



## Letter

Dalit Contini, Maria Laura Di Tommaso, Caterina Muratori,  
Daniela Piazzalunga\* and Lucia Schiavon

# Who Lost the Most? Mathematics Achievement during the COVID-19 Pandemic

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**Abstract:** This article estimates the effect of school closures in the spring of 2020 on the math skills of primary school children in Italy, which was the first Western country hit by the COVID-19 pandemic, responding with a strict lockdown and total school closures through the end of the school year. Leveraging unique longitudinal data collected in the province of Torino, a large metropolitan area in northern Italy, we analyse the learning outcomes of two adjacent cohorts of pupils, the pre-Covid and the Covid cohort. The pandemic had a large mean negative impact on pupils' performance in mathematics ( $-0.19$  standard deviations). Learning loss was greater for girls and for high-achieving children of low-educated parents. Net of individual characteristics, the impact was harshest in schools with a disadvantaged social composition.

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\*Corresponding author: Daniela Piazzalunga, University of Trento, Trento, Italy; IZA, Bonn, Germany; and CHILD-Collegio Carlo Alberto, Torino, Italy, E-mail: [daniela.piazzalunga@unitn.it](mailto:daniela.piazzalunga@unitn.it). <https://orcid.org/0000-0002-4765-4971>

Dalit Contini, University of Torino, Torino, Italy, E-mail: [dalit.contini@unito.it](mailto:dalit.contini@unito.it). <https://orcid.org/0000-0002-6903-4060>

Maria Laura Di Tommaso, University of Torino, Torino, Italy; Collegio Carlo Alberto, Torino, Italy; Frisch Center for Economic Research, Oslo, Norway; and CHILD – Collegio Carlo Alberto, Torino, Italy, E-mail: [marialaura.ditommaso@unito.it](mailto:marialaura.ditommaso@unito.it). <https://orcid.org/0000-0002-4626-0508>

Caterina Muratori, University of Torino, Torino, Italy; and University of Reading, Reading, UK, E-mail: [caterina.muratori@carloalberto.org](mailto:caterina.muratori@carloalberto.org)

Lucia Schiavon, University of Verona, Verona, Italy; and CHILD – Collegio Carlo Alberto, Torino, Italy, E-mail: [lucia.schiavon@univr.it](mailto:lucia.schiavon@univr.it). <https://orcid.org/0000-0002-4874-7539>

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## 1 Introduction

In a bid to contain the infection rate of the virus during the Covid-19 pandemic, most countries imposed a series of strict lockdown measures. Schools worldwide were closed for several months starting in spring 2020, raising concern over children's development and the threat of increasing educational inequality.

School closures risk damaging children's education through the replacement of regular school activities with distance learning – deemed less effective than in-person instruction, and dependent on parental involvement and the availability of digital devices at home – and because of dramatic changes in children's peer interactions (Agostinelli et al. 2022; Andrew et al. 2020). Many pupils have also had to cope with parental job loss, disruptions in social ties, lack of after-school activities, crowded dwellings, illness or death of relatives, isolation, and stress related to the pandemic (Bacher-Hicks and Goodman 2021).

The effect of Covid-19 and school closures on pupils' achievements has been investigated in a handful of papers on Anglo-Saxon and Western European countries. Most available studies compare achievement of a cohort exposed to the school closure and previous cohorts using cross-sectional data. Instead, in this paper, we take advantage of unique longitudinal data that we collected in the province of Torino, a large metropolitan area in northern Italy, to evaluate the impact of the pandemic during spring 2020 on the mathematics achievement of primary school pupils. Individual-level longitudinal data allows to account for possible pre-existing differences across cohorts, mitigating concerns of bias (Engzell, Frey, and Verhagen 2021; Werner and Woessmann 2021).

Existing studies report declining achievement and greater educational losses for disadvantaged children. However, the impact may vary across societies, school systems, and measures adopted to contain the pandemic. Italy is a case of particular interest, because it was the first European country to experience the outbreak and rapid transmission of the virus, and the staggering number of infections completely upended the lives of children and their families. The lockdown was accompanied by strict social distancing measures and the closure of business and service activities, with severe repercussions on employment. Italy experienced one of the longest periods of school closures in Europe (15 weeks against a European average of 10), while having a low degree of technological

preparedness to support distance learning (European Commission 2020a). Teachers had low ICT skills and little experience with technology-enhanced teaching (OECD 2018).<sup>1</sup>

## 2 Data Description and Empirical Strategy

We compare the learning progress over one school year made by two adjacent cohorts: the ‘pre-Covid cohort’, made up of children who attended both grades 2 and 3 before the pandemic, and the ‘Covid cohort’, made up of children who attended grade 2 before the pandemic and grade 3 during the pandemic. The latter were exposed to distance learning instead of in-person classroom lessons from February 2020 until the end of the school year.<sup>2</sup>

We construct a unique longitudinal dataset linking data from the national assessment of children’s skills (INVALSI data)<sup>3</sup> – which includes standardised tests in math and Italian administered at the end of grade 2 (the pre-test), teachers’ marks, and socio-demographic variables – to the results from a novel standardised assessment administered by the research team at the end of grade 3 (the post-test).<sup>4</sup> Both cohorts took the pre-test at the end of grade 2, and the post-test approximately one year later. Children in the pre-Covid cohort sat the test at the end of grade 3 (at the end of April 2019). Because of school closures, children in the Covid cohort took the test at the start of the following school year (at the beginning of October 2020).

Data were collected for 2188 children attending primary schools where the pre-Covid cohort had participated in a randomized controlled trial on active learning math instruction (Di Tommaso et al. 2021). Since that intervention proved to benefit only girls, treated girls who had participated in the project were excluded from our main analyses to rule out possible confounding effects. The final sample contains 1539 children (Appendix B, Table B1 presents the descriptive statistics of the sample before dropping treated girls).

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1 Italy ranked 25th out of 28 EU Member States in the 2020 version in the Digital Economy and Society Index (pre-pandemic). The overall fixed broadband take-up, for instance, was 61% compared to the EU average of 78%. For other dimensions, the gap is even larger, most notably Human capital (encompassing digital skills and ICT specialists) and Use of Internet services (European Commission 2020b).

2 In spring 2020, distance learning was not guaranteed. In our sample, it was offered to 85% of the children.

3 Italian National Institute for the Evaluation of Education and Training System. Test details in Appendix A.

4 For details on the test, see Appendix A.

The effects of the Covid-19 pandemic on the math achievements of children were estimated with a difference-in-difference strategy fully exploiting the longitudinal nature of the data (Contini and Cugnata 2020):

$$Y_{likj} = \beta_0 + \beta_1 C_k + \beta_2 Y_{0ikj} + \beta_3 X_{ikj} + \beta_4 D_j + e_{ikj} \quad (1)$$

where  $Y_{likj}$  is the post-test taken by child  $i$  of cohort  $k$  in school  $j$ ;  $C$  is a dummy variable indicating the Covid cohort;  $Y_0$  is the array of initial skills in grade 2;  $X$  is a vector of sociodemographic variables and  $D$  is the school dummy vector. Errors are clustered at the class level. The identifying assumption is that – conditional on the skills displayed in grade 2 – the math performance of children in grade 3 would have been the same in the two cohorts, had the pandemic not occurred.

### 3 Results and Discussion

Overall, the pandemic negatively affected children’s math skills, with an estimated average loss of 0.19 standard deviations in test scores (Table 1), which corresponds to the learning typically occurring in 3 months of school (Bloom, Black, and Lipsey 2008).<sup>5,6</sup> Assuming normality of the distribution, the average impact can be viewed as a downward shift in the children’s test score distribution of 4–5 percentile points. The result does not change much when controlling for class-level variables instead of school fixed effects (Appendix B, Table B2).

However, not all the children seem to have been affected equally. When we include classroom-level interaction terms in the model, we observe an increase in educational inequality across socioeconomic backgrounds, as children in schools where few parents hold a university degree suffered the greatest loss (up to 0.3 SD, Figure 1). This could be because better teachers may self-select into more advantaged schools (Barbieri, Rossetti, and Sestito 2011) or because teachers

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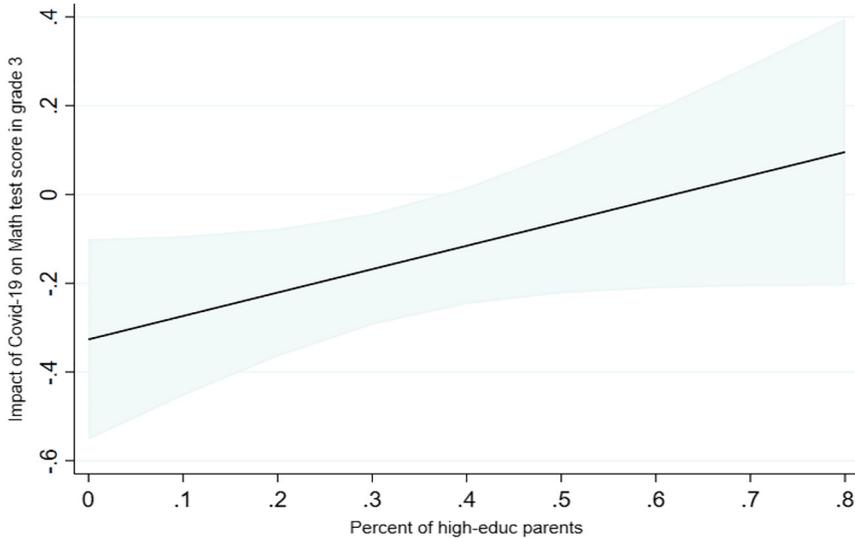
5 The slight misalignment due to the different timing of the post-test (April vs. October) could have two effects: (i) underestimation of the effect, because children in the Covid cohort attended 1.5–2 more months of school; (ii) overestimation of the effect, because children in the Covid cohort experienced a summer break (potentially responsible for learning losses). The two effects may cancel out, but the net effect of the two opposite forces is not known *a priori*. The rough existing estimates of the summer learning loss point to a reduction of about –0.10 standard deviations (Sloan McCombs et al. 2011 – estimates for the US): if we trusted these estimates and disregarded the potential opposite bias, since our average estimate is 0.19 standard deviations, we would conclude that there is still evidence of a sizeable negative effect of the pandemic.

6 We replicate the analysis excluding treated boys from the pre-Covid cohort, and both main and heterogenous results are confirmed (Appendix B, Table B3, Figures B1 and B2).

**Table 1:** Effects of Covid-19 on children’s math achievements.

	Overall Math score (1)	Overall Math score (2)	Low-edu parents Math score (3)	High-edu parents Math score (4)	Low-edu parents Math score (5)	High-edu parents Math score (6)
Covid cohort	-0.188*** (0.053)	-0.167*** (0.056)	-0.198*** (0.065)	-0.164** (0.073)	-0.133* (0.070)	-0.201** (0.085)
Female	-0.226*** (0.031)	-0.189*** (0.055)	-0.215*** (0.041)	-0.240*** (0.066)	-0.105 (0.080)	-0.308*** (0.080)
Covid cohort * female		-0.056 (0.067)			-0.164* (0.092)	0.110 (0.126)
Observations	1539	1539	1038	501	1038	501
R-squared	0.575	0.575	0.585	0.523	0.586	0.524
Initial abilities	Yes	Yes	Yes	Yes	Yes	Yes
Socio-demographic controls	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Standardised math post-test score. Initial abilities: math and Italian standardised test scores in grade 2, teacher-assigned mark in math in grade 2. Socio-demographic controls: high-educated parents (at least one parent with a tertiary degree) and migratory background. Clustered standard errors at class level in parentheses. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1.



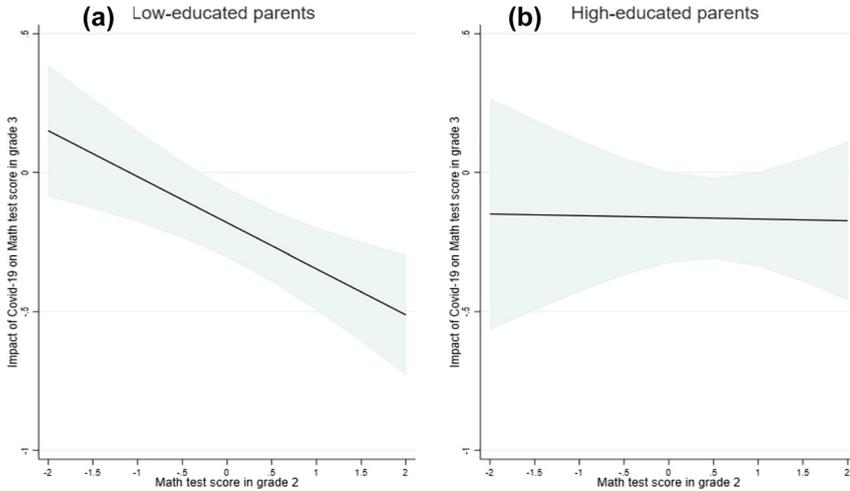
**Figure 1:** Effects of Covid-19 on math achievements by the proportion of high-educated parents in the class.

In the model we control for context variables at the class level and not for school fixed effects. Confidence intervals at 95% based on standard errors clustered at the class level. The results are based on a parametric estimate of model (1), with the addition of an interaction term between the Covid cohort and the percentage of high-educated parents in the class. Full results in Appendix B, Table B2.

in advantaged schools were operating in an environment more conducive to benefiting from distance learning. Similar results were found in Maldonado and De Witte (2022).

Having controlled for class composition, no significant differences appeared at the individual level between children of high and low-educated parents (Table 1). Instead, we find heterogeneity within children with low-educated parents. First, girls experienced a significantly greater loss than boys (Table 1).<sup>7</sup> This result is particularly alarming if we consider that even in ordinary times

<sup>7</sup> We also checked whether heterogeneous effects by gender also emerge in the full sample, but this is not the case (Table 1, column 2): the coefficient of the interaction between being in the Covid cohort and gender is not significantly different from 0. This is due to the fact that the relationship with gender goes in opposite directions for children with low-educated parents (negative and significant) and with high-educated parents (positive and not significant).



**Figure 2:** Effects of Covid-19 on math achievements by initial math skills, by parental education. Low-educated parents: no parent has a tertiary degree. High-educated parents: at least one parent has a tertiary degree. Confidence intervals at 95% based on standard errors clustered at the class level. The results are based on a parametric estimate of model (1), with the addition of an interaction term between the Covid cohort and the Math test score in grade 2, separately for children with low- and high-educated parents. Full results in Appendix B, Table B2.

girls do worse than boys in math in Italy (Contini, Di Tommaso, and Mendolia 2017). One possible explanation for the increasing gender gap is that parents are aware that boys tend to spend less time doing schoolwork and try to compensate by providing additional help (Del Bono et al. 2021). Another explanation is that gender norms are even more influential when school is closed, particularly among children of low-educated parents. Second, among pupils from disadvantaged backgrounds, the ones with the most severe learning loss were those who scored highest on math tests in second grade (Figure 2). Thus, school closure speeds up the process highlighted in Crawford, Macmillan, and Vignoles (2017) of increasing inequality among high-achieving children from different social backgrounds.

The schools in our analytic sample are more advantaged in terms of socioeconomic composition than others at the regional and national levels (Appendix B, Table B4) and the provision of digital technology is higher in the North than in the South of Italy (Istat 2021). Thus, we expect the negative effects of the pandemic on pupil achievement at the national level to be even greater, with harsher consequences on children's skills and on inequalities across socio-demographic groups.

## 4 Conclusions

Italian children faced large learning losses in mathematics resulting from the Covid-19 pandemic and the school closures in the spring of 2020. The pandemic deepened existing inequalities between socio-economic groups, as children attending schools with lower shares of high-educated parents suffered a greater loss. Among children with low-educated parents, the learning loss was greater for those with higher prior mathematical skills; moreover, the loss suffered by girls was double that of boys. If we add to this the possible effects of other disruptions related to Covid-19 pandemic during the following school years and the cumulative effects that these initial losses could develop over time, we can expect dramatic long-term consequences for an entire generation of young people (Cunha et al. 2006). A reduction of about one third of the usual learning gains during grade 3 could yield a loss up to a full year of school by grade 10 (Kaffenberger 2021).

These findings call for urgent policy action. On the one hand, the education system must be given the necessary tools to face possible future crises. On the other hand, remedial measures should be introduced to limit the damage that has already occurred, supporting pupils at high risk of being left behind and encouraging the learning of well-performing children, especially from disadvantaged social backgrounds.

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**Supplementary Material:** The online version of this article offers supplementary material (<https://doi.org/10.1515/bejeap-2021-0447>).