



### Towards Safe Opening of The Education Sector in Covid-19 Times



### **Key messages**

- Worldwide, school closures have been justified for mitigating Covid-19 spread. In Uganda, the lives 15 million learners were saved from Covid-19 infection.
- Prolonged school lockdown has led to 51% of learners across the entire education system to stop learning, majority (60%) of these being from the primary subsector. Approx. 30% of learners are projected not to return to school forever due to teenage pregnancies, early marriages, and child labour. Additionally, about 3,507 primary and 832 secondary schools are likely to close due to financial distress.
- Due to lockdown, already 2 academic years have been lost leading to multiple cohorts (2020 and 2021) being enrolled in primary one, senior one, senior five- and first-year tertiary.
- The Covid-19 risk for reopening schools is lower if phased starting with tertiary, then secondary and primary simultaneously. This is on condition that all teachers (approx. 550,000), and learners who are 18 years and above (approx. 650,000) are vaccinated, and that unvaccinated children particularly those who attend boarding schools are tested on return to school.
- Nonetheless, phased opening makes the primary subsector to wait longer hence increasing the cost of prolonged primary school lockdown, which is already phenomenal in terms of lost learning, limited access to learning platforms, child labour prevalence rates and teenage pregnancies. In addition, education being a system, it operates better as a whole, locking one subsector impacts the flow in those that are open.
- Since opening of primary and secondary schools specifically introduces the highest risk (40% increment) to Covid-19 cases through compromised country stringency index (SI), an alternating model of attendance for day schools is favoured such that lower primary and lower secondary can attend school from Monday to Wednesday while upper primary and upper secondary can attend school from Thursday to Saturday.
- On reopening, it is recommended that learners be automatically promoted to the next grade to avoid a system clog; daily tests and unwarranted assessment of learners should be suspended; the curriculum should be condensed across the entire education sector (save for medical courses) to only focus on the core curriculum knowledge and skills; Saturdays should be added to school days for purposes of learning recovery; and school holidays should be made shorter.

## **Executive Summary**

1. Before the advent of Covid-19, Uganda's education system had registered tremendous achievements attributable to the deliberate interventions by government in the sector. For instance, the presidential directives to have a public primary and secondary school per parish and sub-county respectively, led to 92% of all parishes having a public primary school and 72% of all sub-counties having a government secondary school. In addition, each region now has a government university while majority of the districts have a technical institution. The net effect of these investments is the increased access to education and training opportunities across the country.
2. However, some of the tremendous achievements in the sector are at risk of being reversed due to the effects of Covid-19. When Covid-19 hit the world, majority of the countries including Uganda closed their economies and the education sectors to save lives of

particularly citizens in congested places such as education institutions. Hitherto, the national education system has been locked up for approximately 18 months.

3. Whereas government committed to support the continuation of learning during school lockdown, through various remote learning options, evidence shows that majority (51%) of learners across the entire education system stopped learning with the closure of their schools. More learning has been lost in the primary subsector (60%) compared to secondary (44%) and tertiary (42%) subsectors (FAWE, 2021).
4. In addition, due to prolonged school closures; it is projected that 30% of the learners are likely not to return to school forever; many teachers are likely not to return particularly after engaging in more lucrative commercial activities; 3,507 primary and 832 secondary schools are likely to close due to financial distress; and there is a risk of multiple cohorts getting enrolled in Primary One, Senior One, Senior Five and first year of tertiary.
5. To facilitate evidence-based decision making for school reopening, the National Planning Authority (NPA) has undertaken Covid-19 modeling using various school opening scenarios. Four scenarios were modeled including:
  - a) **Scenario1:** Fully open up all education institutions with status-quo on vaccination. This was found to be unsustainable
  - b) **Scenario2:** Fully open up all education institutions with full vaccination of all the eligible population. This was found to be not timely and unaffordable in the short term.
  - c) **Scenario3:** Fully open up all education institutions with vaccination of only the eligible student (18 years and above) and teacher population. This was found to be plausible but presented a risk of having all learners physically present in school at the same time.
  - d) **Scenario 4:** Phased opening of schools by levels, adoption of alternate models of attendance for day schools with vaccination for only teachers and eligible student population and testing of unvaccinated children starting with those in boarding schools.

Scenario 4 is favoured since the phased option is associated with low risk albeit with a high cost of prolonged lockup of the primary education subsector. In addition, education being a system, it operates better as a whole, locking one subsector impacts the flow in those that are open. Accordingly, to avert the cost of prolonged lockdown of particularly the primary schools, opening **of all institutions with alternated attendance for day schools is highly recommended** as it does not significantly compromise the country's stringency index<sup>1</sup>, and it is inclusive, equitable, timely, affordable, easier to achieve and optimal.

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<sup>1</sup> A stringency index (SI) measures represents the strictness of containment measures and health policies introduced in a country to manage the covid-19 pandemic

6. The school opening scenario chosen entails<sup>2</sup>:
  - (i) Vaccination of all teachers (approx. 550,000) and students who are 18 years and above (approx. 650,000) within the shortest time. Choice of age 18 is on the basis of absence of evidence on the suitability of vaccinating children below 18.
  - (ii) Testing of the unvaccinated learners for Covid-19 on return to school starting with those who attend boarding schools. Parents can share the cost of testing their children while government can provide support to those who attend UPE and USE schools.
  - (iii) **Opening of education institutions by adopting the alternating school attendance model for day primary and secondary learners where particular classes study on different days of the week including Saturday.** This can be arranged such that lower primary and lower secondary attend Monday to Wednesday while upper primary and upper secondary attend Thursday to Saturday. With regard to full-boarding schools, it is possible for all learners to report to their schools on condition that they have taken Covid-19 tests and their teachers fully vaccinated.
7. We further suggest that if the option to open schools is carried forward, there are common practices that have worked elsewhere in comparable countries that we recommend for prioritization.
8. **Health and hygiene:** we recommend prioritization of (i) wearing of masks as part of the school uniform (ii) handwashing (iii) social distancing.
9. **Education budget:** there is need to ringfence the education budget from further cuts and concentrate it on key budget lines including: (i) students' capitation (ii) instruction materials (iii) Teachers' salaries (iv) University Research and Innovation fund for use for researching Covid-19 health and business solutions, and (v) capacity building for lower secondary teachers to rollout the new curriculum. Financially distressed schools will need to be included amongst the business categories destined to benefit from low-cost funding from the Uganda Development Bank (UDB).
10. **Remedial measures to address learning gap on reopening:** we recommend that learners should be automatically promoted to the next grade regardless of the amount of learning achieved to avoid clogging the entire education with multiple cohorts in the same grade and delayed enrolment. This should be followed by learning recovery measures

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<sup>2</sup> These options presume that key SoPs particularly wearing masks, handwashing and to some extent social distancing are to be enforced.

including:(i) Suspension of daily tests and unwarranted testing of learners such that time is dedicated to teaching (ii)Condensing of the curriculum across the entire education sector (save for medical courses) to enable teachers only focus on the core curriculum knowledge and skills (iii)adding Saturdays to school days for purposes of learning recovery (iv)resorting to shorter holiday breaks

11. **Preventing dropout and early school leaving:** we recommend that (i) a multi-stakeholder approach involving parish chiefs, village churches, local cultural/clan leaders, similar to that used to combat HIV, be adopted to implement a parish level outreach strategy for engaging families with learners that are at high risk of dropping out of school to ensure that such children are (re)enrolled in school (ii) a campaign to encourage economically struggling households who might fail to cope with private education tuition to enroll their children in public schools in the neighborhood be undertaken
12. **Building better against future pandemics:** in the medium term, we recommend the need to (i) digitize the education service by leveraging ICT in the teaching, learning, management and monitoring and evaluation processes (ii) develop off-school learning options including village-based learning communities (iii) provide the basic minimum infrastructure to ensure that all who enroll into the system stay on for atleast 11 years as a precondition for harnessing the demographic dividend.

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## **1.0. Introduction**

This technical note seeks to inform government on options available towards reopening of the education sector. It comes at a time of the increasing collateral damage to the education sector and anxiety and uncertainty amongst the education stakeholders in regard to the continued closure of education institutions due to Covid-19.

The note draws on evidence from the National Planning Authority (NPA) Covid-19 modeling, the rapid assessment of the Covid-19 impact on the education sector, the common practices of other comparable countries and the concerns of learners, parents, and teachers; to recommend informed scenarios to guide re-opening of education institutions.

## **2.0. Background**

When Covid-19 hit the world, majority of the countries including Uganda closed their economies and the education sectors to save lives of particularly citizens in congested places such as education institutions. Closure of schools was as well for purposes of slowing down the spread of the pandemic while at the same time prop up the health and education systems capacities to manage the pandemic.

Uganda first closed its education institutions on the 20<sup>th</sup> March 2020 during the first wave of the pandemic with some phased reopening for candidates, final year students and medical students. The country was destined to open up the entire system in June 2021 with the return of the lower primary and secondary learners. Unfortunately, this did not materialize due to the second wave spike in May-June 2021 that led to the reversal in the reopening efforts.

Hitherto, Uganda is one of the countries whose education systems remain closed. Some peers including Kenya, Tunisia, Equatorial Guinea, Tanzania, Djibouti, and Burundi have opened their education systems. Relatedly, 21 African states have partially opened schools with limitations (World Bank, 2021).

## **3.0. The Cumulative Impact of Covid-19 on the Education Sector**

Closure of education institutions saved the lives of 15 million learners in the education system who were at a high risk of contracting Covid-19. Also, available evidence shows that while learners in basic education are sometimes not severely affected by Covid-19, they can be a serious vector to the community including their parents. Therefore, it very important to note that school lockdowns helped to flatten the curve for Covid-19 infections in the entire population prior to the second wave. This has also been the case with the second lockdown.

However, the prolonged school lockdown (now for 18 months) has already severely affected the education sector generally and in particular learners, parents, education institutions, the economy

and the key human capital development results. The findings from the NPA rapid assessment rapid assessment of the significant effects, threats and opportunities to the education sector due to COVID-19 project the following:

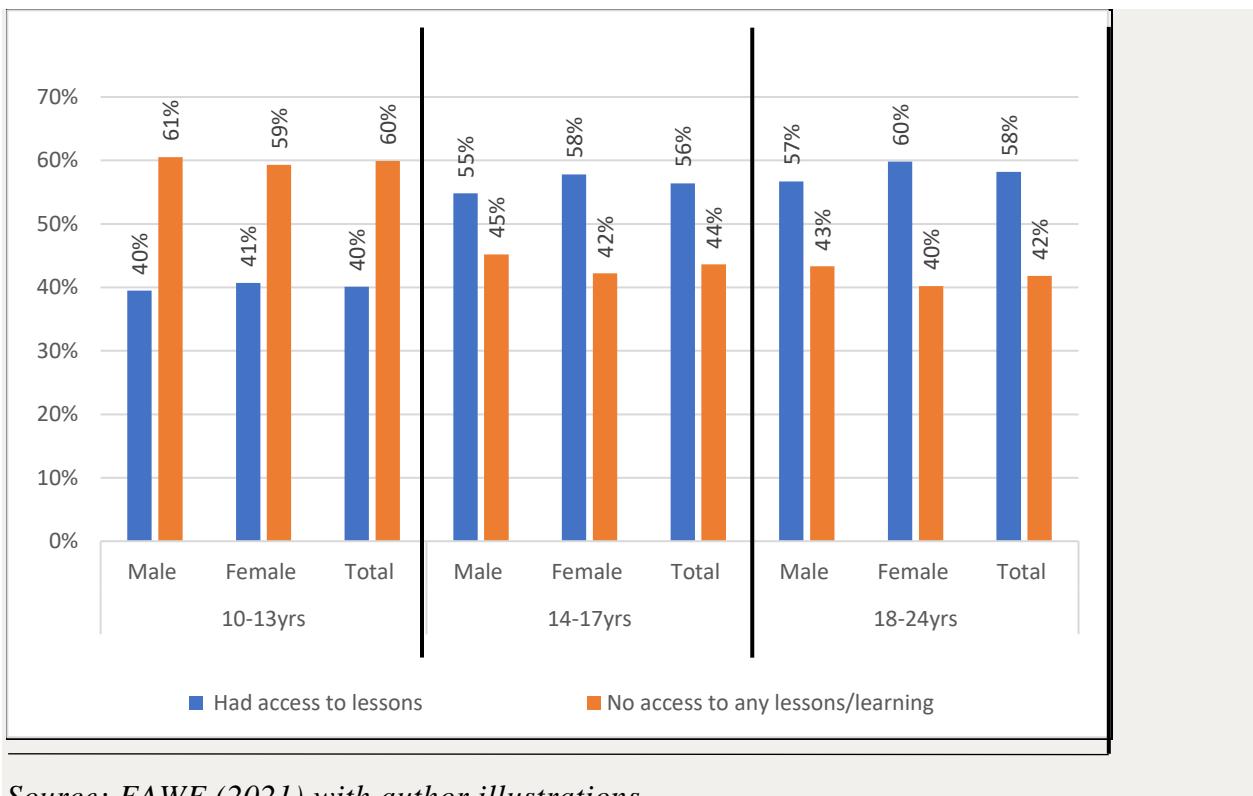
### **3.1. Continuity of Learning in the Country During Covid-19**

The Ugandan government adopted and supported a multipronged approach to ensure continuity of learning through remote learning models. Key among these include: the use of print learning materials developed by the National Curriculum Development Centre (NCDC), TV lessons, Radio lessons, Internet-based learning and home schooling that entails parents teaching their children. As a result, about 49% of the learners have been able to continue learning from home.

Overall, majority (51%) of learners in Uganda across the various education subsectors have no access to learning. By gender, fewer males (47.6%) have access to learning during the lockdown compared to females (50.4%). Majority (52.2%) of those who are not learning during covid-19 school lockdown are found in the rural areas while atleast 50.2% of their urban counterparts have continued to learn during Covid-19 lockdown (FAWE,2021).

By age, majority (60%) of children in primary schools (10-13years) are not learning during Covid-19 compared to their older counterparts. The regions with limited access to learning during the lockdown include Ankole (30.8%), Teso (31.8%), Lango (32.4%), Bukedi (35.3%), Kigezi (37.4%), and Acholi (39.3%). On the other hand, majority of learners living in refugee communities (62.7%), Sebei (74.3%), Karamoja (65.3%), and Kampala (60.7%) have continued learning during Covid-19 lockdown (FAWE, 2021).

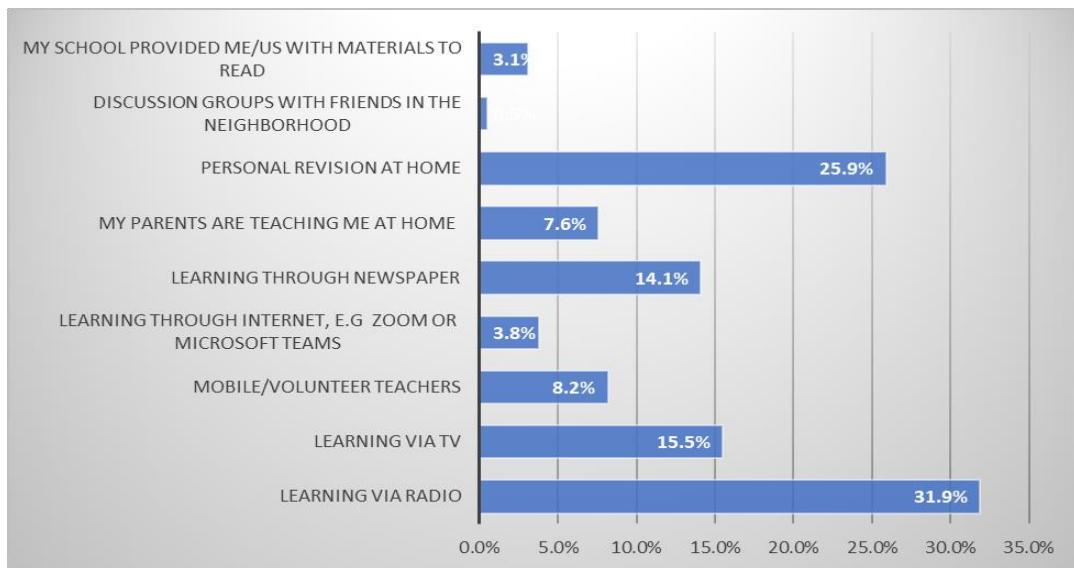
Figure 1: Status on access to continued learning during Covid-19 lockdown



*Source: FAWE (2021) with author illustrations*

Learning via radio (32%), home schooling (25.9%), and learning via TV (15.5%) are the most commonly used platforms for learning. On the other hand, print materials provided by schools (3.1%), learning through internet ie zoom (3.8%), mobile/volunteer teachers (8.2%) and parental teaching at home (7.6%) are the least used learning platforms during Covid-19 lockdown. Limited use of the various learning platforms in Uganda is mainly attributed to cost, limited coverage and limited access by households. For instance, TV platforms exclude 85% of the households without access, Radio platforms exclude 56% of the households without access, while platforms that require electricity and internet exclude 72% and 49% of the households respectively.

*Figure 2: Platforms used to continue learning during covid-19 school lockdown*



Source: FAWE (2021) with authors' illustrations

### **3.2. Likely reversals in the significant gains made in the education sector**

Beyond the exponential increase in enrolments across the entire education system due to deliberate government policies and interventions, the government of Uganda has ensured that 92% of all parishes gets a public primary school and 72% of sub-counties have a government secondary school. In addition, each region now has a government university while majority of the districts have a technical institution. The net effect of these investments is the increased access to education and training opportunities.

However, due to Covid-19, there is a likelihood that the achievements registered in the education sector could be constrained and or be reversed. Evidence from school closures due to pandemics such as Ebola in Sierra Leone shows that about 30% of learners particularly girls never return to school after prolonged lockdowns. There are vivid signals that this could happen in Uganda after schools open. Secondly, there is evidence that many teachers, after exposure to very many alternative options of making money may not return to schools. Those who will return are likely to be more absent as they try to balance school and private business times. This might leave the country with a lot of school infrastructure without education service.

According to the Health Management Information System data, there has been a surge in teenage pregnancies across the country during the lockdown. For instance, pregnancy cases among girls aged 10-14 increased by 366.5% between March 2020 and September 2020. In addition, pregnancy cases among girls aged 10-24 increased by 22.5% between March 2020 to June 2020 while the pregnancy cases among those aged 15-19 increased by 25.5% over the same period. The District Health Information System 2 (DHIS2) indicates that districts within Busoga region, North Central, Lango, South Central, West Nile and Tooro have been severely affected in regard to teenage pregnancies compared to others. For instance, between March and June 2020, Bugweri District

registered 106% increase in pregnancies of girls aged 15-19, followed by Kibaale (89.4%), Dokollo (80%), Mubende (77.3%), Kiryandongo (75.7%), Kyegegwa (68.4%), among others. Besides teenage pregnancies, closure of schools is providing a perfect pretext for parents to push their girls into marriage. Given that teenage pregnancies and early marriages are significant correlates of school dropout, it suffices to project that many girls will not return to school after reopening. This is likely to affect one of the key human capital development programme targets of keeping girls in school for atleast 11 years in school, as a precondition for the Uganda to achieve the Demographic Dividend. In addition, keeping girls longer in school reduces the fertility rate, consequently reducing maternal and infant mortality.

### **3.3. Two years have already been lost across the entire education system due to non-progression of learners**

- i. An irreversible consequence of the lock down is that each learner (save for those in international schools) has already lost 2 years. This implies that each learner has been in the same grade for now 2 years since 2020. There are two serious consequences to this. Foremost, learners particularly in the basic education subsector have outgrown their grades and this makes them prone to dropping out since evidence shows a higher likelihood for older learners to drop out of lower grades.
- ii. Secondly, the lost two years have led to two cohorts enrolled in the entry and transition grades: (i) Two Primary one (P1) Cohorts ie 2020 cohort and the 2021 cohort (ii) Two Senior One (S1) cohorts ie 2020 cohort and the 2021 cohort, (iii) Two Senior Five (S5) cohorts ie 2020 and 2021 and (iv) Two year one cohorts at tertiary institutions. In terms of numbers, P1 2020 cohort is estimated at 2.4Million children while that of 2021 cohort is estimated at 2.5Million. For Senior one, cohort 2020 is estimated at 0.503Million while that of 2021 is estimated at 0.58Million students. In addition, the S5 cohorts for 2020 and 2021 are estimated at 0.113million and 0.115 students respectively. At tertiary, the average intake per year is about 70,000 students. If the 2020 cohorts remain stark in P1, S1 and S5, the country will need an additional UGX 4.31Trillion to build 62,000 additional classrooms, assuming a pupil classroom ratio of 53:1; and to recruit 73,700 additional teachers assuming a teacher pupil ratio of 1:43, within one financial year.

### **3.4. Increased loss of learning due to the intermittent closures of schools and training institutions due to COVID-19 flareups**

It has become increasingly clear that there few inclusive and equitable options to continue learning particularly in developing countries. This is against the backdrop of only 30% of the total students' population is having access to the various learning interventions provided by various stakeholders including the government. Also, given that the lockdowns have always coincided with the planting season and or harvesting seasons in the countryside, 24% of the learners particularly from the poorest quintile are fully in gardens providing labour without time to continue learning using the alternative measures.

### **3.5. Shrinking supply of education due to economic shock to schools/training institutions**

It is projected that without significant support, about 3,507 (1,749 urban and 1,758 rural) poor private primary schools are at risk of forced closure due to financial distress and indebtedness. Consequently, the future of approximately 1,534,000 primary school children remains uncertain. At secondary, a total of 832 (472 urban and 360 rural) poor private schools face closure due financial distress and indebtedness thereby putting the future of 390,000 learners at stake. The situation is more precarious for higher education as 80% of the private universities have already communicated financial distress to their staff. Consequently, about 1,131 of full-time staff in the private universities are likely to lose their jobs and or get suspended contracts. Similarly, about 106,336 students attending these institutions are at risk of dropping out and or taking dead years, should these institutions close permanently. While pre-school subsector was not assessed in the research, given that it is 100% privately provided, the risk seems even higher than the rest of the subsectors.

### **3.6. Shrinking demand for education due to economic shock to households and government**

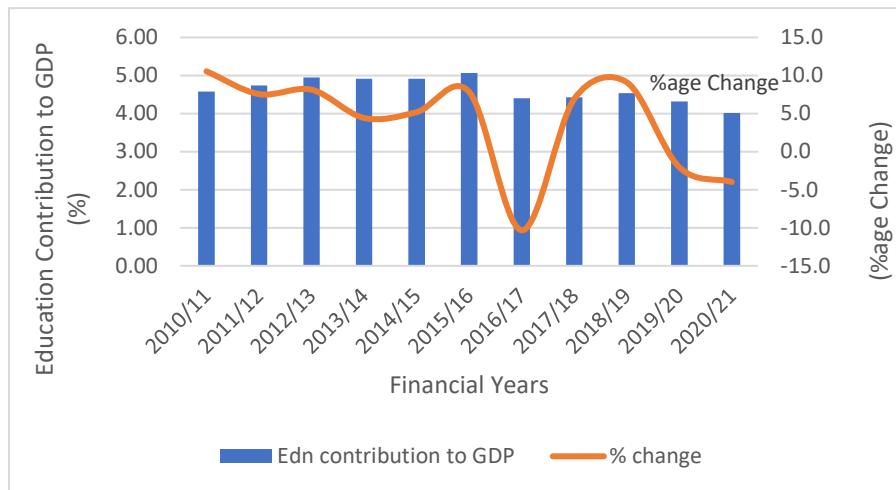
It is projected that the COVID-19 coping measures would push poverty levels from 21% to 24% and also increase the likelihood of 40.6% of non-poor households becoming poor. Consequently, about 64.6% of the parents with students who pay fees will struggle or even fail to pay tuition. This will increase non-enrolments, school dropouts and dead years. We estimate a 19-20% increase in the number of young girls becoming the main breadwinners for families through among others, sexual exploitation, child labour and early marriages. Besides, just as it happened in Liberia after the Ebola outbreak, many Ugandan parents might not know about the reopening of the schools and the implementation of the strict protocols to ensure safety. Similarly, we anticipate that some parents may prevent their children from returning to schools because of the continued pandemic. On the government side and other donors, there has been a squeeze on education financing due to the need to pump resources into among others the health sector in the short term. In the long run public revenue is likely to plummet thereby constraining the country's ability to invest more in education.

### **3.7. Economic Loss due to Education Institutions' Closure**

The education sector accounts for quite a measurable contribution to Uganda's GDP, hovering between 4.01% and 5.01% in the last decade, with the lowest, 4.01% coming in FY 2020/21. This is as shown in figure 1. The Education sector is therefore a significant sector in Uganda's GDP, especially because education has economy wide effects given the number of both intra and inter-sectoral linkages across various value chains. The sectors affected by closure of schools include: education; agriculture; business; printing businesses; health; management; construction; research;

and industry among others. The sector also has significant effects on Uganda's employment, employing about 4% of Uganda's total labour directly and many other indirectly.

*Figure 3: Contribution of the Education Sector on Uganda's GDP*

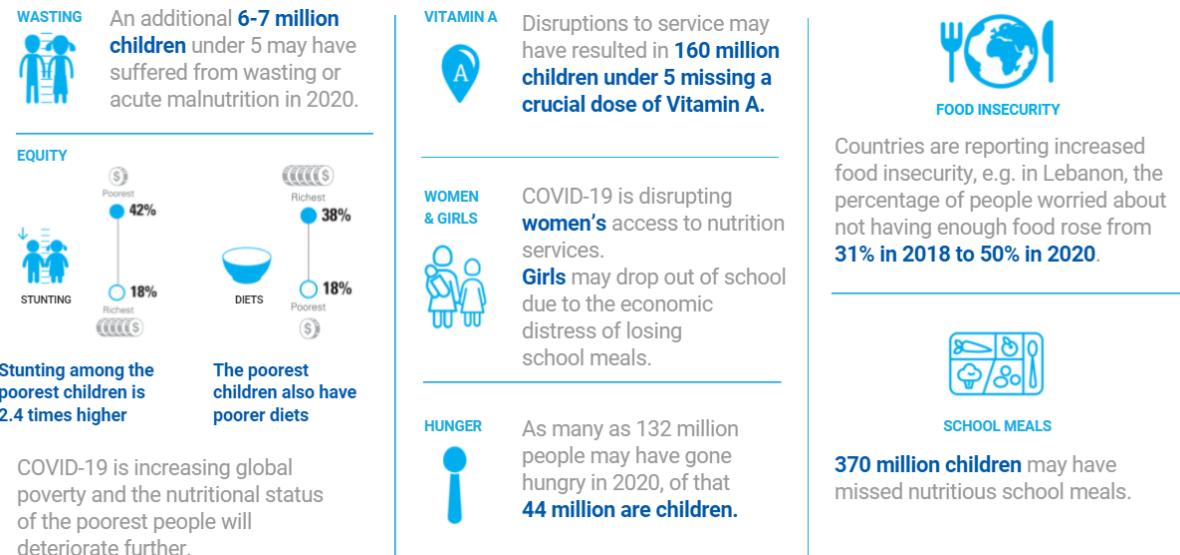


*Source: UBOS (2020/21)*

Beyond the economy, the Covid-19 pandemic has increased exposure of children to violence, exploitation and child labour. This based on the backdrop of the decreasing role of the family in safe child upbringing and an increasing role of the school in child upbringing. For instance, when schools shut down, early marriages, sexual exploitation of girls and young women, teenage pregnancies and child labour have all significantly increased.

As illustrated in Figure 4, there have been significant negative impacts of Covid-19 on malnutrition; increased HIV infections; increase in violence, abuse and exploitation; and an additional 10 million child marriages (UNICEF, 2020).

*Figure 4. Impact of COVID-19 on children's nutrition*



## 4.0. Options Available for School (re)Opening

Discussions and actions towards reopening of education institutions can invoke a sigh of relief as well as anxiety to stakeholders including government, parents, the community and school managers. Decisions to continue locking education institutions and or reopening them are faced with the challenge of balancing between:

- Saving life, as the ultimate consideration
- Saving livelihood; and
- Saving the future of a generation whose lives have been saved.

Evidence shows that there is no single best option. For instance, while school closures are ultimately about saving lives, such a benefit would be discounted if the prolonged closures rob a generation whose lives have been saved of a future.

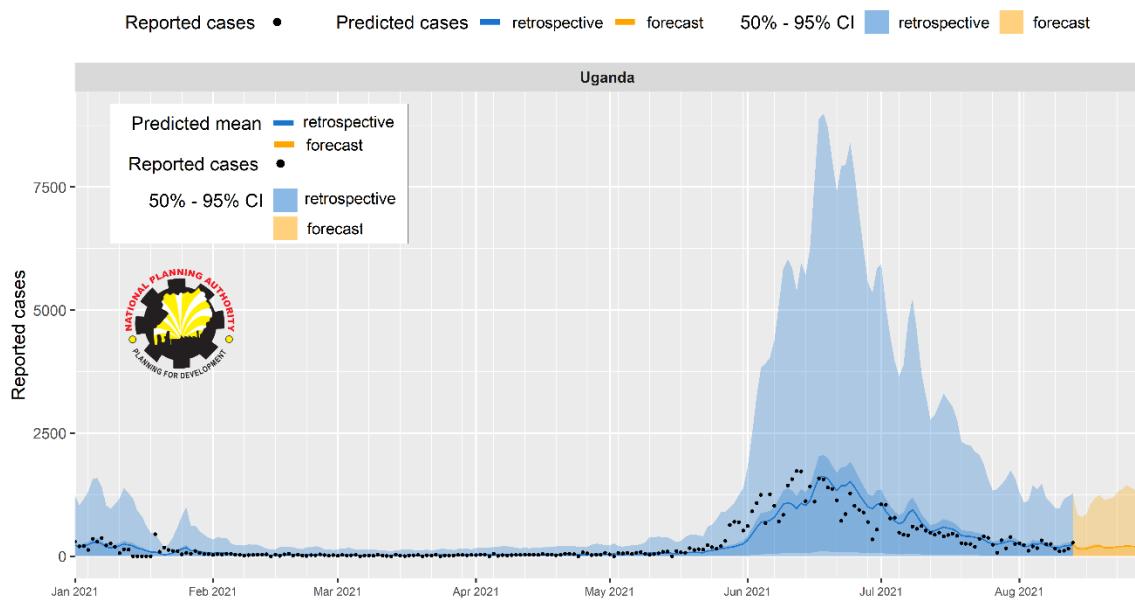
In light of the above, the common practice for countries that have reopened have been using evidence. In this paper, NPA tries to provide evidence to support decision making on the education sector. Below, we model different scenarios aimed at providing the short-term likely behaviour in covid-19 cases using various school parameters.

### 4.1. COVID-19 trends as of 16<sup>th</sup> August, 2021

According to the Ministry of Health Statistics, the number of cumulative COVID-19 cases are 97,124 and the active cases (hospitalizations) are about 471. The daily new COVID-19 cases for the last 7 days were; 137, 309, 181, 273, 157, 112 and 132, respectively, giving a daily average new cases of 186 over the last 7-day period. It can be observed from Figure 5 that the trend of

the number of daily cases has been going down since the beginning of August, 2021. The current number of daily cases is projected to increase to 179 in the week ending 21st August and 197 in the week ending 28th August, 2021. This increase is due to the effects of easing the lockdown (increased movement).

Figure 5: COVID-19 daily cases and projections since March, 2021



## 4.2. Possible School Opening Scenarios

The options modeled considered what would happen to the daily COVID-19 cases in the short-term (ie 28 days commencing 20<sup>th</sup> August 2021 and ending 14<sup>th</sup> September 2021) if education institutions were to be opened under the various scenario. It is critical to note that the assumption of vaccination has no bearing on the Covid-19 cases cited in the various scenarios modeled in this exercise. This is because the maximum impact of vaccination on covid-19 cases has a time lag of about 7 days after the second dose<sup>3</sup>, which is beyond the 28 days' period covered by the projection model currently being used.

**Table 1. Summary of modeled scenarios**

Scenario	Description	Cost implication	Risks	Benefits	Conclusion
<b>Scenario1:</b> Fully open up all education institutions with status-quo on vaccination	This scenario considers opening of all education institutions under the current levels of vaccination	This will require capitation for government schools and tertiary institutions	Compromise of the stringency index from 50% to 21.6% due to increased movements of students particularly in day schools leading to a likely spike in Covid-19 cases by 46% with daily average of 327 compared to the status quo of 224 over the modelled period.	Immediately relieves government of pressure to reopen schools; ensures increases short-term access to learning; and likely to stimulate the economy due to increased aggregate demand	Not sustainable
<b>Scenario2:</b> Fully open up all education institutions with full vaccination of all the eligible population	This scenario considers opening up of all education institutions after vaccinating 22 million eligible Ugandans	•Capitation for all schools and tertiary institutions •Cost of vaccination for 22 million persons	•Time spillover as it requires approx. 6 months to implement with availability of required stock of vaccines •Increases the pressure and anxiety from stakeholders to open	Sustainably lowers the risk of covid-19. Available evidence indicates that 95.3% <sup>4</sup> of vaccine effectiveness can be achieved at 7 days or longer after the second dose	Not timely and not affordable in the short to medium term
<b>Scenario3:</b> Fully open up all education institutions with vaccination of <u>only</u> the eligible student (18 years and above) and teacher population	This scenario considers opening up of all education institutions after vaccinating approx. 550,000 teachers and	•Capitation for all schools and tertiary institutions	Possibility of continued community level spread particularly from learners (at primary and secondary) to their parents	•Lowers the risk of learners infecting their teachers and vice-versa but may not significantly impact Covid-19 weekly averages	It is timely, affordable, easier to achieve.

<sup>3</sup> Haas et al. 2021

<sup>4</sup> Haas et al. 2021

Scenario	Description	Cost implication	Risks	Benefits	Conclusion
	approx. 650,000 eligible students (18 years and above)	•Cost for vaccination for 1.2 million persons		•Relieves government of pressure to reopen schools; ensures increases short-term access to learning	
<b>Scenario 4:</b> Phased opening of schools by levels, adoption of alternate models of attendance with vaccination for only teachers and eligible student population and testing of unvaccinated children starting with those in boarding schools	This scenario considers: (i)opening of education institutions in a phased manner ie Primary only, secondary only, tertiary only (ii)opening of a combination of education levels (iii)Vaccination of teachers and learners 18 years and above (iv)School-based testing of the unvaccinated children	•Capitation for all schools and tertiary institutions •Cost of vaccination for 1.2 million persons •Cost of testing approx.. 8.2 million learners in government primary and secondary schools.	Possibility of continued community level spread particularly from learners. (i)Opening tertiary only increases new cases by 8% from 224 to 242 within the 28 days of model projection (ii) Opening secondary only increases new cases by 18% from 224 to 264 (iii)Opening of primary only increases new cases by 38% from 224 to 310 (iv)Combining Tertiary and Secondary increases new cases by 32% from 224 to 295 (v)Opening following the order Tertiary+Secondary&Primary would increase new cases by 46% from 224 to 327	•Lowers the risk of learners infecting their teachers and vice-versa  •Improves surveillance of infection particularly among unvaccinated learners in primary and lower secondary	The phased option is associated with low risk albeit with a high cost of prolonged lockup of the primary education subsector. Accordingly, opening of all institutions with alternated attendance for day schools is <b>highly recommended</b> as it is timely, affordable, easier to achieve and optimal.

## 4.3. Details for Modeling the School Opening Options

### 4.3.1. About the Model

The National Planning Authority together with the Pennsylvania State University (USA) produced a surveillance tool for COVID-19 based on a data-driven auto-regressive model known as HHH4 originally developed by Leonard Held et al. in 2005. The modeling tools can be used to understand the drivers of new infections and as well identify areas and population of high-risk areas. A Pan African version of the model provides an efficient way to explore and understand dominant risk factors in countries on the African continent and the contribution of neighbouring countries to new cases.

To understand the behaviour of Covid-19 cases various factors are included in the model. Some of these included:

- i) *Population:* A higher population density increases the frequency, intensity and duration of human contact thereby increasing the risk of rapid spread of the pandemic. In this case, our population consists of the total enrolment in the education system.
- ii) *Population mean age:* This depicts the age structure of a country in the model. Data shows that COVID-19 severity varies with age group. Older people, for example, are more vulnerable. Table 2 shows the median ages of the school population.

**Table 2: Total enrolment and median age of learners**

Education Level	Enrolment	Median Age
Pre-primary	2 million	4
Primary	10.7 million	11
Secondary	2 million	16
Tertiary	311,556	20
Total enrolment	15.1 million	
Tertiary & Secondary	2.311 million	

Source: Total enrolment is based on UBOS' Report on the Master List of Education Institutions in Uganda (MEIU, 2019), median ages are imputed by author

- i) *Human Development Index:* HDI (derived from GDP, life expectancy, education level) is indicative of a country's resources towards its response to the epidemic
- ii) *UN Region:* United Nations defines regions as either Sub-Saharan Africa or North Africa. In the model, this metric is an indication of the genetic, climatic and socio-cultural differences of African population.
- iii) *Access to coast:* Landlocked status may influence how well border lockdown policies are enforced.
- iv) *Neighboring countries:* The likelihood of importing cases from a given country partly depends on the number of borders one has to get through.

- i) *Stringency Index:* In the model, Government control policies are represented by a Stringency Index which represents the strictness of containment measures and health policies introduced in a country to manage the epidemic. During the current lockdown, Uganda's stringency index is at 50%. However, this can be affected by whether a decision taken increases the strength in enforcement of Covid-19 control measures or if the decision weakens such enforcement.

Given that enforcement of lockdown measures in place becomes a challenge with an increased rate of movement by students on opening of schools, the stringency Index, (SI) was adjusted to account for the risk introduced by the number of students being put back in the population in terms of movement. Considering that in the current lockdown the country is at 50% SI, the impact of the school opening options on the SI was modeled as follows:

**Table 3: Changes in stringency index on opening of the different levels of education**

Level of education	Stringency Index if the level is opened
Pre-primary	45.7%
Primary	26.6%
Secondary	45.7%
Tertiary	50.7%
Tertiary & Secondary	45.0%
Tertiary, Secondary and Primary	21.6%

Source: Author computation

The lower the SI percentage, the higher the likelihood of spreading the virus among the population. Opening all schools has the greatest impact on the SI, putting it at 21.6%, followed by opening of Primary Schools, which puts the SI at 26.6%. This is on the backdrop of Primary level having the highest number of children in the education system.

- ii) Weather (temperature, humidity, rainfall): Most respiratory diseases are more prevalent in cold, humid conditions
- iii) COVID-19 testing: This gives an indication of the testing capacity of a country. A higher testing capacity leads to early detection and isolation of cases thereby limiting transmission.
- iv) COVID-19 reported cases: A higher number of cases in a given location increases the rate of spread and risk of overwhelming the health facilities.

#### 4.3.2. Key model assumptions taken

In undertaking this modeling exercises, the following were assumed:

- i) The modeling reference date is 20<sup>th</sup> August 2021. Accordingly, the computations are based on the assumption that schools were to be opened on the 20<sup>th</sup> August 2021. This is hypothetical but necessary for anchoring the projections.
- ii) Model projection period is 28 days (20<sup>th</sup> August 2021 to 14<sup>th</sup> September 2021)

iii) Vaccination effect lag: The model assumes that there is a time lag for vaccination to impact Covid-19 numbers. To this end, it is critical to note that the assumption of vaccination stated in the different modeled scenarios has no bearing on the Covid-19 cases reported in the various scenarios in this exercise, since according to evidence, 95.3% of vaccine effectiveness can be achieved at 7 days or longer after the second dose (Haas et al. 2021).

#### **4.3.3. Results**

##### ***Scenario1: Fully open up all education institutions with status-quo on vaccination***

Under this scenario, the possibility of opening up all schools and training institutions under the current levels of vaccination was examined. The analysis indicates that whereas this option immediately relieves government of pressure to reopen schools; ensures increases short-term access to learning; likely to stimulate the economy due to increased aggregate demand and achieves inclusive access to education, it was not found to be sustainable. Foremost, the scenario is associated with a spike in Covid-19 cases reaching a daily average of 327 in comparison to a status quo of 224 for the modeled period. This may significantly contribute to subsequent waves necessitating other lockdowns and closures. Relatedly, this scenario compromises the stringency index from 50% to 21.6% due to increased movements of students particularly in day schools (see table 3).

##### ***Scenario2: Fully open up all education institutions with full vaccination of all the eligible population***

This scenario considers opening up of all education institutions after vaccinating 22 million eligible Ugandans. Whereas this would be the most ideal situation to open schools given that it serves many benefits including sustainably lowering the risk of Covid-19 cases given that 95.3% vaccine effectiveness can be achieved at 7 days or longer after the second dose, the scenario was dropped on the backdrop of not being timely and affordable in the short to medium term.

##### ***Scenario 3: Fully open up all education institutions with vaccination of only the eligible student (18 years and above) and teacher population***

This scenario considers opening up of all education institutions after vaccinating approx. 550,000 teachers and approx. 650,000 eligible students (18 years and above). This scenario was found worthy to consider since it would lower the risk of learners infecting their teachers and vice-versa albeit with the possibility of continued community level spread particularly from learners (at primary and secondary) to their parents. Overall, the scenario was found to be timely, cost effective and easy to achieve.

##### ***Scenario 4: Phased opening of schools by levels, adoption of alternate models of attendance for days schools with vaccination for only teachers and eligible student population and testing of unvaccinated children starting with those in boarding schools***

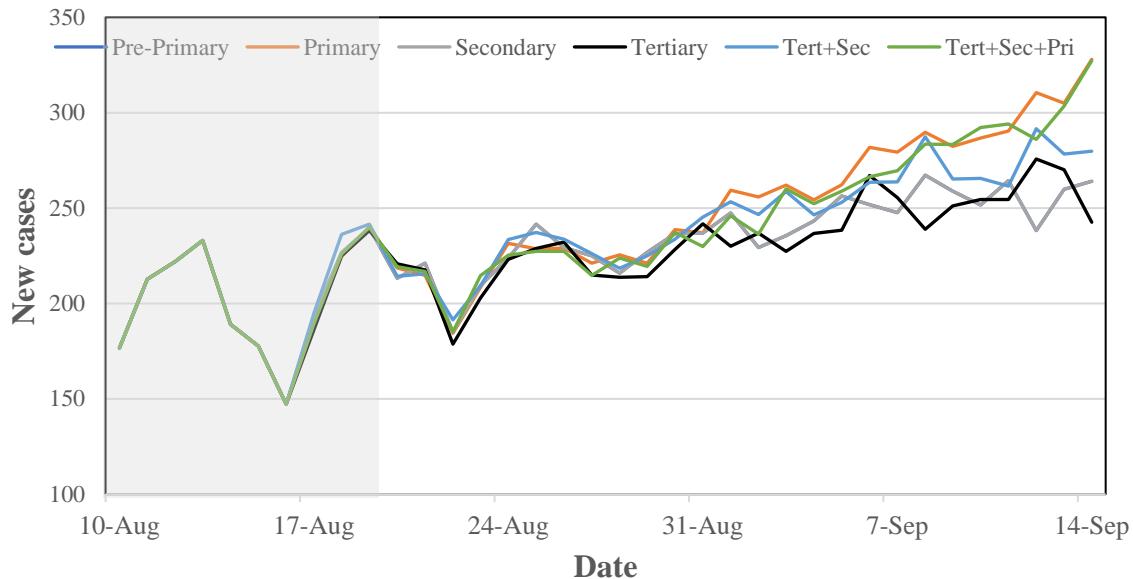
This scenario is informed by the fact that the bigger the number of learners concentrated in one place at ago, the more the Stringency Index is compromised (see table 3). Accordingly, the elements of phasing, alternating school attendance for day learners and testing of especially boarding students are introduced to address the challenge of mass movement of learners. The scenario considers:

- i) Opening of education institutions in a phased manner ie Primary only, secondary only, tertiary only with school-based testing of the unvaccinated children particularly in boarding schools and vaccination of teachers and learners 18 years and above
- ii) Opening of a combination of education levels with school-based testing of the unvaccinated children particularly in boarding schools and vaccination of teachers and learners 18 years and above

As shown in figure 6, opening all schools and tertiary institutions without phasing and or alternating attendance for day schools increases the average daily new Covid-19 cases by 46%, that is, from **224** (if schools were opened on 20th August21) to **327** after 28 days. This would be the **worst-case scenario** which should not be attempted.

With a population number of approx. 10 million in Primary Schools, their opening up comes in as the **second worst case scenario** with new daily cases of COVID-19 projected to increase by 38%, that is, from **224** to **310** after 28 days. The **least impact**, is observed with the opening up of Tertiary Institutions where the daily Covid-19 cases would increase by only 8%, from **224** to **242**. On the other hand, opening up secondary schools only would increase to average daily cased by 18%, that is, from **224** to **264**.

*Figure 6: School opening scenarios and daily Covid-19 cases*



Different combinations for phased opening were tried. The combination of opening **both Primary and Secondary** schools together is similar to the one of opening up all schools. This is because, this combination would increase the number of new daily cases by **40%**, that is, from 224 to 314 by the end of 28 days projection period. On the other hand, opening up of **Secondary and Tertiary** Institutions will make the number of new daily case to increase by **32%**, that is, from **224** to **295** after 28 days, which is also similar to the opening up of Primary Schools only.

*Whereas scenario 4 analysis indicates that tertiary and secondary contribute the least risk if opened, the cost of prolonged lockdown is already phenomenal at the primary subsector in terms of lost learning (figure 1), limited access to learning platforms (figure 2), child labour prevalence rates and teenage pregnancies. This therefore implies that opening options that leave out primary schools hurt the education system further.*

*Accordingly, to mitigate the risk of covid-19 cases as a result of large numbers of students, we recommend the alternated day school attendance model and testing of learners to be added to scenario 4. To this end, all education institutions would open but with alternated attendance for basic education. This entails lower primary and lower secondary attending from Monday to Wednesday while upper primary and upper secondary attends from Thursday to Saturday for each week.*

## 5.0. Common Plans and Practices of Countries that have (re)opened Schools

### 5.1. Focus area 1: Health and hygiene

Majority of the countries that have reopened have planned for:

- (i) Physical distancing
- (ii) Hand hygiene

- (iii) Respiratory hygiene
- (iv) Vaccination

However, the practice has shown that: (i) 50% of low-income countries lack commitment from public to Covid-19 measures (ii) 64% of low-income countries lack resources for implementing public health and social measures (iii) 50% of low-income countries have poor safety culture (iv) 64% of low-income countries lack medical facilities at community level, and (v) 43% of low-income countries lack door-to-door services during quarantine period (OECD et al., 2021)<sup>5</sup>.

In addition, the findings show that 57% of low-income countries have managed to institute health and hygiene guidelines against a global record of 73%; only 50% of low-income countries have managed to enforce physical distancing against a global record of 78%; and fewer of the low-income countries have enforced safety and hygiene on public and shared transport (43%) and health and hygiene monitoring measures in schools (36% schools monitored) (OECD et al., 2021).

Whereas vaccination is an area that has been prioritized in planning for reopening by countries that have opened, it is ironical to note that majority of such countries have low vaccination rates. For example, Namibia has 7.2% vaccination rate, Kenya, 2.4%, Rwanda, 5.4%, and Tanzania, 0.2%. This implies that the decision to reopen schools is not very much linked to the proportion of the wider population vaccinated. Rather, such countries have specifically targeted vaccination of teachers and other school support and mass testing of learners, besides the wider population interventions.

Wearing of masks as a respiratory hygiene measure is widely planned and practiced in most of the countries that have reopened schools.

In addition, though not widely documented, some countries have prioritized open air classes and tent-based classrooms as a health and hygiene measure. Also, varied local concoctions have been used particularly at house level, albeit with undocumented efficacy and contraindication rates.

***Figure 10: Open air classrooms that some countries are adopting on reopening***

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<sup>5</sup> This was a collaborative third round survey of National Education Responses from 143 countries including low income, lower middle, middle income and upper income countries.



Source: Ghanaweb.com



Source: Maya Tubic, Patch Media

### **5.2. Focus Area 2: Education Budgets**

Majority (56%) of low-income countries have increased their education budgets on reopening schools due to the surge in education costs particularly aimed at complying to the SoPs and redemption of the deteriorated infrastructures. The increased budgets are also on the backdrop of the need to redeem especially private schools which are on the verge of closure due to financial distress. Nonetheless, 22% of the low-income countries have so far failed to increase their education budgets. Rather, they opted to maintain the same budget but reprioritize and reallocate the previously earmarked funding. External donors remain the major sources of additional funding for school reopening.

### **5.3. Focus Area 3: Remedial measures to address learning gap on reopening**

In 80% of low-income countries that have reopened, remedial measures particularly in primary and secondary schools have been implemented. These mainly related to school-based learning recovery plans that among others entail:

- i) Condensing the curriculum with prioritized focus on key knowledge and skills for the education level
- ii) Readjusting the school routines ie prioritizing teaching than assessment/testing of learners, reduction of school holidays
- iii) Adding weekend days to the normal school to catch up on lost learning time.

### **5.4. Focus Area 4: Preventing dropout and early school leaving**

Given that many learners (particularly girls and vulnerable children) are likely not to return to school even when they reopen, and given that majority may report but eventually dropout due to various reasons, majority (85%) of countries surveyed by OECD and partners put in place

measures to ensure children return and remain in schools. Majority entail community-based sensitization and mobilization efforts.

### **5.5. Focus Area 5: Mode of reopening**

Depending on the risk factors, countries that have reopened have used various models. Some of these include:

- i) *Phased opening* i.e in Rwanda, candidates, semi candidates and TVET were given priority during reopening. South Africa also chose a phased opening model. Uruguay phased opening based on surveillance maps such that places particularly the rural schools were opened first due to low Covid-19 rates.
- ii) *Alternate attendance for days schools and multiple shifts by grades* i.e Brazil and Japan adopted these models to limit traffic of children in schools at any one time. Some children were required to attend on particular days of the week or time of day i.e morning or afternoon.
- iii) *Full opening for all*: there are fewer countries that have chosen this path due to the known risks associated with it. Those that have chosen this option have in place other risk mitigation measures such as massive testing and robust case surveillance systems.

## **6.0. Options for Uganda**

Based on the evidence from modeling, and given the irreversible effects the prolonged lockdown has caused on the student generation; and based on the increasing pressure from key education stakeholders such as parents; we favour reopening of education institutions as detailed in scenario 4. This entails:

- i) Vaccination of all teachers (approx. 550,000) and students 18 years and above (approx. 650,000) within the shortest time. Choice of 18 years is on the basis of absence of evidence to prove efficacy of vaccination to children below 18 years.
- ii) Testing of the unvaccinated learners for Covid-19 starting with boarding schools on return to school. Parents can share the cost of testing while government provides support to those who attend UPE and USE.
- iii) Opening of all education institutions by adopting attendance models for day schools that limit the numbers physically present at any one time. Accordingly, we favour the alternating model where particular classes study on different days of the week including Saturday. This can be arranged such that lower primary and lower secondary attend Monday to Wednesday while upper primary and upper secondary attend Thursday to Saturday. With regard to full-boarding schools, all learners can report on condition that they have taken Covid-19 tests and their teachers are fully vaccinated.

## **7.0. When the decision to open schools is taken**

Reopening of schools during Covid-19 times brings relief and as well as anxiety to various stakeholders. From the common practices by various countries that have reopened their education system during Covid-19, it is clear that the entire education production process changes and turns very expensive. IT CAN NEVER BE BUSINESS AS USUAL.

### **7.1. Health and hygiene**

- (i) Lessons learnt from common practices of other comparable countries that have reopened schools indicate that it is critical to prioritize (i) wearing of masks as part of the school uniform (ii) handwashing (iii) social distancing. The same should be prioritized for Uganda's case, besides the MoH elaborate protocols.
- (ii) Given that many schools do not have water, we recommend that children should carry atleast a litre of water to school every day for handwashing. This is a common practice in some parts of South Africa.
- (iii) In addition, the MoH should urgently examine the benefits and possible contraindications of Uganda's maiden herbal Covid-19 remedies, particularly Covidex and Covilyce1 to children. If the remedies carry the desired beneficial effect in children, then routine drops should be served to learners as a preventive measure.
- (iv) Also, where weather permits, open air classrooms and tent-based classrooms (for those who can afford) should be prioritized

### **7.2. Education budget**

Experiences from other comparable countries indicate that reopening of schools costs much more than the pre-covid-19 budgets. Some of the key drivers include the cost of observing of SoPs, repair of deteriorated furniture and classrooms and wash facilities.

The Ugandan education budget has already suffered cuts, an indication that it is unlikely that additional funds will be available for reopening schools. Accordingly, the education budget will need to be concentrated on key budget lines including: (i) students' capitation (ii) instruction materials (iii) Teachers salaries (iv) University Research and Innovation fund for use for researching Covid-19 health and business solutions, and (v) capacity building for lower secondary teachers to rollout the new curriculum.

Areas of budget support by development partners include children nutrition, (re)enrolment of vulnerable children including pregnant teenage girls and children of the poor who are likely not to return to school.

Further, given that an estimated 3,507 poor private primary schools and 832 poor private secondary schools are at risk of forced closure due to financial distress, it is recommended that they be

included in the existing beneficiary categories destined to benefit from low-cost funding from the Uganda Development Bank (UDB).

### **7.3. Remedial measures to address learning gap on reopening**

When schools open, we recommend that learners should be automatically promoted to the next grade regardless of the amount of learning achieved. This should be followed by learning recovery measures including:

- (i) Suspension of daily tests and unwarranted testing of learners such that time is dedicated to teaching
- (ii) Condensing of the curriculum across the entire education sector (save for medical courses) to enable teachers only focus on the core curriculum knowledge and skills
- (iii) Add Saturdays to school days for purposes of learning recovery.
- (iv) Shorter holiday breaks

### **7.4. Preventing dropout and early school leaving**

There are signals that many children particularly girls and poor children will not return to school even when schools reopen. Already, many girls are pregnant while many boys are engaged in economic activities which have increased the opportunity cost of returning to school. To mitigate further dropout and early school leaving, we recommend the following:

- (i) The Ministry of Education and Sports will be required to implement a campaign to encourage economically struggling households who might fail to cope with private education tuition to enroll their children in public schools in the neighborhood.
- (ii) Adopt a multi-stakeholder approach involving parish chiefs, village churches, local cultural/clan leaders, similar to that used to combat HIV, be adopted to implement a parish level outreach strategy for engaging families with learners that are at high risk of dropping out of school to ensure that such children are (re)enrolled in school.

### **7.5. Building better against future pandemics**

- i) In the medium to long term, the education sector should seize the opportunity to focus on decongesting classrooms in the educational institutions at all levels and as well entrench quality assurance and support supervision mechanisms within each educational institution. Ultimately, the system should be buttressed to ensure that all who enroll into the system stay on for atleast 11 years (P1-S4). Additionally, the system should be rebuilt to increase on enrolment and graduation in the STEM/STEI areas.
- ii) Inevitably, there is need for digitizing the education service by leveraging ICT in the teaching, learning, management and monitoring and evaluation processes.

- iii) In addition, focus will be directed towards the development of off-school learning options. Currently NPA is exploring the possibilities of establishing village-based learning communities that would guarantee continuity of learning in case schools close

## **8.0. Conclusion**

The need to reopen schools during Covid-19 times brings relief as well as anxiety to various stakeholders. School closure has been used as a key intervention worldwide to scale down the rate of Covid-19 spread. For Uganda, 15 million children in the school system were saved from contracting Covid-19 when schools were closed.

However, prolonged closure of schools has put the future of learners whose lives have been saved at stake. Evidence has showed that majority of learners have never access the learning platforms for continuation of learning, many learners are poised not to return due to being pregnant or married off. In poor communities, the opportunity cost for returning to school has already been increased due to the short-term economic benefits associated with child labour.

Evidence from modeling the impact of school opening on Covid-19 cases has showed that reopening schools still carries a risk but of a lesser magnitude in terms of additional cases to the status quo. This is explained by the less effect of Covid-19 on young persons. The greatest Covid-19 risk associated with young persons is based on their ability to infect the adult population including their parents.

Common practices of countries that have reopened schools highlight the critical challenge of balancing between: saving life, as the ultimate consideration; saving livelihood; and saving the future of a generation whose lives have been saved. In addition, stakeholders' concerns are key in any decision to reopen schools. This makes an optimal solution hard to reach. For instance, while it is critical to save lives of learners by closing schools, such a benefit may be discounted if the same generation whose lives have been saved does not have a future.

Therefore, our consideration for school reopening by adopting alternated attendance model for day schools is against the backdrop of the need to save life, livelihood and the future of the generation whose lives have been saved.

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## Annex

### About the NPA COVID-19 Model

The model called was developed in partnership with Pennsylvania State University, under a 5-year project that is building modelling capacity at NPA. It started in 2018 and so far, 2 models have been developed: 1) analysing the effects of weather changes and environmental factors on the implementation of development plans, 2) the Pan-African COVID-19 Model and 3) Prediction of likeliness of neonatal sepsis in unborn babies given a combination of factors including environment, nutrition, mother's genetics, among others (under development).

The Pan-African model, which was used in developing the option presented in this paper, was peer reviewed and published in the **Proceedings of the National Academy of Sciences of the United States of America** on 28<sup>th</sup> June, 2021 (PNAS 2021 Vol. 118 No. 28 e2026664118).

#### **Overview.**

Our analyses included 46 countries of mainland Africa. We do not provide estimates for Equatorial Guinea, Guinea-Bissau, and Western Sahara, due to the missing data on stringency index, or the six island nations (Madagascar, Comoros, Mauritius, Seychelles, Cape Verde, São Tome', and Príncipe), due to the lack of spatial connectivity. Modeling the spread of COVID-19 over the African continent poses challenges, given the extensive cultural, political, and environmental heterogeneity between countries. Indeed, this heterogeneity results in substantial variability of reported case counts across countries. It is this variability in case counts that motivates our choice of a relatively simple data-driven autoregressive modeling approach. Such a modeling approach focuses on the interaction of cases reported in time and space without hidden variables to be estimated.

#### **Meteorology/Weather Factors.**

The seasonality of influenza transmission has been associated with cycles of temperature, rainfall, and specific humidity, although, in different regions of the world, transmission may peak during the “cold-dry” season (temperate climates) or during “humid-rainy” season (tropical climates).

We estimated the influence of meteorological factors on the transmission dynamics of COVID-19 in Africa. Real-time, daily, in situ synoptic weather observations are sparse across much of Africa. Therefore, daily, 10-km spatial resolution mean temperature, rainfall, and specific humidity data were obtained from UK Met-Office numerical weather prediction model output. These data are extracted from the early time steps of the model following data assimilation, to more closely approximate an observational dataset. This approach also has the advantage that future studies have access to the same coherent dataset at a global scale for applications outside of continental Africa. The weather product that generates these data closely approximates an observational dataset at locations that have dense observation coverage, whereas, in observation-sparse areas, the dataset relies more heavily upon the numerical weather prediction model (a physics based rather than statistical model). The meteorological dataset contained no missing data.

A population density-weighted spatial average was then applied for each day and country using the R package “exactextractr”. Population density was obtained from the Gridded Population of the World version 4 (GPWv4) from the Centre for International Earth Science Information

Network. Weighting climate variables by population gives a closer approximation to the weather conditions faced by humans living in that country compared to an unweighted average over total land area. For example, the country of Algeria, in which much of the population resides along the coast, demonstrates a cooler, wetter, and more humid climate when weighting by population.

### **Stringency Index and Testing Policy.**

To include an aggregate measure of countries' social policies, the stringency index sourced from the OxCGRT dataset was used. This composite measure reflects government policies related to school and workplace closures, restrictions on public gatherings, events, public transportation, limitations of local and global travel, stay-at-home orders, and public education campaigns.

Containment Policies		Health Policies	
C1	School Closing	H1	Public Information Campaigns
C2	Workplace Closing	H2	Testing Policy
C3	Cancel Public Events	H3	Contact Tracing
C4	Restrictions on Gatherings	Score for each measure ranges from 0 (Not enforced) to 5 (Enforced countrywide)	
C5	Close Public Transport		
C6	Stay at Home		
C7	Internal Movement		
C8	International Travel		

The stringency index is calculated from these categorical variables using a weighted average, with a range of 0 to 100 indicating weak to strict stringency measures, respectively. A time-dependent metric of testing policy was also extracted from this dataset. Ranging from zero to four, this categorical metric increases with more open and comprehensive testing policy.

### **HDI, Demography, United Nations Geographic Regions, and Coastline Access.**

In our modeling strategy, we incorporate key socioeconomic and sociodemographic epidemiological data, including HDI, population, United Nations geographic regions, and coastline access. HDI represents the national data on key aspects of development, namely, education, economy, and health. The HDI is the geometric mean of normalized indices for each of the three dimensions. The education dimension is measured by average years of schooling for adults aged 25 y and more and expected years of schooling for children of school-entering age. The economy dimension is measured by gross national income per capita, and the health dimension is assessed by life expectancy at birth. In Africa, the majority of the countries fall in the low-HDI category. The northern part of Africa and South Africa have a considerably higher HDI compared to the rest of the continent. Country-specific median age was correlated with HDI (Pearson's correlation coefficient  $R = 0.71$ ,  $P < 0.0001$ ; therefore, we excluded this covariate from the model). We include in the model the 2020 population obtained from the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. The categorization of sub-Saharan and northern Africa was based on the United Nations geo-scheme for Africa. This regional factor captures the human genetics, environment and climate, and sociocultural and sociodemographic variations of the African population. Finally, lack of direct access to the coastline may influence the flow of infections from neighboring countries, as border trade remains an essential operation. For example, Uganda introduced border closures and tighter preventive measures on truck drivers' movements during the epidemic; despite this, a substantial number of new infections have been imported from truck drivers crossing the border for trade. Such

crossborder commerce remains a crucial part of the supply chain for landlocked African countries such as Uganda and Rwanda.

### Model Formulation.

We chose a class of multivariate time series models for case count data introduced by Held et al., and further extended by Bracher and Held (51) with the addition of higher-order distributed lags. Conditional on past observations  $Y_{i,t-d}$ ,  $i=1, \dots, N$ , and  $d=1, \dots, D$ , new COVID-19 cases  $Y_{it}$  from country  $i$  at time  $t$  are assumed to follow a negative binomial distribution with mean  $\mu_{it}$  and overdispersion parameter  $\psi$  as

$$[Y_{it} | Y_{t-1}, \dots, Y_{t-D}] \sim \text{NegBin}(\mu_{it}, \psi).$$

The conditional variance is  $\mu_{it} + \psi\mu_{it}^2$ , which demonstrates the role of the overdispersion parameter to capture variability greater than the mean. The conditional mean  $\mu_{it}$  is decomposed into three additive components,

$$\mu_{it} = \epsilon_i + \lambda_{it} \sum_{d=1}^D u_d Y_{i,t-d} + \phi_{it} \sum_{d=1}^D \sum_{j \neq i} u_d w_{ji} Y_{j,t-d}, \quad [1]$$

where  $\epsilon_i$ ,  $\lambda_{it}$ , and  $\phi_{it}$  represent three contributions to case incidence. The first term,  $\epsilon_{it}$ , is the so-called endemic component and captures infections arising from sources other than past observed cases (e.g., contributions from areas that are not included in the neighbor set). The two other terms in [1],  $\lambda_{it}$  and  $\phi_{it}$ , constitute the epidemic part of the model and modulate how infective individuals reported in the past  $d$  days both locally and from neighboring countries will contribute to the average future number of reported cases. The strength of connection between countries is described by spatial weights  $w_{ji}$ . This intercountry transmission susceptibility is defined using a power-law formulation proposed by Meyer and Held,

$$w_{ji} = o_{ji}^{-\rho}, \quad [2]$$

where  $o_{ji}$  is the path distance between countries  $j$  and  $i$  (with  $o_{ii} = 0$ ,  $o_{ji} = 1$  for direct neighbors  $i$  and  $j$  and so on), and  $\rho$  is a decay parameter to be estimated from the data. The path distance  $o_{ji}$  is on an ordinal scale based upon the adjacency index. The spatial weights are normalized such that  $\sum_k w_{jk} = 1$  for all rows  $j$  of the weight matrix.

The normalized autoregressive weights  $u_d$  are shared between the local and global epidemic components, and represent the probability for a serial interval of up to  $D$  days—which is the average time in days between symptom onset in an infectious individual (or primary case) and symptoms appearing in a newly infected individual (or secondary case) when both are in close contact.

The parameters  $\epsilon_{it}$ ,  $\lambda_{it}$ , and  $\phi_{it}$  are constrained to be nonnegative and modeled as the natural log-transformed linear combination of different country-specific covariates. The endemic component,

$$\log(\epsilon_{it}) = \alpha^{(e)} + \log(N_i), \quad [3]$$

is decomposed as a constant  $\alpha^{(e)}$  specific to the baseline endemic and a term proportional to the country-level population  $N_i$ . In the epidemic part of the model, we expect new cases to also be driven by country-specific factors: Population ( $N_i$ ), HDI classifications of low, medium, or high ( $HDI_i = \{0, 1, 2\}$ ), and land-locked ( $LL_i$ ) status for each country are assumed constant over the time scale of analysis. Other forces driving new cases vary over time, as a response to either policy changes or natural fluctuation in environmental or societal patterns. Time-dependent covariates

include mean daily temperature ( $T_{i,t-\tau}$ ), rainfall ( $R_{i,t-\tau}$ ), specific humidity ( $H_{i,t-\tau}$ ), testing policy ( $X_{i,t-\tau}$ ), and government stringency index ( $S_{i,t-\tau}$ ), lagged at  $\tau$  days. The full set of explanatory variables that contribute to the model from both internal and external epidemic components are formalized in [4] and [5] as

$$\begin{aligned}\log(\lambda_{it}) = & \alpha_i^{(\lambda)} + \beta^{(\lambda)} \log(N_i) + \gamma^{(\lambda)} HDI_i + \delta^{(\lambda)} LL_i + \\ & \sigma^{(\lambda)} S_{i,t-\tau} + \chi^{(\lambda)} X_{i,t-\tau} + \\ & \theta^{(\lambda)} T_{i,t-\tau} + \omega^{(\lambda)} R_{i,t-\tau} + \nu^{(\lambda)} H_{i,t-\tau}\end{aligned}\quad [4]$$

and

$$\begin{aligned}\log(\phi_{it}) = & \alpha_i^{(\phi)} + \beta^{(\phi)} \log(N_i) + \gamma^{(\phi)} HDI_i + \delta^{(\phi)} LL_i + \\ & \sigma^{(\phi)} S_{i,t-\tau} + \chi^{(\phi)} X_{i,t-\tau},\end{aligned}\quad [5]$$

where  $\alpha_i^{(\lambda)} \approx N(\alpha_0^{(\lambda)}, \sigma_\lambda^2)$  and  $\alpha_i^{(\phi)} \approx N(\alpha_0^{(\phi)}, \sigma_\phi^2)$  are a set of independent country-level random effects. This modeling framework is implemented in the R package “surveillance”.

**Model Fitting.** We selected models based on AIC if random effects were not present. To compare models that included random effects, we used proper scoring rules for count data. Scoring rules are functions  $S(P, y)$  that evaluate the accuracy of a predictive distribution  $P$  against an outcome  $y$  that was observed. We chose the model with the lowest AIC or with the lowest logarithmic score computed as minus the logarithm of the predictive distribution evaluated at the observed count. We began with the first-order autoregressive modeling ( $D=1$  in [1]) of daily COVID-19 incidence using intercept-only model population offset and country connectivity. In a mechanistic interpretation of such a first-order model, the time between the appearance of symptoms in successive generations is assumed to be fixed to the observation interval at which the data are collected, here as 1 d.

After the estimation and illustration of this basic model, we expand the model by sequentially adding the following additional covariates: country-specific HDI, population both within country and in neighboring countries, meteorology factors, stringency index, testing policy, landlocked status, and random effects to more fully account for unobserved heterogeneity of the cases. Social policies and meteorological data were included in the model, testing for fit at different lags (for example,  $T_{i,t-\tau}$ ,  $\tau \in 0, 7, 14$  d).

### Model Predictions.

As in previous work by Held and Meyer, we use plug-in forecasts: forecast from the fitted model without carrying forward the uncertainty in the parameter estimates. We assess both the model fit and 1-wk-ahead forecast of the higher-order autoregressive model with the logarithmic score. The smaller the score, the better the predictive quality. Mean scores were generated for each country’s forecast, by averaging the log-score obtained for each day of the validation week.

### Data Availability.

All code and data are available, to both replicate the results and enable users to examine past and future time windows of interest, is posted online at GitHub, <https://github.com/Schiff-Lab/COVID19-HHH4-Africa>.