 0.6 SD below the level of the top quartile). This could explain the results. It should however be noted that in light of the data issues presented in Section 3.2,

⁽³⁰⁾ It is worth pointing out that this does not say anything about performance in absolute terms; indeed, in our estimates, the higher the ESCS quartile the student belongs to, the higher the scores.

the evidence provided here should be handled with caution: while sample selection issues were stronger in 2023, Table A3 in Appendix A showed a considerable share of missing information for ESCS in 2019 as well, which might be playing a role in these results ⁽³¹⁾.

Table 2: Learning losses due to online learning by gender and foreign origin

	Reading			Mathematics		
	(1)	(2)	(3)	(4)	(5)	(6)
Grade 13 × 2021	- 0.250*** (0.006)	- 0.276*** (0.007)	- 0.254*** (0.007)	- 0.146*** (0.006)	- 0.168*** (0.008)	- 0.151*** (0.008)
Grade 13 × 2022	- 0.251*** (0.006)	- 0.289*** (0.008)	- 0.252*** (0.007)	- 0.138*** (0.008)	- 0.174*** (0.008)	- 0.142*** (0.009)
Grade 13 × 2023	- 0.262*** (0.009)	- 0.308*** (0.011)	- 0.266*** (0.010)	- 0.123*** (0.010)	- 0.172*** (0.011)	- 0.128*** (0.011)
Grade 13 × 2021 × Female		0.054*** (0.008)			0.044*** (0.010)	
Grade 13 × 2022 × Female		0.078*** (0.009)			0.072*** (0.008)	
Grade 13 × 2023 × Female		0.093*** (0.008)			0.102*** (0.006)	
Grade 13 × 2021 × Foreign			- 0.001 (0.023)			0.020 (0.020)
Grade 13 × 2022 × Foreign			- 0.023 (0.028)			0.023 (0.023)
Grade 13 × 2023 × Foreign			0.028 (0.023)			0.058*** (0.014)
Adjusted R ²	0.156	0.157	0.159	0.157	0.159	0.158
Number of observations	3 147 144	3 147 144	3 147 144	3 097 014	3 097 014	3 097 014

Notes: Estimates of a triple DiD specification comparing the performance of grade 13 (online) and grade 8 (presence) students by gender and foreign origin, with respect to 2019, in reading and mathematics standardised tests. Treated observations are matched to untreated ones using a first-nearest-neighbour matching strategy without replacement. Differences are expressed in SDs. Control variables are gender, if ever retained, origin, month of birth, decile in the national distribution of class size and province-by-year fixed effects. Standard errors are clustered at the region by school grade level. ***, **, * denote significance at the 1 %, 5 % and 10 % level, respectively. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

5.5. Learning losses and intensity of online learning

As discussed in Section 3.1, during the 2020/2021 school year, there was great variability between regions in the amount of time spent in a red zone, where the containment measures, including a greater use of online rather than hybrid learning among grade 13 students, were the strictest. This section tries to quantify the additional impact on student performance of the length of time in online learning by looking at the intensive margin of its impact. To do so, the analysis uses the periods in which online learning mandates were implemented for grade 13 students in each region, as described in Table A1 in Appendix A, to identify areas of the country that, and therefore students who, were exposed to this learning modality for longer than the national median level ⁽³²⁾. This is captured by the ‘online region’ dummy in the regression presented in Table 4, which is then interacted with year dummies to see the impact over time. The table shows that, indeed, spending a relatively longer period in online learning produces a small, but significant, additional learning loss in both reading and mathematics.

⁽³¹⁾ A further caveat was mentioned in Section 3.2, regarding the suitability of grade 8 students as controls for grade 13 when carrying out the analysis within quartile.

⁽³²⁾ Table A4 in Appendix A shows the number of weeks in online learning across regions, which ranges from less than 7 to almost 12 weeks, with a student weighted mean of 9.5 weeks.

Table 3: Learning losses due to online learning by ESCS (2021)

	Reading		Mathematics	
	(1)	(2)	(3)	(4)
Grade 13 × 2021	- 0.250*** (0.006)	- 0.167*** (0.018)	- 0.146*** (0.006)	- 0.056*** (0.013)
Grade 13 × 2021 × 2nd quartile		- 0.065*** (0.015)		- 0.092*** (0.012)
Grade 13 × 2021 × 3rd quartile		- 0.113*** (0.020)		- 0.164*** (0.015)
Grade 13 × 2021 × Top quartile		- 0.192*** (0.027)		- 0.176*** (0.020)
Adjusted R^2	0.156	0.215	0.157	0.215
Number of observations	3 147 144	1 403 303	3 097 014	1 392 507

Notes: Estimates of a triple DiD specification comparing the performance of grade 13 (online) and grade 8 (presence) students by ESCS quartiles, with respect to 2019, in reading and mathematics standardised tests. Treated observations are matched to untreated ones using a first-nearest-neighbour matching strategy without replacement. Differences are expressed in SDs. Control variables are gender, if ever retained, origin, month of birth, decile in the national distribution of class size and province-by-year fixed effects. Standard errors are clustered at the region by school grade level. ***, **, * denote significance at the 1 %, 5 % and 10 % level, respectively. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

Table 4: Effects of online learning by intensity

	Reading	Mathematics
Grade 13	0.029 (0.029)	0.033 (0.028)
Grade 13 × 2021	- 0.236*** (0.008)	- 0.129*** (0.010)
Grade 13 × 2022	- 0.240*** (0.009)	- 0.116*** (0.010)
Grade 13 × 2023	- 0.243*** (0.011)	- 0.100*** (0.013)
Grade 13 × Online region	0.071 (0.052)	0.099** (0.039)
Grade 13 × Online region × 2021	- 0.025*** (0.009)	- 0.030** (0.012)
Grade 13 × Online region × 2022	- 0.022* (0.011)	- 0.042*** (0.013)
Grade 13 × Online region × 2023	- 0.036** (0.014)	- 0.043** (0.018)
Adjusted R^2	0.156	0.157
Mean dependent variable	- 0.106	- 0.127
Number of observations	3 147 142	3 097 014

Notes: Results of a triple difference estimator augmenting Equation 1 with an indicator variable, 'online region', taking a value of 1 for those regions for which the number of weeks in online learning for grade 13 students in the 2020/2021 school year was above the median, and 0 otherwise. Control variables are gender, if ever retained, origin, month of birth, decile in the national distribution of class size and province-by-year fixed effects. Standard errors are clustered at the region by school grade level, ***, **, * denote significance at the 1 %, 5 % and 10 % level, respectively.

5.6. Discussion

While this study sheds light on the impact of additional online learning on coexisting cohorts of students who were exposed to online learning to varying degrees in 2020/2021, it is still very hard to explain why this impact occurred.

It is possible to identify three main potential channels through which exposure to online learning might have affected grade 13 students' performance compared with that of grade 8 students. The first channel is lower motivation levels due to changes in the learning environment. During the 2020/2021 school year, students, especially those in grade 13, were forced to study from home, where conditions were probably not ideal. As explained by [Yates et al. \(2021\)](#), without the extrinsic drivers of school routine and easy access to teacher and peer support, many students find it difficult to find the intrinsic motivation to study, and motivation is widely recognised to play a critical role in successful online learning ([Ng, 2019](#)). As [De Paola, Gioia and Scoppa \(2023\)](#) find for university students, students with a stronger tendency to procrastinate were more negatively affected by the shift to online teaching, most likely because it became harder to commit to studying when face-to-face interactions with instructors and peers were missing; a similar mechanism could apply to secondary school students. To understand whether this channel might explain our results, ideally, we would like to check whether students felt their motivation level was affected by online learning. Unfortunately, this information is not available in INVALSI data. However, some useful insights might come from information available from teachers' and headmasters' questionnaires administered by INVALSI in 2020/2021, in particular from questions on aspects related to the online/hybrid learning modality adopted during that school year. Indeed, nearly half of the grade 13 teachers who completed the questionnaire reported that one of the biggest challenges was motivating students; this appears to confirm that, without the extrinsic drivers of school routine and regular interaction with teachers and classmates, many students struggled to find the intrinsic motivation to study.

A second channel involves peer effects. School represents the primary social environment for children, and peer interactions contribute to fostering the development of their academic and socioemotional skills. Especially when social interactions outside of school are limited due to confinement measures put in place during the pandemic, the school environment can represent the main opportunity to interact with peers in person. Online learning prevents this type of interaction. Moreover, as explained by [Agostinelli et al. \(2022\)](#), school closures drastically change the peer environment students are exposed to. Schools allow children from different socioeconomic backgrounds to mix in a common environment, thereby potentially playing a 'social equaliser' role. Online learning reduces this opportunity. Even when peer interactions are allowed to continue, they are likely to be confined to the residential neighbourhood, while interactions with classmates living far away become harder to maintain. School closures therefore likely had an impact on the psychological well-being of students. No information is available on the way students were able to interact with their peers, nor on whether their peer environment changed while doing lessons online, making it impossible to investigate this channel.

The third potential channel works through teachers. Effective, high-quality remote teaching requires specific training ([Bozkurt et al., 2020](#)) and careful planning. While online learning had started to be available at the university level, secondary education schools normally did not have either the technical support or the instructor experience to deliver courses online ([Lynch, 2020](#)). Online teaching practices that emerged during the pandemic are often defined as 'emergency remote education', clearly denoting the exceptional nature of such practices and the impossibility of planning ahead to be prepared, from both a technical and a pedagogical perspective. The need to quickly move to online learning most likely put a lot of strain on teachers, who may have struggled to adapt their teaching methods to the new format, possibly resulting in less effective instruction. This seems to be the case; in the teachers' survey mentioned above, around 55 % of teachers reported the increased workload in preparing lessons as one of the main challenges. Around 40 % of them stated that they would need further support from the school in terms of training to make their online teaching more effective. This suggests that a further channel through which online learning impacted students was the difficulty of ensuring high-quality remote teaching from teachers who were not prepared for this type of instruction.

6. Conclusion

This study investigates the impacts on academic performance of widespread online learning implemented in the 2020/2021 school year due to the pandemic, in one of the countries that was most severely hit by the pandemic, namely, Italy. The analysis sheds light on the effectiveness of online learning at an education level (secondary education) for which not much evidence is currently available. The study also contributes to disentangling the impact of online learning (and therefore school closures) from the overall impact of the pandemic.

The first main result is that losses associated with online learning seem to be persisting. Comparing the performance of different cohorts of high-school students who were exposed to online learning at different grades, we see that the attainment loss among those who were in grade 13 when they were exposed to online learning was considerable: 0.25 SD in reading and 0.15 SD in mathematics. Our estimated learning losses due to online learning represent, for reading, roughly three fifths and, for mathematics, one third of the identified effect of the overall pandemic on high-school students' academic performance. These losses correspond to around 75 % and 45 % of a year's worth of learning in reading and mathematics, respectively. The losses registered by the subsequent cohorts are very similar to those experienced in 2021. This suggests that, even 1 or 2 years after being exposed to online learning, students are still suffering from the associated learning losses, with no clear sign that they are catching up, in terms of performance, in reading, and only a small improvement in mathematics, despite the return to a relatively normal learning format in the 2021/2022 and 2022/2023 school years.

Second, the additional learning losses due to online or hybrid learning appear to be greater in reading than in mathematics. This is somewhat surprising, since available research not only on the pandemic, but also the previous strands of literature on summer learning, student absenteeism and extreme weather events, suggests that learning progress in mathematics is more dependent on formal instruction than learning progress in reading (Betthäuser, Bach-Mortensen and Engzell, 2023). This explanation could be partly due to parents being more able to help children with reading than with mathematics; however, considering the education levels used in the analysis, which are both at secondary level, this might be less applicable to the case investigated in this study.

Third, some important differences emerge when looking into population subgroups. Gender differences in the impact of online learning are significant: on average, girls appear to have suffered less than boys. By contrast, no significant difference in the impact of online learning was registered between native students and students of foreign origin.

Finally, the evidence shows that a higher intensity of online learning, that is attending a school in an area subjected to online learning mandates for longer (which, for grade 13 students, meant full online learning rather than a hybrid modality), produced small, but significant, additional losses in performance.

Overall, this study shows that the learning losses produced by online learning during the 2020/2021 school year in Italy are persisting. This result has important policy implications. Policymakers should continue to devote attention to this issue, as the return to regular schooling modalities did not bring students back to pre-pandemic learning levels. The learning losses are still evident and are likely to have repercussions in the years to come. This is especially true for more senior students, who are reaching the end of secondary schooling without having been able to recover from the initial losses. The evidence that learning deficits are hard to overcome points to a need to strengthen education systems, making them more resilient to future disruptions.

References

- Agostinelli, F., Doepke, M., Sorrenti, G. and Zilibotti, F. (2022), 'When the great equalizer shuts down: Schools, peers, and parents in pandemic times', *Journal of Public Economics*, Vol. 206, 104574 (<https://linkinghub.elsevier.com/retrieve/pii/S0047272721002103>).
- Alpert, W. T., Couch, K. A. and Harmon, O. R. (2016), 'A randomized assessment of online learning', *American Economic Review*, Vol. 106, No 5, pp. 378–382 (<https://doi.org/10.1257/aer.p20161057>).
- Altindag, D. T., Filiz, E. and Tekin, E. (2021), 'Is online education working?', *NBER Working Papers*, No 29113, National Bureau of Economic Research, Cambridge (www.nber.org/papers/w29113.pdf).
- Azevedo, J. P., Hasan, A., Goldemberg, D., Geven, K. and Iqbal, S. A. (2021), 'Simulating the potential impacts of COVID-19 school closures on schooling and learning outcomes: A set of global estimates', *The World Bank Research Observer*, Vol. 36, No 1, pp. 1–40 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8108634/>).
- Bazoli, N., Marzadro, S., Schizzerotto, A. and Vergolini, L. (2022), 'Learning loss and students' social origins during the COVID-19 pandemic in Italy', *FBK-IRVAPP Working Papers*, No 2022-03, Research Institute for the Evaluation of Public Policies, Trento.
- Bethhäuser, B. A., Bach-Mortensen, A. M. and Engzell, P. (2023), 'A systematic review and meta-analysis of the evidence on learning during the COVID-19 pandemic', *Nature Human Behaviour*, Vol. 7, No 3, pp. 375–385 (www.nature.com/articles/s41562-022-01506-4).
- Bettinger, E. P., Fox, L., Loeb, S. and Taylor, E. S. (2017), 'Virtual classrooms: How online college courses affect student success', *American Economic Review*, Vol. 107, No 9, pp. 2855–2875 (<https://doi.org/10.1257/aer.20151193>).
- Borgonovi, F. and Ferrara, A. (2023), 'COVID-19 and inequalities in educational achievement in Italy', *Research in Social Stratification and Mobility*, Vol. 83, p. 100760 (<https://linkinghub.elsevier.com/retrieve/pii/S0276562423000045>).
- Bozkurt, A., Jung, I., Xiao, J., Vladimirschi, V., Schuwer, R., Egorov, G., et al. (2020), 'A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis', *Asian Journal of Distance Education*, Vol. 15, No 1, pp. 1–126 (<https://doi.org/10.5281/zenodo.3878572>).
- Cacault, M. P., Hildebrand, C., Laurent-Lucchetti, J. and Pellizzari, M. (2021), 'Distance learning in higher education: Evidence from a randomized experiment', *Journal of the European Economic Association*, Vol. 19, No 4, pp. 2322–2372 (<https://doi.org/10.1093/jeaa/jvaa060>).
- Contini, D., Di Tommaso, M. L., Muratori, C., Piazzalunga, D. and Schiavon, L. (2022), 'Who lost the most? Mathematics achievement during the COVID-19 pandemic', *The B.E. Journal of Economic Analysis & Policy*, Vol. 22, No 2, pp. 399–408 (<https://doi.org/10.1515/bejeap-2021-0447>).
- Contini, D., Di Tommaso, M. L., Piazzalunga, D., Muratori, C. and Schiavon, L. (2023), 'A lost generation? Impact of COVID-19 on high school students' achievements', *IZA Discussion Papers*, No 16008, Institute of Labor Economics, Bonn.
- Coates, D., Humphreys, B. R., Kane, J. and Vachris, M. A. (2004), 'No significant distance' between face-to-face and online instruction: evidence from principles of economics', *Economics of Education Review*, Vol. 23, No 5, pp. 533–546 (<https://doi.org/10.1016/j.econedurev.2004.02.002>).
- De Paola, M., Gioia, F. and Scoppa, V. (2023), 'Online teaching, procrastination and student achievement', *Economics of Education Review*, Vol. 94, p. 102378 (<https://linkinghub.elsevier.com/retrieve/pii/S0272775723000250>).
- De Witte, K. and François, M. (2023), 'Covid-19 learning deficits in Europe: analysis and practical recommendations', EENEE Analytical report. doi: 10.2766/881143.
- Di Pietro, G. (2023), 'The impact of COVID-19 on student achievement: Evidence from a recent meta-analysis', *Educational Research Review*, Vol. 39, 100530 (<https://doi.org/10.1016/j.edurev.2023.100530>).
- Duckworth, A. L., Kautz, T., Defnet, A., Satlof-Bedrick, E., Talamas, S., Lira, B. and Steinberg, L. (2021), 'Students attending school remotely suffer socially, emotionally, and academically', *Educational Researcher*, Vol. 50, No 7, pp. 479–482 (<https://doi.org/10.3102/0013189X211031551>).
- Figlio, D., Rush, M. and Yin, L. (2013), 'Is it live or is it internet? Experimental estimates of the effects of online

- instruction on student learning', *Journal of Labor Economics*, Vol. 31, No 4, pp.763–784 (<https://doi.org/10.1086/669930>).
- Hammerstein, S., König, C., Dreisörner, T. and Frey, A. (2021), 'Effects of COVID-19-related school closures on student achievement – A systematic review', *Frontiers in Psychology*, Vol. 12, p.746289 (www.frontiersin.org/articles/10.3389/fpsyg.2021.746289/full).
- Hanushek, E. A. and Woessmann, L. (2020), 'The economic impacts of learning losses', *OECD Education Working Papers*, No 225, OECD Publishing, Paris (www.oecd-ilibrary.org/education/the-economic-impacts-of-learning-losses_21908d74-en).
- Joyce, T., Crockett, S., Jaeger, D. A., Altindag, O. and O'Connell, S. D., (2015), 'Does classroom time matter?', *Economics of Education Review*, Vol. 46, pp. 64–77 (<https://doi.org/10.1016/j.econedurev.2015.02.007>). -
- Kofoed, M. S., Gebhart, L., Gilmore, D. and Moschitto, R. (2021), 'Zooming to class?: Experimental evidence on college students' online learning during COVID-19', *IZA Discussion Papers*, No 14356, Institute of Labor Economics, Bonn.
- Lynch, M. (2020), 'E-Learning during a global pandemic', *Asian Journal of Distance Education*, Vol. 15, No 1, pp. 189–195.
- Mazrekaj, D. and De Witte, K. (2023), 'The impact of school closures on learning and mental health of children: Lessons from the COVID-19 pandemic', *Perspectives on Psychological Science*, p. 17456916231181108 (<https://journals.sagepub.com/doi/10.1177/17456916231181108>).
- Mullis, I. V. S., von Davier, M., Foy, P., Fishbein, B., Reynolds, K. A. and Wry, E. (2023), *PIRLS 2021 International Results in Reading*, Boston College, TIMSS & PIRLS International Study Center, Chestnut Hill (<https://pirls2021.org/wp-content/uploads/2022/files/PIRLS-2021-International-Results-in-Reading.pdf>).
- Ng, C. (2019), 'Shifting the focus from motivated learners to motivating distributed environments: A review of 40 years of published motivation research in *Distance Education*', *Distance Education*, Vol. 40, No 4, pp. 469–496 (<https://doi.org/10.1080/01587919.2019.1681892>).
- OECD (Organisation for Economic Co-operation and Development) (2023), *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*, PISA, OECD Publishing, Paris (<https://doi.org/10.1787/53f23881-en>).
- Orlov, G., McKee, D., Berry, J., Boyle, A., DiCiccio, T., Ransom, T., Rees-Jones, A. and Stoye, J. (2021), 'Learning during the COVID-19 pandemic: It is not who you teach, but how you teach', *Economics Letters*, Vol. 202, p. 109812 (<https://linkinghub.elsevier.com/retrieve/pii/S0165176521000896>).
- Patrinos, H. A., Vegas, E. and Carter-Rau, R. (2022), 'An analysis of COVID-19 student learning loss', *World Bank Policy Research Working Papers*, No 10033, World Bank, Washington, D. C.
- Woessmann, L. (2016), 'The importance of school systems: Evidence from international differences in student achievement', *Journal of Economic Perspectives*, Vol. 30, No 3, pp. 3–32 (<https://pubs.aeaweb.org/doi/10.1257/jep.30.3.3>).
- Xu, D. and Jaggars, S. S. (2013), 'The impact of online learning on students' course outcomes: Evidence from a large community and technical college system', *Economics of Education Review*, Vol. 37, pp.46–57 (<https://doi.org/10.1016/j.econedurev.2013.08.001>).
- Yates, A., Starkey, L., Egerton, B. and Flueggen, F. (2021), 'High school students' experience of online learning during COVID-19: The influence of technology and pedagogy', *Technology, Pedagogy and Education*, Vol. 30, No 1, pp. 59–73 (<https://doi.org/10.1080/1475939X.2020.1854337>).

List of abbreviations

CBT	computer-based testing
DiD	difference-in-difference
ESCS	economic, social and cultural status
IEA	International Association for the Evaluation of Educational Achievement
INVALSI	Italian National Institute for the Evaluation of the Education and Training System
OECD	Organisation for Economic Co-operation and Development
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
SD	standard deviation
TIMSS	Trends in International Mathematics and Science Study

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Appendix A: Additional figures and tables

Table A1: Online learning mandates over the 2020/2021 school year

Dates	Legislation	Zone	Primary school	Lower secondary school		Upper secondary school
			Grades 1–5	Grade 6	Grades 7–8	Grades 9–13
7 August 2020– 7 October 2020	DPCM 7 August 2020; DPCM 7 September 2020	No	In person	In person	In person	In person
		No	In person	In person	In person	In person
		No	In person	In person	In person	In person
6 November 2020– 6 January 2021	DPCM 3 November 2020	Yellow	In person	In person	In person	E-learning
		Orange	In person	In person	In person	E-learning
		Red	In person	In person	E-learning	E-learning
7 January–5 March 2021	DPCM Dec 3, 2020; Ordinance of Ministry of Health and DL 1/2021; DPCM 14 January 2021	Yellow	In person	In person	In person	50–75 % in person
		Orange	In person	In person	In person	50–75 % in person
		Red	In person	In person	E-learning	E-learning
6 March–6 April 2021	DPCM 2 March 2021	Yellow	In person	In person	In person	50–75 % in person
		Orange	In person	In person	In person	50–75 % in person
		Red	E-learning	E-learning	E-learning	E-learning
7 April–25 April 2021	DL 44/2021 and DL 52/2021	Yellow	In person	In person	In person	50–75 % in person
		Orange	In person	In person	In person	50–75 % in person
		Red	In person	In person	E-learning	E-learning
26 April 2021 to school end	DL 44/2021 and DL 52/2021	Yellow	In person	In person	In person	70–100 % in person
		Orange	In person	In person	In person	70–100 % in person
		Red	In person	In person	In person	50–75 % in person
2021/2022 school year		Yellow	In person	In person	In person	In person
		Orange	In person	In person	In person	In person
		Red	In person*	In person*	In person*	In person*

Notes: Evolution in the online/hybrid learning mandates that took place during the 2020/2021 school year. DL: Decreto Legge (Decree Law); DPCM: Decreto del Presidente del Consiglio dei Ministri (Ministerial Decree). From 6 March 2021, regions and autonomous provinces were allowed to impose a stricter mandate (i.e. to change colour) in their territories if specific epidemiological conditions were met, implying that mandates of different colours could be in place within a region. *Waivable only under exceptional and extraordinary circumstances. Source: <https://www.camera.it/temiap/documentazione/temi/pdf/1218064.pdf?%201664977295664>.

Table A2: Data availability by school grade and academic year

Academic year	Grade 2	Grade 5	Grade 6	Grade 8	Grade 10	Grade 13
2022/2023	✓	✓	—	✓	✓	✓
2021/2022	✓	✓	—	✓	✓	✓
2020/2021	✓	✓	—	✓	—	✓
2019/2020	—	—	—	—	—	—
2018/2019	✓	✓	—	✓	✓	✓
2017/2018	✓	✓	—	✓	✓	—
2016/2017	✓	✓	—	✓	✓	—
2015/2016	✓	✓	—	✓	✓	—
2014/2015	✓	✓	—	✓	✓	—
2013/2014	✓	✓	—	✓	✓	—
2012/2013	✓	✓	—	✓	✓	—
2011/2012	✓	✓	✓	✓	✓	—
2010/2011	✓	✓	✓	✓	✓	—
2009/2010	✓	✓	✓	✓	—	—

Note: Available micro datasets in INVALSI by school grade and academic year.

Table A3: Share of students with missing information

	2019	2021	2022	2023
Grade 13 (reading)				
Female	0.000	0.001	0.003	0.000
Ever retained	0.000	0.001	0.001	0.000
Native	0.044	0.009	0.021	0.008
ESCS quartile	0.302	0.130	0.054	0.029
Birth month	0.000	0.001	0.001	0.000
Class size decile	0.000	0.000	0.000	0.000
Number of students	459 082	408 382	462 363	481 279
Grade 8 (reading)				
Female	0.000	0.000	0.000	0.000
Ever retained	0.000	0.000	0.000	0.000
Native	0.013	0.012	0.022	0.029
ESCS quartile	0.025	0.005	0.024	0.114
Birth month	0.000	0.000	0.000	0.000
Class size decile	0.000	0.000	0.000	0.000
Number of students	542 625	520 462	535 303	535 012
Grade 13 (mathematics)				
Female	0.000	0.001	0.003	0.000
Ever retained	0.000	0.001	0.001	0.000
Native	0.044	0.009	0.022	0.008
ESCS quartile	0.302	0.135	0.060	0.031
Birth month	0.000	0.001	0.001	0.000
Class size decile	0.000	0.000	0.000	0.000
Number of students	458 028	408 186	463 614	483 276
Grade 8 (mathematics)				
Female	0.000	0.000	0.000	0.000
Ever retained	0.001	0.000	0.000	0.000
Native	0.013	0.012	0.022	0.030
ESCS quartile	0.032	0.006	0.022	0.114
Birth month	0.001	0.000	0.000	0.000
Class size decile	0.000	0.000	0.000	0.000
Number of students	546 411	523 032	538 017	538 099

Note: Share of students with missing information in the selected variable, year, school grade and subject.

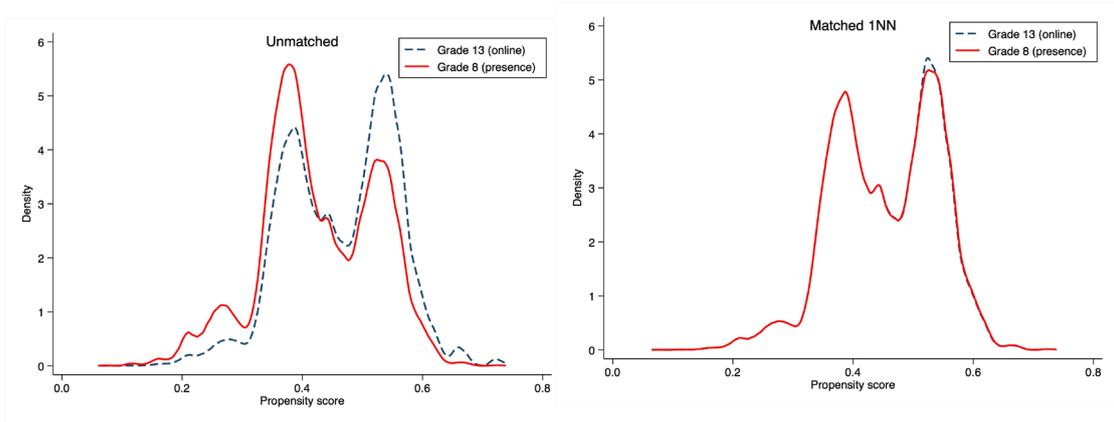
Table A4: Weeks under online learning mandates by grade

Region	Grade 13	Grade 8
Abruzzo	6.67	2.83
Basilicata	8.67	2.00
Calabria	7.83	4.50
Campania	11.83	8.17
Emilia-Romagna	9.83	3.17
Friuli-Venezia Giulia	9.83	3.17
Lazio	8.83	2.17
Liguria	6.67	0.00
Lombardia	10.83	7.50
Marche	9.17	2.50
Molise	9.67	3.00
Piemonte	9.83	6.50
Provincia Autonoma Bolzano	8.67	5.83
Provincia Autonoma Trento	9.17	2.50
Puglia	11.83	5.17
Sardegna	8.67	2.00
Sicilia	8.67	2.00
Toscana	7.83	4.17
Umbria	6.67	0.00
Valle d'Aosta	9.83	7.50
Veneto	9.17	2.50

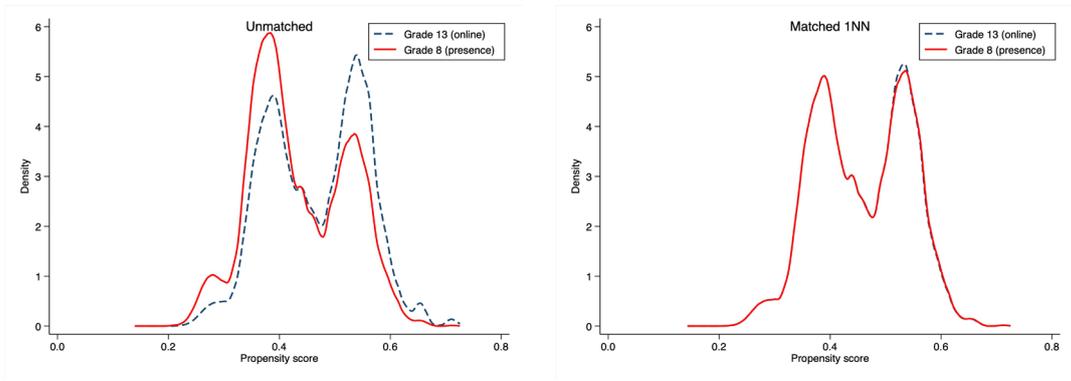
Note: Number of weeks that online learning mandates were in place in each region in the 2020/2021 school year.

Figure A1: Propensity score densities

Mathematics

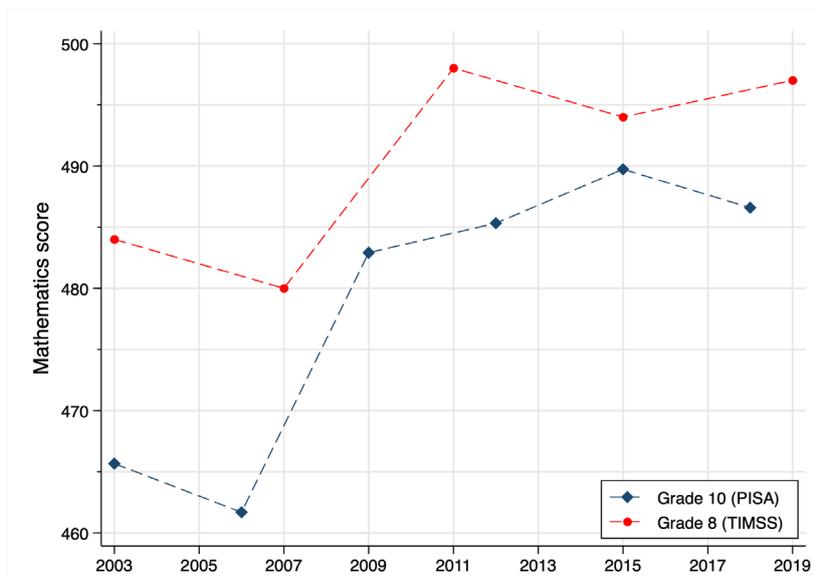


Reading



Notes: Estimates of the kernel densities of the estimated propensity scores for each school subject sample. Propensity score of attending grade 13 instead of grade 8 estimated using a probit model conditioning on gender, origin, month of birth, decile in the national distribution of class size, province and year. 1NN, first nearest neighbour.

Figure A2: Pre-trends in international assessments (mathematics)



Notes: Unconditional means of the standardised test scores from Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA). Note that none of the changes taking place over the ten years before 2019 are statistically significant

Appendix B: Online learning effects for grade 8 students

This appendix describes the empirical strategy and results of comparing the standardised test scores of grade 8 students subject to some online learning with those who were taught entirely in person. The different decrees introduced in the 2020/2021 school year stipulated that grade 8 students had to attend their lessons online during red-zone mandates (see Table A1 for details). Therefore, we exploit geographical variation in the introduction of online learning mandates caused by red-zone declarations across different regions of the country, as shown in Figure 1, to identify grade 8 students who were subject to online learning and those who were not. In particular, we compare the test scores of grade 8 students in regions where online learning was in place for more than 20 % of days in the school year with those of grade 8 students who had all their lessons in person⁽³³⁾. We estimate the following event study specification:

$$Y_i = \lambda_{t(i)} + \gamma_{r(i)} + \sum_t (\beta_t \lambda_{t(i)} \times Online_{r(i)}) + X_i' \delta + \epsilon_i \quad (2)$$

where λ represents year fixed effects, γ represents region fixed effects and the variable 'online' takes a value of 1 for regions where more than 20 % of school days were subject to online schooling mandates and 0 for those with none. The following individual characteristics are included as controls: gender, quartile of the parental socioeconomic and cultural level, origin, month of birth and decile in the national distribution of class size. All other variables are defined as in Equation 1. Our interest lies in the β coefficients, as these capture the difference in test performance between students with the highest share of online school days and those who attended all their lessons in person. We bootstrap and cluster standard errors at the region level, since this is the relevant level for the implementation of online learning mandates. The analysis covers the school years from 2014/2015 to 2022/2023.

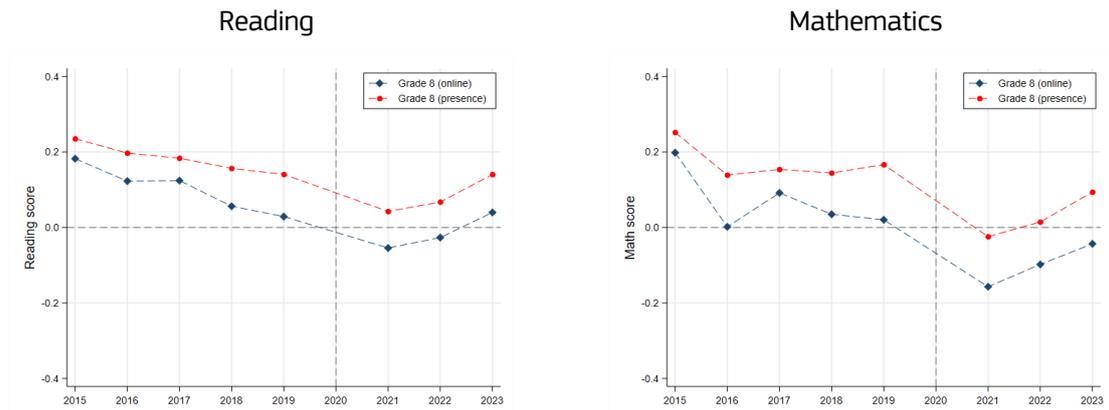
Figure B1 shows the evolution of the mean of the standardised test scores in each subject for grade 8 students in each group of regions. Standardised test scores in both subjects appear to have evolved in parallel in the period leading up to the 2020/2021 school year, when online learning mandates were introduced, which speaks in favour of the comparability of the two groups, as established by the parallel-trends assumption.

It is worth mentioning that, while the two groups' relative differences in performance in each subject can be assessed for all years, this is not the case for the absolute level of performance. This is because test difficulty was not necessarily kept constant before 2017/2018. Thus, only from that year onwards, when test difficulty was anchored, can the within-group performance level be compared across subsequent years. Nevertheless, the evolution of the difference in performance across the two groups of students in the period before the anchoring of the test difficulty is still informative of the plausibility of the parallel-trends assumption because all the students were administered the same test.

Figure B2 plots each year's β coefficients from estimating Equation 2 by ordinary least squares. These represent the difference in the standardised test performance between students who were exposed to the highest share of online school days and those who attended all their lessons in person. As anticipated by Figure B1, there was no difference in the test performance in both subjects between the two groups of students in the years leading up to the introduction of online learning. Similarly, we find that both groups of students had the same level of performance in the standardised tests in both subjects in 2021 and subsequent years. The precisely estimated null effect implies that students who followed their lessons online for 20 to 25 % of their schooling days obtained the same results in the standardised test as those who attended their lessons in person. We argue that such a null effect of online learning on grade 8 students supports our choice of using this group as a valid comparison group for grade 13 students.

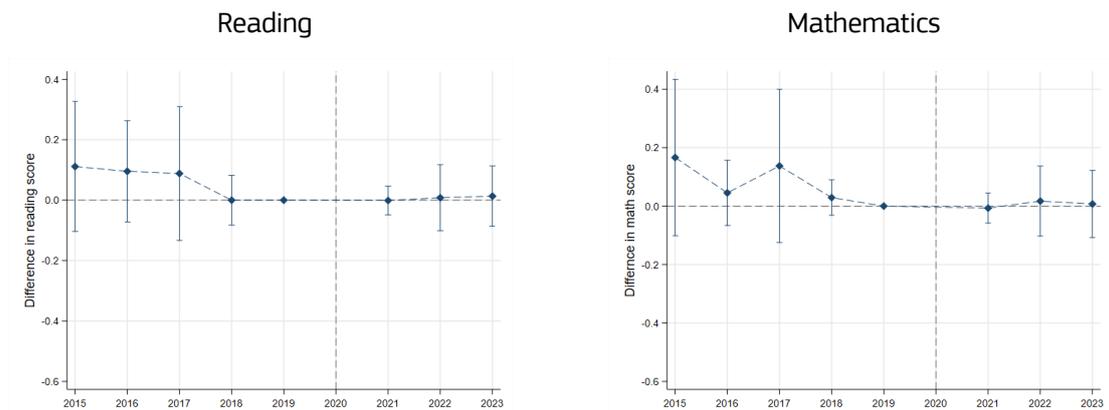
⁽³³⁾ The regions are Lombardia (online learning for 21 % of schooling days), Campania (24 %) and Valle d'Aosta (21 %), while the regions that had all their lesson in person were Liguria and Umbria.

Figure B1: Mean standardised test scores in grade 8



Notes: Mean standardised test scores for reading (left) and mathematics (right) between 2015 and 2023 for grade 8 students in regions with online learning for more than 20 % of the schooling days (online) and those attending fully in-person lessons (presence) using observation without missing information in the covariates used in the regression analysis. Online regions are Lombardia, Campania and Valle d'Aosta; in-person regions are Liguria and Umbria. Test scores are standardised within grade and subject to have a mean of 0 and an SD of 1 in 2019 using the overall population of students. Years on the x axis represent years in which students took the test. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

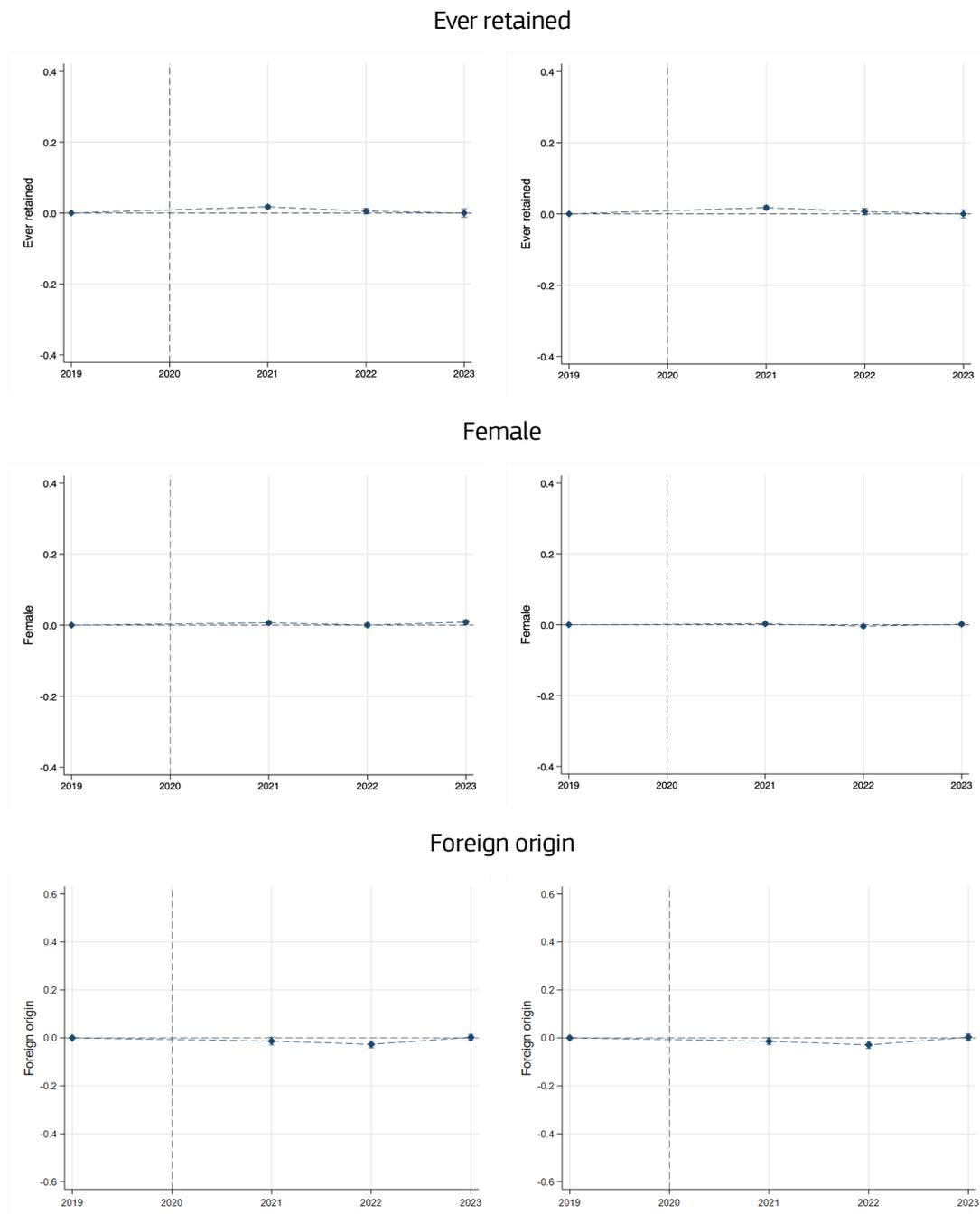
Figure B2: Learning losses due to online learning mandates in grade 8



Notes: Estimates of the DiD specification detailed in Equation 2 comparing the performance of grade 8 students in reading (left) and mathematics (right) standardised tests in regions in online learning for more than 20 % of the schooling days (online) and attending fully in person (presence). Differences are expressed in SDs. Years on the x axis represent years in which students took the test. Control variables are gender, if ever retained, origin, month of birth, ESCS quartile, decile in the national distribution of class size, region and year fixed effects. Vertical bars represent 95 % confidence intervals. Bootstrapped standard errors are clustered at the region level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

Appendix C: Evidence on the stationarity assumption

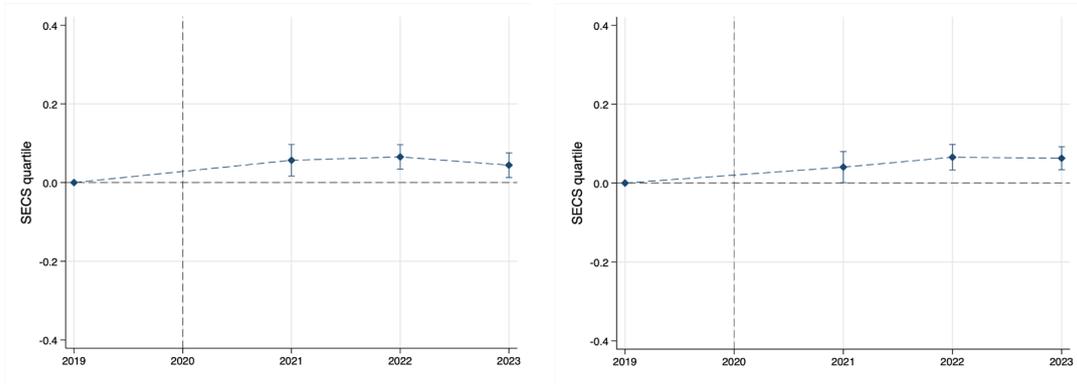
Figure C1: Change in covariates in grades 13 and 8



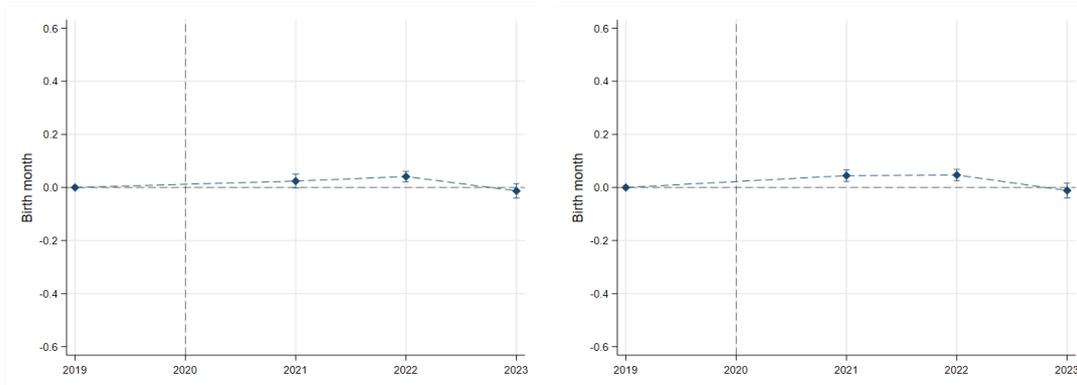
Notes: Estimates of an event study specification representing the difference in the specified covariate between grade 13 and grade 8 students in each year and for each school subject sample: reading (left) and mathematics (right). Controls comprise all the other covariates used in the main analysis as controls and province-by-year fixed effects. Vertical bars represent 95 % confidence intervals. Standard errors are clustered at the region by school grade level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

Figure C2: Change in covariates in grades 13 and 8

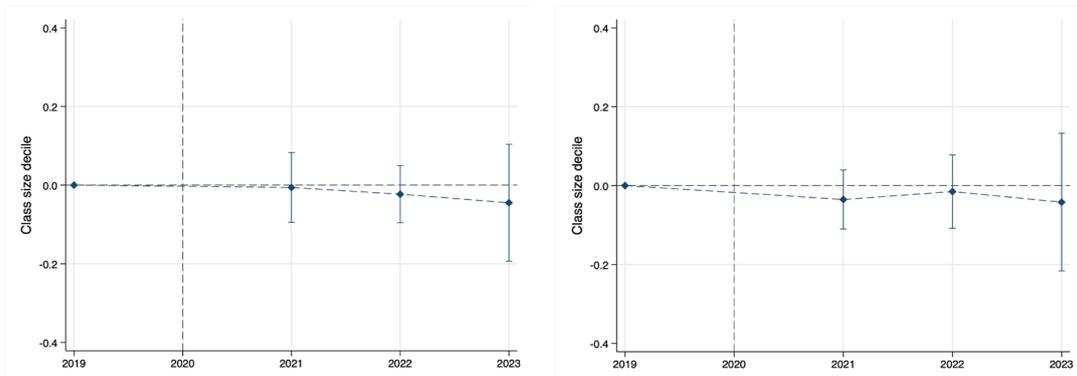
ESCS quartile



Month of birth



Class size deciles



Notes: Estimates of an event study specification representing the difference in the specified covariate between grades 13 and grade 8 students in each year and for each school subject sample: reading (left) and mathematics (right). Controls comprise all the other covariates used in the main analysis as controls and province-by-year fixed effects. Vertical bars represent 95 % confidence intervals. Standard errors are clustered at the region by school grade level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

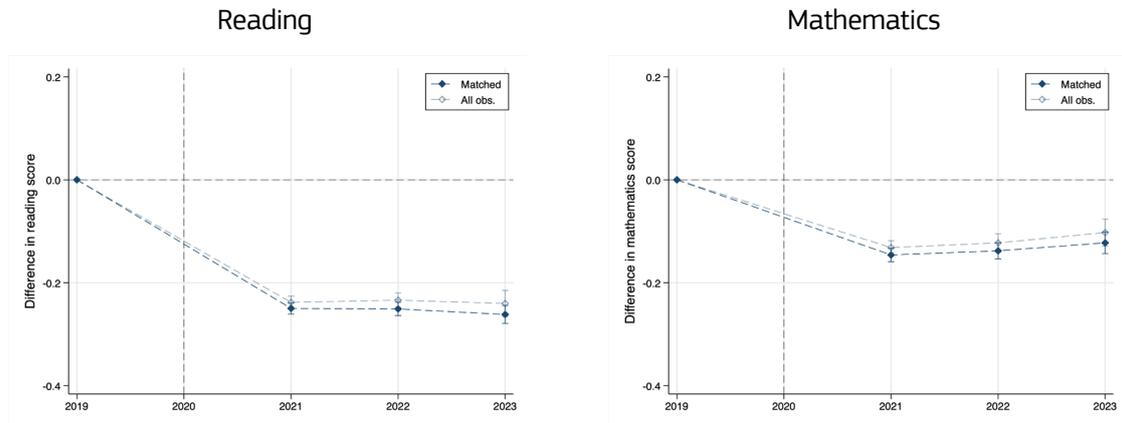
Appendix D: Robustness tests

Table D1: Learning losses due to online learning in different samples

	(1)	(2)	(3)	(4)	(5)	(6)
	All	All	No missing information	No missing information	Matched	Matched
(A) Reading						
Grade 13 × 2021	- 0.228*** (0.010)	- 0.238*** (0.006)	- 0.250*** (0.011)	- 0.249*** (0.006)	- 0.262*** (0.013)	- 0.250*** (0.006)
Grade 13 × 2022	- 0.239*** (0.012)	- 0.234*** (0.007)	- 0.252*** (0.010)	- 0.243*** (0.006)	- 0.251*** (0.009)	- 0.251*** (0.006)
Grade 13 × 2023	- 0.251*** (0.022)	- 0.240*** (0.013)	- 0.278*** (0.025)	- 0.261*** (0.011)	- 0.264*** (0.016)	- 0.262*** (0.009)
Province × Year fixed effects		✓		✓		✓
Controls				✓		✓
Adjusted R^2	0.016	0.062	0.017	0.157	0.019	0.156
Number of observations	3 944 508	3 944 508	3 865 776	3 865 776	3 147 144	3 147 144
(B) Mathematics						
Grade 13 × 2021	- 0.120*** (0.012)	- 0.132*** (0.007)	- 0.140*** (0.012)	- 0.143*** (0.007)	- 0.162*** (0.014)	- 0.146*** (0.006)
Grade 13 × 2022	- 0.131*** (0.016)	- 0.122*** (0.009)	- 0.143*** (0.012)	- 0.130*** (0.007)	- 0.138*** (0.011)	- 0.138*** (0.008)
Grade 13 × 2023	- 0.118*** (0.024)	- 0.103*** (0.013)	- 0.141*** (0.025)	- 0.116*** (0.010)	- 0.124*** (0.015)	- 0.123*** (0.010)
Province × Year fixed effects		✓		✓		✓
Controls				✓		✓
Adjusted R^2	0.009	0.088	0.010	0.153	0.010	0.157
Number of observations	3 958 663	3 958 663	3 879 125	3 879 125	3 097 014	3 097 014

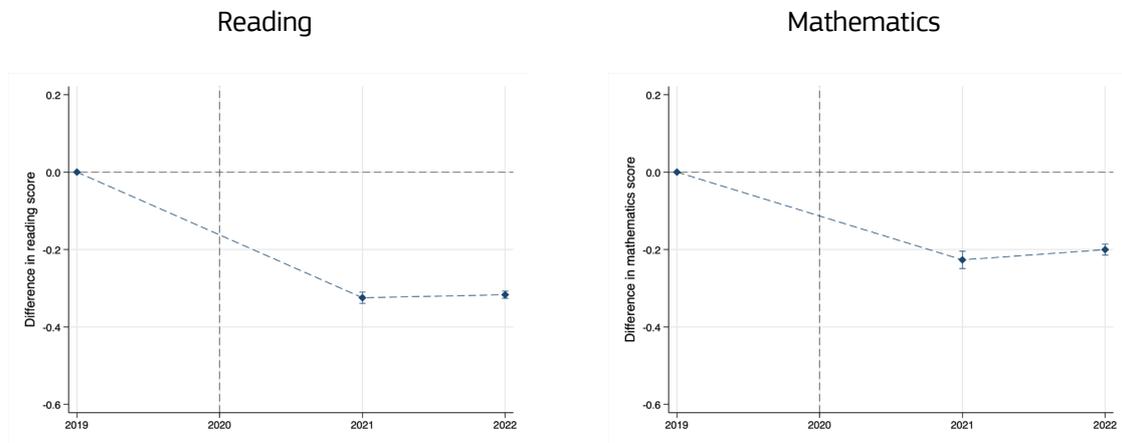
Notes: Estimates of the DiD specification detailed in Equation 1 comparing the performance of grade 13 (online) and grade 8 (presence) students in reading and mathematics standardised tests with respect to 2019 and for different samples. 'All' includes all students; the 'No missing information' sample excludes students with missing information for any variable used in the analysis. The 'Matched' sample is further restricted to students matched using a first-nearest-neighbour matching strategy without replacement. Differences are expressed in SDs. Control variables are gender, origin, if ever retained, month of birth, decile in the national distribution of class size and province-by-year fixed effects. Standard errors are clustered at the region by school grade level. ***, **, * denote significance at the 1 %, 5 % and 10 % level, respectively. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

Figure D1: Learning losses due to online learning mandates



Notes: Estimates of the DiD specification detailed in Equation 1 comparing the performance of grade 13 (online) and grade 8 (presence) students in reading (left) and mathematics (right) standardised tests in two different samples. The 'All observations' sample contains all student observations while the 'Matched' sample is the sample resulting from the matching exercise. Differences are expressed in SDs. Years on the x axis represent years in which students took the test. Control variables are gender, origin, month of birth, if ever retained in a grade, decile in the national distribution of class size and province-by-year fixed effects. Vertical bars represent 95 % confidence intervals. Standard errors are clustered at the region by school grade level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

Figure D2: Learning losses due to online learning mandates, controlling for previous performance

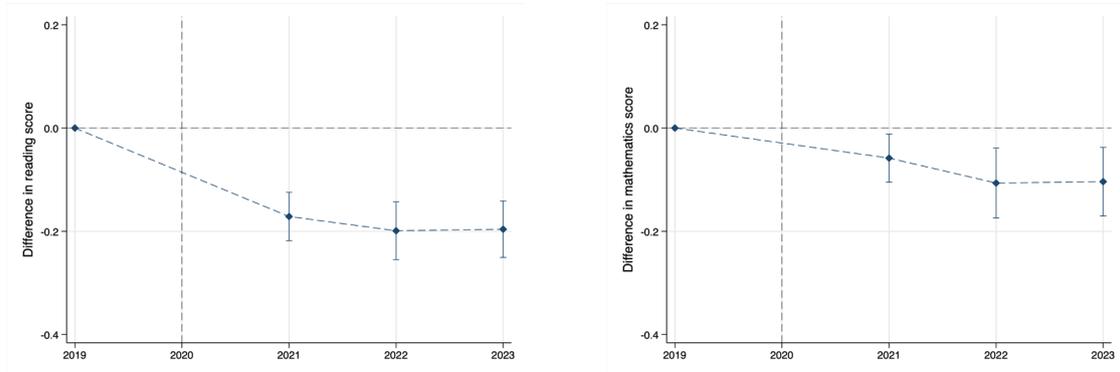


Notes: Estimates of the DiD specification detailed in Equation 1 comparing the performance of grade 13 (online) and grade 8 (presence) students in reading (left) and mathematics (right) standardised tests. Differences are expressed in SDs. Years on the x axis represent years in which students took the test. Control variables are gender, origin, month of birth, if ever retained in a grade, decile in the national distribution of class size, decile of previous test score and province-by-year fixed effects. Vertical bars represent 95 % confidence intervals. Standard errors are clustered at the region by school grade level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

Figure D3: Learning losses due to online learning mandates (sample)

Reading

Mathematics



Notes: Estimates of the DiD specification detailed in Equation 1 comparing the performance of grade 13 (online) and grade 8 (presence) students in reading (left) and mathematics (right) standardised test using the INVALSI sample. Differences are expressed in SDs. Years on the x axis represent years in which students took the test. Control variables are gender, origin, month of birth, if ever retained in a grade, decile in the national distribution of class size and province-by-year fixed effects. Vertical bars represent 95 % confidence intervals. Standard errors are clustered at the region by school grade level. Results for 2020 are not shown, as no INVALSI assessment was carried out that year.

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