

The impact of the COVID-19 pandemic on high-school students' achievements*

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Abstract

This paper estimates the effect of the Covid-19 pandemic on student's achievements in mathematics and literacy, focusing on students in upper secondary school. We compare the achievements of two cohorts of students in Italy, an untreated cohort never exposed to Covid-19 and a treated one who completed upper secondary school in 2021, taking advantage of longitudinal data from national standardised tests for the entire population of students and controlling for initial learning outcomes. We evaluate changing learning inequalities by implementing a novel empirical strategy to address the lack of anchoring in the initial learning outcomes. The pandemic had a substantial negative impact on students' performance in mathematics and in literacy (-0.39 standard deviations and -0.41 s.d., respectively), larger in scientific lyceums and technical tracks. Low-achieving students suffered the most. Learning losses are greater for boys than for girls and for students in the North compared to students in the South of Italy.

JEL codes: I21, I24

Keywords: COVID-19; school closure; learning loss; standardised tests; inequality.

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1. Introduction

Covid-19 pandemic took a toll on the lives of many children both in poor and in rich countries. Children experienced intensified poverty, rise in malnutrition and mortality, worse health outcomes (stemming from strained health systems), mounting risks of violence, exploitation and abuse (as a result of heightened tensions in the household), and learning loss (UNICEF 2022).

In this paper, we concentrate only on the last aspect of this long list, learning loss. At the beginning of the pandemic, in spring 2020, many countries imposed total school closures. The duration of the closures varied considerably between countries, both in relation to timing as the contagion developed and in how governments chose to structure the closures (UNESCO 2023). Learning loss can occur, in particular among weak social groups, through different channels: difficulty accessing remote teaching (as a replacement for in schools teaching), greater absence of children and teachers (due to the contagion), lack of support from parents, lack of relationships and collaboration with classmates, concentration difficulties, and socio-emotional loss. Learning loss is of enormous importance, given the repercussions on social and economic development (UNDP 2020, OECD 2021, Hanusheck and Woessmann 2020).

This paper focuses on the effect of the Covid-19 pandemic on high school students' achievements in Italy, one of the OECD countries with the longest period of school closure. We compare numeracy and literacy achievements of two cohorts of students in Italy, one that experienced the pandemic in their last two years of high school and an untreated cohort. We control for initial learning outcomes exploiting a longitudinal data set including all students.

There are several empirical studies aimed at quantifying the effect of the pandemic on school learning in various contexts. They report a general decline, with greater loss for children with a weaker social background. Average learning loss reported in a meta-analysis was equal to -0.17 standard deviations (Betthäuser et al. 2022, Patrinos et al. 2022). Considering that one year of school learning is equivalent to 0.33 s.d. (Hanushek and Woessmann 2020), the loss is equivalent to about 50 percent of a school year. However, the impact varies considerably across countries, age groups and measures taken to contain the pandemic. Since these studies, in part due to data availability, adopt different methods of analysis, it is difficult to make precise comparisons. Nevertheless, it is clear that losses have been heavier where schools have been closed for longer. Among European countries the average school closure at the end of the school year 2019/2020

was 11 weeks with an average learning loss of -0.16 s.d., implying that a week of school closure is equivalent to a loss of 0.015 s.d. The pandemic increased educational inequalities by socio-economic background and initial skills. Most studies found that low-performing students lost the most, with an exception for a study done in Denmark (Birkelund and Karlson 2022).

Our contribution to the existing literature is twofold. We look at the case of Italy, one of the countries that experienced the longest school closures and, in addition, focus on the learning loss suffered by students affected by the pandemic at the end of high school (grade 13), a schooling level for which there are still no dedicated studies.

During the first outbreak of the pandemic (Spring 2020) schools were closed for 15 weeks from the beginning of March 2020 until end of the school year. In the following school year, 2020/2021, schools were closed intermittently, with alternating periods of total closure, total opening, and closure limited to regions with a high spread of infections. Closures were also based on the occurrence of cases in each class/ school. Since November 2020, the closures have especially affected children in high school, where schools were closed in between 10 and 24 weeks. Relative to other countries, Italy lacked digital skills and proper infrastructures for remote learning as a replacement for face-to-face teaching, leading to worse outcomes. Before the outbreak of the pandemic, Italy had one of the lowest scores in the Digital Economy and Society Index (DESI) in the European Union, one of the lowest shares of households with a fixed broadband subscription, and one of the lowest shares of individuals with at least basic software skills (European Commission 2020). These figures are mirrored within school settings, with teachers usually having low ICT skills and little experience with blended and technology-enhanced teaching (OECD 2018, European Schoolnet 2012).

In addition to focusing on the end of high school we also analyse losses by subject specialisation (school tracks). High school students in their last year are of particular interest both because high schools were closed longer than other grades and because they are about to enter the labour market or embark on a university course without having an opportunity to catch up. Taking advantage of longitudinal administrative data on students' learning over their school career, we apply difference-in-difference techniques to examine the achievements in language and math. We compare results of the cohort of students hit by the pandemic in grade 13 with that of the previous cohort, controlling for previous achievements in grade 10. Controlling for previous achievements is important because initial skills could vary among cohorts for reasons not related to the pandemic

(Werner and Woessman 2022). We also analyse how inequalities in educational outcomes have changed in relationship to prior performances, gender, parental education, migration background and geographical area. We use a difference-in-difference model for standardised test scores within each cohort, to address the fact that not all the assessments examined provide horizontally anchored scores. Horizontal anchoring is a way to construct standardised tests for the same grade that are comparable across cohorts. In our data set, test scores for grade 13 are anchored and therefore comparable but test scores for grade 10 are not. To overcome this issue, we apply a novel statistical methodology that consists of standardising within cohort. This is a strategy that can be applied whenever assessments are not horizontally anchored.

In Italy, previous studies focused on primary and lower secondary schools and reported mixed results. Contini et al. (2022) estimated the effects of the pandemic on the mathematics achievement of primary school children in the city of Turin and found a loss in math achievements due to the pandemic. Borgonovi and Ferrara (2022) examined the impact of COVID-19 on students' achievement in mathematics and reading in primary and lower secondary schools. They found a positive effect of the pandemic on primary school children's' achievements and a negative effect for lower upper school students. Another study (Bazoli et al. 2022) estimated the effects of the pandemic on the overall level of reading and mathematics achievement of samples of Italian students from primary, lower secondary and upper secondary schools as well as the effects on students with different levels of socio-economic condition (SES). Their study does not directly control for students' achievements in previous grades. To overcome compositional effects between different cohorts of students, their identification strategy relies on a matching procedure (coarsened exact matching). Our paper differs from these previous papers both in focusing on students in the last year of high school (also differentiated by subject specialisation) and in the methodological approach.

Our results reveal that students at the end of high school (grade 13) suffered huge learning losses during the pandemic, in both Italian and mathematics (-0.39 standard deviations and -0.41 s.d., respectively). The effect is larger for the scientific academic track (lyceum) and for technical schools than for other academic tracks or vocational schools. On average, each week of school closure implies a loss of -0.013 s.d. both in math and in Italian (comparable to the finding of -0.014 in the meta-analysis by Betthäuser et al. 2022). Losses vary by regions even after controlling for the different lengths of school closure. The analysis also shows that low-achieving students suffered

the most. Students with low prior skills in grade 10 lose more than students with higher prior skills. One standard deviation more in skills in grade 10 implies an increase in achievements in grade 13 of +0.11 in Italian and +0.16 in math for the Covid cohort compared to the pre-Covid cohort. Overall, inequalities between immigrant and native students and between southern and northern students decreased substantially when comparing students with similar previous achievements. However, due to increased differences in previous skills, the gap has increased overall. In contrast, there is no evidence of an increase in achievement gaps related to parental education. Boys lost ground to girls both in Italian (where girls already did better, so the gap widened) and, to some extent, in mathematics (where girls typically do worse, narrowing the gap).

2. Italian context

2.1 The schooling system

In Italy, children enter formal and compulsory school at the age of 6 yrs. Primary school lasts five years (grade 1 to grade 5; ISCED 1). Then, at age 11 students directly enrol in lower secondary school, which lasts three years (grade 6 to grade 8; ISCED 2). In primary and lower secondary school, schooling is comprehensive, compulsory, and free of charge. The curriculum is the same across schools and students, with minor choices from parents.

At the end of lower secondary school, in grade 8, students take a national exam and choose among several different types of upper secondary schools (ISCED 3), which last 5 years (grade 9 to grade 13)¹. Alternatively, at the end of lower secondary school students can choose to enrol in three-year regional vocational education and training. As compulsory education lasts ten years overall, until age 16, it also includes the first two years of upper secondary school.

Upper secondary schools can be broadly grouped into general (lyceums), technical, and vocational tracks. More specifically, general programs include traditional lyceums – the most academic-oriented options, divided into the humanistic lyceum (classical) and the scientific lyceum – and other lyceums, which include for instance schools with a focus on foreign languages, social sciences, etc. The aim of lyceums is to give students a strong background to pursue higher education, to prepare them both in terms of competences, methodological aspects, and skills such as critical thinking (Eurydice 2023). Technical schools combine general and technical education; they aim at providing students a strong

¹ Students also receive non-binding recommendations by their teachers during the final year of lower secondary school.

background in technological and/or economic subjects, and at preparing them for skilled technical or administrative professions. Vocational schools provide students with vocational background to access a variety of low-skilled occupation, and deliver both three- and five-years program. Upon completion of the five-year school and successful pass of a national exam, students obtain a high school diploma. In theory, then students coming from any track can have access university, but in fact there is a clear gradient across the different tracks on the probability of enrol and in particular completing a college degree (Contini and Salza 2020). In high school, national standardized tests are conducted in grade 10 and grade 13, as described in Section 3.

2.2 The Covid-19 pandemic and school closure

Italy was the first country to enforce strict social restrictions due to the widespread outbreak of Covid-19. During the school year 2019/2020, schools were closed at the national level for about 15 weeks, from the end of February until the end of the school year. In-person instruction was replaced, whenever possible, by distance education, with teachers, pupils, and schools alike largely unprepared and left struggling to cope.

In 2020/2021, school closures were decided at the regional level according to the severity of the pandemic and to the political decisions of the regional authorities. Upper secondary schools were closed for the longest period, with respect to lower grades. During this second year, the replacement of in-person instruction with distance learning was instead mandatory, even if the implementation to distance learning was very uneven.

[to be completed]

3. Data and descriptive statistics

The paper utilises data from the national standardised tests administered by the National Institute for the Evaluation of the Education and Training System (INVALSI). Tests are administrated to the entire population of Italian students (about 500,00 students per grade) in grades 2, 5, 8, 10, and 13 and evaluate students' literacy and numeracy skills.²

The standardised tests have been conducted in late Spring every year since 2008/2009, with some variation depending on the grade: for upper-secondary students, who constitute the focus of our analysis, the assessment in grade 13 was first administered in Spring 2019, in 2020 the survey was suspended due to the pandemic, and it was administered

² Recently, standardized tests in English proficiency have also been introduced.

again in 2021 and in 2022. The assessment in grade 10 was first administered in 2011, but suspended both in 2020 and in 2021 due to the pandemic, and resumed in 2022. Moreover, starting from the 2018/2019 school year onward, INVALSI tests have been horizontally anchored for all school grades, meaning it is possible to compare the test scores of different cohorts in the same grade and detect learning trends. Indeed, the anchoring, introduced to make it possible to compare the results of students exposed to the pandemic with those of previous cohorts, ensure that tests administered in different years share the same psychometric features and difficult level. This paper compares test scores of students enrolled in grade 13 in 2020/2021 – a cohort that experienced school closure due to the pandemic – with the test scores of students enrolled in grade 13 in 2018/2019 – a cohort that did not experience the school closure. The pre-Covid cohort took the INVALSI tests in spring 2019, the Covid cohort in spring 2021. Moreover, thanks to the longitudinal nature of the survey, it is possible to link test scores in grade 10 at the individual level. In particular, for the pre-Covid cohort we match the data set for grade 13 in 2019 with the dataset for grade 10 in 2016 and for the Covid cohort the data set for grade 13 in 2021 with the dataset for grade 10 in 2018 (Figure 1).

[Figure 1. Data used in the empirical analysis]

As mentioned above in Section 2, upper secondary schools in Italy consists of three tracks: general (lyceums), technical, and vocational tracks. The Italian test is the same across the different tracks, whereas the mathematics test has a common part and a specific part that varies between scientific lyceums and the other tracks.

The initial sample of students in grade 13 is composed by 879,786 students, including both students in the Covid and in the pre-Covid cohort. Students were excluded because they were absent either at the math or Italian INVALSI assessments in grade 13, our outcome of interest; other were excluded because it was not possible to match them with their prior test scores, due to absences in grade 10 or grade retention in between. Still, the longitudinal match has been possible for the majority of the students. In the end, our final sample – comprising the two cohorts of interest – is composed of 618,226 individual observations, 289,938 in the pre-Covid cohort (47%) and 329,029 in the Covid cohort (53%) (see Table A1 in the Appendix).

Table 1 reports the descriptive statistics both for the entire sample and separately for the two cohorts. Test scores are standardized by INVALSI to have mean 200 and standard

deviation 40. To ease comparability with other studies and the interpretation of the results, we have rescaled test scores to mean 0 and standard deviation 1 in the original full population. When horizontally anchored (as in grade 13), this means that students' scores are directly comparable. In Table 1, we observe that the mean for grade 13 test scores is above 0 because of sample selection. Also, grade 13 tests scores are higher for the pre-Covid cohort respect to the Covid cohort both in Italian and in Math.

As horizontal anchoring has been implemented since school year 2018/2019, test scores for grade 10 for 2016 and for 2018 were not horizontally anchored. Therefore, they are standardised by INVALSI to have mean 200 and s.d. 40 within each cohort (rescaled to mean 0 and s.d. 1 in our samples), and are not directly comparable (the averages should be equal to 0 for both cohorts and the differences are due to the sample selection).

In addition to scores in the standardized test, INVALSI collects information about the teacher's grades in Italian and mathematics at the end of the first term³, students' sociodemographic characteristics, and family background. The set of variables includes the students age, gender, and migratory status, parents' level of education and occupation, and geographic area. All the variables used in the analysis are described in Table A.2 of the Appendix.

[Table 1. Descriptive statistics by cohort]

4. Identification strategy

4.1 Average effects

Our starting point is a model for achievement at a given stage of schooling, based on a standard education production function:

$$Y_{1ij} = \alpha + \lambda X_{ij} + \gamma Y_{0ij} + \delta_j + \varepsilon_{ij} \quad (1)$$

where Y_{1ij} is a standardized test in numeracy or literacy set by child i in school j , Y_{0ij} is a vector of prior skills measured at the time of the previous assessment; X_{ij} is a vector of controls, including sociodemographic variables (age, gender, migratory background, parental education and occupation). δ_j are schools fixed effects interpretable as the schools' value-added and ε_{ij} are normally distributed stochastic errors.⁴

³ They can range between 0 and 10 (6 is the pass grade).

⁴ Due to the presence of school fixed effects, we cannot identify geographical effects, that are nevertheless kept under control.

To assess the average impact of the pandemic on children's learning, we could resort to a difference-in-difference model comparing achievements of children in the post-pandemic cohort with those of children in the pre-pandemic cohort:⁵

$$Y_{1ikj} = \alpha_0 + \alpha_1 C_k + \lambda X_{ikj} + \gamma Y_{0ikj} + \delta_j + e_{ikj} \quad (2)$$

C_k is a dummy variable equal to 1 if the child is in the Covid cohort k and 0 otherwise and X_{ikj} and Y_{0ikj} are the explanatory variable previously defined corresponding to cohort k . α_1 is the coefficient of interest, ideally capturing the causal effect of being in the Covid cohort rather than in the pre-Covid cohort, given previous performance in math and Italian. The untestable identifying assumption is that, conditional on prior abilities, the performance of children in the Covid cohort would have been the same as the pre-Covid cohort, had the pandemic not occurred.

4.2 Length of school closure and regional differences

Regional differences of the impact of the pandemic can be investigated by estimating an extended version of model (2), where θ_r are the coefficients of the interaction terms between regional dummies and the Covid cohort.

$$Y_{1ijkr} = \alpha_0 + \theta_r C_k + \lambda X_{ijkr} + \gamma Y_{0ijkr} + \delta_{jr} + e_{ijkr} \quad (3)$$

As we will see, territorial differences are marked. Since the duration of school closures was defined regionally and varied significantly across regions, it is interesting to assess whether the observed regional differences can be explained by the duration of school closures. In this perspective, we estimate a model that includes the number of weeks of school closures W_{kr} , which varies only at the regional level, and takes value 0 in the pre-Covid cohort:

$$Y_{1ijkr} = \alpha_0 + \theta_r C_k + \beta W_{kr} + \lambda X_{ijkr} + \gamma Y_{0ijkr} + \delta_{jr} + e_{ijkr} \quad (4)$$

⁵ Assuming constant effects of explanatory variables across cohorts, the effect of the pandemic would be captured by constant term variation. If these assumptions are not valid, the coefficient of the cohort dummy can be considered an approximation of the average impact of the pandemic.

If closing weeks were entirely responsible for spatial differences, the region-specific coefficients of the Covid-cohort variable should become non-statistically significant.^{6,7}

4.3 Heterogeneous effects and the anchoring issue

In addition to the average effect, we are interested in assessing how inequalities between socio-demographic groups have evolved due to the pandemic. Allowing coefficients and school-specific fixed effects in (1) to vary across cohorts – and naming coefficients of the pre-Covid cohort with subscript 0 and coefficients of the Covid cohort with subscript 1 – we obtain the following specification:

$$Y_{ijk} = \alpha_0 + (\alpha_1 - \alpha_0)C_k + \lambda_0 X_{ijk} + (\lambda_1 - \lambda_0)C_k X_{ijk} + \gamma_0 Y_{0ijk} + (\gamma_1 - \gamma_0)C_k Y_{0ijk} + (\delta_{jk} + \varepsilon_{ijk}) \quad (5)$$

where the coefficients of interest are those of the interaction terms, capturing the extent to which the effects of individual variables and prior abilities varied before and after Covid. If only the constant term is allowed to vary across the two cohorts, this model boils down to (2).

A possible limitation of this empirical strategy in the present context – that has not been acknowledged in the literature – is that for the school years of interest, the assessments in grade 10 were not horizontally anchored. Thus, in equations (2)-(5) what we are doing is regressing the appropriately anchored results relative to grade 13 (conceivable as absolute measures of performance), on within-cohort standardised test scores in grade 10 (conceivable as relative measures of performance). This could provide biased estimates of the impact of the pandemic. If, for example, children's performance in grade 10 has deteriorated on average between the two cohorts, when we analyse the absolute performance of students in grade 13 given their relative position in the ability distribution in grade 10, we end up equating students who actually have different prior absolute performance. In this case, sharing the same relative position in the two cohorts

⁶ This model has one extra coefficient, so identification is obtained by setting one of the regions' θ_r (in this case, Lombardy) to 0. The effect of the pandemic in Lombardy is represented by β_1 times the n° of weeks of closures in Lombardy. The remaining θ_r s represent the additional effect in region r that is not captured by $\beta_1 W_r$.

⁷ We could also estimate a model with W_r and no θ_r s. The coefficient of the weeks of closures captures in this case the average effect of one week of closure over the country and is approximately equal to the total effect of the pandemic divided by the average number of weeks of closures (see results in the Appendix).

would imply a lower absolute performance in the post-pandemic cohort. Consequently, we would overestimate the negative effect of the pandemic.

A naive alternative, empirically feasible in our context, would be to compare the outcomes of the Covid and pre-Covid cohorts in a regression framework, but not controlling for prior ability. However, as pointed out by Werner and Woessman (2022), the causal effect of the pandemic on student outcomes should not be estimated with cross-sectional data on different cohorts, because the two cohorts might have different abilities for reasons not attributable to the pandemic per se.

To tackle the ‘anchoring’ issue we propose an alternative strategy that does not allow to identify the average effect of the pandemic but allows to analyse how inequalities across social groups evolved during the pandemic. This strategy applies to all circumstances where some (or all) assessments provide unanchored scores.⁸ Instead of focusing on absolute performance measures, we analyse the changes in the relative positions of each social group in grade 13 before and after Covid-19 school closures, given their prior relative position.

Let us define Z_1 and Z_0 as the within-cohort standardized test scores in the two grades of interest, so that $E(Z_1) = E(Z_0) = 0$. It can be shown that if we standardize scores, single cohort models have the same structure of (1):

$$Z_{1ij} = \alpha' + \lambda'X_{ij} + \gamma'Z_{0ij} + \delta'_j + \varepsilon'_{ij} \quad (6)$$

and consequently, the DiD model becomes:

$$\begin{aligned} Z_{1ijk} = & \alpha'_0 + (\alpha'_1 - \alpha'_0)C_k + \lambda'_0X_{ijk} + (\lambda'_1 - \lambda'_0)C_kX_{ijk} + \gamma'_0Z_{ijk} \\ & + (\gamma'_1 - \gamma'_0)C_kZ_{ijk} + (\delta'_{jk} + \varepsilon'_{ijk}) \end{aligned} \quad (7)$$

The parameters of interest are the coefficients of the interaction terms $(\gamma'_1 - \gamma'_0)$ and $(\lambda'_1 - \lambda'_0)$, capturing the differential effects on learning in the two cohorts. The first, by prior skills; the second, by gender, parents’ education, and migratory background. The coefficient of the cohort variable has no meaningful interpretation here, as it is simply a rescaling term that ensures a 0 mean for Z . Geographical differences are not identified with school fixed effects: to analyse whether the pandemic increased territorial

⁸ It could also be applied if the outcome variable is not anchored.

disparities, we also estimate a version of this model incorporating regional dummies but no school fixed effects.

While the coefficients of the interactions between each X and the cohort variable represent how differentials across social groups have changed before and after the pandemic when comparing students with the same prior achievements and school features, we also want to answer a more descriptive but very relevant question: what happened to the overall differentials between social groups? To do so we estimate a reduced form of (7), that does not include prior ability, nor school-fixed effects:

$$Z_{1ijk} = \alpha''_0 + (\alpha''_1 - \alpha''_0)C_k + \lambda''_0 X_{ijk} + (\lambda''_1 - \lambda''_0)C_k X_{ijk} + u_{ijk} \quad (8)$$

We will then look at the net effects estimated by model (7) and the overall effects estimated by (8), for each of the coefficients of the X explanatory variables. Again, the parameters of interest are the coefficients of the interaction variables.

What exactly do these coefficients capture in (8)? Consider one single cohort. From (6), the average distance between achievements across social groups (assume here only one binary explanatory variable for simplicity) can be decomposed into three components:

$$\begin{aligned} & E(Z_{1ij}|X=1) - E(Z_{1ij}|X=0) = \\ & = \lambda' + \gamma' [E(Z_{0ij}|X=1) - E(Z_{0ij}|X=0)] [E(\delta'_j|X=1) - E(\delta'_j|X=0)] \end{aligned} \quad (9)$$

The first component captures ‘new’ social inequalities that developed between moment 0 and moment 1 between children with the same prior abilities and in similar schools; the second captures carryover effects of prior achievement gaps; the third is related to possible differences in the average quality of schools attended by children in different social groups. Hence, the coefficient of the interaction terms in (7) capture the gross gain (or loss) of different social groups relative to each other that occurred in the pandemic years, that could be attributed to one of the following mechanisms: differences in ‘new’ gaps developed between grades 10 and 13 given prior abilities and school features, differences in carryover effects of prior ability, differences in the attended schools’ value-added. Schools value-added might have changed relative to each other after the pandemic because some schools were better equipped to deal with critical

moments (good management, good teachers) or had more ICT knowledge, which is particularly important during school closures. Differences in the carryover effects of prior skills may have occurred because higher-achieving students probably show greater attachment to school, are more resilient to unexpected shocks in the teaching environment, and perhaps possess greater ICT skills. Differences in the relative learning between social groups, net of prior achievement and school effects, could be the result of the different resources available to face the difficulties associated with school closures.

5. Results

5.1 Average treatment effects

Table 2 reports the average treatment effects of the Covid-19 pandemic on students' performance in math and in Italian, for all students in grade 13 and by school track, according to the estimates based on equation (2), including all the available set of controls at the individual level and school fixed effects.

Overall, high school students suffered an average loss of 0.39 standard deviations for mathematics and 0.41 standard deviations for Italian due to the pandemic. These can be conceived as huge losses, comparable to the average gain in one year of schooling⁹. The effect is similar for all tracks, although those who suffer the most severe losses are students at Scientific High Schools and Technical institutes, while students at Vocational Institutes suffer the least.

[Table 2. Impact of Covid-19 on math and Italian test scores, grade 13 overall and by school track]

5.2 Length of school closure

Italy is characterized by high regional variation. The South is penalised in terms of school facilities and average test scores are lower (INVALSI 2022). Moreover, the pandemic hit the different regions with different severity, and some choices regarding school closure were done at the regional level, based on idiosyncratic motivations or preferences. Table 3 summarizes the total weeks of school closure over school years 2019/2020 and

⁹ For the US, Bloom et al. (2008) estimated an average gain in reading of about 0.06 s.d. between grades 11 and 12 and of 0.01 in math. Average gains for grade 13 are not available.

2020/2021 across Italian region, which range from 23.4 (Trentino) up to 37.4 (Puglia).¹⁰ Puglia is the region with the longest period of school closure, almost two months longer than the Italian average.

[Table 3. Length of school closure in 2019/20 and 2020/21 school years
across Italian regions]

Figure 2 presents the heterogeneous impact of the pandemic by region, controlling or not for the number of weeks of school closure. The region of reference is Lombardia, where learning loss are equal to -0.41 s.d. in Italian and math.

Learning losses are very different across regions when we do not control for school closures (blue dots and lines). Learning losses in math vary between -0.55 s.d. (Puglia) and -0.20 s.d. (Valle d'Aosta and Molise). Literacy learning losses vary between -0.58 s.d. (Puglia) and -0.22 (Valle d'Aosta).

Regional differences are partially due to the different number of weeks of school closure. Hence, we replicated the analysis controlling also for the number of weeks of school closures (red lines). Regional differences are reduced as expected but they are not zero i.e. weeks of school closure do not fully explain regional differences.

[Figure 2. Regional differences of COVID-19 on Italian and math school achievements,
grade 13, with and without weeks of school closure]

5.3 Effects on inequalities

With the aim of analysing the effects of the pandemic on inequalities and address the potential problem related to unanchored scores in the pre-test, we estimate models (7), (8) and (9) in terms of z-scores, including interaction terms with all the explanatory variables of interest, for which we wish to evaluate how inequalities have changed between the Pre-Covid and the Covid cohorts.

At first, we focus on results relative to prior skills. In Figure 3 we report average marginal effects of the corresponding interaction term in equation (7). Overall, for one

¹⁰ The total number of weeks of school closure are calculate as the sum of the weeks of school closure in 2019/2020 and 2020/2021. In 2019/2020, schools were closed at national level for about 15 weeks (with minor differences between regions according to the regional school calendars). In 2020/2021, school closures were decided at the regional level according to the spread of the contagion and to the political choices of the regional authorities.

standard deviation increase in test scores in grade 10 in mathematics/Italian, mathematics/Italian test scores in grade 13 increase by 0.11/0.16 s.d. more in the Covid cohort than in the previous cohort i.e. previously low-performing children have lost more than high-performing ones during Covid and inequalities by ability have widened significantly. Looking at the results by school track, we see that this trend is more pronounced in lyceums for Italian and in technical schools for achievement in mathematics.

[Figure 3. Changes in the achievement gaps by prior skills due to COVID-19, grade 13]

Next, we describe the results on inequalities by socio-demographic dimensions. The average marginal effects of the cohort by characteristics interaction terms conditional on prior abilities are reported in red (equation 7); unconditional on prior abilities and school fixed effects are presented in blue (equation 8). The former can be thought of as the pandemic effect when comparing students with the same relative positions of previous performance, the latter without controlling for previous performance. We also estimated the model in equation (9), in which school fixed effects are excluded to capture the variation in the overall gaps, but the results end up being very similar to those in model (8)¹¹.

The results for gender differences are presented in Figure 4. Overall, the relative position of girls compared to boys improves after the pandemic, particularly in Italian, but also in mathematics in technical and vocational schools (no differences are observed in scientific lyceums). In view of the result that better performers suffer smaller losses, since on average girls perform lower than boys in mathematics, it is not surprising that the positive effect without controlling for prior attainment is smaller than that observed when the analysis is made *ceteris paribus* also with respect to prior attainment.

Results on differences by parental education are shown in Figure 5. Overall, these inequalities remained virtually unchanged. Most of the observed effects are small and not statistically significant. Figure 6 reports the results by migrant background. Children from migrant backgrounds gain a little compared to natives with the same prior achievement. However, since they perform more poorly on average and the lowest-achieving students lost more, overall, they have lost further ground relative to natives. The total gap increased

¹¹ Results are available from the authors upon request.

on average by 0.06 standard deviations in math and by 0.04 standard deviations in Italian between the pre-Covid and Covid cohorts.

[Figure 4. Changes in gender differences due to COVID-19 (girls vs boys), grade 13]

[Figure 5. Changes in parental education inequalities due to COVID-19 (high vs low),
grade 13]

[Figure 6. Changes in migrant vs native inequalities due to COVID-19, grade 13]

The effect of the pandemic on geographical achievement gaps is shown in Figure 7¹². When comparing equally proficient students in grade 10, students living in the South improve significantly over those living in the Northern regions. This improvement is quite impressive, particularly in mathematics, and difficult to explain. It should be noted, however, that achievement gaps along the North-South divide have always been large, with southern students vastly underperforming (INVALSI 2022). The reasons for these differences have been ascribed to the role of the contexts and school quality (Bratti et al??). Thus, the gap, gross of previous performance, appears essentially unchanged due to the widening gap between good and poorly performing students.

[Figure. 7. Changes in geographical inequalities due to COVID-19 (North vs South),
grade 13]

6. Robustness checks

To confirm the validity of our results, we discuss potential issues and present robustness checks to address those concerns. Robustness checks are presented on the main estimates but results are confirmed also in terms of heterogeneous analysis.¹³

Our analytical sample is a subsample of the full population of students who participated to INVALSI assessment in grade 13. Mostly, differences are due because only a subgroup of the total population can be matched to the assessment in grade 10. This can be either due to absences in grade 10, or to grade retention/dropout between

¹² Note that since these differences are not identified with school fixed effects, these results derive from the estimation of a version of models (7) and (8) that does not include them.

¹³ Results are available from the authors upon request.

grade 10 and grade 13. However, if different selection between grade 10 and grade 13 has occurred, this may bias our results.

First, we would like to compare our main results with those for the entire population of students present at the math and Italian assessment in grade 13. For them, by construction, it is not possible to control for prior abilities in grade 10; moreover, instead of having information on parental education and occupation (available from grade 10), only the ESCS is available (Economic, Social and Cultural Status). Table 4 below presents the results for different group of children: (i) for our final sample (obs. 618,226), without controlling for prior abilities, but controlling for the same control variables as in the main specification (parental occupation and education included) (column 1); (ii) for our final sample (obs. 618,226), without controlling for prior abilities, and using the student's ESCS (column 2); (iii) for the entire population of students in grade 13 (obs. 852,862), without controlling for prior abilities, and using the student's ESCS (column 3). The learning deficit due to the pandemic is slightly smaller when we do not control for prior abilities (-0.33 s.d. in math and -0.36 s.d. in Italian, vs. -0.39 s.d and -0.41 s.d. in our preferred specification). No difference emerges due to other control variables and – most importantly – to sample selection.

[Table 4. Impact of COVID-19 on math and Italian school achievements in grade 13, not controlling for prior achievements in grade 10 - final sample and the entire population]

A second robustness takes into consideration the lack of grade retention in school year 2019/20. In school year 2019/2020 grade retention was suspended for all students because of the school closure implemented in February-March 2020. School and teachers were unprepared to cope with the new situation, remote learning was not mandatory and only oral exams would have been feasible. Therefore, the Italian government decided to suspend grade retention for all students. 12 grade low performing students (who would have been retained in grade 12 otherwise) enrolled in grade 13 and they attended the grade 13 INVALSI test in May 2021. To account for this, we retrieved the proportion of students who have been held back between grade 12 and grade 13 in school year 2018/2019 for each school track: 3.33% in Scientific high school, 2.95% in other lyceums, 7.15% in

Technical track, and 10% in Vocational track.¹⁴ Then, we eliminated the same proportion of low-performing students by the schools of each track. Results are presented in Column 2 of Table 5, and are very similar to the main estimates, reported in Column 1.

A third robustness check excludes two outlier regions (Puglia and Campania) that had a much longer school closure during the pandemic (37.4 and 34.8 weeks, respectively). Puglia also has a much larger proportion of attrition in the Covid cohort, namely the proportion of students present in grade 10 who did not participate to grade 13 assessment (0.59) (Table A.3 in the Appendix –). We have thus estimated the main regression excluding Puglia (Column 3 of Table 5) and Campania (Column 4). Results are confirmed.

[Tab. 5. Additional robustness checks of the impact of COVID-19 on Italian and math school achievements: lack of grade retention; outlier regions]

Last, one major issue with national assessments performed during the Covid-19 pandemic is attrition bias. As pointed out by Werner and Woessmann (2022), a larger fraction of students did not participate to the assessments during the pandemic than in normal time. If these students are low achievers, as one would expect, then the learning deficit is underestimated. In our data, we can measure the attrition as the proportion of students who participated in grade 10 assessments and not in grade 13 ones, separately for the Covid and the pre-Covid cohort. As can be seen from Table A.3 in the Appendix, results confirm the expectations: attrition in the Covid cohort amounts to 28% versus 21% in the pre-Covid cohort, with large regional variation. Attrition bias is partially reduced by controlling for prior ability in the main estimates. Nevertheless, we perform two additional exercises.

We estimate the probability of attrition, separately for the pre-Covid and Covid cohort, with a linear probability model. The sample is composed by the population of students who undertook the national assessment in math and Italian in grade 10, and the dependent variable is a dummy variable equal to 1 if the student has not participated to the assessment in grade 13, 0 otherwise. Columns 1 and 2 of Table A.4 in the Appendix report the estimates controlling only for the math and Italian test score in grade 10: the highest the score, the lowest the probability of attrition. One standard deviation

¹⁴ Source of data: .

increase in the Italian test score increases the probability of participating by about 6% in the pre-Covid cohort and 7% in the Covid one; for math, the figures are 4% and 5% respectively. As expected, high-performing students in grade 10 are more likely to participate in the grade 13 assessment, slightly more in the Covid cohort. This result is confirmed when controlling for gender, parental education, and migratory background (Columns 3 and 4). Results indicate that also sociodemographic variables predict the probability of attrition: girls, students with high-educated parents, and natives are less more to participate in grade 13 assessment, conditional on their prior ability. Overall, these results point towards a small underestimation of the learning deficit, due to non-participation, as suggested by Werner and Woessmann (2022). However, one may question that the same ability distribution is confirmed three years later.

7. Discussions and conclusions

This paper deals with learning losses due to Covid-19 for high school students in Italy. The topic is particularly important at the macro level because learning losses have a strong negative effect on economic growth and Italy is a country where GDP growth has been very low compared to other European countries in the last 20 years. In terms of human capital accumulation (micro level), we focus on learning losses of students hit by the pandemic during the last two years of high school who entered the labour market and/or academia without the possibility to catch up. Moreover, even before the pandemic, Italy was a country with a very low level of adult literacy and numeracy. The mean proficiency scores of Italian adults in literacy and numeracy are significantly below the average of the OECD countries participating in the Survey of Adult Skills (PIAAC). Also, the young adult population (25-34 year-olds) scores at 260 in literacy, compared to 277 on average in the OECD countries participating in the survey. In numeracy, they score at 262 (272 in average). In addition, more than one quarter of the adult population (16-65 year-olds) report no prior experience with computers or lack very basic computer skills.

In this paper we estimate two main models for learning losses. The first model provides estimates of the average impact of the pandemic on students' learning with a difference in difference model comparing achievements of students in the pandemic cohort (measured in spring 2021 at the end of 13 grade) with students in a pre-pandemic cohort (measured in spring 2019 at the end of grade 13). The average impact is very large both for math (-0.39 s.d.) and in Italian (-0.41 s.d). It is higher for students attending the scientific academic track and the technical schools compared to students in other

academic tracks and vocational track. The magnitude of these losses is comparable to more than one year of schooling and it varies among regions even after controlling for regional differences in length of schools' closure. These results are very worrying considering both the Italian economic situation and the lack of human capital accumulation.

The second model used in the paper provide heterogeneous effect by prior skills (measured in grade ten), gender, parental educational levels, migrant status, geographical areas. This second model introduces a statistical strategy to address the lack of comparability between cohorts for grade 10 tests. We find that grade 13 students with lower abilities in grade ten lost most. The relative position of girls compared to boys improved after the pandemic i.e. boys lost more than girls during the pandemic. Students with a migratory background (both first- and second-generation migrants) lost further ground respect to natives. We did not find any statistically significant difference by parental education.

Our results call strongly for educational policies both at the state and regional level to support the formation of human capital for this generation of students and in particular for the most fragile groups. One possible consequence, given the huge learning losses, is the decrease of students with tertiary education in future years. And unfortunately, Italy in 2021 (last available figure in OECD 2022) was also one of the OECD country with the lowest share of young adults (24-35 years old) with tertiary education (28%) compared with the OECD average of 50 %. Italy in 2021 had also high share of NEET (18-24 yrs adults not in Employment or Formal Education or Training), 26% in 2021 compared to an OECD average of 16%.

In the absence of educational policies to fill these gaps, the increasing inequalities in educational outcomes due to the pandemic will be transmitted to the labour market and boost an increase in income inequalities in the medium and long term

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Tables and Figures

January 26, 2023

Table 1: Descriptive statistics, by cohort

VARIABLES	Overall		Pre-covid cohort		Covid cohort	
	mean	sd	mean	sd	mean	sd
Covid cohort	0.536					
Students' ability						
Italian Invalsi test score in G10	0.095	1.030	0.079	1.125	0.109	0.940
Math Invalsi test score in G10	0.092	1.048	0.056	1.098	0.123	1.001
Italian Invalsi test score in G13	-0.082	1.032	0.130	1.013	-0.266	1.012
Math Invalsi test score in G13	0.009	1.007	0.211	0.999	-0.165	0.981
Italian teachers' mark first term (grade 10)	6.257	1.631	6.282	1.545	6.236	1.702
Math teachers' mark first term (grade 10)	5.953	1.898	5.990	1.836	5.921	1.950
Female	0.519		0.524		0.514	
Age	18.446	0.621	18.449	0.625	18.443	0.617
Native	0.863		0.896		0.834	
Migrant first generation	0.037		0.033		0.040	
Migrant second generation	0.047		0.044		0.050	
At least one parent with university degree	0.277		0.266		0.286	
Paternal occupation						
Unemployed	0.027		0.028		0.025	
Househusband	0.005		0.006		0.004	
Manger/univ. professor/personnel	0.044		0.047		0.043	
Entrepreneur	0.068		0.068		0.069	
Freelance professional	0.176		0.176		0.176	
Self-employed	0.191		0.192		0.191	
Employee, teacher or military	0.120		0.131		0.111	
Other occupation	0.238		0.240		0.236	
Retired	0.020		0.020		0.020	
Maternal occupation						
Unemployed	0.030		0.032		0.028	
Housewife	0.278		0.285		0.272	
Manger/univ. professor/personnel	0.023		0.025		0.022	
Entrepreneur	0.021		0.024		0.018	
Freelance professional	0.108		0.108		0.109	
Self-employed	0.083		0.085		0.081	
Employee, teacher or military	0.196		0.202		0.191	
Other occupation	0.170		0.165		0.174	
Retired	0.003		0.003		0.003	
School track						
Scientific Lyceum	0.268		0.271		0.264	
Other Lyceum	0.300		0.293		0.305	
Technical	0.292		0.296		0.289	
Vocational	0.141		0.140		0.142	
Geographic area						
North	0.470		0.484		0.457	
Centre	0.202		0.191		0.211	
South	0.328		0.325		0.332	
Number of Obs.	618,226		289,197		329,029	

Source:

INVALSI

data.

Table 2: Impact of Covid-19 on math and Italian school achievements, grade 13 overall and by school track

	Grade 13	Lyceum Scientific	Lyceum Other	Technical	Vocational
Math					
Covid	-0.389*** (0.004)	-0.415*** (0.007)	-0.359*** (0.006)	-0.400*** (0.006)	-0.299*** (0.007)
Italian					
Covid	-0.410*** (0.004)	-0.415*** (0.007)	-0.399*** (0.007)	-0.446*** (0.006)	-0.327*** (0.007)
Number of Obs.	618,226	166,859	185,426	180,543	85,398
Initial Abilities	Yes	Yes	Yes	Yes	Yes
Socio-Demogr.	Yes	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes	Yes

Note: Initial abilities include math and Italian INVALSI test scores, and teacher-assigned marks in the subject related to the assessment test (either math or Italian) in grade 10. Sociodemographic controls include gender, first and second generations migrant status, age, parental occupations, and high-educated parents (at least one parent has a tertiary degree). Standard errors in parentheses are clustered at the class level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Length of school closure in 2019/20 and 2020/21 school years across Italian regions

Region	Weeks of school closure
Abruzzo	31.0
Basilicata	31.6
Bolzano	32.2
Calabria	29.2
Campania	34.8
Emilia-Romagna	30.2
Friuli-Venezia Giulia	32.8
Lazio	27.0
Liguria	30.4
Lombardia	32.4
Marche	30.8
Molise	26.8
Piemonte	30.8
Puglia	37.4
Sardegna	27.8
Sicilia	26.8
Toscana	24.4
Trentino-Alto Adige	23.4
Umbria	30.2
Valle D'Aosta	27.8
Veneto	30.2
Italia	29.9

Note: Total weeks of school closure across Italian region for the 2019/20 and 2020/21 school years. For the former school year, the weeks of closure have been measured using the regional planned school calendars provided by the Ministry of Education and Research. For the latter school year, the weeks of closure were retrieved from Duranti et al. (2021)

Table 4: Impact of COVID-19 on math and Italian school achievements in grade 13, not controlling for prior achievements in grade 10 - final sample and the entire population

	Final Sample (1)	Final Sample (2)	Entire Population (3)
Math			
Covid cohort	−0.329*** (0.004)	−0.329*** (0.004)	−0.334*** (0.003)
Number of Obs.	618,226	618,226	852,862
Italian			
Covid cohort	−0.356*** (0.004)	−0.358*** (0.004)	−0.369*** (0.004)
Number of Obs.	618,226	618,226	852,862
Initial Abilities	No	No	No
Socio-Demogr.	Yes	Yes	Yes
School FE	Yes	Yes	Yes

Note: Sociodemographic controls include gender, first and second generations migrant status, age. In Column (1) we control for parental occupations and high-educated parents (at least one parent has a tertiary degree) as in our main specification, while in columns (2) and (3) we control for the student ESCS. Standard errors in parentheses are clustered at the class level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

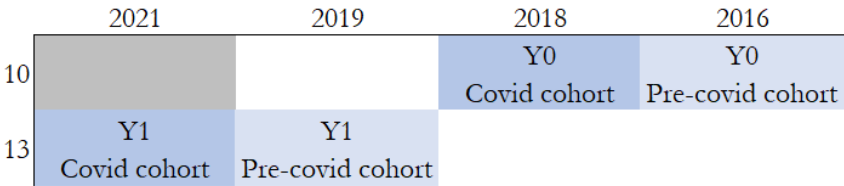
Table 5: Additional robustness checks of the impact of COVID-19 on Italian and math school achievements: lack of grade retention; outlier regions

	Main results (1)	W/o Puglia (2)	W/o Campania (3)	W imputed grade retention ¹ (4)
Math				
Covid cohort	−0.389*** (0.004)	−0.382*** (0.004)	−0.391*** (0.004)	−0.386*** (0.004)
Number of Obs.	618,226	583,892	554,457	601,308
Italian				
Covid cohort	−0.410*** (0.004)	−0.403*** (0.004)	−0.408*** (0.004)	−0.404*** (0.004)
Number of Obs.	618,226	583,892	554,457	601,117
Initial Abilities	Yes	Yes	Yes	Yes
Socio-Demogr.	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes

Note: ¹Deferment was suspended in school year 2019-20, we imputed to the covid cohort a grade retention differentiated by school track (3.33% Scientific Lyceum, 2.95% Other Lyceum, 7.15% Technical and 10% Vocational) based on their performing at the INVALSI test assessment in grade 10. Initial abilities include math and Italian INVALSI test scores, and teacher-assigned marks in the subject related to the assessment test (either math or Italian) in grade 10. Sociodemographic controls include gender, first and second generation migrant status, age, parental occupations, and high-educated parents (at least one parent has a tertiary degree). Standard errors in parentheses are clustered at the class level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

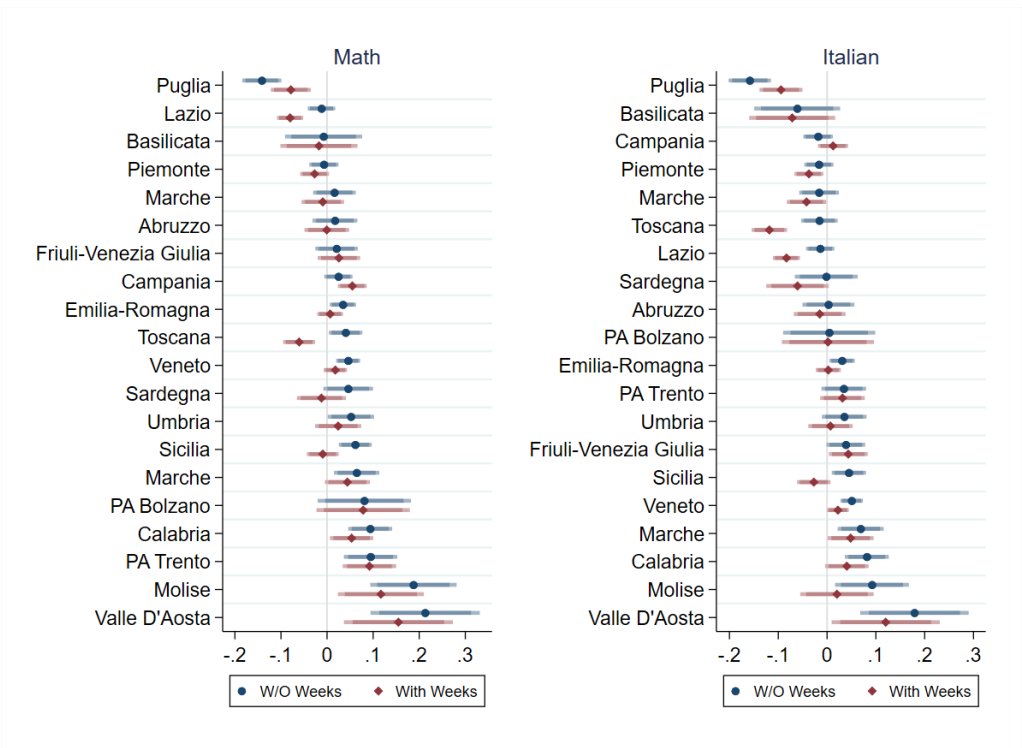
Figures

Figure 1: Data used in the empirical analysis



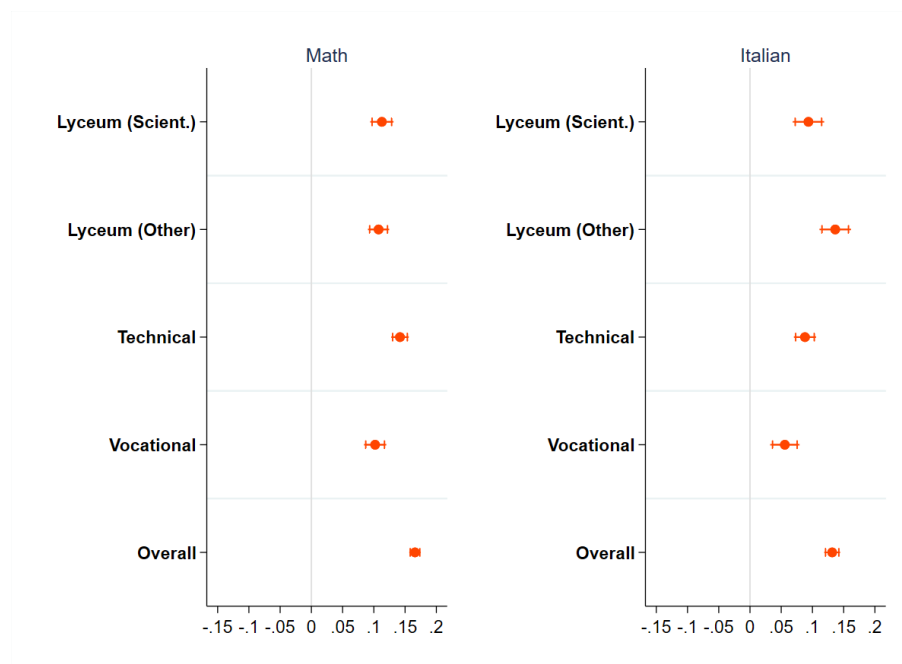
Source: INVALSI data

Figure 2: Regional differences of COVID-19 on math Italian school achievements in grade 13, with and without weeks of school closure



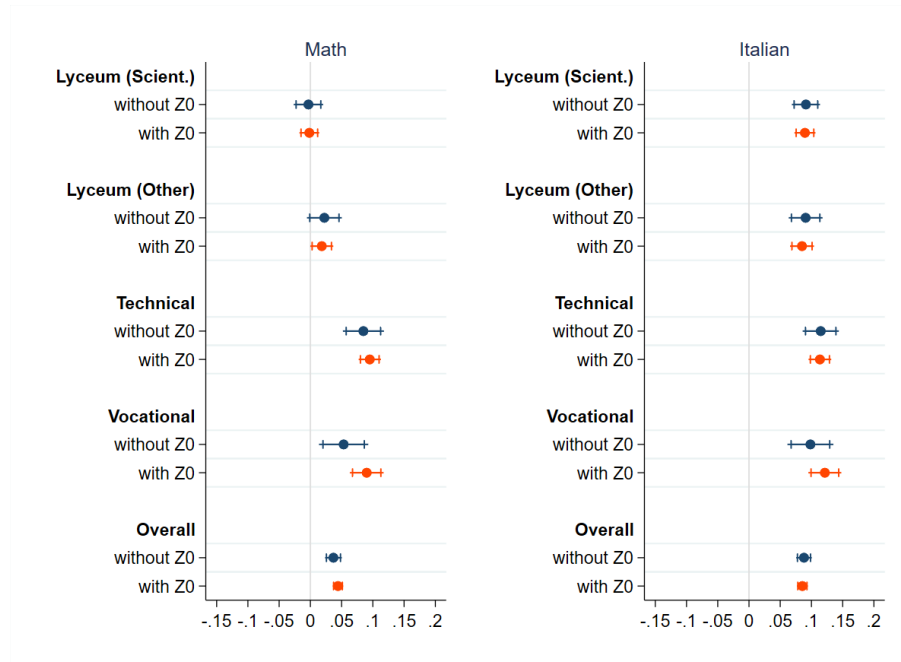
Note: The region of reference is Lombardia, where learning loss are equal to -0.41 s.d. in Italian and math. The estimation models include control for initial abilities (math and Italian INVALSI test scores, teacher-assigned marks in the subject related to the assessment test in grade 10), sociodemographic characteristics (gender, first and second generation migrant status, age, parental occupations, and high-educated parents - at least one parent has a tertiary degree). Confidence intervals at 95% and 90% level.

Figure 3: Changes in the achievement gaps by prior skills due to COVID-19, grade 13



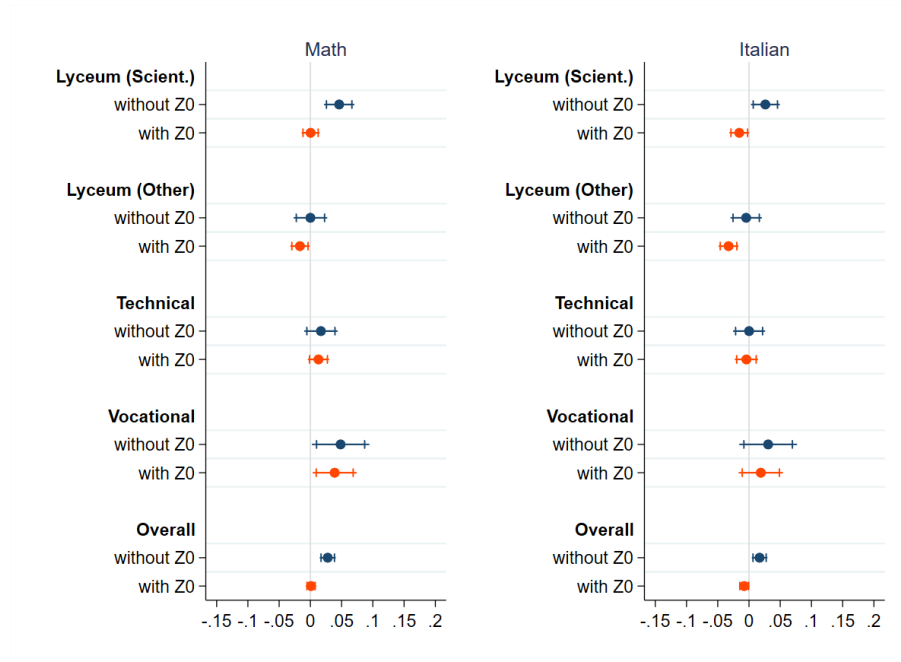
Note: We control for sociodemographic characteristics gender, first/second generation migrant status, age, and high-educated parents (at least one parent has a tertiary degree), school fixed effects. When we consider grade 13 overall, we include a school track variable. Confidence intervals at 95% and 90% level.

Figure 4: Changes in gender differences due to COVID-19 (girls vs boys), grade 13



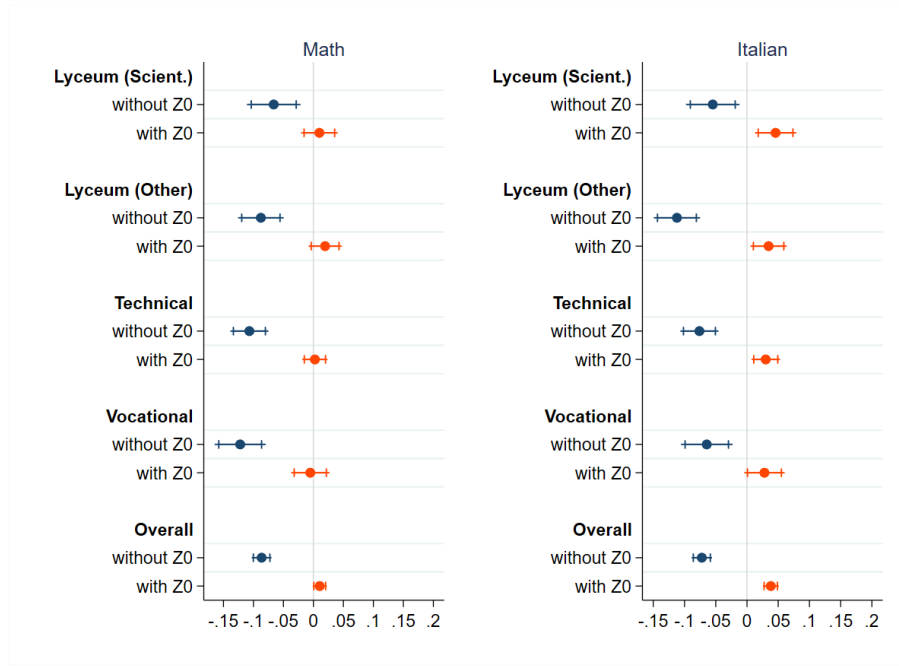
Note: Z0 is student's prior ability in G10 in math (left-hand side analysis) and in Italian (right-hand side analysis), measured with INVALSI test scores in G10 respectively in math and in Italian standardised at cohort level. In the model with Z0, we also control for sociodemographic characteristics (gender, first/second generation migrant status, age, and high-educated parents - at least one parent has a tertiary degree), and school fixed effects. In the model without Z0, we control only for sociodemographic characteristics. When we consider grade 13 overall, we include a school track variable in both models. Confidence intervals at 95% and 90% level.

Figure 5: Changes in parental education inequalities due to COVID-19 (high vs low), grade 13



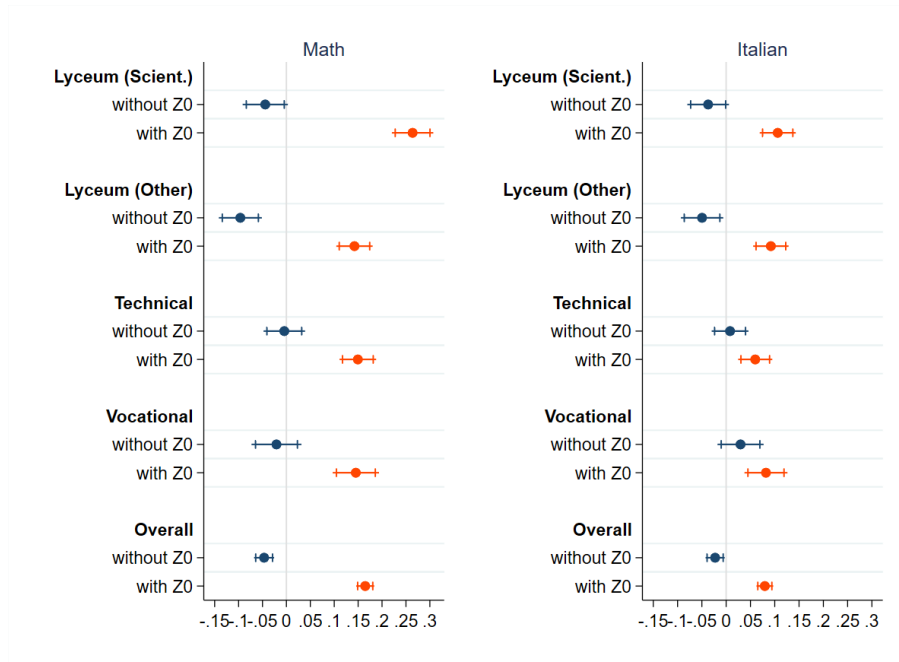
Note: Z0 is student's prior ability in G10 in math (left-hand side analysis) and in Italian (right-hand side analysis), measured with INVALSI test scores in G10 respectively in math and in Italian standardised at cohort level. In the model with Z0, we also control for sociodemographic characteristics (gender, first/second generation migrant status, age, and high-educated parents - at least one parent has a tertiary degree), and school fixed effects. In the model without Z0, we control only for sociodemographic characteristics. When we consider grade 13 overall, we include a school track variable in both models. Confidence intervals at 95% and 90% level.

Figure 6: Changes in migrant vs native inequalities due to COVID-19, grade 13



Note: With the term migrant we refer to students born either in Italy or outside Italy from non-Italian parents (first and second-generation migrant). Z0 is student's prior ability in G10 in math (left-hand side analysis) and in Italian (right-hand side analysis), measured with INVALSI test scores in G10 respectively in math and in Italian standardised at cohort level. In the model with Z0, we also control for sociodemographic characteristics (gender, first/second generation migrant status, age, and high-educated parents - at least one parent has a tertiary degree), and school fixed effects. In the model without Z0, we control only for sociodemographic characteristics. When we consider grade 13 overall, we include a school track variable in both models. Confidence intervals at 95% and 90% level.

Figure 7: Changes in geographical inequalities due to COVID-19 (North vs South), grade 13



Note: Z0 is student's prior ability in G10 in math (left-hand side analysis) and in Italian (right-hand side analysis), measured with INVALSI test scores in G10 respectively in math and in Italian standardised at cohort level. In the model with Z0, we also control for sociodemographic characteristics (gender, first/second generation migrant status, age, and high-educated parents - at least one parent has a tertiary degree). In the model without Z0, we control only for sociodemographic characteristics. When we consider grade 13 overall, we include a school track variable in both models. Confidence intervals at 95% and 90% level.

Appendix

Table A1: Sample selection, by cohort

	Overall	Pre-Covid cohort	Covid cohort
Initial sample G13	879,786	465,774	414,012
Excluding absents from one of the G13 tests or students with duplicate SIDI	853,112	456,879	396,233
Observations without missing values	852,862	456,878	395,984
Excluding not-matched/mismatched observations with sample G10	618,226	289,197	329,029
Final Sample	618,226	289,197	329,029

Note: ¹Pre-covid and covid cohort students who performed at least one grade 13 INVALSI assessment tests in math or in Italian, in the schooling year 2018-19 and 2020-21 respectively. Data source INVALSI.

Table A2: Variable definition

Variable	Definition
Math Invalsi test score in G10	Score in Math INVALSI test, grade 10 (standardised at national level)
Math Invalsi test score in G13	Score in Math INVALSI test, grade 13 (standardised at national level and horizontally anchored)
Italian Invalsi test score in G10	Score in Italian INVALSI test, grade 10 (standardised at national level)
Italian Invalsi test score in G13	Score in Italian INVALSI test, grade 13 (standardised at national level and horizontally anchored)
Math teachers' mark first term (grade 10)	Teachers' mark in math, first term grade 10 (mark that teachers assign to students at the end of the first semester, based on their overall performance during the term; it can range between 0 and 10, and 6 is the pass grade)
Italian teachers' mark first term (grade 10)	Teachers' mark in Italian, first term grade 10 (mark that teachers assign to students at the end of the first semester, based on their overall performance during the term; it can range between 0 and 10, and 6 is the pass grade)
Covid cohort	1 if Covid cohort, 0 if pre-Covid cohort
Female	1 if female, 0 if male
Age	Age of the student
Native	1 if the student is born in Italy with at least one parent born in Italy, 0 otherwise
Migrant 1st generation	1 if the student is born outside Italy from non-Italian parents, 0 otherwise
Migrant 2nd generation	1 if the student is born in Italy from non-Italian parents, 0 otherwise
Low-educated parents	1 if no parent has a tertiary degree, 0 otherwise
High-educated parents	1 if at least one parent has a tertiary degree, 0 otherwise
<i>Mother/father's occupation</i>	
Unemployed	1 if the parent is unemployed, 0 otherwise
Housewife/Househusband	1 if the parent manages the home and often raises children instead of earning money from a job, 0 otherwise

Table A2: Variable definition

Manger/univ. professor/personnel	1 if the parent is a manager, a university professor or a university staff member, 0 otherwise
Entrepreneur	1 if the parent is an entrepreneur, 0 otherwise
Freelance professional, military personnel	1 if the parent is a freelance professional or a military staff member, 0 otherwise
Self-employed	1 if the parent is self-employed, 0 otherwise
Employee, teacher or military	1 if the parent is an employee, a teacher or a military, 0 otherwise
Other occupation	1 if the parent works in none of the mentioned occupational categories, 0 otherwise
Retired	1 if the parent is retired, 0 otherwise
<i>Geographic area</i>	
North	1 if the student lives in the North of Italy, 0 otherwise
Centre	1 if the student lives in the Center of Italy, 0 otherwise
South & Islands	1 if the student lives in the South of Italy or in an Italian island, 0 otherwise
<i>School track</i>	
Scientific Lyceum	1 if the student is in a scientific lyceum, 0 otherwise
Other Lyceum	1 if the student is in a classical, linguistic or other lyceum, 0 otherwise
Technical	1 if the student is in a technical school, 0 otherwise
Vocational	1 if the student is in a vocational school, 0 otherwise

Table A3: Differential attrition from G10 to G13 by cohort

Region	Covid cohort	Pre-Covid cohort	Region	Covid cohort	Pre-Covid cohort
Abruzzo	0.21	0.18	Piemonte	0.28	0.21
Basilicata	0.24	0.18	PA Bolzano	0.25	0.25
Calabria	0.36	0.17	PA Trento	0.16	0.21
Campania	0.36	0.14	Puglia	0.59	0.18
Emilia-Romagna	0.24	0.22	Sardegna	0.34	0.30
Friuli-Venezia Giulia	0.24	0.21	Sicilia	0.22	0.21
Lazio	0.22	0.19	Toscana	0.24	0.23
Liguria	0.24	0.24	Umbria	0.17	0.17
Lombardia	0.24	0.22	Valle D'Aosta	0.26	0.33
Marche	0.20	0.19	Veneto	0.18	0.19
Molise	0.21	0.18			
Italia ¹	0.28	0.21			

Note: Proportion of students who participated in grade 10 assessments and not in grade 13 ones, separately for the Covid and the pre-Covid cohort, across Italian Regions. ¹Average at national level.

Table A4: Probability of not participating in grade 13 assessments given grade 10 participation

	Pre-Covid cohort	Covid cohort	Pre-Covid cohort	Covid cohort
Italian test score, grade 10	−0.057*** (0.001)	−0.069*** (0.001)	−0.039*** (0.001)	−0.051*** (0.001)
Math test score, grade 10	−0.037*** (0.001)	−0.052*** (0.001)	−0.045*** (0.001)	−0.061*** (0.001)
Female			−0.085*** (0.001)	−0.074*** (0.001)
High-educated parents			−0.029*** (0.001)	−0.027*** (0.001)
Migrant first generation			0.206*** (0.003)	0.119*** (0.003)
Migrant second generation			0.113*** (0.003)	0.074*** (0.003)
Constant	0.181*** (0.001)	0.257*** (0.001)	0.214*** (0.001)	0.292*** (0.001)
Number of Obs.	363,025	458,506	363,025	458,506

Note: Estimation of the probability of not participating in grade 13 INVALSI assessment tests in math and in italian, given participation in grade 10, using a linear probability model. High-educated parents: at least one parent has a tertiary degree. Standard errors in parentheses are clustered at the class level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Impact of COVID-19 on math and Italian school achievements by weeks of school closure, grade 13

	Final Sample	Covid cohort Sample
	Math	
Weeks school closure	-0.013*** (0.000)	-0.009*** (0.001)
	Italian	
Weeks school closure	-0.013*** (0.000)	-0.012*** (0.001)
Number of Obs.	618,226	329,029
Initial Abilities	Yes	Yes
Socio-Demogr.	Yes	Yes
School FE	Yes	Yes
Pre-covid cohort	Yes	No

Note: Initial abilities include math and Italian INVALSI test scores, and teacher-assigned marks in the subject related to the assessment test (either math or Italian) in grade 10. Sociodemographic controls include gender, first and second generations migrant status, age, parental occupations, and high-educated parents (at least one parent has a tertiary degree). Standard errors in parentheses are clustered at the class level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.