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Quantifying the Macroeconomic Impact of COVID-19-Related School Closures through the Human Capital Channel

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Abstract: This paper uses a new measure of human capital, which distinguishes both quality and quantity components, to estimate the long-term effect of the COVID-19-related school closures on aggregate productivity through the human capital channel. Productivity losses build up over time and are estimated to range between 0.4% and 2.1% after 45 years, for 12 weeks and 2 years of school closure, respectively. These results appear to be broadly consistent with earlier findings in the literature. Two opposing effects might influence these estimates. Online teaching would lower economic costs while learning losses in tertiary education (not considered here) would inflate them. Policies aimed at improving the quality of education and adult training will be needed to offset or, at least, alleviate the impact of the pandemic on human capital.

Keywords: COVID-19; human capital; PISA; PIAAC; productivity; education policies; OECD countries

JEL Classification: E24; I19; I20; I25; I26; I28

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1. Introduction

The COVID-19 pandemic has entailed the partial or full closure of schools in almost all countries around the world. The loss in learning can hardly be made up and so may have a long-term economic impact on the students affected, with possible enduring macroeconomic consequences. This paper provides estimates of the long-term macroeconomic effect of the COVID-19 shock on multi-factor productivity and per capita income. First, the impact of school closure is estimated on both the quantity and quality of education, where the latter is represented by the likely effect on internationally standardised school tests (the OECD's Programme for International Student Assessment, PISA). These quantity and quality effects are then combined into an overall effect on a new measure of human capital using estimated weights based on recent work described in Égert et al. (2022). Human capital is an important pillar of the United Nations' Sustainable Development Goals (SDG): one SDG indeed focuses on education and argues that enhancing human capital to confront future challenges should preferably go through improving the quality of human capital rather than via an increase in the quantity of education. The OECD's PISA assessments is an effective way to monitor progress in the education SDG (OECD 2017).[1]

The impact of these human capital losses on productivity are estimated to range between 0.4% and 2.1% after 45 years for 12 weeks and 2 years of school closure, respectively. These results are broadly in line with earlier findings for the US economy by Dorn et al. (2020) and Viana Costa et al. (2021). They are, admittedly, on the conservative side as they do not include the effects of the pandemic on tertiary education. On the other hand, online learning in primary and secondary schools implemented by countries have presumably alleviated those losses. Policies aiming at improving the quality of education and adult training will be needed to offset or, at least, alleviate the impact of the pandemic on human capital.

The remainder of the paper is organised as follows. Section 2 discusses school closures in OECD countries. Section 3 presents some mitigation measures. Section 4 summarises the findings of the existing literature with regard to the macroeconomic impact of the COVID-19 pandemic. Sections 5 and 6 provide new estimates on the impact of the pandemic on human capital and productivity, respectively. Section 7 provides concluding remarks.

2. Stylised Facts about School Closures in OECD Countries

From March 2020, most countries took the decision to close schools as one of the first actions to fight the spread of the virus. On average across OECD countries, school buildings have been fully closed for 13 weeks and partially closed for a further 24 weeks, between March 2020 and October 2021, which combined is equivalent to around one full school year.[2] These average numbers hide large disparities across countries. While schools in Switzerland and Iceland were closed less than 10 weeks, school closures in Korea, Chile and Colombia lasted nearly one and a half years (Figure 1). These decisions, which were taken with the aim of combating the spread of COVID-19, are likely to have substantial long-term impacts on well-being and the economy via the loss in learning that they entailed. Previous occurrences of school closures, albeit not on a global scale, suggest they shrink the scope of new knowledge and erode previously acquired skills, depending on the extent and quality of virtual learning.[3]

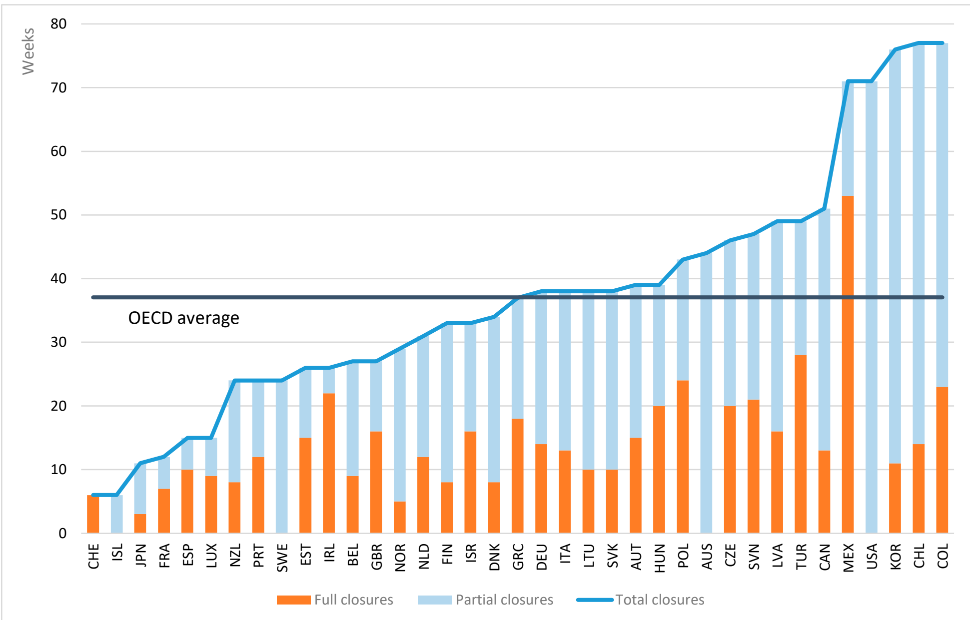

Figure 1. Duration of school closures between March 2020 and October 2021. Note: Full school closures refer to situations where all schools were closed nation-wide due to COVID-19. Partial school closures refer to school closures in some regions or for some grades, or with reduced in-person instruction. Total closures are defined as the simple unweighted sum of these two aggregates. Source: UNESCO.

3. Mitigation Measures Have Been Implemented to Alleviate School Closures

In most OECD countries, teaching continued online or through email and photocopies. In some countries, such as Latvia or the United Kingdom, radio and TV educational programmes were provided.[4] The impact of those measures varies with households' IT endowment[5] and internet access across regions and countries, teacher experience in remote teaching and the ability of parents to help children. Indeed, evidence suggests that students in disadvantaged households, students who do not speak the language of instruction at home, pre-primary students and students at the key point of learning (how to read–write) have been more affected by the pandemic (Azevedo et al. 2020 and Hanushek and Woessmann 2020). Teenagers suffered more in terms of engagement (for those who struggled with autonomous learning), socialisation and mental well-being (isolation, cyberbullying).

As regards internet access, in many OECD countries, less than half of rural households are located in areas where fixed broadband or mobile internet at sufficient speeds was available at the time of school closures. Even when there was no connection problem, some students did not receive a sufficient number of hours of schooling. For instance, at the beginning of the pandemic, in the United Kingdom, 71% of children in State schools received no or less than one daily online class (Green 2020). In Germany, only 6% of students had online lessons on a daily basis and more than half had them less than once a week (Woessmann et al. 2020). Those mitigation measures have probably partly offset the effect of school closures but almost no evaluation of their effectiveness is available yet.

4. The GDP Effect of Pandemic School Closures in the Existing Literature

Human capital plays a key role in growth theory with various empirical macroeconomic studies suggesting that human capital is an important determinant of growth (Lucas 1988; Romer 1990; and Aghion and Howitt 1998). While the pandemic is not fully over, some researchers have already provided estimates of the economic cost of school closures through the human capital channel. Most of them have looked at the loss in lifetime earnings for students affected by the pandemic. These studies suggest that there will be a significant impact on the individuals most directly affected (for a review see Psacharopoulos et al. 2021).

A few papers have tried to quantify the macroeconomic consequences of school closures. Researchers have used different methodologies. For instance, Dorn et al. (2020) set up various scenarios to produce back-of-the-envelope calculations. Viana Costa et al. (2021) derive the economic costs using microsimulation model calculations. The calculations of Hanushek and Woessmann (2020) use macro regression analysis, which links GDP per capita to student test scores in a multi-country error-correction framework.[6] The approach used here is similar in spirit to Hanushek and Woessmann (2020), though it differs in important ways: here a measure of the stock of human capital is used rather than student test scores of specific cohorts and multivariate productivity regressions are estimated linking productivity to human capital in the presence of a number of control variables such as innovation intensity, product market regulation and trade openness.

The empirical findings of the literature, standardised to a one-year school closure, imply a non-negligible impact of the crisis on the level of GDP ranging from −1.1% to −4.7% around 2040–2050 (Table 1). According to Dorn et al. (2020) and Viana Costa et al. (2021), by around 2040/2050, school closures inflict a loss of up to 1.8% on the level of GDP. Hanushek and Woessmann (2020) find a much larger impact of −4.7%.[7]

Table 1. Studies estimating the effect of pandemic-related school closures. Estimated GDP effects rescaled to represent the effect of closing schools for one year.

Authors	Countries	Effect on GDP level
Dorn et al. (2020)	United States	−1.1 to −1.8% (in 2040)
Hanushek and Woessmann (2020)	OECD countries and some emerging economies	−4.7% (in 2050)
Viana Costa et al. (2021)	United States	−1.8% (in 2051)

Note: Impact was calculated for 7 months and 0.8 school-year of school closure for Dorn et al. (2020) and Viana Costa et al. (2021), respectively. For comparison purposes, they have been converted proportionally into an impact for one school-year. The effect reported for Hanushek and Woessmann (2020) in 2050 is the authors' calculation which is based on replicating the Hanushek and Woessmann simulation that reduces GDP by 7.5% in 2100. Source: Authors' compilation.

5. The Impact of School Closures on the Stock of Human Capital

5.1. The Assumptions Underlying the Calculations

All pupils at school in 2020 have been affected by the pandemic. To calculate the effect of the loss in schooling on human capital, a number of simple stylised assumptions are made (Appendix A):

- A child attends school between the age of 3 and 18, so that 16 cohorts are potentially impacted in any year and any country;
- Each cohort impacted will enter the labour market one after the other with the first cohort entering in 2021 (those aged 18 in 2020) and the last one in 2036 (those aged 3 in 2020) (Table 2);
- Assuming a working life of 47 years (roughly between the ages 19 and 65 and assuming no increase in the retirement age), one cohort affected by the pandemic, representing 1/47th of the labour force, will enter the labour force each year. Under these stylised assumptions, by 2033 all the affected cohorts will be in the working age population. At that point, they will represent 32% of the working age population, which will be the peak impact on human capital and will be sustained for around 30 years until the retirement of the first cohort that was affected by school closures (Figure 2). At the same time, cohorts in the labour force in 2021 will gradually retire. By 2083, all the affected cohorts will have retired.

Table 2. Cohorts affected by the pandemic: assumptions.

	Oldest Cohort Affected	Youngest Cohort Affected
Age in 2020	18	3
Year of entry in the labour market	2021	2036
Year of retirement	2068	2083

Note: For the purposes of the stylised example, a person is assumed to go to school from ages 3 to 18 and to work 47 years from ages 19 to 65. Thus, 47 cohorts are in the labour market each year. This is reflected in the fact that the youngest cohort, aged 3 in 2020 enters the labour market in 2036 at the age of 19.

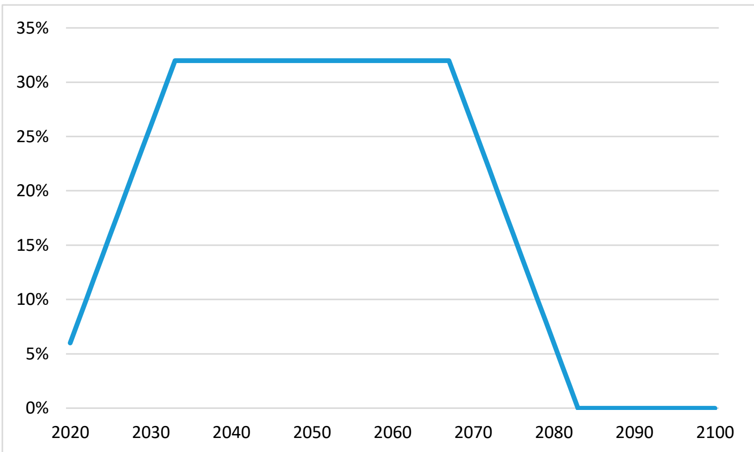

Figure 2. The pandemic's impact on the future labour force. Share of cohorts affected. Note: Figure 2 shows the share of cohorts affected by the pandemic in the working age population. Each cohort is assumed to enter the labour market at age 19 and has a working life of 47 years. The oldest cohort (those aged 18 in 2020) enters in 2021 and the youngest one (those aged 3 in 2020) in 2036. Source: Authors' calculations.

An important assumption is that all cohorts are affected the same way. This might not be completely true for two reasons. First, younger cohorts might suffer more than older ones, if the Heckman hypothesis about the importance of early childhood education holds true (Elango et al. 2015). Second, remote working was working better for older cohorts mastering digital tools better than young kids in kindergarten. This is partly offset by learning losses in the final year of secondary school with no opportunity to catch up the following year (except at university), whereas for younger students, the education system will have many more years to help them catch up.

5.2. The Empirical Estimations Underlying the Impact Analysis

This paper exploits a new measure of human capital, derived in Égert et al. (2022), that makes use of mean years of schooling and OECD data from the Programme for International Student Assessment (PISA) and the Programme for the International Assessment of Adult Competencies (PIAAC). The new measure is a cohort-weighted average of past PISA scores (representing the quality of education) of the working age population and the corresponding mean years of schooling (representing the quantity of education). Weights for PISA and mean years of schooling are estimated from the data. The idea underlying the new measure can be summarised as follows:

- PIAAC adult test scores could be used to calculate a cohort weighted stock measure of human capital. Nevertheless, PIAAC has limited country coverage and the PIAAC-based human capital measure has one observation in time, hence making it ill-suited for cross-country time series regression analysis to establish a link with productivity.
- For this reason, PIAAC adult test scores are matched with mean years of schooling and PISA student test scores of the corresponding cohort who took the student tests as 15-year-olds. PIAAC test scores are then regressed on matched PISA test scores and mean years of schooling. This approach has two important advantages. First, the estimated human capital measure covers a wider set of countries and many more years than is available for PIAAC. Second, and very importantly, the relative weights of the quality and quantity components are not imposed or calibrated, unlike in the existing literature, but are estimated directly.
- Feeding the new stock measure of human capital into productivity regressions shows that the elasticity of the stock of human capital with respect to the quality of education is three to four times larger than for the quantity of education (Table 3). The new measure of human capital shows a robust correlation with productivity for OECD countries in cross-country time-series panel regressions, suggesting that a negative shock to human capital may generate important macroeconomic losses. Annex A visualises the COVID-19 impact.

Table 3. Regression results explaining adult test scores.

			Coefficient of Variation
Dependent variable: log(adult test scores)			1.4
α	Constant	3.732 *** (0.25)	
β	log (Student test score), all cohorts (baseline effect)	0.278 *** (0.04)	1.5
δ	log (Student test score), cohorts 50–59 (additional effect)	−0.009 *** (0.00)	1.4
θ	log (Student test score), cohorts 60–65 (additional effect)	−0.015 *** (0.00)	1.1
λ	log (Mean years of schooling (MYS))	0.083 *** (0.01)	5.0
Adjusted R-squared		0.934	
Number of observations		220	
Number of countries		34	
Country fixed effects		YES	

Note: *** denotes statistical significance at the 1% level, based on heteroscedasticity-robust standard errors (in brackets). PIAAC adult test scores are the average of scores on literacy, numeracy and problem solving. Student test scores are PISA scores extended backwards with two vintages of World Bank data (Altinok et al. 2018) using chain linking the different series in order to obtain the longest time series possible. Student test scores denote the average scores for reading, maths and science. The mean years of schooling represent the average number of years of education of a specific age group by country. The coefficient of variation is equal to the standard deviation divided by the median multiplied by 100. Source: Égert et al. (2022).

Based on this new measure and the elasticities reported in Table 3, the effect of the pandemic can be computed separately on PISA scores and mean years of schooling (MYS).

The existing literature, reported in Table 4, provides the extent of learning losses, as reflected in student tests scores, related to school closures occurring because of pandemic restrictions. These studies compare student test scores before and after school closures in 2020 and 2021. Most results suggest substantial learning losses, despite generalised reliance on distant learning arrangements in all OECD countries.

Table 4. Studies estimating the effect of school closures on student test scores.

Paper	Country	Duration in Weeks	Effect on PISA in Standard Deviation
Gore et al. (2021)	Australia	8	0.00
Maldonado and Witte (2020)	Belgium (Flanders)	9	−0.24
Gambi and de Witte (2021)	Belgium (Flanders)	10	−0.18
Angrist et al. (2020)	Botswana	12	−0.29
Lichand et al. (2021)	Brazil	26	−0.32
Clark et al. (2021)	China	7	−0.22
Vegas (2022)	Colombia	40	−0.20
Korbel and Prokop (2021)	Czech Republic	9	−0.11
Birkelund and Karlson (2021)	Denmark	22	0.00
Schult et al. (2021)	Germany	10	−0.08
Ludewig et al. (2022)	Germany	10	−0.14
Depping et al. (2021)	Germany	8	−0.03
Contini et al. (2021)	Italy	15	−0.19
Asakawa and Ohtake (2021)	Japan	11	0.00
Hevia et al. (2021)	Mexico	48	−0.56
Engzell et al. (2021)	Netherlands	8	−0.08
Haelermans et al. (2021)	Netherlands	10	−0.17
Schuurman et al. (2021)	Netherlands	8	−0.09
Meeter (2021)	Netherlands	10	0.00
van der Velde et al. (2021)	Netherlands	10	0.00
Skar et al. (2021)	Norway	7	−0.24
Jakubowski et al. (2022)	Poland	20	−0.30
Chaban et al. (2022)	Russia	14	−0.27
Ardington et al. (2021)	South Africa	22	−0.22
Arenas and Gortazar (2022)	Spain (Basque country)	12	−0.05
Tomasik et al. (2020)	Switzerland	8	−0.20
Education Policy Institute (2021)	United Kingdom (England)	10	−0.09
UK Department of Education (2021)	United Kingdom	18	−0.17
Blainey and Hannay (2021)	United Kingdom	9	−0.08
Rose et al. (2021)	United Kingdom	13	−0.16
Kuhfeld et al. (2022)	USA	28	−0.19
Kogan and Lavertu (2021)	USA	25	−0.23
Pier et al. (2021)	USA (California)	25	−0.10

Note: The studies cited above estimate the impact of school closures by comparing student test scores before and after school closures. Source: Based on Patrinos et al. (2022) and Storey and Zhang (2021); Authors' compilation.

On the one hand, it seems reasonable to assume that the longer the school closure the larger the learning loss. On the other hand, the additional marginal learning losses due to extended school closures might become weaker over time in the presence of online learning,[8] as (i) students and teachers learn the use of online learning tools over time, (ii) internet access can be improved/subsidised by the government, and (iii) the curriculum and teaching methods can be adjusted.

The hypothesis that learning losses might have become smaller after the 2020 summer break is tested by regressing learning losses on the duration of school closures reported in Table 4. Estimation results reported in Table 5 indicate that marginal learning losses get slightly smaller for school closures longer than 12 weeks.

Table 5. Regression results explaining the effect of the duration of school closure on student test scores by week.

Dependent Variable: Effect of School Closures on Student Test Score in Terms of Standard Deviation	
School closure less than 13 weeks	−0.012 *** (0.002)
School closure equal to or more than 13 weeks	−0.009 *** (0.001)
Adjusted R-squared	0.26
Number of observations	36

Note: *** denotes statistical significance at the 1% level, based on standard errors (in brackets). The impact and the duration of school closure come from Table 4. No constant is included in the regression because no school closure should have no effect on PISA scores. Source: Authors.

Using these estimates, three scenarios are considered:

- The effect of the Spring 2020 school closures experienced in many OECD countries, roughly corresponding to one-third of a school year closure. Such a period of school closure translates into a −2.6% decrease in mean years of schooling[9] and, using the rule-of-thumb described above, a 0.14 standard deviation fall in PISA scores,[10] corresponding to a 1.1% decrease in PISA scores.[11]
- The effect of a one-year school closure, broadly corresponding to the average total (full and partial) school closures observed across OECD countries since the start of the pandemic and, according to a first assessment, to the learning loss of the most disadvantaged students in the United States (U.S. Department of Education 2022). This scenario translates into a −8.2% decrease in MYS and a −0.37 standard deviation fall in PISA scores, corresponding to a 2.9% decrease in PISA scores.
- The effect of a two-year school closure, which occurred only rarely and broadly corresponding to the total (full and partial) school closure in Colombia, Chile, Korea, and Mexico since the start of the pandemic which translates into a −16.5% decrease in MYS and a 5.6% and a −0.72 standard deviation fall in PISA scores.

5.3. The Negative Effect of School Closures in the Alternative Scenarios

For each cohort impacted, the effects of the pandemic on MYS and PISA test scores are added up to estimate the overall effect on human capital. They are calculated using the elasticities of MYS and PISA with respect to human capital from the regression in Table 3. A population-weighted average of the impact of each cohort affected is then calculated to provide the global effect on human capital.

As noted earlier, three scenarios are computed corresponding to three different durations of school closure. For instance, if one observes 2036, the year when the last impacted cohort enters the labour force, in the first scenario (12 weeks of school closures), the combined effect of the loss due to reduced PISA scores and MYS on human capital will amount to −0.2% (−0.1% PISA score and −0.1% MYS) (Table 6). In the second scenario, the combined effect of the losses coming from a reduced PISA score and MYS on human capital will be −0.4% (−0.2% PISA score and −0.2% MYS) and in the last scenario it will reach −0.9% (−0.5% PISA score and −0.4% MYS).

Table 6. The effect of the pandemic on human capital. Effect on human capital and its components in 2038.

	1st Scenario (12-Week Closure)	2nd Scenario (38-Week Closure)	3rd Scenario (76-Week Closure)
Country examples in line with the scenarios	CHE, ISL	GRC, DEU, ITA, LTU, SVK	CHL, KOR, MEX
Mean years of schooling (in school year)	−0.32	−1.00	−2.00
PISA score (in standard deviation)	−0.14	−0.37	−0.72
Human capital (in %)	−0.16	−0.45	−0.87

Note: The school year consists of 38 weeks in an average OECD country. The effect on human capital is a weighted average of the effects on Mean years of schooling and PISA scores, where the weights are estimated in Égert et al. (2022). Source: Authors' calculation.

The overall impact of school closures on human capital will be quite small in the coming years but could amount to a loss of almost 0.9% when all cohorts impacted will have entered the working age population from 2033 onwards, lasting until 2067 when the first cohort retires. The impact is the most important in 2067 as it is the year when all the impacted cohorts are in the older part of the labour force. The impact is the most important as their PISA score is the smallest. The effect of the pandemic will diminish until the last cohort affected retires in 2083 when the pandemic effect disappears (Figure 3).

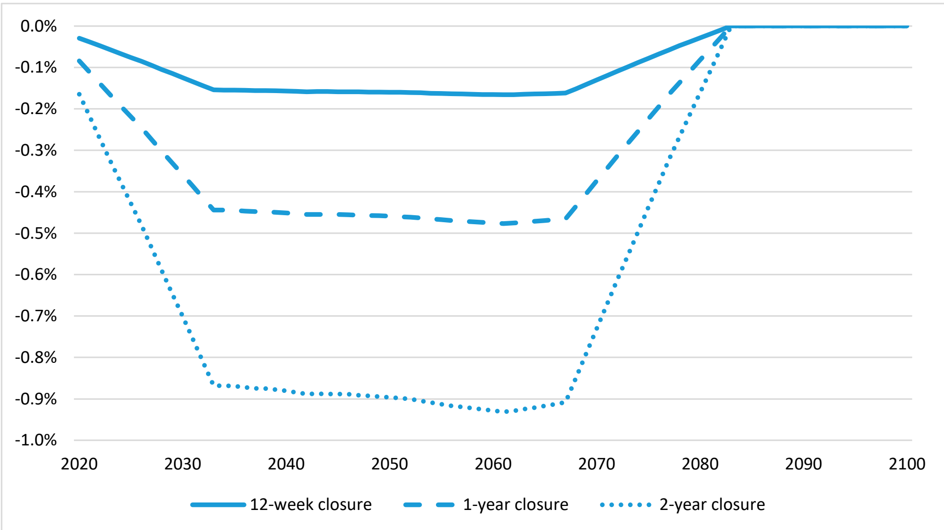

Figure 3. The impact of school closure on human capital. Source: Authors' calculations.

6. The Impact of the Pandemic on Productivity

The impact of the pandemic on productivity (and per capita income) is assessed based on the productivity regressions linking human capital to multi-factor productivity (Table 6). They provide short-run and total long-run impacts and the trajectory to the long-run impact using an error correction model. The adjustment path is calculated using the estimated error correction term and the short-run policy effect from the error correction model.

Compared to most other policies included in the regression analysis, the long-run elasticity from human capital to productivity is relatively large (β = 2.4). The long lags mostly come from the cohort effect. These regressions imply that a one percent increase (decrease) in human capital is associated with a more than 2 percent rise (fall) in long-term productivity (Table 7). The impact on productivity is calculated for each cohort to take into account their differentiated entry in the labour force and their short-run and long-run impacts. A population-weighted average of each single cohort impact is then calculated to provide the total impact on the labour force.

Table 7. Cross-country time series productivity regression. (OECD countries, 1987–2018).

Dependent Variable: Logged Multi-Factor Productivity	Long Run	Short Run
Constant	−2.463	
ETCR indicator	−0.041 **	−0.140 **
Trade openness (adjusted for country size) divided by 100	0.114 **	0.044 **
Business expenditures on R&D (% of GDP)	0.080 **	n.s.
log(Human capital stock)		
Population aged 16–39	2.359 **	1.426 *
Error correction term	−0.049 **	
Adjusted R-squared	0.960	
Number of observations	524	
Number of countries	32	
Time fixed effects	NO	
Country fixed effects	YES	

Note: The human capital stock is based on log-log regression, with CFE. * and ** denote statistical significance at the 10 and 5% levels. Source: Égert et al. (2022).

The impact of school closures on productivity through the human capital effect is estimated for the three above scenarios. The impact will increase gradually as the student cohorts hit by the pandemic enter the labour force, reaching its peak in 2067. At that date, the impact of school closures on productivity will be −0.4%, −1.1% and −2.1% in the first, second and third scenarios, respectively. The impact will then vanish gradually until the last impacted cohort retires in 2083 (Figure 4). The impact is the most important in 2067 as it will be the year when all the impacted cohorts are in the older part of the labour force and the impact on human capital is the most important. These results are broadly consistent with much of the literature except for Hanushek and Woessmann (2020) who found a much larger effect. Those results would be equivalent, *ceteris paribus*, for the effect on GDP per capita.

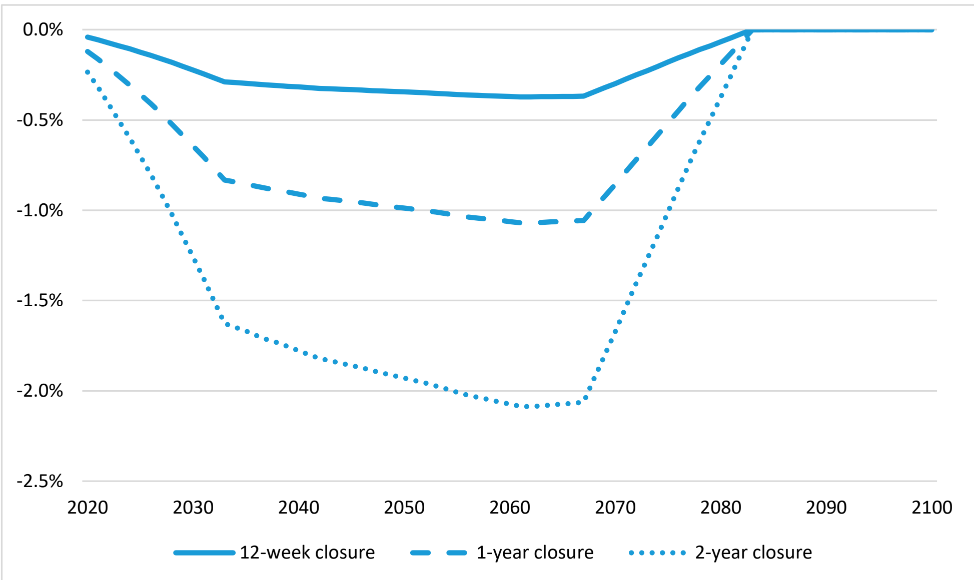

Figure 4. The impact of school closure on productivity. Note: For each year, the impact of the school closures is calculated as $[1-(1+\rho)^{t-1}](\beta x-\gamma x)+\gamma x$, where ρ (−0.49)−, β (2.4) and γ (1.5) are the estimates for the speed of adjustment, the long run and the short run impact of the school closures, and x is the impact on human capital for each year. Source: Authors' calculations.

7. Concluding Remarks

The COVID-19 pandemic has generated long weeks of school closures in many OECD countries that may have a long-lasting impact on human capital, productivity and per capita income levels. Based on the new measure of human capital developed in Égert et al. (2022), this paper suggests that school closure effects might be increasing over time and amounting to a loss of between 0.2% and 0.9% in human capital at the peak when all cohorts impacted will have entered the labour force between 2036 and 2067. The effect will diminish until the last cohort affected retires from the labour force at the age of 65 in 2083, the year the pandemic effect vanishes. These losses in human capital will in turn be translated into lower productivity by about 0.4% to 2.1% in 2067, broadly consistent with earlier findings in the literature. School closures will also have an impact on students' mental health and social capital, which will also possibly affect productivity in addition to wellbeing. These results should be taken with some caution. First, they are based on the literature primarily looking at the effect of school closures at the first stage of the pandemic. Longer-term effects, measured in future PISA and other student assessments at different ages would provide more precision on negative educational outcomes due to school closures. Second, school closure might have affected macroeconomic productivity through a variety of other channels including homework.

To mitigate the COVID-19 impact on human capital is a non-trivial policy challenge because most if not all education policy reforms have long implementation lags implying that education policies mitigating the pandemic's effect will not be able to reach the oldest student cohorts affected by COVID-19. An additional difficulty is that some policies concern the youngest students. For instance, extending and improving the quality of pre-school education, considered by many as the best bang for the buck, would come far too late for almost all student cohorts affected by the pandemic. Other education policy reforms, which are found to have a positive correlation with student test scores during normal times, but which might also help offset some of the losses for the younger generations in the aftermath of the pandemic, include increased school accountability and school autonomy, reduced early tracking and improved teacher quality and qualifications.

Further measures that could be implemented to help the catch-up of affected student generations include the following OECD (2020b); OECD-Education International (2021) and Molato-Gayares et al. (2022):

- Extending the teaching time by reducing temporarily school holidays and/or adding hours in a school day.
- Revising the curriculum to focus on key skills. Providing teachers with some training.
- Considering the use of digital technologies to improve diagnosis of learning gaps and facilitate more individualised teaching practices.
- Spreading collaboration and professional ways of working to increase teachers' effectiveness.

For the cohorts that have already left school, it is important to strengthen the young adult training programmes. Yet, they are notoriously not very cost effective, and offsetting losses in learning at younger ages can turn out to be very costly for the government budget.

Overall, governments should do their best to compensate for the learning losses caused by the pandemic and to carefully monitor students' learning to see whether some catch-up occurs. This is important not only because of the direct economic effects reported in this paper but also because such losses might have repercussions for future generations as the currently suffering young generations become parents: their offsprings' education attainment might be affected by their parents' misfortune. Solutions exist to avoid such a dire outcome but they need to be implemented quickly.

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Data Availability Statement: We have done simulations, so no empirical data underlies our study.

Conflicts of Interest: The authors declare not conflict of interest.

Appendix A

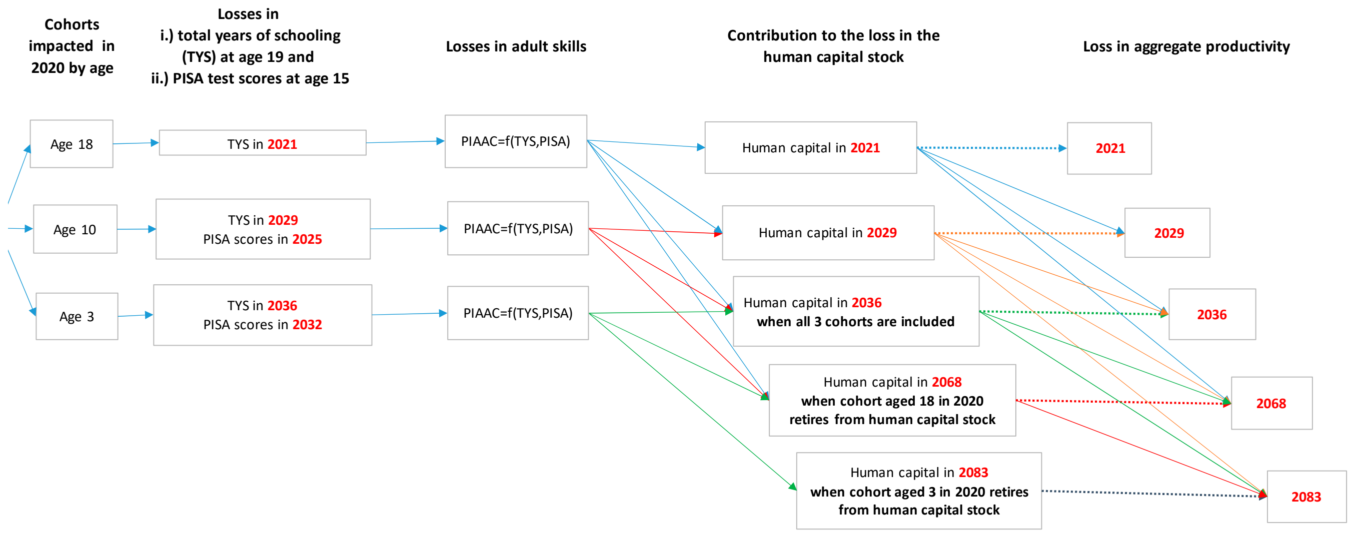

Figure A1. The framework to assess the macroeconomic impact of the COVID-19 pandemic.

Notes

1 On SDG, see also Manioudis and Meramveliotakis (2022) and Tomislav (2018).

2 Data on the number of weeks of closures come from UNESCO and are available for full, partial and total closures. It is assumed for the purpose of calculations throughout the paper that a full school year is 38 weeks.

3 See Kuhfeld et al. (2020) for a summary of the literature on the loss of learning due to summer holidays, weather-related school closures and student absenteeism.

4 In some low income countries and disadvantaged areas, no offsetting measures were put in place leaving students without education for months (Vincent-Lancrin et al. 2022). See also Mazrekaj and De Witte (2023).

5 In some countries, children from lower-income households were provided digital material to participate in online learning activities (OECD 2020a).

6 Using a different perspective, Psacharopoulos et al. (2021) calculate the losses due to school closures in earnings in net present value terms.

7 The impact for 2050 has been computed by the authors by replicating the simulation that generates a GDP loss of 7.5% in 2100 reported in Hanushek and Woessmann (2020).

8 Some papers point out that online learning might even improve outcomes by providing the opportunity to review curriculum and provide more efficient teaching methods. Home learning might facilitate a more focussed learning environment for students, who can practice more if needed (Spitzer and Musslick 2021).

9 The percentage loss in MYS is calculated as the loss in schooling expressed in school years divided by the average MYS for the entire labour force. For example, for a loss of 0.32 school years assuming an average MYS for the entire labour force of 12 years implies a loss in MYS for that cohort of 2.6% (=0.32/12 × 100%).

10 For 12 weeks, the fall in PISA score is equivalent to 0.14 (12 × 0.012) standard deviation; for 1 year, it is 0.37 (12 × 0.012 + (38 − 12) × 0.009) standard deviation and for 2 years it is 0.72 (12 × 0.012 + (76 − 12) × 0.009) standard deviation.

11 Percentage loss in PISA = (Estimated impact × PISA standard deviation)/Base PISA score = (−0.14 × 36.1)/462.

References

Aghion, Philippe, and Peter Howitt. 1998. *Endogenous Growth Theory*. Cambridge: MIT Press.

Altinok, Nadir, Noam Angrist, and Harry A. Patrinos. 2018. *Global Data Set on Education Quality (1965–2015)*. World Bank Policy Research Working Paper No. 8314. Washington: World Bank.

Angrist, Noam, Peter Bergman, Caton Brewster, and Moitshepi Matsheng. 2020. *Stemming Learning Loss during the Pandemic: A Rapid Randomized Trial of a Low-Tech Intervention in Botswana*. CSAE Working Paper Series 2020-13. Oxford: Centre for the Study of African Economies, University of Oxford.

Ardington, Cally, Gabriele Wills, and Janeli Kotze. 2021. COVID-19 learning losses: Early grade reading in South Africa. *International Journal of Educational Development* 86: 102480. [CrossRef]

Arenas, Andreu, and Lucas Gortazar. 2022. *Learning Loss One Year after School Closures: Evidence from the Basque Country*. Institut d'Economia de Barcelona Working Paper 2022/03. Barcelona: Universitat de Barcelona.

Asakawa, Shinsuke, and Fumio Ohtake. 2021. *Impact of Temporary School Closure Due to COVID-19 on the Academic Achievement of Elementary School Students*. Osaka University Discussion Papers in Economics and Business No. 21-14. Osaka: Osaka University.

Azevedo, Joáo Pedro, Amer Hasan, Diana Goldemberg, Syedah Aroob Iqbal, and Koen Geven. 2020. *Simulating the Potential Impacts of COVID-19 School Closures on Schooling and Learning Outcomes, A Set of Global Estimates*. World Bank Policy Research Working Paper No 9284. Washington: World Bank.

Birkelund, Jesper F., and Kristian. B. Karlson. 2021. No Evidence of a Major Learning Slide 14 Months into the COVID-19 Pandemic in Denmark. *SocArXiv*. [CrossRef]

Blainey, Katie, and Timo Hannay. 2021. The Effects of Educational Disruption on Primary School Attainment in Summer 2021: An Analysis of Attainment in Reading, Maths and Grammar, Punctuation and Spelling in Mainstream State Schools in England. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj526noi-mCAxVWa94KHYhYDdAQFnoECBIQAQ&url=https%3A%2F%2Fwww.risingstars-uk.com%2Fmedia%2FRising-Stars%2FAssessment%2FWhitepapers%2FRSA_Effects_of_disruption_Summer_Aug_2021.pdf&usg=AOvVaw07KcQi1OIjRJKo4DjM3BmX&opi=89978449(accessed on 27 November 2023).

Chaban, Tatyana, Roza Rameeva, Ilya Denisov, Julia Kersha, and Roman Zvyagintsev. 2022. Russian Schools during the COVID-19 Pandemic: Impact of the First Two Waves on the Quality of Education. *Educational Studies* 1: 160–88. [CrossRef]

Clark, Andrew E., Huifu Nong, Hongjia Zhu, and Rong Zhu. 2021. Compensating for academic loss: Online learning and student performance during the COVID-19 pandemic. *China Economic Review* 68: 101629. [CrossRef] [PubMed]

Contini, Dalit, Maria L. Di Tommaso, Caterina Muratori, Daniela Piazzalunga, and Lucia Schiavon. 2021. Who Lost the Most? Mathematics Achievement during the COVID-19 Pandemic. *The BE Journal of Economic Analysis and Policy* 22: 399–408. [CrossRef]

Depping, Denise, Markus Lücken, Franck Musekamp, and Franzisca Thonke. 2021. *Kompetenzstände Hamburger Schüler innen vor und während der Corona-Pandemie [Alternative Pupils' Competence Measurement in Hamburg during the Corona Pandemic], während der Corona-Pandemie. Neue Ergebnisse und Überblick über ein dynamisches Forschungsfeld*. Edited by D. Fickermann and B. Edelste. Münster: Waxmann, pp. 51–79.

Dorn, Emma, Bryan Hancock, Jimmy Sarakatsannis, and Ellen Viruleg. 2020. *COVID-19 and Student Learning in the United States: The Hurt Could Last a Lifetime*. Chicago: McKinsey.

Education Policy Institute. 2021. *Understanding Progress in the 2020/21 Academic Year: Interim Findings*. London: Department for Education UK, Renaissance Learning.

Égert, Balázs, Christine de la Maisonneuve, and David Turner. 2022. *A New Macroeconomic Measure of Human Capital Exploiting PISA and PIAAC: Linking Education Policies to Productivity*. OECD Economics Department Working Papers No. 1709. Paris: OECD Publishing.

Elango, Sneha, Jorge L. Garcia, James J. Heckman, and Andrés Hojman. 2015. *Early Childhood Education*. NBER Working Paper No. 21766. Chicago: University of Chicago Press.

Engzell, Per, Arun Frey, and Mark D. Verhagen. 2021. Learning loss due to school closures during the COVID-19 pandemic. *Proceedings of the National Academy of Sciences of the United States of America* 118: e2022376118. [CrossRef] [PubMed]

Gambi, Letizia, and Kristof de Witte. 2021. *The Resiliency of School Outcomes after the COVID-19 Pandemic. Standardised Test Scores and Inequality One Year after Long Term School Closures*. Discussion Paper Series DPS21.12. Leuven: Leuven Economics of Education Research.

Gore, Jennifer, Leanne Fray, Andrew Miller, Jess Harris, and Wendy Taggart. 2021. The impact of COVID-19 on student learning in New South Wales primary schools: An empirical study. *The Australian Educational Researcher* 48: 605–37. [CrossRef]

Green, Francis. 2020. *Schoolwork in Lockdown: New Evidence on the Epidemic of Educational Poverty*. LLAKES Research Paper 67. London: UCL Institute of Education.

Haelermans, Carla, Madelon Jacobs, Lynn van Vugt, Bas Aarts, Henry Abbink, Chayenne Smeets, Rolf van der Velden, and Sanne van Wetten. 2021. *A Full Year COVID-19 Crisis with Interrupted Learning and Two School Closures: The Effects on Learning Growth and Inequality in Primary Education*. ROA Research Memoranda No. 009. Maastricht: ROA. [CrossRef]

Hanushek, Erik A., and Ludger Woessmann. 2020. *The Economic Impacts of Learning Losses*. OECD Education Working Papers, No. 225. Paris: OECD Publishing. [CrossRef]

Hevia, Felipe J., Samana Vergara-Lope Tristan, Anabel Velásquez-Durán, and David Calderón Martín del Campo. 2021. Estimation of the fundamental learning loss and learning poverty related to COVID-19 pandemic in Mexico. *International Journal of Educational Development* 88: 102515. [CrossRef]

Jakubowski, Maciej, Tomasz Gajderowicz, and Sylwia Wrona. 2022. *Achievement of Secondary School Students after Pandemic Lockdown and Structural Reforms of Education System*. Evidence Institute Policy Note 1/2022. Warszawa: Evidence Institute Policy.

Kogan, Vladimir, and Stéphane Lavertu. 2021. *The COVID-19 Pandemic and Student Achievement on Ohio's Third-Grade English Language Arts Assessment*. Columbus: The Ohio State University, John Glenn College of Public Affairs.

Korbel, Václav, and Daniel Prokop. 2021. *Czech Students Lost 3 Months of Learning after a Year of the COVID-19 Pandemic*. Prague: PAQ Research.

Kuhfeld, Megan, James Soland, and Karyn Lewis. 2022. *Test Score Patterns across Three COVID-19-Impacted School Years*. EdWorkingPapers No. 22-521. Providence: Annenberg, Brown University.

Kuhfeld, Megan, James Soland, Beth Tarasawa, Angela Johnson, Erik Ruzek, and Jing Liu. 2020. *Projecting the Potential Impacts of COVID-19 School Closures on Academic Achievement*. EdWorkingPapers No. 20-226. Providence: Annenberg, Brown University.

Lichand, G., C. A. Doria, O. L. Neto, and J. Cossi. 2021. *The Impacts of Remote Learning in Secondary Education: Evidence from Brazil during the Pandemic*. Technical note No IDB-TN-02214. Washington: Inter-American Development Bank.

Lucas, Robert E., Jr. 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22: 3–42. [CrossRef]

Ludewig, U., R. Kleinkorres, R. Schaufelberger, T. Schlitter, R. Lorenz, C. Koenig, A. Frey, and N. McElvany. 2022. COVID-19 Pandemic and Student Reading Achievement—Findings from a School Panel Study. *Frontiers in Psychology* 13: 876485. [CrossRef]

Maldonado, Joana E., and Kristof De Witte. 2020. The Effect of School Closures on Standardised Student Test Outcomes. KU Leuven, Faculty of Economics and Business. Available online: https://lirias.kuleuven.be/retrieve/588087 (accessed on 27 November 2023).

Manioudis, Manolis, and Giorgos Meramveliotakis. 2022. Broad strokes towards a grand theory in the analysis of sustainable development: A return to the classical political economy. *New Political Economy* 27: 866–78. [CrossRef]

Mazrekaj, Deni, and Kristof De Witte. 2023. The Impact of School Closures on Learning and Mental Health of Children: Lessons From the COVID-19 Pandemic. *Perspectives on Psychological Science*. [CrossRef]

Meeter, Martijn. 2021. Primary school mathematics during the COVID-19 pandemic: No evidence of learning gaps in adaptive practicing results. *Trends in Neuroscience and Education* 25: 100163. [CrossRef]

Molato-Gayares, Rhea, Albert Park, David A. Raitzer, Daniel Suryadarma, Milan Thomas, and Paul Vandenberg. 2022. *How to Recover Learning Losses from COVID-19 School Closures in Asia and the Pacific*. ADB Briefs No 217. Manila: Asian Development Bank.

OECD. 2017. *PISA for Development and the Sustainalble Development Goals*. PISA for Development Brief No. 17. Paris: OECD.

OECD. 2020a. *Strengthening Online Learning When Schools Are Closed: The Role of Families and Teachers in Supporting Students during the COVID-19 Crisis*. Paris: OECD publishing.

OECD. 2020b. *Lessons for Education from COVID-19: A Policy Maker's Handbook for More Resilient Systems*. Paris: OECD Publishing. [CrossRef]

OECD-Education International. 2021. *Principles for an Effective and Equitable Educational Recovery*. Paris: OECD Publishing.

Patrinos, Harry A., Emiliana Vegas, and Rohan Carter-Rau. 2022. *An Analysis of COVID-19 Student Learning Loss*. World Bank Policy Research Working Paper No 10033. Washington: World Bank Group.

Pier, Libby, Michael Christian, Hayley Tymeson, and Robert H. Meyer. 2021. COVID-19 Impacts on Student Learning, Evidence from Interim Assessments in California. [Report]. Policy Analysis for California Education. Available online: https://edpolicyinca.org/publications/COVID-19-impacts-student-learning (accessed on 27 November 2023).

Psacharopoulos, George, Victoria Collis, Harry A. Patrinos, and Emiliana Vegas. 2021. The COVID-19 Cost of School Closures in Earnings and Income across the World. *Comparative Education Review* 65: 271–87. [CrossRef]

Romer, Paul M. 1990. Endogenous technological change. *Journal of Political Economy* 99, Pt 2: S71–S102. [CrossRef]

Rose, Susan, Karim Badr, Lydia Fletcher, Tara Paxman, Pippa Lord, Simon Rutt, Ben Styles, and Liz Twist. 2021. *Impact of School Closures and Subsequent Support Strategies on Attainment and Socio-Emotional Wellbeing*. London: Education Endowment Foundation.

Schult, Johannes, Nicole Mahler, Benjamin Fauth, and Marlit A. Lindner. 2021. Did students learn less during the COVID-19 pandemic? Reading and mathematics competencies before and after the first pandemic wave. *PsyArXiv*. [CrossRef]

Schuurman, Tessa M., Lotte F. Henrichs, Noémi K. Schuurman, Simone Polderdijk, and Lisette Hornstra. 2021. Learning Loss in Vulnerable Student Populations After the First COVID-19 School Closure in the Netherlands. *Scandinavian Journal of Educational Research* 67: 309–26. [CrossRef]

Skar, Gustaf B. U., Steve Graham, and Alan Huebner. 2021. Learning Loss During the COVID-19 Pandemic and the Impact of Emergency Remote Instruction on First Grade Students' Writing: A Natural Experiment. *Journal of Educational Psychology* 114: 1553. [CrossRef]

Spitzer, Markus W. H., and Sebastian Musslick. 2021. Academic performance of K-12 students in an online-learning environment for mathematics increased during the shutdown of schools in wake of the COVID-19 pandemic. *PLoS ONE* 16: e0255629. [CrossRef]

Storey, Nathan, and Qiyang Zhang. 2021. A Meta-analysis of COVID Learning Loss. *EdArXiv*. [CrossRef]

Tomasik, Martin J., Laura A. Helbling, and Urs Moser. 2020. Educational gains of in-person vs. distance learning in primary and secondary schools: A natural experiment during the COVID-19 pandemic school closures in Switzerland. *International Journal of Psychology* 56: 566–76. [CrossRef] [PubMed]

Tomislav, Klarin. 2018. The concept of sustainable development: From its beginning to the contemporary issues. *Zagreb International Review of Economics & Business* 21: 67–94.

U.S. Department of Education. 2022. *Institute of Education Sciences, National Center for Education Statistics. National Assessment of Educational Progress (NAEP), 2020 and 2022 Long-Term Trend (LTT) Reading and Mathematics Assessments*. Washington, DC: U.S. Department of Education.

UK Department of Education. 2021. *Understanding Progress in the 2020/21 Academic Year, Complete Findings from the Spring Term London*. Manchester: UK Department of Education.

van der Velde, Maarten, Florian Sense, Rinske Spijkers, Martijn Meeter, and Hedderik van Rijn. 2021. Lockdown Learning: Changes in Online Study Activity and Performance of Dutch Secondary School Students during the COVID-19 Pandemic. *Frontiers in Education* 6: 712987. [CrossRef]

Vegas, Emiliana. 2022. *COVID-19′s Impact on Learning Losses and Learning Inequality in Colombia*. Washington: Center for Universal Education at Brookings.

Viana Costa, Daniela, Erbabian Maddison, and Youran Wu. 2021. *COVID-19 Learning Loss: Long-Run Macroeconomic Effects Update*. Philadelphia: University of Pennsylvania.

Vincent-Lancrin, Stéphan, Cristóbal Cobo Romaní, and Fernando Reimers, eds. 2022. *How Learning Continued during the COVID-19 Pandemic: Global Lessons from Initiatives to Support Learners and Teachers*. Paris: OECD Publishing. [CrossRef]

Woessmann, Ludger, Vera Freundl, Elisabeth Grewenig, Philipp Lergetporer, Katharina Werner, and Larissa Zierow. 2020. Education in the Coronavirus Crisis: How Did Schoolchildren Spend Their Time When Schools Were Closed, and What Educational Measures Do the Germans Advocate? *Ifo Schnelldienst* 73: 25–39.