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DISSERTATION

HOW DID THE SCHOOL CLOSURES DURING THE COVID-19 PANDEMIC AFFECT STUDENTS' PERFORMANCE AT SCHOOL?

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To all my family and friends
who were a part of my
academic journey.

GLOSSARY

COVID-19 - Coronavirus disease 2019

DiD – Difference-in-Differences

GDP – Gross Domestic Product

JEL – Journal of Economic Literature

MFW – Master's Final Work

OECD - Organisation for Economic Co-operation and Development

PISA - Programme for International Student Assessment

StataSE 18.0 - Stata Standard Edition 18.0

SD – Standard Deviation

UNESCO - United Nations Educational, Scientific and Cultural Organization

ABSTRACT, KEYWORDS AND JEL CODES

This dissertation analyses how school closures affected the Programme for International Student Assessment (PISA) test scores in 2022 using the 2018 PISA test scores. Multiple regressions and control variables were used to create models based on the three evaluated topics - mathematics, reading, and science. The models started small and were slowly built. The empirical analysis suggests a clear negative correlation between school closures and PISA test scores, with causality being more ambiguous. Mathematics was the most affected out of the three.

KEYWORDS: School closures; Students' performance; PISA test scores; COVID-19 pandemic; Learning loss.

JEL CODES: C31; C52; I18; I21; O15

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1. Introduction

The COVID-19 pandemic is a global pandemic that profoundly shaped and transformed our society. Most of the world was grounded to a halt, with the outbreak hitting all aspects of daily life. Four years have passed since its start and the associated school closures, the most significant disruption to learning in history, which affected about 95% of the world's student population (roughly around 1.6 billion students in 190 countries) (United Nations, 2020). Students had to continue their schooling from home using different learning tools such as videoconferencing, radio, and TV. However, concerns remain about its effects on schools and students worldwide.

According to the United Nations and UNESCO, education is a human right firmly rooted in the *Universal Declaration of Human Rights*. The COVID-19 pandemic proved to be a significant disruptor because, while children were "spared" from the health consequences of contracting the virus – except in some rare cases and at least to date –, the crisis is still having a profound effect on their well-being: both physical and mental. The reduced number of hours of physical activity, uncertainty and isolation from their friends and peers may have led to a deterioration in their welfare.

The long-term effects of COVID-19 are unknown, but past disruptions suggest they will be significant and lasting. A review of the 1916 polio pandemic revealed that after schools reopened, parents hesitated to send their children back (Meyers & Thomasson, 2017). The study found that individuals aged 14–17 during the pandemic later achieved lower educational achievement than their slightly older peers.

United Nations (2020) projects that the impact will be lifelong and more damaging to children in poorer countries with weaker infrastructures. Unfortunately, mitigation measures to contain the virus may have unintentionally done more harm than good. Therefore, governments and policymakers must weigh the benefit-to-loss ratio when considering such decisions.

The pandemic has likely contributed to global school closures, reduced learning outcomes, and decreased student performance, but the full extent and specific impacts on children's education are still being studied. Still, this is where this dissertation will mainly focus.

Previous literature suggests students' performance declined (Engzell, et al., 2021; Haelermans et al., 2022), the duration of school closures mattered greatly, and students from low socio-economic backgrounds were at a disadvantage when compared to their peers.

The pandemic presented new challenges to students, parents, and teachers. The shift to remote learning proved to be a hard transition, with access and control of remote learning devices challenging for some. Parents found themselves in serious difficulties balancing their work/life balance (if not jobless) from home.

While existing literature largely concurs that student learning suffered a setback due to COVID-19 (Engzell et al., 2021; Jakubowski et al., 2023), the need for further research is pressing. The shocks created by the COVID-19 pandemic are still unfolding, underscoring the urgency and importance of continued research in this area.

This dissertation aims to further contribute to the growing research on school closures' effect on learning by using PISA test scores and linear regressions at a country level. Our contribution is based on the analysis of comparing countries with varying lengths of school closure by testing the importance of the intensive margin. We aim to prove that school closures may have had a (causal) effect on the decrease in students' performance.

To achieve this, we built several models using linear regressions. By starting small, we slowly built to a bigger and final model with the intent that our control variables would reflect the causality/apples-to-apples comparison intended.

Our main dependent variables were the PISA test scores for all the three school subjects evaluated: mathematics, reading and science. We then controlled for other variables, such as the number of weeks that schools were totally closed/partially opened – with this being our treatment variable of interest. We also used the PISA test scores in 2018 and found that countries with high school closures had already performed poorly in 2018. We also found that previous performances highly influenced PISA scores measured in the current period (2022). In other words, countries that performed well in 2022 were already performing well in 2018.

We will demonstrate the effect of school closures on students' performance in the PISA test scores and interpret the results shown by our regressions. First, we saw a negative correlation between PISA test scores and school closures. However, causality is more ambiguous.

The remainder of this dissertation is as follows: section 2 presents the literature review about the impact that school closures had on students' performance divided into 3 subsections – school closures and test scores, school closures and other outcomes, school closures' effects on children physical and mental health; section 3 displays data, section 4 methodology, section 5 results, and discussion divided into 2 subsections – 2022 scores analysis, results and discussion and 2018 scores analysis, results and discussion; section 6 concludes.

2. LITERATURE REVIEW

2.1. SCHOOL CLOSURES AND TEST SCORES

According to recent literature, the COVID-19 pandemic may have negatively affected students' performance, with multiple countries observing a decrease in students' scores and learning loss. Socioeconomic factors, changes in teaching methods, or the duration of the school closure may have affected this decline.

The term "learning loss" is often used in academic literature to describe the decline in student knowledge and skills or, in other words, that students are not learning at the same rate they typically would be (Pier et al., 2021).

The majority of countries around the globe decided to close schools as an emergency response to contain the spread of COVID-19, yet school interruptions are known to have short and long-term negative effects on students' academic outcomes and perseverance, whether it be teachers' strikes, summer vacation, also known as summer learning loss, or a pandemic (Belot & Webbink, 2010; Cooper, 2003; Meyers & Thomasson, 2017).

Various authors and researchers have studied this phenomenon in the context of the COVID-19 pandemic and associated school closures, suggesting possible implications.

A paper by Azevedo et al., (2021) suggested that school closures could lead to a loss of 0.3 to 1.1 years of schooling adjusted for quality. This would reduce the number of effective years of basic schooling that students achieve during their lifetime from 7.8 years to between 6.7 and 7.5 years. Moreover, the income shock of the COVID-19 pandemic alone could force 11 million students to drop out of school from primary to secondary education. Many may not return.

A review demonstrated that students' international reading scores severely declined from a period between 2016 and 2021, roughly equivalent to more than one year of schooling, a staggering and alarming amount (Jakubowski et al., 2023). The review also noted that schools with longer closures experienced a larger decline in reading scores. For example, scores declined by 23 per cent in schools that faced 25 weeks of school closures against a 9 per cent decline in 8 weeks of school closures.

Another study aimed at analysing learning losses during the pandemic in the Netherlands suggested that learning losses were equivalent to the same period that schools remained closed - approximately 8 weeks - which means that students made little to no progress while having remote classes at home. In other words, students did not learn much during those weeks when schools remained closed. These researchers found a decrease in student performance on a national exam of 0.08 standard deviations (SD). Furthermore, this effect may have been exacerbated in countries with weaker infrastructure and longer school closure duration (Engzell, et al., 2021).

It is important to note that the Netherlands is considered a “best-case scenario” as schools remained closed for only 8 weeks, and it is a country renowned for its robust infrastructure. Unfortunately, not all countries were this lucky. For example, in Belgium, researchers observed a decrease in mathematics performance of 0.19 SD and a decline in Dutch performance of 0.29 SD (Maldonado et al., 2020).

Haelermans et al., (2022) review also supports Engzell, et al., (2021) findings, pointing instead at a 7.5 weeks average lower learning growth. The review also suggests that mathematics was the most affected course.

However, the duration of school closures was not the only factor to consider. In Belgium, despite schools being closed for 9 consecutive weeks, more than one-third of the school year was affected by the restrictions that followed after schools reopened (Azevedo et al., 2021).

UNESCO et al., (2021) report gives further insights on the effect of school closures: students in São Paulo, Brazil, only learned 28 per cent compared to what they would learn if they had classroom lessons. This made these students 3 times more likely to drop out of school.

Moreover, due to their slower and less effective response and longer school closure durations, low- and middle-income countries saw their students' learning loss as more significant than in high-income countries, which usually had lower durations of school closures. Additionally, the percentage of children living in learning poverty is projected to increase to 70 per cent from the initial 50 per cent value.

Therefore, it is essential to note school closures may not have affected all students equally. Schuurman et al (2023) analysed the impact of the first school closure for vulnerable student groups in the Netherlands and found that this group was severely more affected than their peers. The average learning loss for these students for mathematics and reading was 2.47 and 2.35 months, respectively; this exceeded the duration of the lockdown. The data supports the notion that school closures increased educational inequalities and exacerbated existing socioeconomic discrepancies.

A study conducted in the United Kingdom reported that students from better-off families had access to more resources for distance learning and were given more support, such as online teaching, than children from lower-income families (Andrew et al., 2020). Furthermore, the study also suggests that school closures increased educational inequalities.

However, although mitigation strategies rolled out during COVID-19 were branded as remote learning, in practice, they were mostly emergency responses rolled out by governments. It is also important to note that past reviews on the evidence of the effectiveness of remote learning appear to be mixed at best. They range from unequivocally positive (Allen et al., 2006; US DoE, 2010) to negative and null effects (Bernard et al., 2004).

Remote learning should not be discarded entirely despite these grim conclusions and observations. According to a national study conducted in Uruguay, researchers found that when comparing students who had used an adaptive math platform to students who did not, the first group showed a positive effect of 0.20 SD in mathematical gain. Not only that but as the student's socioeconomic status decreased, the effect was stronger (Perera & Cinve, 2018).

On the other hand, other reviews suggest that conventional learning cannot be substituted by remote learning/computer assistive learning and obtain the same expected results (Bettinger et al., 2020).

A recurring theme in all studies is that numerous elements must be properly aligned and functioning for remote learning to fulfil its potential and deliver on its promises. Due to the sudden need for speed to rapidly roll out or increase remote learning programs, not all governments could ensure that all the pre-conditions required to meet all standards were met.

Nevertheless, most reviews suggest declining student performance and significant learning losses due to school closures. They also support the idea that the duration of closures was crucial, with more extended shutdowns linked to worse learning losses compared to those with shorter durations. Moreover, the pandemic only exacerbated education discrepancies, affecting some students more than others – especially those from lower socioeconomic backgrounds.

2.2. SCHOOL CLOSURES AND OTHER OUTCOMES

Current literature also suggests that the lockdown and subsequent school closures might affect students' labour market prospects due to the decrease in performance – and consequently scores - that the pandemic brought (Betthäuser et al., 2023).

There is an urgent need to address the learning disruption caused by COVID-19, as it may have long-lasting effects. Thus, Psacharopoulos et all., (2021) highlights the economic impact of school closures on future earnings. The findings imply that the financial loss is highly significant, potentially reducing global economic growth by an annual rate of 0.8 per cent.

The World Bank Global Economic Prospects Report of 2020, conducted by the World Bank, gave essential details about the economic stress that the COVID-19 pandemic caused worldwide. The immense shock led to rising unemployment numbers, falling family incomes and the shrinking of government fiscal space. Out of the 179 examined economies, as many as 93 per cent are expected to suffer from falling gross domestic product (GDP per capita) levels. Compared to the Great Depression of the 1930s, 85 per cent more nations are suffering from economic recession.

This significant global shock immensely affected individuals: the economic impact on students affected by the school closures is more significant than initially anticipated in 2020. This generation of students may lose a staggering US$17 trillion in lifetime earnings, far more than the initially predicted US$10 trillion (UNESCO et al., 2021). This value is equivalent to governments losing roughly 16 per cent of their investments in the education sector (Azevedo et al., 2021).

Multiple studies from different countries (Bratti et al., 2004; Dabalen et al., 2001; Koda & Yuki, 2013) show that the final grade awarded to a student significantly predicts their labour market prospects. Individually speaking, each student could potentially lose between US$6,680 and US$32,397 in earnings over their lifetime (Azevedo et al., 2021).

Currie and Thomas (2001) observed that a 0.20 standard deviation decrease in standardised test scores could reduce the probability of future employment by 0.86%. Furthermore, recent literature (Azevedo et al., 2021) indicates that some students may have lost an additional year of schooling, depending on school closure duration. On average, this extra year of education is associated with an 8–9 per cent increase in future earnings (G. Psacharopoulos & Patrinos, 2018).

To combat this, along with the learning losses suffered by students, the UNESCO report stated that in the third quarter of 2020, many countries were looking to implement support programs to reduce the learning losses students experienced earlier in the year.

However, the report emphasises the urgent need to further increase resources for education and training. From the US$16 trillion invested in stimulus packages, only US$467 billion was allocated to education, with 97% coming from higher income countries. This underlines the crucial need for more investment in education.

It is crucial to assess whether and to what extent children affected by COVID-19 disruptions have caught up and mitigated their learning losses. Additionally, it is essential to understand how the pandemic's impact is different from student to student. This could help educators and policymakers identify which groups of students may need extra help to recover from the learning losses they have suffered.

Furthermore, recent literature on the COVID-19 pandemic supports the notion that there are challenges regarding learning at a distance, specifically access to digital learning devices (Chetty et al., 2024) and rising problems at home due to economic stress, such as the uncertainty and demands from working remotely, make parents – especially lower-income parents - less equipped to provide support to their children, with pressures mounting on them (Adams-Prassl et al., 2020; Witteveen & Velthorst, 2020).

According to a survey conducted by the School Education Gateway (2020), the majority of teachers were unprepared for remote learning. They cited an increase in workload and stress, students' access to technology, and keeping pupils motivated and engaged as the main challenges that they faced when switching to online teaching.

While most studies focused a lot on teachers and students, and rightfully so, parents were also given a new role. They were asked to support and help their children transition to remote learning. In a study conducted in Cyprus, Panaoura (2020) examined parents' role, capability, and involvement in supporting their children's mathematical understanding and perseverance strategies during homework. She found that parents were willing to help their children, but they believed they needed more training and guidance.

2.3. School closures effects on children physical and mental health

The pandemic's impact on children's mental and physical health, as well as their out-of-school learning environment, may have exacerbated the effects brought by the lack of in-person school education and playground interaction with their peers.

Therefore, it is important to acknowledge the negative consequences of school closures beyond learning losses and a decline in students’ performance. Abbas et al., (2023) observed that reduced physical activity due to lockdowns and lack of peer interaction severely affected students' well-being, with depression, anxiety and uncertainty being the most common symptoms reported. Vaillancourt et al., (2021) hinted that longer periods of social isolation might have also negatively impacted students’ performance.

Dunton et al., (2020) examined the early effects of the COVID-19 pandemic on school-aged children, observing an increase in sedentary behaviour and diminished physical activity. These authors expressed concern that if these problems were not mitigated, they could lead to a prolonged increase in obesity, diabetes, and other cardiovascular diseases.

This decrease in student well-being may have contributed to negatively impacting students’ performance, given the close association between mental and physical health and educational/academic outcomes (Joe et al., 2009).

Furthermore, current evidence suggests that children in younger grades are more dependent on in-person teaching. Younger kids need a lot of movement, exploration, and trial by error to learn. This simply is not possible to do remotely in front of a computer while staring at a screen (Hilton, 2020).

Despite the fact that the COVID-19 outbreak began four years ago at the time of this writing, it is important to note that ongoing research is necessary to fully understand the lasting effects of this pandemic on students.

3. DATA

This study relies on the Programme for International Student Assessment (PISA) database, a globally recognized resource. The PISA, conducted by the Organisation for Economic Co-operation and Development (OECD), was launched in 2000 to evaluate the academic performance of 15-year-old students in member countries. Its primary objective is to assess education systems by measuring students' mathematics, reading and science proficiency. The PISA database, known for its comprehensive data, is a valuable tool for conducting studies and aiding policymakers in understanding the effectiveness of education systems worldwide. In this dissertation, it will be used to investigate the (causal) impact of school closures on student performance.

Moreover, our treatment variable of interest is the number of weeks each school around the globe remained closed. The dataset was provided by the United Nations Educational, Scientific and Cultural Organization (UNESCO), which "monitored on a daily basis the status of the schooling system according to the closures of schools and the methods selected for delivery across the world since the outbreak of the pandemic."

Our study mainly used the World Bank Open Data, an extensive repository provided by the World Bank, to obtain data regarding country-level variables – such as GDP, GDP per capita or population density - for each country in our dataset. The other data sources will be appropriately mentioned in Table I.

Table I displays the variables' names, definitions, and sources.

TABLE I

NAMES, DEFINITIONS AND SOURCES OF ALL THE VARIABLES PRESENTED

score_math_2018 score_science_2018 score_read_2018	The scores of students on the three evaluated topics in 2018	PISA
score_math_2022 score_science_2022 score_read_2022	The scores of students on the three evaluated topics in 2022	PISA

n_weeks_part_open n_weeks_tot_clos	Number of weeks schools remained partially open. Number of weeks schools remained totally closed.	UNESCO UNESCO
PopDens2018; PopDens2022	Population density for each country in our dataset in 2018 and 2022.	World Bank
covid_per_million	The number of COVID-19 reported cases per million inhabitants in 2022.	PISA
gdp_pc_2018; gdp_pc_2022	Gross domestic product (GDP) per capita for each country in our dataset in 2018 and 2022	World Bank
unemp_2018; unemp_2022	Unemployment, total (% of total labour force) for each country in our dataset in 2018 and 2022.	World Bank
gini_2018; gini_2022	Gini index for each country in our dataset in 2018 and 2022.	World Bank; Knoema; countryeconomy.com; CEIC Data
gov_effec_est_2018 gov_effec_est_2022	The government effectiveness estimate for each country is in our dataset for 2018 and 2022.	World Bank

4. Methodology

This paper will evaluate the PISA test scores for 2018 and 2022. For our analysis in those periods, we will present various regressions, starting our analysis small and progressing towards a bigger and final model.

We used Stata Standard Edition 18.0 (StataSE 18.0) to run the linear regressions and all econometric analyses presented in this dissertation. We used the Linear Regressions functionality and imported the Excel dataset file composed of our variables to Stata.

Despite having multiple dependent variables, they all have one thing in common: the students' scores for the three school topics evaluated on the PISA report. Our main treatment variable of interest was the number of weeks that schools remained closed/partially opened, with the other variables being control variables that would help us reach the causal effect between school closures and the decrease in students' scores. All the regressions in our model used the "vce(robust)" command on Stata to avoid concerns about heteroskedasticity.

It is essential to control for other factors that could influence PISA test scores to establish a possible (causal) relationship between school closures and the decrease in students' scores. The control variables included in our model ensure that we compare countries similar in key aspects but differ in their experiences with school closures. This allows us to isolate the effect of school closures from other factors. By including these control variables, we aim to create a more accurate apples-to-apples comparison. This means that we are comparing countries with similar conditions.

The general form of the regression equation used in this analysis is as follows:

$$y = \alpha_0 + \alpha_1 * sc + \alpha_2 * x + \epsilon \quad (1)$$

Where:

- y represents the PISA test scores. These scores are used as the dependent variable to measure student performance;
- sc is the school closure variable, which captures the extent and duration of school closures. This is the main treatment variable of interest;
- x represents a vector of control variables. These control variables include various factors that might influence student performance;
- α_0 is the intercept term;
- α_1 is the coefficient for the school closure variable. This coefficient measures the (causal) impact of school closures on student performance;
- α_2 is a vector of coefficients for the control variables;
- ϵ is the error term, capturing unobserved factors that might affect student performance.

Our initial country-level sample size has 81 observations. However, in conducting our regressions, we encountered unbalanced panel data, with the number of observations varying across different regressions. This sample size variation could affect the regression results' consistency and comparability. In order to address the issue of unbalanced panel data, we aimed to keep the number of observations for each regression as similar as possible.

5. Results and Discussion

Our primary focus will be on the 2022 PISA scores; however, to provide a comprehensive understanding, we will also control for the 2018 PISA scores to hint at causality. This will allow us to establish baseline relationships and facilitate a comparative analysis to evaluate the stability and changes in the factors influencing student achievement.

5.1. 2022 Scores Analysis, Results and Discussion

We start this section by presenting a linear regression that shows the relationship between the student's scores in the three evaluated topics and the number of weeks schools remained closed/partially opened. **Table II** demonstrates a Linear Regression with the number of weeks schools remained closed as the only control variables. In contrast, **Table III** presents a Linear Regression with the number of weeks schools remained partially opened.

When analysing the data in Tables II and III, we can observe statistical significance for all three school topics. Furthermore, for every additional week students remain at home due to school closure, their PISA test scores are expected to drop ~2.5 points. This value is smaller when schools remain partially open, which may imply that students performed better when schools were not totally closed.

We discovered a negative correlation between the two, meaning that school closures may have negatively impacted students' performance during the pandemic, with longer closures resulting in lower scores. Furthermore, despite the small difference, math appears to have been the most affected course.

TABLE II

INTRODUCTION MODEL WITH THE MAIN TREATMENT VARIABLE OF INTEREST

Linear regression

score_math_2022	Coef.	p-value	Sig
n_weeks_tot_clos	-2.676	0	***
Constant	491.013	0	***
R-squared	0.419	Number of obs	80

*** *p*<.01, ** *p*<.05, * *p*<.1

Linear regression

score_read_2022	Coef.	p-value	Sig
n_weeks_tot_clos	-2.309	0	***
Constant	481.37	0	***
R-squared	0.339	Number of obs	80

*** *p*<.01, ** *p*<.05, * *p*<.1

Linear regression

score_science_2022	Coef.	p-value	Sig
n_weeks_tot_clos	-2.466	0	***
Constant	496.253	0	***
R-squared	0.391	Number of obs	80

*** *p*<.01, ** *p*<.05, * *p*<.1

TABLE III

INTRODUCTION MODEL

Linear regression

score_math_2022	Coef.	p-value	Sig
n_weeks_part_open	-.979	.022	**
Constant	464.792	0	***
R-squared	0.083	Number of obs	80

*** *p*<.01, ** *p*<.05, * *p*<.1

Linear regression

score_read_2022	Coef.	p-value	Sig
n_weeks_part_open	-.546	.203	
Constant	450.787	0	***
R-squared	0.028	Number of obs	80

*** *p*<.01, ** *p*<.05, * *p*<.1

Linear regression

score_science_2022	Coef.	p-value	Sig
n_weeks_part_open	-.654	.112	
Constant	465.475	0	***
R-squared	0.041	Number of obs	80

*** *p*<.01, ** *p*<.05, * *p*<.1

Before moving to our final model, our research found an interesting result. We noticed something when running a regression with the scores from 2022 as a dependent variable and the scores from 2018 as an independent variable. The regressions suggest that PISA scores measured in the current period (2022) were highly correlated with previous performances. This can be demonstrated through the high R-squared, at around 95%. This indicates that approximately 95% of the variation in the scores in 2022 can be explained by the variation in the scores in 2018. In other words, countries that performed well in 2022 were already performing well in 2018. This is because past performance may be a strong predictor of future performance. **Table IV** will present our results.

TABLE IV

RELATIONSHIP BETWEEN 2022 AND 2018 SCORES

Linear regression

score_math_2022	Coef.	p-value	Sig
score_math_2018	.932	0	***
Constant	19.828	.106	
R-squared 0.944		Number of obs	73

*** p<.01, ** p<.05, * p<.1*

Linear regression

score_read_2022	Coef.	p-value	Sig
score_read_2018	.956	0	***
Constant	11.099	.382	
R-squared 0.941		Number of obs	72

*** p<.01, ** p<.05, * p<.1*

Linear regression

score_science_2022	Coef.	p-value	Sig
score_science_2018	.984	0	***
Constant	5.952	.668	
R-squared 0.947		Number of obs	72

*** p<.01, ** p<.05, * p<.1*

We proceed with our model by adding more appropriate control variables in order to reach our apples-to-apples comparison. **Table V** will demonstrate that we controlled for GDP per capita, number of COVID cases per million inhabitants, population density, unemployment rate (% of labour force), Gini Index and government effectiveness estimate. Compared with countries with similar GDP per capita, population density, and

COVID cases per million, countries with the longest school closures did worse. However, it is important to note that GDP per capita is not statistically significant in this case.

When analysing the effect of the number of weeks schools remained totally closed, we can observe that the coefficient was smaller in our bigger model when compared to the model in Table II, with the statistical significance remaining the same. In this case, for every additional week of school closures, scores decreased by ~0,9. Despite the small difference, science was the most affected school topic.

Furthermore, higher unemployment rates are associated with lower scores in the 2022 PISA assessment. For every percentage point increase in unemployment, PISA scores decrease by ~1.6. Perhaps parents find it more difficult to support their kids, or a bad financial situation can cause distress within the household, which would then pass to the child as a form of worse grades. This aligns with the current literature.

Rising problems at home due to economic stress make parents – especially lower-income parents - less equipped to provide support to their children, with pressures mounting on them to find or keep their jobs (Adams-Prassl et al., 2020; Witteveen & Velthorst, 2020).

Recent literature hints that students from disadvantaged backgrounds were worse off than their peers, suffering greater losses in student achievement (Andrew et al., 2020; Schuurman et al., 2023). The Gini Index, which measures the extent to which income distribution among individuals or households within an economy deviates from a perfectly equal distribution, presents itself in our regressive with a negative coefficient, which means that more unequal countries did worse in the PISA test scores. However, this only proved to be statistically significant for math.

Another important control variable added to this model is the Government Effectiveness Estimate. It appears that higher government effectiveness is associated with higher grades, as demonstrated by our positive and large coefficient. Our interpretation for this is that for each unit increase in government effectiveness, the PISA test scores increased by ~30, a considerable amount. This is especially important in the context of the COVID-19 pandemic.

TABLE V

MORE COMPACT MODEL AND FINAL MODEL

Linear regression

score_math_2022	Coef.	p-value	Sig
n_weeks_tot_clos	-.924	0	***
gdp_pc_2022	0	.659	
covid_per_million	0	.017	**
PopDens2022	.009	0	***
unemp_2022	-1.388	.052	*
gini_2022	-1.283	.009	***
gov_effec_est_2022	29.812	.002	***
Constant	475.717	0	***
R-squared 0.755		Number of obs	76

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_read_2022	Coef.	p-value	Sig
n_weeks_tot_clos	-.944	.003	***
gdp_pc_2022	0	.434	
covid_per_million	0	.029	**
PopDens2022	.003	.032	**
unemp_2022	-1.598	.066	*
gini_2022	.544	.33	
gov_effec_est_2022	24.637	.021	**
Constant	407.71	0	***
R-squared 0.655		Number of obs	76

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_science_2022	Coef.	p-value	Sig
n_weeks_tot_clos	-.993	0	***
gdp_pc_2022	0	.798	
covid_per_million	0	.05	**
PopDens2022	.005	0	***
unemp_2022	-1.591	.035	**
gini_2022	-.2	.697	
gov_effec_est_2022	31.894	.002	***
Constant	451.442	0	***
R-squared 0.699		Number of obs	76

**** p<.01, ** p<.05, * p<.1*

To gain further insights, we extend our regression model to include the scores from the previous period in our final model. This expanded model allows us to assess whether the number of weeks schools were closed remains a significant predictor of 2022 PISA scores when another important influential factor is considered – the scores from the previous period, which we had established before is a strong predictor for future performances.

Our preliminary results suggest that while school closures alone show a statistically significant impact on 2022 PISA scores, this effect diminishes when the 2018 scores are included in the model. This finding highlights the dominant influence of past academic performance over the disruptions caused by school closures.

Upon examining the regression results for the three topics—mathematics, reading, and science - a pattern of inconsistencies emerges. Notably, the only consistency among the three regressions is that the PISA test scores from the previous period remain strongly significant and that the number of weeks schools were totally closed is not. The positive coefficient for the school topics hints at what we had already presented before: countries that did well in 2022 were already performing well in 2018. It is also important to note its high statistical significance. Furthermore, the Gini Index is now also significant in reading, and it is positive in all models. This means that more equal countries performed better.

These results hint that while school closures may have affected academic performance, the effect is relatively small compared to the predictive power of past performance. This suggests that academic abilities and prior learning may substantially impact current performance more than the disruptions caused by school.

Table VI demonstrates our results.

TABLE VI

FINAL MODEL INCLUDING THE SCORES FROM THE PREVIOUS PERIOD

Linear regression

score_math_2022	Coef.	p-value	Sig
score_math_2018	.843	0	***
n_weeks_tot_clos	-.042	.786	
gdp_pc_2022	0	.9	
covid_per_million	0	.203	
PopDens2022	.003	0	***
unemp_2022	-1.419	.009	***
gini_2022	.356	.083	*
gov_effec_est_2022	2.357	.64	
Constant	51.106	.036	**
R-squared 0.958		Number of obs	68

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_read_2022	Coef.	p-value	Sig
score_read_2018	.955	0	***
n_weeks_tot_clos	.056	.696	
gdp_pc_2022	0	.544	
covid_per_million	0	.055	*
PopDens2022	0	.696	
unemp_2022	-1.564	.002	***
gini_2022	.707	.001	***
gov_effec_est_2022	-4.05	.435	
Constant	-9.781	.662	
R-squared 0.960		Number of obs	67

*** *p*<.01, ** *p*<.05, * *p*<.1

Linear regression

score_science_2022	Coef.	p-value	Sig
score_science_2018	.93	0	***
n_weeks_tot_clos	-.001	.996	
gdp_pc_2022	0	.66	
covid_per_million	0	.149	
PopDens2022	.002	.007	***
unemp_2022	-1.118	.067	*
gini_2022	.365	.101	
gov_effec_est_2022	-.862	.859	
Constant	19.283	.542	
R-squared 0.954		Number of obs	67

*** *p*<.01, ** *p*<.05, * *p*<.1

5.2. 2018 Scores Analysis, Results and Discussion

The preceding analysis has highlighted the role that past academic performance may have, particularly the 2018 PISA scores, in predicting 2022 PISA scores. By incorporating control variables so that our model would reflect causality, we observed that these controls exhibited varying levels of significance across different subjects when included with the scores from the previous period (2018).

To further investigate the factors influencing academic performance, we now shift our focus to an analysis using the 2018 PISA scores as the dependent variable, alongside a set of important control variables. This approach aims to understand the underlying factors of student performance before the COVID-19 pandemic disruptions affected students worldwide. The purpose of this new analysis is two-fold: it lies in examining the 2018 data and establishing baseline relationships between student performance and control variables such as socio-economic factors and educational resources. This in turn will allow us to compare and contrast the pre-pandemic and post-pandemic results and draw conclusions.

Our main objective with our 2018 analysis is to set a benchmark and explain why the scores from the previous period held the scores of the current period with such a tight grip. Perhaps the decline in student performance was already an ongoing problem even before the COVID-19 pandemic hit, and said pandemic only helped emphasise those problems. For example, countries that remained closed longer during the pandemic might have been struggling already with pre-existing resource constraints, leading to lower performance in 2018. These countries might have struggled more with transitioning to remote learning, exacerbating existing inequalities.

Furthermore, those same regions could have faced pre-existing economic vulnerability or weaker infrastructure, which might have affected access to healthcare and a slower vaccine rollout, forcing governments to longer school closures due to health risks.

We will begin our analysis similarly to our approach with the 2022 scores. Specifically, we will use the PISA test scores from 2018 and run a regression with our main treatment variable of interest, the number of weeks schools were totally closed. Although there were no school closures in 2018, this analysis can provide insightful baseline data. Interestingly, our regression results for the three school topics revealed that the number of weeks totally closed was statistically significant and had a negative coefficient. This suggests that countries which experienced prolonged school closures during the pandemic were already performing poorly in the 2018 PISA scores. Furthermore, when we tested for schools that remained partially open, our findings aligned with the data from 2022: the coefficient was weaker and also statistically significant.

Tables VII and **VIII** will present our results.

TABLE VII

INTRODUCTION MODEL WITH THE MAIN TREATMENT VARIABLE OF INTEREST

Linear regression

score_math_2018	Coef.	p-value	Sig
n_weeks_tot_clos	-2.897	0	***
Constant	509.643	0	***
R-squared 0.467		Number of obs	72

*** *p<.01*, ** *p<.05*, * *p<.1*

Linear regression

score_read_2018	Coef.	p-value	Sig
n_weeks_tot_clos	-2.518	0	***
Constant	498.601	0	***
R-squared 0.416		Number of obs	71

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_science_2018	Coef.	p-value	Sig
n_weeks_tot_clos	-2.573	0	***
Constant	503.174	0	***
R-squared 0.448		Number of obs	71

**** p<.01, ** p<.05, * p<.1*

TABLE VIII

INTRODUCTION MODEL

Linear regression

score_math_2018	Coef.	p-value	Sig
n_weeks_part_open	-1.08	.018	**
Constant	481.867	0	***
R-squared 0.093		Number of obs	72

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_read_2018	Coef.	p-value	Sig
n_weeks_part_open	-.756	.087	*
Constant	470.645	0	***
R-squared 0.055		Number of obs	71

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_science_2018	Coef.	p-value	Sig
n_weeks_part_open	-.756	.069	*
Constant	474.166	0	***
R-squared 0.057		Number of obs	71

**** p<.01, ** p<.05, * p<.1*

We proceed with our analysis by adding more control variables to our model to further study the PISA test scores in 2018. The following model will control for two key variables: GDP per capita and the Gini coefficient. We aim to demonstrate that countries that faced more inequality performed worse in 2018, the same as in 2022. Our results demonstrate that countries that face more inequality performed worse when compared with countries with similar GDP per capita. However, the statistical significance of the Gini Index only proved true to mathematics and science, as opposed to 2022 which only math was statistically significant.

An important factor to consider is the stronger and larger coefficient for the Gini Index in math compared to other school topics. Current literature states that math was the most affected course [Haelermans et al., 2022], and our preliminary results support this claim. In this particular case, the Gini index measures income inequality within a country. Higher inequality can lead to disparities in educational opportunities, particularly affecting subjects that require more structured and resource-intensive instruction, such as math.

Table IX will demonstrate our results.

TABLE IX

TESTING INEQUALITY

Linear regression

score_math_2018	Coef.	p-value	Sig
gdp_pc_2018	.002	0	***
gini_2018	-2.305	.014	**
Constant	489.76	0	***
R-squared 0.543		Number of obs	73

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_read_2018	Coef.	p-value	Sig
gdp_pc_2018	.002	0	***
gini_2018	-1.013	.146	
Constant	440.578	0	***
R-squared 0.503		Number of obs	72

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_science_2018	Coef.	p-value	Sig
gdp_pc_2018	.001	0	***
gini_2018	-1.557	.03	**
Constant	466.868	0	***
R-squared 0.504		Number of obs	72

**** p<.01, ** p<.05, * p<.1*

To gain further insights, we will move to our final model. Our final regression model will include the same control variables used in the 2022 model: the main treatment variable of interest, GDP per capita, population density, the Gini Index, the unemployment rate, and the Government Effectiveness Estimate

The results demonstrate that schools that faced longer periods of school closures in 2022 were already performing badly in 2018. The number of weeks schools remained closed is statistically significant for the three topics, albeit less significant than in 2022. Unemployment appears as non-significant in all topics, a complete opposite of our 2022 model. Similar to our previous model where we tested inequality, this final model shows statistical significance for the Gini Index in math and science. A possible explanation for this is that, while math and science require a more structured education plan and more resources, reading is slightly less dependent on those economic factors. Parental involvement and literacy practices at home, which can be less influenced by income inequality, might play a large role in reading development.

The Government Effectiveness Estimate demonstrates results in all three models, with a strong coefficient and statistically significant, similar to our final model from 2022, shown in Table V. The results suggest an important role that effective governance has in educational outcomes. Effective government can enhance educational quality through better policy implementation or better resource allocation, which may benefit students. It is important to note that while Government Effectiveness remains a significant factor, its effect was weaker in 2022. This reduction in impact could be possibly attributed to the disruptions caused by the COVID-19 pandemic.

Table X will demonstrate our results.

TABLE X

2018 FINAL MODEL

Linear regression

score_math_2018	Coef.	p-value	Sig
n_weeks_tot_clos	-.744	.012	**
gdp_pc_2018	0	.062	*
PopDens2018	.006	0	***
gini_2018	-1.717	.003	***
unemp_2018	.208	.813	
gov_effec_est_2018	57.871	0	***
Constant	495.627	0	***
R-squared 0.803		Number of obs	72

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_read_2018	Coef.	p-value	Sig
n_weeks_tot_clos	-.781	.037	**
gdp_pc_2018	0	.891	
PopDens2018	.003	0	***
gini_2018	-.234	.66	
unemp_2018	.572	.603	
gov_effec_est_2018	47.654	0	***
Constant	435.014	0	***

R-squared	0.714	Number of obs	71

**** p<.01, ** p<.05, * p<.1*

Linear regression

score_science_2018	Coef.	p-value	Sig
n_weeks_tot_clos	-.766	.011	**
gdp_pc_2018	0	.117	
PopDens2018	.004	0	***
gini_2018	-.84	.098	*
unemp_2018	.067	.938	
gov_effec_est_2018	52.935	0	***
Constant	468.076	0	***
R-squared 0.768		Number of obs	71

**** p<.01, ** p<.05, * p<.1*

6. Conclusion

In this paper, we investigated the association/correlation between school closures and PISA test scores and tried to hint at causality via the inclusion of control variables. Previous studies have found, mostly at a school or student level, that school closures may have had a negative effect on students' performance, with multiple countries observing a decrease in students' scores and learning loss. This study attempted to achieve these results on a country-level, by comparing one country to another and contributing to the literature on school closures and students' performance during the COVID-19 pandemic.

Our contribution is based on comparing countries with varying lengths of school closure by testing the importance of the intensive margin. It also lies in understanding how national policies influence educational outcomes during crises such as the COVID-19 pandemic. Country-level analysis provides a more comprehensive view of the broader policy landscape. Furthermore, this study provided insights into resource allocation and equity issues on a national scale. We have discovered that more unequal countries performed worse in the PISA test scores, for example.

Our findings suggest that while school closures may have affected academic performance, the effect is relatively small compared to the predictive power of past performance. Countries with longer school closures during the pandemic also had worse test performance in 2018. This pre-existing difference suggests that the observed negative association between school closures and test performance in 2022 is partly due to the fact that countries with lower baseline performance tended to have longer school closures. Therefore, the correlation does not imply that longer school closures caused the decline in test performance in 2022. Instead, it reflects underlying differences in educational performance that were already present before the pandemic. In sum, it is possible that countries were already struggling before the COVID-19 pandemic started, and said pandemic made matters worse by exacerbating ongoing problems.

Future research could explore the option of employing a difference-in-differences (DiD) model in order to provide a more robust analysis of the causal impact of school closures. By comparing the changes in PISA scores over time between countries that experienced different extents of school closures, the DiD approach could better isolate the effect of school closures.

As with any study, it has its limitations; specifically, the country-level analysis may mask important regional differences within countries, leading to an oversimplified understanding of the impact of school closures. Furthermore, while the study hints at a negative correlation between school closures and student performance, establishing causality remains challenging. The results may be subject to endogeneity issues without more robust causal inference methods, such as difference-in-differences (DiD).

One potential source of endogeneity could be the unobserved variable of digital infrastructure and access to online learning resources. If countries with better digital infrastructure also experienced fewer negative impacts from school closures on PISA scores, failing to account for this factor could bias the results.

Despite this study's limitations, the results presented in this paper demand attention because they provide possible insights into the complex relationship between school closures and student performance on a global scale.

Finally, this paper also highlights the importance of being well-prepared in case another challenge, such as the COVID-19 pandemic, emerges. As we move forward, leveraging all findings to maintain robust educational foundations worldwide and improve our educational infrastructure is essential.

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