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Digital Education in Africa

Conditions and Opportunities for Support and Collaboration

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Contents

1. Executive Summary

This study sets out to identify digitalization's potential to improve access to and the quality of tertiary education in sub-Saharan Africa. It does so, first, by measuring the quality of education, the magnitude of existing barriers to education, and the state (read: progress towards full) of digitalization. It then identifies and assesses the feasibility and potential impact of a series potential interventions – all of them geared towards improving digital skills & demand for digital education, access to computing devices, and access to internet & electricity in the region.

There are significant opportunities associated with the rollout of digital education in sub-Saharan Africa. As the number of sub-Saharan Africans rounding off secondary school is set to increase substantially in the coming years, so, too, is the region's demand for high-quality tertiary education. African universities have a 50% higher student-teacher ratio than the global average, something which had already contributed to approximately 375,000 – more than double of 1997's 156,000 – opting to pursue their studies overseas as early as 2017. The challenges associated with educators' (lack of) institutional capacity are compounded by the region's cost and environment-related hurdles. A staggering 38% of sub-Saharan Africa's population lived on less than $1.90 a day as recently as 2018, meaning they do not have the means of commuting to metropolitan areas or of paying for any of the ever-increasing numbers of privately organized educations that are on offer. Environmental factors mean that many miss out on, at the very least, parts of their tertiary educations. These include gender inequality, the stigmas (and shame) associated with disease and, in many sub-Saharan African countries, the uncertainty brought on by widespread conflict and political instability. These factors have a negative impact on the future economic competiveness of sub-Saharan countries.

Digital education offers a potential pathway for improving access to and increasing the macro-level quality of tertiary education. Because it bypasses or partially mitigates several of the challenges facing the region's education system, and because it creates financial opportunities for both students and educators, it promises to make a positive contribution to both access to and macro-level quality of tertiary education in those countries which preside over the digital infrastructure (or state of digitalization) to allow for its in-earnest rollout and applicability. This is, unfortunately, not the case in most of the

sub-Saharan African countries covered within this study.[1] Mozambique, Chad, Malawi, Burundi, and Tanzania have the least-developed education systems in the region; many of them are also in the top-5 as far as barriers to education are concerned (Chad, Burundi, Mozambique) and in the bottom-5 for state of digitalization (Table 1).

Table 1 - Needs assessment: top 5 most in-need countries per metric

Metric Country rank	Quality of education	Barriers to education	State of digitalization
1	Mozambique	Chad	Chad
2	Chad	Nigeria	Burundi
3	Malawi	Burundi	Madagascar
4	Burundi	Mali	Benin
5	Tanzania	Mozambique	Malawi

Of these high-need countries, only Tanzania is identified within the research's second step (feasibility and potential impact assessment) as being a high-potential country to intervene in. Expanding digitalization is difficult, and is contingent on the existence of infrastructure and/or other facilitating factors which are not present in the (relatively low-income) countries identified in Table 1. Most of the countries with high implementation potential – Benin, Kenya, Botswana, Rwanda, Senegal, South Africa, Cameroon, Ethiopia, and Namibia – fall within the medium to medium-low spectrum on all three metrics. They, along with the interventions which this research has identified as being particularly feasible and as having particularly high potential impact, are outlined in Table 2 below:

[1] The 22 countries included in this study are Benin, Botswana, Burundi, Cameroon, Chad, Ethiopia, Gabon, Ghana, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Uganda, Zambia.

Table 2 - High implementation potential interventions

Do away with laws that discourage internet use	Botswana Senegal South Africa Namibia
Design and deploy government retraining programs	Benin Kenya Tanzania
Incentivize return, retention, and attraction within academia	Kenya Botswana Rwanda
Invest in affordable alternatives to wired broadband	Benin Rwanda Ethiopia

A set of concrete suggestions for these interventions' implementation are outlined below:

Do away with laws that discourage internet use

- Due to time constraints, this study has not assessed the degree to which these countries have discouraging laws in place. As such, this intervention – which places a heavy emphasis on countries' levels of freedom – should be viewed more as an indication that the countries it is recommended for are countries that are likely to be most agreeable as far as regulatory overhauls are concerned.
- The focus here should be on policies that artificially inflate the cost of internet, which increase the cost of devices, or which limit access to social media.

Design and deploy government retraining programs

- The specifics of these programs will likely differ significantly between countries and focus groups. They should generally focus on imparting skills such as the basics of using a smartphone, surfing the web, and using programs such as Microsoft Word and Excel.
- A useful first step presents in the identification of programs already offered by these countries Min-

istries of Education and (where applicable) of these Ministries current implementation partners.

Incentivize return, retention, and attraction within academia

- To maximize this intervention's impact on digitization, research programs in areas relating to computer science, artificial intelligence, and advanced mathematics should be prioritized.
- A first step involves the identification of potential partner universities, and an analysis of their capacity to expand existing or to host new advanced research programs.

Invest in affordable alternatives to wired broadband

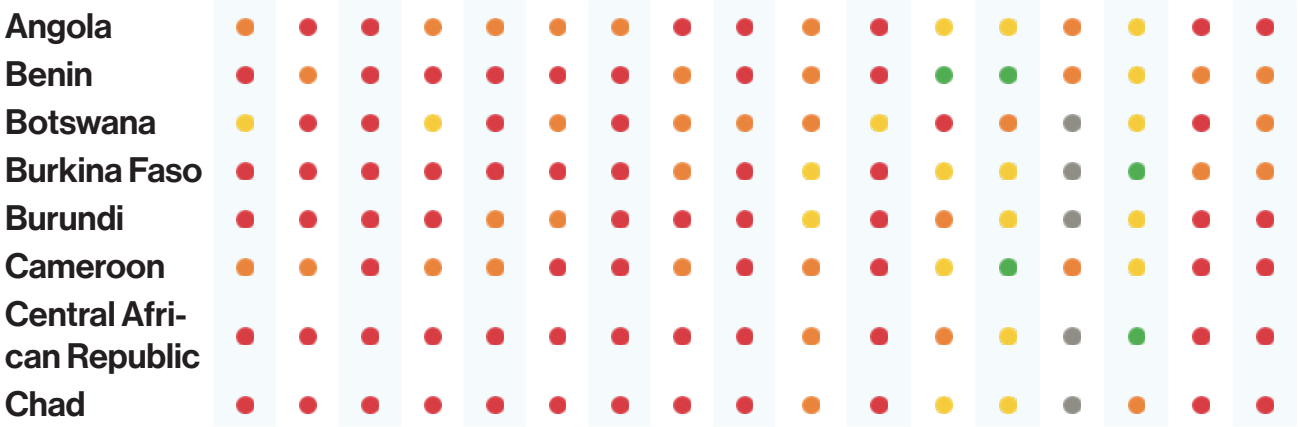
- This intervention focuses on the small-scale, localized purchase and deployment of high-speed satellite internet dishes. These are manufactured by (among others) SpaceX (StarLink) and Amazon (Kuipers) and offer speeds that match or exceed average broadband connections (100+ MB/s).
- A first (prerequisite) step entails the approaching of national communication authorities.
- This intervention's optimal configuration involves the provision of this type of internet to primary and/or secondary schools in rural communities.

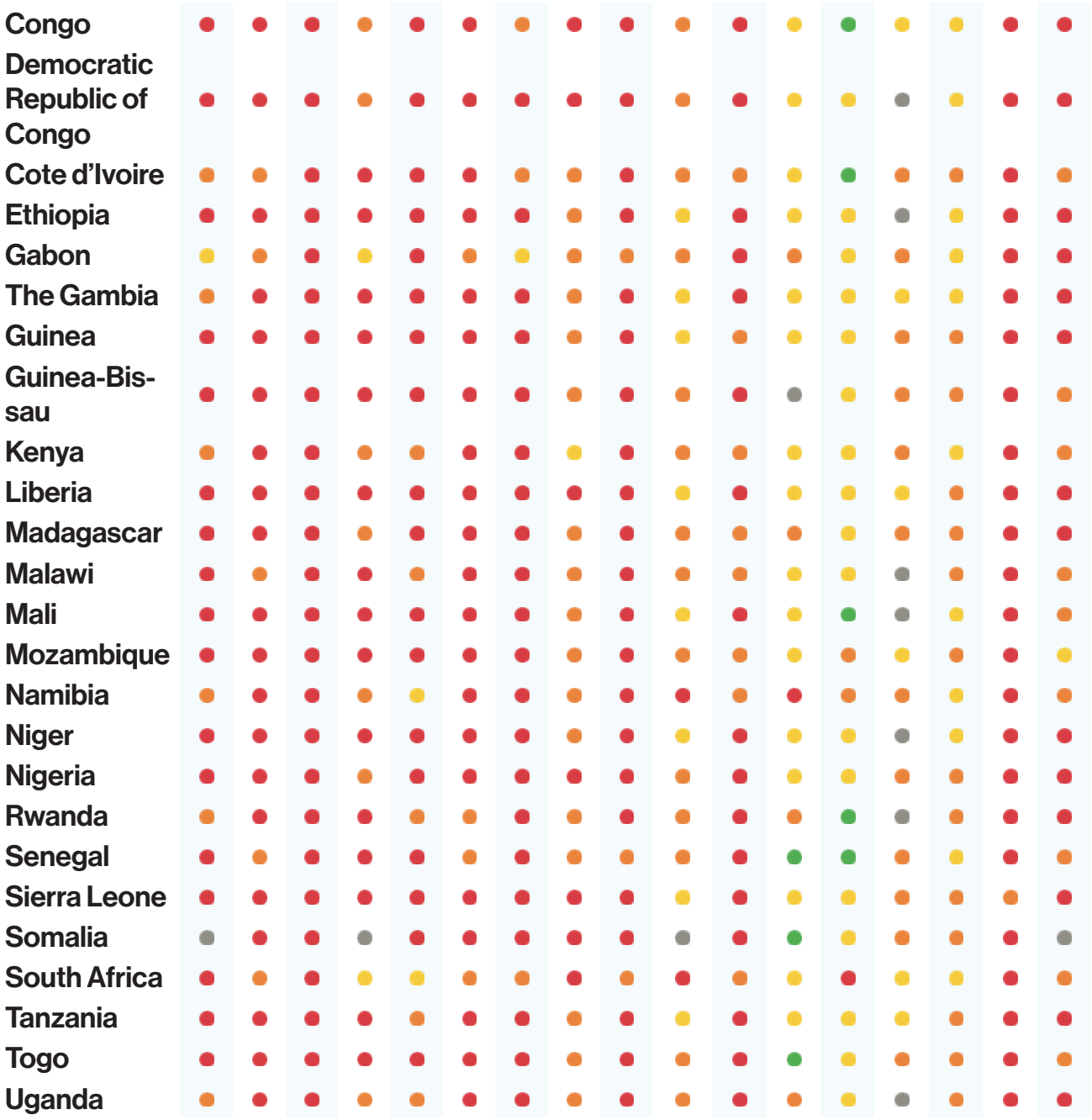
2. Introduction

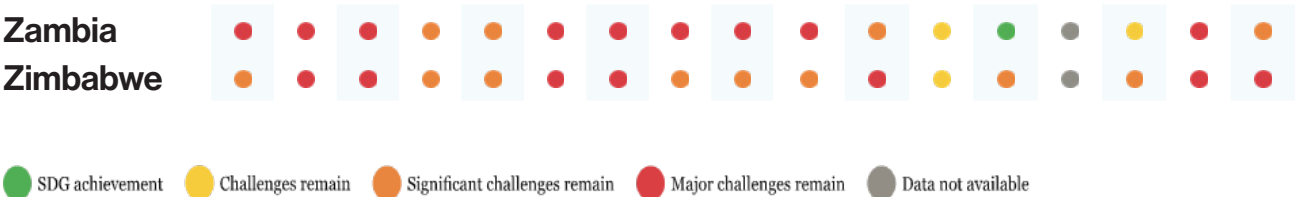
Despite the introduction of ambitious policy agendas such as the African Union Agenda 2063 and the 2030 Agenda for Sustainable Development, living standards for many in sub-Saharan Africa lag behind those in much of the rest of the world. Progress towards eradicating poverty in the region had slowed even before the coronavirus (COVID-19) pandemic, and – as the world anticipates the worst economic fallout since the Great Depression – millions in the region are likely to be pushed back into poverty.[i] 56.8% of the region's population suffered from severe (21.3%) or moderate (35.4%) food insecurity in 2019, up from 50.3% in 2014.[ii] Though the region had generally become healthier prior to the onset of the COVID-19 pandemic,[iii] this trend is likely to reverse as a result of increased pressure on healthcare systems.

These observations speak to a larger (negative) trend within the region. A 2020 report published by The Sustainable Development Goals Center for Africa (SDGC/A) – an international organization that supports governments, civil society, businesses and academic institutions in accelerating progress towards the achievement of the SDGs in Africa – estimates that, with the exception of Sustainable Development Goals (SDGs) 13 (climate action) and 15 (life on land), progress towards achieving SDGs in the sub-Saharan Africa region can be understood as facing either significant or major challenges (Figure 1).

Figure 1 - SDG progress sub-Saharan Africa[iv]




Congo
Democratic Republic of Congo
Cote d'Ivoire
Ethiopia
Gabon
The Gambia
Guinea
Guinea-Bis-sau
Kenya
Liberia
Madagascar
Malawi
Mali
Mozambique
Namibia
Niger
Nigeria
Rwanda
Senegal
Sierra Leone
Somalia
South Africa
Tanzania
Togo
Uganda



In the case of many of the SDGs, a negative trend – while abstract at first sight – equates to tangible misery at the individual and/or community level. Goals 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), 5 (gender equality), 6 (clean water and sanitation), 10 (reduced inequalities), and – though to a lesser extent – 16 (peace, justice, and strong institutions) are all goals for which progress can be measured in a reduction of human suffering. Addressing the factors underlying countries' inability to improve their performance when it comes to achieving the SDGs – and, by extension, alleviate human suffering – isn't easy. Deeply entrenched social and/or traditional norms and practices, vested (political) interests, and corruption are all examples of structural factors which undermine governments' ability to effectively implement policies geared towards achieving SDGs. Perhaps more importantly, different countries experience these structural factors to different degrees, in different ways, and different ratios and/or combinations – something which means that, in many cases, overcoming them requires the formulation of case-specific interventions.

2.1. Access to education

One exception to this rule presents in the form of improving access to education. While hamstrung by many of the same factors that limit governments' success when it comes to improving performance on the other SDGs, goal 4 (quality education) is one which arguably represents something of an opportunity as far as improving the welfare of sub-Saharan Africa's populations is concerned. This opportunity stems from two factors. The first is that access to even a rudimentary education – and access to higher education in particular – has consistently been shown to positively impact health and

wellbeing,[v] gender equality,[vi] and poverty rates at the macro level. The notion that improving access to education – and secondary and tertiary education in particular – is key to facilitating virtually all other types of sustainable development, has also been explicitly touched upon by a wide range of UN-affiliated agencies and actors. The 2013 iteration of the Action Agenda for Sustainable Development identifies "knowledge" as having a key role in achieving sustainable development,[vii] something which was later reaffirmed in the UN's Development Agenda for the same year.[viii] A 2011 report projected that, if all students in low-income countries left school with basic reading skills, 171 million people could be lifted out of poverty – something which is equivalent to a 12% drop in the number of people living on less than $1.25 a day.[ix] Previously conducted research has also found that providing mothers in low-income countries with a secondary education would save as many as 1.7 million children from stunting,[x] and that – in low-income countries – every year of additional schooling for mothers reduces the probability of infant mortality by as much as 10%, with infants whose mothers can read being 50% more likely to live past age 5.[xi] This means that improving access to education potentially represents a viable tool for increasing countries' performance on all 17 of the SDGs.[xii]

2.2. Digitalization

The second factor that potentially positions investing in improving access to education in sub-Saharan Africa as a cost-effective means of improving countries' performance within the SDGs is the advent of digital education. Reliance on a digital medium allows these forms of education to mitigate the impact of, or even to circumvent, many of the factors which act as barriers to traditional forms of education. For example, the negative impacts of norms that might – in some communities – preclude women from accessing an education can be partially mitigated by the fact that digital education can be accessed from home. The overcrowding of universities, and many of the negative implications for the quality of education associated therewith, can be alleviated through the virtually infinite scalability of digital learning platforms – many of which, as a result of increased demand during COVID-19, have developed curricula, teaching and grading methods, and technologies which allow them to offer a quality of

education which is on par with that offered by traditional institutions. Modern tools are so robust that a number of elite US institutions – Princeton University, Williams College, Spelman College, and American University included – have discounted tuition for their fully online experiences and voiced their intentions to continue doing so in the future.[xiii] These institutions are following in the footsteps of massive open online course (MOOC) platforms, industry-driven certification programs, and coding boot camps – all of which had previously recognized the utility of leveraging the data generated by tens of millions to learners to automatically grade assignments and to deliver adaptive content and assessments.[xiv]

Access to digital education is something which, in most high-income countries – where the majority of the population owns (and is well-practised in the use of) smartphones, tablets, and laptops – is limited mainly by institutions' willingness to make their courses available online, whether through MOOCs or otherwise.[xv] Many of these assumptions do not hold water when applied to the sub-Saharan Africa context, where barriers exist not only to accessing tertiary education but also to digitalization – a precondition for accessing education through online mediums. Within this context, this report – which strives to provide a high-level overview of those countries in Africa's sub-Saharan region in which conditions are most conducive to the introduction of initiatives which might improve access to digital education – features a three-pronged research approach. First, it leverages an in-depth literature review to arrive at a longlist of generic barriers to tertiary education on the one hand, and for measuring the state of digitalization on the other. Second, it explores instances in which interventions have been introduced which have succeeded (or not) at overcoming these barriers, and under what circumstances. Third, based on a quantitative analysis of sub-Saharan African countries' (non)alignment with these circumstances, the final chapter explores whether, where, to what degree, and through which types of initiatives access to (and the quality of) tertiary education in sub-Saharan Africa might be expanded by digital means.

3. Theory of Change

To facilitate ease of understanding – and to clearly define the scope of this research – this chapter first provides an overview of the definitions which have been adhered to as far as education, digital education, and digitalization are concerned. It also maps out and describes recent trends and developments within the digital education space, and formulates a theoretically grounded argument for why digitalization (and digital education by extension) has potential as a tool for increasing access to education in sub-Saharan Africa. These explanations are accompanied by a series of tables (Table 6, Table 7, Table 8) which outline a qualitative, literature-review-based assessment of digital education's potential ability (high, medium, low) to mitigate barriers to education (Table 3). For a full overview of this analysis, see (Annex I).

3.1. Tertiary education

This study focuses on tertiary education, a term that encapsulates higher education on the one hand, and technical and vocational education and training (TVET) on the other. Higher education is generally understood as leading to the award of an academic degree and to the aggregation of knowledge and curiosity that enables the individual to contribute within professional environments. TVET is a form of tertiary education in which the individual receives education and training which provide them with (oftentimes specific) knowledge and skills that enable them to find employment. This means that, within the context of this study, digitalization and digital education are explored as concepts only insofar as

they have the potential to impact – either by improving access to or by improving the quality of – higher education and TVET. Secondary and primary education are referred to on occasion, largely within the context of the quality of education individuals receive from primary and secondary-level institutions within rural sub-Saharan Africa manifesting as a barrier to those individuals' access to tertiary education. In these cases, this is either because the degrees they receive are not recognized by higher institutions or because the education they receive does not adequately prepare them to succeed within tertiary education.

Shortcomings in sub-Saharan Africa's tertiary education system hamstring both students' access to and the quality of said system. They can be attributed to several factors, including (but not limited to) the costs – both direct and indirect – associated with enrollment, environmental factors such as gender discrimination, crisis, and instability, and – finally – a lack of institutional capacity. These factors, hereafter referred to as barriers to tertiary education, are outlined in further detail in the following sections (Table 3).

Table 3 - Barriers to tertiary education

Factor category	Barrier	Impacts access	Impacts quality
Costs	Direct costs	Yes	No
	Indirect costs	Yes	No
Environment	Local attitudes	Yes	No
	Health and nutrition	Yes	Indirectly
	Crisis and instability	Yes	Indirectly
Institutional capacity	Infrastructure	Yes	No
	Funding for tertiary education	Yes	Yes
	Government support (other)	Yes	Yes

3.2. **Costs**

Cost-related barriers to tertiary education can take the form of either direct or indirect costs (Table 4).

Table 4 - Direct vs. indirect costs[xvi]

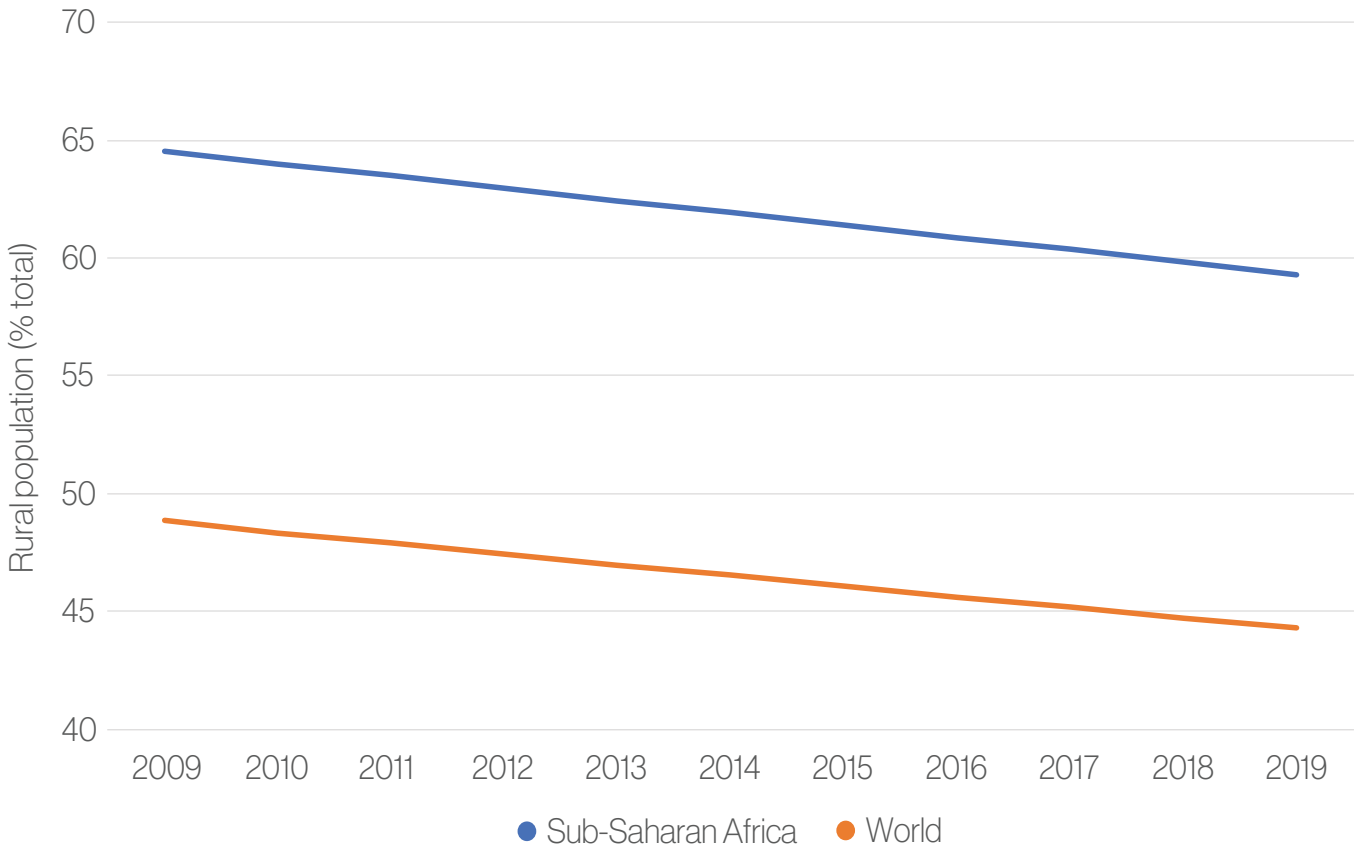
Direct costs	Indirect costs
Out-of-pocket expenses borne by a student or a student's family, including:	Income foregone by a student's family as a result of a student going off to pursue tertiary education, such as:
• Fees paid • Transportation costs incurred • Costs of study supplies • Costs of lodging and living	• Earnings foregone • Value of production foregone in family business (farm, etc.) • Value of services performed in the household

Within the context of sub-Saharan Africa – where a staggering 38% of the population lived on less than $1.90 a day as recently as 2018 – cost constitutes a pervasive barrier to tertiary education. Tuition fees – even those charged by relatively affordable (private sector) institutions such as ALX, a for-profit institution which charges students $2,000 per year on the promise that its brand recognition is so strong that employers will be willing to overlook its graduates' lack of a formal (university) degree – are prohibitively high for most, though they are arguably within reach of many within the region's growing middle class.[xvii]

And tuition fees are not the only costs associated with pursuing tertiary education. Both TVET and higher-level courses typically require students to purchase course material (whether in the form of books, supplies, etc.), something which increases the direct costs of attendance for students, some-

times by hundreds of US$ annually. Because the vast majority of institutions offering tertiary education are situated within metropolitan areas, learners also need to be able to foot the bill for the logistics associated with attending them. The ability to relocate from rural to metropolitan areas – arguably a prerequisite for attending the time-intensive courses that make up most forms of tertiary education – is contingent on access to significant capital, meaning that it is out of reach for people living on $1.90 a day. Because the costs of living in metropolitan areas are significantly higher than the costs of living in rural areas, the direct costs associated with a relocation do not stop at the relocation itself. Individuals which are able to afford the move also need to budget for increases in the cost of food, rent, and amenities. Considering the fact that, in 2019, almost 60% of sub-Saharan Africa's population lived in rural areas, these non-tuition fee-related barriers constitute a significant barrier to tertiary education (Figure 2).[xviii]

Figure 2 - Rural population trends, sub-Saharan Africa



Individuals – and those living in low-income, rural communities in particular – also need to contend with significant indirect costs when pursuing a tertiary education. Many individuals living within rural areas, and those falling within the 18-25 age group and living on less than $1.90 a day in particular, make meaningful contributions to their families' businesses or generate income on which their loved ones depend. While completing a tertiary education is likely to (in most cases) increase these individuals' income potential in the long term, doing so requires them to sacrifice part of their income in the short term. For many, this means that responsibilities forced upon them due (in no small part) to their being

born into low-income households preclude them from being able to follow a tertiary education.

3.3. Environment

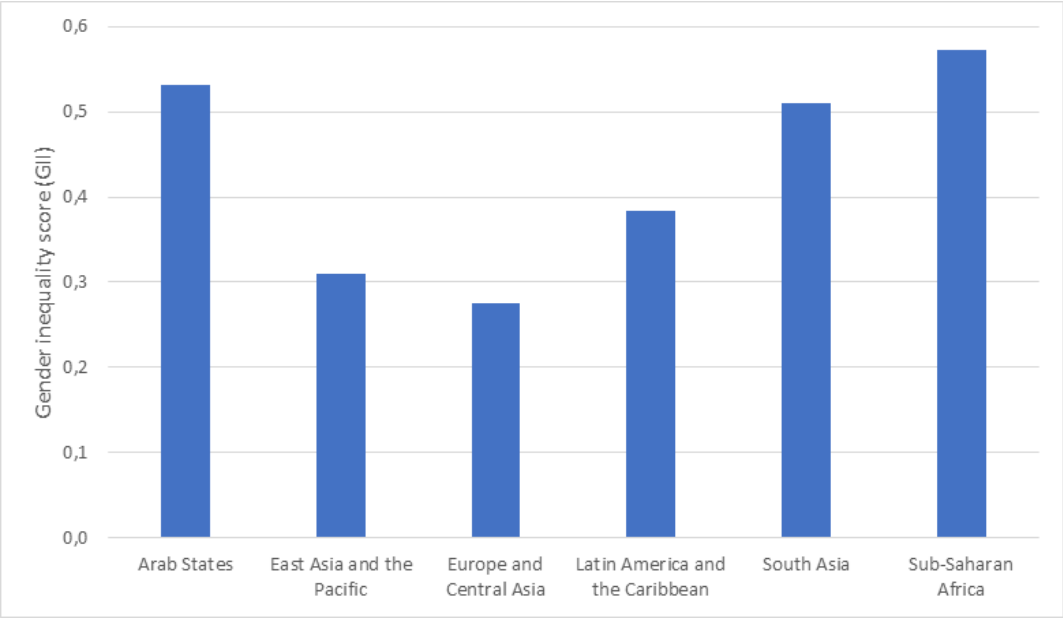
Local attitudes, health & nutrition, crisis & instability, and the quality of infrastructure – categorized (within the context of this study) as environmental factors – supplement cost-related factors in acting as barriers to accessing tertiary education.

The most immediately obvious barrier within the environment category is crisis & instability. Sub-Saharan Africa continues to be ravaged by civil war, (terrorist) insurrections, other forms of political instability, and corruption. A staggering three-quarters of all countries in the region have been affected by armed conflict in the last two decades[xix] – something which serves to reduce state funding for primary, secondary, and tertiary education (thereby eroding both quality and accessibility). Empirical research has confirmed this relationship time and time again, with an uptick in conflict and conflict-related expenditures (read: military spending) being established as strong predictors of reductions in individual-level enrollment rates in primary, secondary, and tertiary levels of education.[xx] While these reductions can be partially explained by governments diverting funds from education to conflict (read: underfunding education and reducing institutional capacity), they can also be partially explained by conflicts precluding individuals from accessing education in other ways. Individuals within the 18-25 age group are disproportionately affected by conflict, whether because (in men's case) they are of fighting age or (in women's case) because they tend to be subjected to cruelties.[xxi]

Local attitudes constitute another significant barrier to education in sub-Saharan Africa. Though these can theoretically impact men and women alike, the reality is that girls and young women are disproportionately impacted. In many cases, harmful traditional practices erode girls' access to education long before they reach the age at which pursuing a tertiary education emerges as an option. In sub-Saharan Africa, girls and young women are routinely subjected to practices such as female genital mutilation,

virginity testing, early and forced marriages, and abductions.[xxii] Cultures of gender discrimination such as these, result in girls needing to contend with gender violence, teenage pregnancies, and debilitating diseases such as HIV at early ages. This negatively impacts their ability to complete primary and secondary educations (if it doesn't preclude them from completing them outright), meaning that it also gets in the way of their eligibility to access and succeed within tertiary education. Though gender inequality in the sub-Saharan Africa region has improved over the course of the past decades, it has far from eliminating its prevalent culture of gender discrimination. The Gender Inequality Index (GII) ranks the region as performing worse than South Asia and Latin America and the Caribbean (Figure 3).

Figure 3 - Gender inequality by region



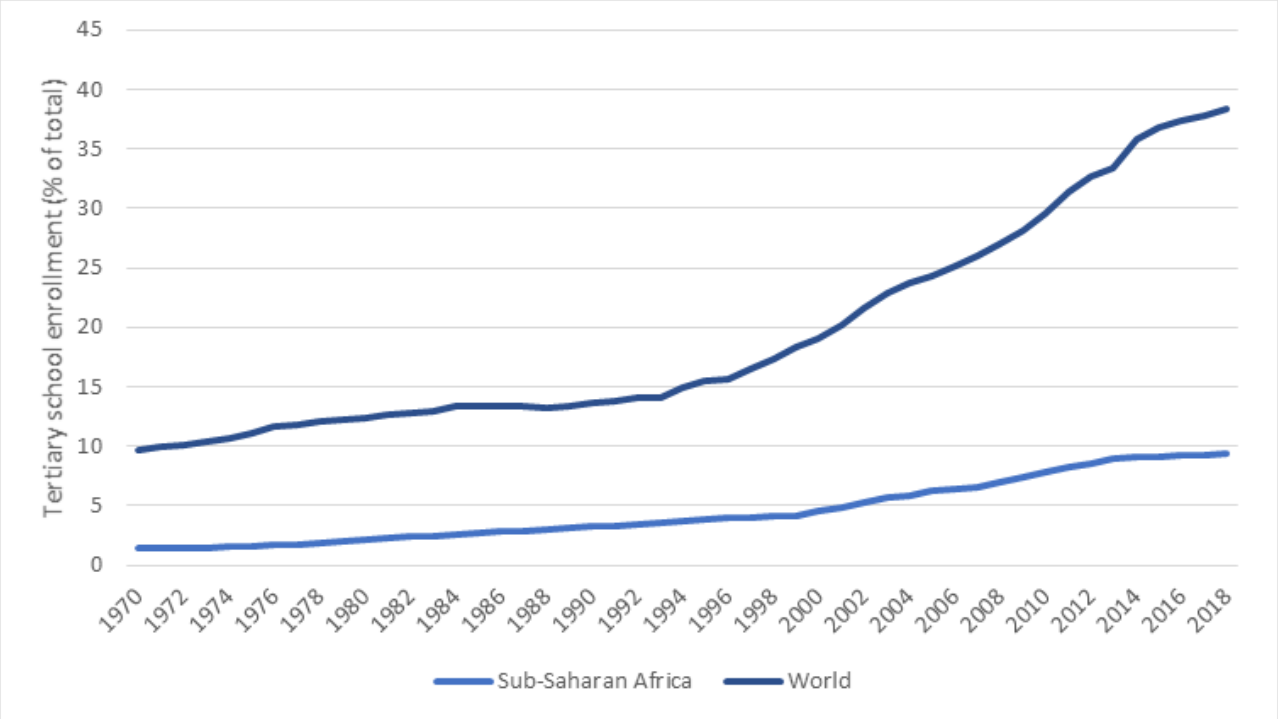
The final environmental factors worth flagging within the context of the exploration of barriers to (tertiary) education in sub-Saharan Africa are the quality of (digital) infrastructure and health & nutrition. The causality linking these variables to (access) to education is relatively straightforward. In the case of the quality of (digital) infrastructure – something that is negatively affected by (among others) corruption and by conflict & other types of political instability – this acts as a barrier to rural communities'

ability to access metropolitan areas, meaning that it erodes their ability to access tertiary education by proxy. The causality underpinning health & nutrition is similarly straightforward. Societies that suffer from a high burden of disease – something which can be caused by, among other things, the widespread presence of chronic diseases such as HIV – are faced with significant direct and indirect costs. Chronic diseases reduce the productivity of afflicted individuals while they are alive. In cutting their lives short, they also negatively impact their lifetime earning potential – both factors which reduce tax revenues and decrease governments' ability to implement a healthcare system capable of mitigating the underlying problem. Perhaps more worryingly, superstitions in rural areas (sub-Saharan Africa included) mean that diseases play an important role in societal discrimination, something which (once again) translates into children being denied access to primary and secondary education and into them not being eligible to pursue tertiary educations. Though discrimination against HIV-afflicted individuals (and even individuals whose parents are afflicted by the disease) in the past, other diseases – COVID for example – are also widely demonized. In sub-Saharan Africa, discrimination against AIDS-affected children can directly impede both their access to formal schooling and the treatment they receive in the classroom.[xxiii]

3.4. Institutional capacity

The final barrier to accessing tertiary education in the sub-Saharan Africa region has to do with a (lack of) institutional capacity, a factor which also serves as a major hamstring to the quality of tertiary education within the region. This can be attributed, in no small part, to increases in the demand for tertiary education that have accompanied explosive population growth in the region. At 9.4%, tertiary school enrollment in sub-Saharan Africa lagged well behind the world average of 38.4% in 2018 – something which speaks to the relative inaccessibility of this type of education (Figure 4).[xxiv] It also lags behind other low-income regions – south and west Asia, Central Asia, and the Middle East and North Africa (MENA) included.

Figure 4 - Tertiary school enrollment (sub-Saharan Africa vs. world)



This notwithstanding, the number of people in tertiary education in sub-Saharan Africa is likely to keep growing in both absolute and relative terms.[xxv] More than 90 million people are projected to have completed secondary school in the coming 30 years, a value that represents a 17% increase over 2014.[xxvi]

Keeping up with this increase in demand is already proving itself a challenge for the region's (largely publicly-funded) tertiary education system. African universities have a 50% higher pupil-student ratio than the global average, something which has been shown to reduce the quality of education. A 2014 study found that there is a significant relationship between pupil-student ratios and academic achievement, with higher ratios being associated with lower academic performance.[xxvii] This has prompted proliferation of two trends. First, with African universities struggling to meet demand for places and

falling short as far as offering a high-quality education is concerned, many young Africans are heading abroad. Approximately 375,000 – more than double of 1997's 156,000 – studied overseas in 2017.[xxviii] Many of these emigrants never return, with many being incentivized to emigrate specifically due to their perception that they are likely to have access to better education abroad.[xxix] The Institute for International Education found that, in the 2018-2019 academic year, there were 40,290 (up from 31,113 in 2013-2014) students from sub-Saharan African enrolled at colleges and universities in the United States alone.[xxx] Though brain drain offers some opportunities from the African perspective (remittances, diaspora options, technology transfer, etc.),[xxxi] it is generally viewed as a net-negative as far as sustainable development is concerned.[xxxii] Not only does it force governments increase their expenditures into education and training to compensate for those who have left – something which, because investments in tertiary education benefit elites and come at the expense of investments into improving primary education in rural areas,[xxxiii] exacerbates inequality – it also results in a shortage of technical know-how in critical sectors, such as healthcare.[xxxiv]

The second development which has been prompted by African (public) universities' lack of capacity to service new students is the advent of privately funded and for-profit institutions. These institutions play an important role in sub-Saharan Africa's education ecosystem not only because they alleviate some of the stress on the region's universities – something which contributes to meeting growing demand for opportunities to pursue (high-quality) forms of higher education – but also because they (in many cases) specifically target individuals which are in the market for shorter educations that offer work-relevant experience. ALX, a for-profit institution, is a good example within TVET. The organization runs a six-month boot camp in soft skills and helps students find six-month internships. It charges students $2,000 per year on the promise that its brand recognition is so strong that employers will be willing to overlook its graduates' lack of a formal (university) degree.[xxxv] Though the feasibility of establishing such institutions is hamstrung by, among others, the bureaucracy associated with gaining accreditation, the private sector has seen significant growth in recent years. Whereas the number of public universities in sub-Saharan Africa increased from 100 to 500 between 1990 and 2014, the number of private institutions grew from 30 to more than 1,000.

One relevant development to emerge within the education space in recent years – and one which

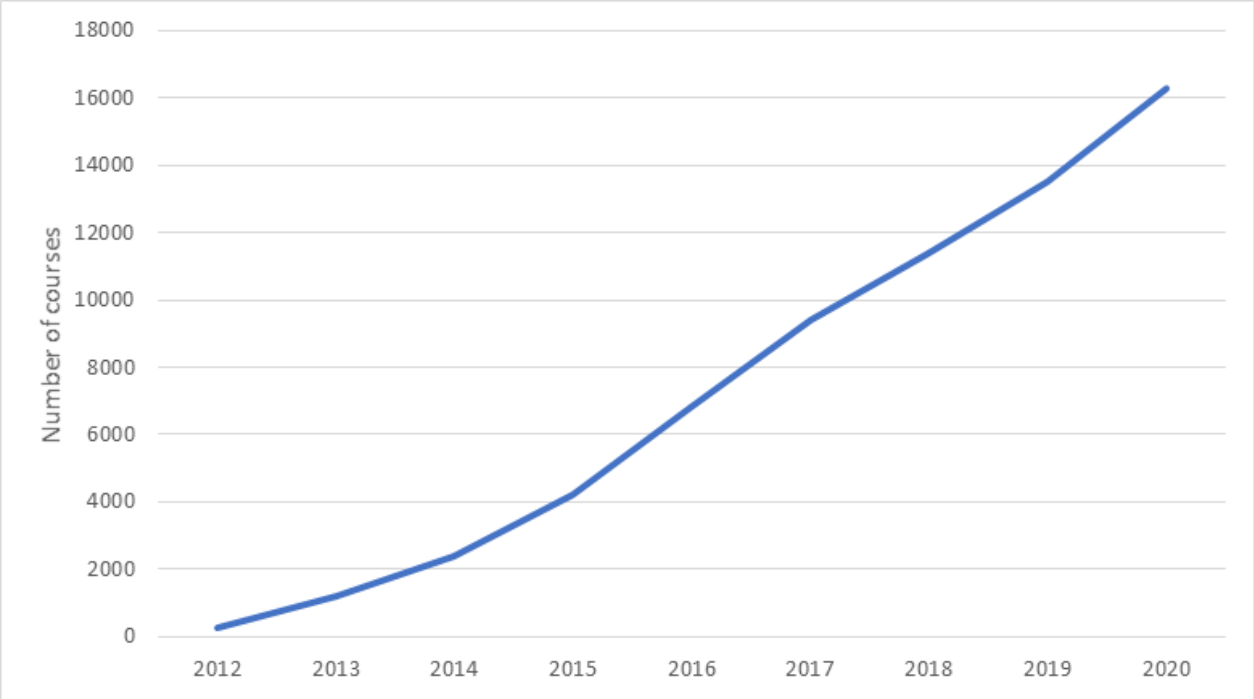
holds the potential to mitigate many of the shortcomings associated with sub-Saharan Africa's tertiary education system – is the in-earnest advent of digital learning as an alternative to traditional forms of education. Business Insider estimates that global investments into online education technologies (ed-tech) reached $18.66bn in 2019, with the total market for these technologies being expected to reach $350bn by 2025.[xxxvi] This growth was formerly driven primarily by investor expectations that – as population growth in low-income countries continues to increase demand for higher education – demand for the services online program managers (OPMs) offer has far from peaked. It has been bolstered by the coronavirus pandemic (COVID-19). Coursera reported 70 million active users in 2020, up from 50 million in 2019 and 42 million in 2018.[xxxvii] Its largest competitor, edX, reported 32 million in 2020, with Future Learn and Class Central – a few of the runners up – reporting 13.5 and 2.2 million respectively.[xxxviii]

This study defines digital education as the use of digital tools and/or technologies to deliver tertiary education. Within the context of tertiary level education, digital education refers to the use of, among others, OPMs, massively open online courses (MOOCs), automated grading systems, game-based learning, open education resources (OERs), online education and other digital environments, to obtain an academic degree. Technology Enhanced Learning (TEL), or e-learning, can take the form of either Computer Managed Learning (CML) or Computer Assisted Learning (CAI). These forms of learning can be distinguished from one another primarily on the basis of the degree to which they allow for some form of human interaction during the learning process. In the case of CML, human interaction is extremely limited or nonexistent. The student sets his or her own goals and a computer (read: an online service or platform) serves them a course (whether predefined or generated based on a preexisting dataset) that services their or the program's needs. This type of learning is widely accessible through OPMs such as Coursera, edX, Future Learn, Class Central, Udemy, Udacity, and Codeacademy – all of which, in addition to hosting courses for partner organizations, provide learners with access to MOOCs.[xxxix] CAI is a form of blended learning in which students are exposed to both online resources (courses, exercises, etc. – hosted either by OPMs or on institutions' intranets) and to "traditional" teaching methods (online or in-person lectures, workgroups, etc.).

In addition to seeing meteoric growth in learners, these platforms have also enjoyed robust growth as

far as institutional partnerships are concerned. Coursera estimates that its Campus Response Initiative – which provided every university in the world with access to Coursera's public course catalogue – prompted 10,000 colleges and universities to activate programs on the platform,[xl] with the highest learner growth taking place in Bangladesh, Thailand, Kazakhstan, Argentina, and the Philippines. Many of these initiatives have manifested in the introduction and/or accreditation of MOOCs. Class Central, one of the world's largest search engines for digital course offerings, found that 950 universities worldwide were offering 16,300 distinct MOOCs on OPMs by the end of 2020 (Figure 5).[xli]

Figure 5 - Worldwide growth of the MOOCs



Other trends which are arguably of great relevance to the digital education space are the increasing relevance of gamification and modern implementations of artificial intelligence (AI). The relevance of gamification (often also referred to as "microlearning") is on full display in the success of apps such as

Duolingo, which have pioneered ways of learning that cater to the needs of learners with limited attention spans and whose primary (and, in some cases, sole) means of accessing the internet is through their smartphones.[xlii] Duolingo increased its active users from 0.125 million in 2012 to 30 million in 2019, and saw its downloads increase from 0.25 million to 300 million over the same period.[xliii] The relevance of modern AI applications – though less immediately evident – is also significant. The University of Illinois' and Georgia Tech's online endeavours (next paragrafh) would not be feasible if the OPMs that hosted their courses did not have access to AI that could assist in automating the grading process (among others). The technology is also fundamental to the provision of personalized learning experiences and introduction of virtual tutors, a technological development that is expected to significantly mitigate shortcomings associated with CML's – and MOOCs' more generally – lack of human interaction.[xliv]

3.5. Benefits of digital education

The use of digital education offers various benefits. On the student side, benefits take the form of (among others) increased information retention,[xlv] access to personalized education, temporal & geographic flexibility as far as attending and qualifying for courses is concerned, and (perhaps more importantly) increased financial accessibility. Education providers benefit – first and foremost – from access to markets of scale. When made available online, courses only need to be conceptualized and recorded once to be accessed by millions of students – something which drastically alters the equation surrounding a course's returns on investment (ROIs). The costs of running a course online are further reduced by COVID-19's contribution to the refining of artificial intelligence (AI)-based technologies which enable the automation of not only personalized content generation, but also of previously FTE-heavy jobs such as grading and feedback provision. Early adopters of this business model include the University of Illinois and Georgia Tech, which are respectively offering an entire M.B.A. for $22,000 and an online master's in computer science for $7,000 (Table 5).[xlvi]

Table 5 - Benefits of digital education

Benefits to learners	Benefits to educators
• Increased information retention – retention rate increased by as much as 60%. • Increased financial accessibility. • Access to algorithmic learning (platform dependent). • Increased flexibility – students can learn at their own pace and in their own environments (platform and/or educator dependent).	• Scalability – institutions only need to invest in the designing and recording of a class once for it to be consumed by millions of learners. • Automation – modern tools mean that many FTE-heavy jobs (grading of papers, tutoring, etc.) can be increasingly outsourced to machines. • Taken together, this increases university staff's ability to conduct original research.

Many of these benefits are of direct relevance when viewed through the lens of their potential to mitigate barriers to education in sub-Saharan Africa. The comparatively low cost of following a digital course, particularly when combined with the flexibility students enjoy as far as being able to learn within their own environments and at their own pace is concerned, significantly reduce the severity of direct and indirect costs' role as a barrier to accessing tertiary education. In the case of direct costs, this is partially digital education allows educators to offer lower tuition fees (a direct result of these courses' scalability) and partially because not needing to live in metropolitan areas – or, at the very least, not needing to commute to them on as regular a basis – as a result of increased flexibility means students no longer need to budget for increased costs of living. On the indirect side, digital education's potential to allow learners to follow courses at distance and (in many cases) at their own pace means that far fewer will need to choose between following education and holding down a job or doing their part to keep the family business afloat (Table 6).

Table 6 - How digital education mitigates cost-related barriers to (tertiary) education

Barrier	Mitigation potential	Explanation
Direct costs	High	Reductions in cost of admission result in reduced tuition fees; ability to follow courses remotely reduces costs associated with paying for life in or commuting to metropolitan areas.
Indirect costs	High	Ability to follow courses remotely at one's own leisure reduces indirect (opportunity) costs.

Digital education also has indirect – though pronounced – potential to mitigate many of the barriers this study associates with the infrastructure category (Table 7). The majority of this potential derives from how the flexibility it offers interacts with the causality which underpins these barriers. Starting with local attitudes, it is worth noting that digital education does relatively little to mitigate the impact of life-shattering and/or traumatic events. Nor does it necessarily play a significant role in reducing the impact of cultural practices and/or value systems that preclude girls from accessing education – largely because these value systems also tend to preclude them from accessing the internet. What the flexibility associated with digital education does do, however, is reduce the logistical severity of scaling these barriers for determined individuals. Girls which would otherwise drop out of secondary school as a result of an unwanted pregnancy can now opt to complete their educations online, and (as a result) potentially qualify for tertiary education further down the line. Girls precluded from travelling to metropolitan areas as a result of forced marriages can now strive to follow a course from home, if need be from their phones.

The view as it relates to health & nutrition and crisis & instability is similar. Digital education cannot fully mitigate the negative impact of reductions in productivity resulting from chronic disease or of a conflict's impact on a university's ability to open a course and on students' ability to attend it, but it can contribute to mitigating the severity of these effects in some cases. As an example, students which would be discriminated against in school (something which leads to them dropping out and/or retaining less

information) might be empowered to complete their primary and secondary educations, and to qualify for tertiary educations. Universities, unable to welcome students due to an ongoing conflict, can now offer courses online – mitigating the impact of government spending cuts and allowing those who are relatively unaffected by the conflict to continue accessing learning materials.

Infrastructure barriers are perhaps among the most heavily mitigated. Just as was the case with the costs associated with funding life in a metropolitan city, the flexibility remote learning offers, allows students to sidestep many of the hassles associated with low-quality national infrastructure.

Table 7 - How digital education mitigates infrastructure-related barriers to (tertiary) education

Barrier	Mitigation potential	Explanation
Local attitudes	Low	Empowers individual agency: individuals wishing to pursue an education regardless of circumstances now face fewer obstacles to doing so.
Health & nutrition	Low	Empowers individual agency: individuals wishing to pursue an education regardless of circumstances now face fewer obstacles to doing so.
Crisis & instability	Medium	Offers alternative venue for offering education to educators; individuals unaffected by the conflict can continue to access learning materials.
Infrastructure	High	Ability to follow courses remotely reduces costs associated with overcoming obstacles deriving from low infrastructure investment.

Finally, in allowing universities to scale and to adopt new business models, digital education enables them to overcome many of the downsides associated with institutional capacity (Table 8). These allow universities to simultaneously become less dependent on government funding and support and to offer full-featured educational experiences to more students, something which improves both access to and the quality of tertiary education.

Table 8 - How digital education mitigates institutional capacity-related barriers to (tertiary) education

Barrier	Mitigation potential	Explanation
Funding for tertiary education	High	Course scalability and automation reduce educators' operating costs, making them less dependent on government support.
Government support (other)	High	Course scalability and automation increase educators' profitability, allowing them to invest in resources which they would otherwise have depended on state funding for to access.

Digital education has had a slow – but pronounced – start in sub-Saharan Africa, particularly at the tertiary level. Whereas various organized initiatives are underway to improve access to primary and secondary education through digital means – see the DEAN initiative[xlvii] – public institutions involved in sub-Saharan Africa's tertiary education have been slow to adopt digital education models. This is reflected in, among others, Coursera's lack of partnerships with any such institutions and in African students' relative underrepresentation on the platform.[xlviii] The situation is different among the region's private educators. While digital education is far from being commonplace among these institutions, signs point towards their openness to exploring the feasibility of business models which place a heavier emphasis on digital education. Unicaf, an African institution founded in 2012, is a good example. Offering programs in fields such as business, education, and health care management through largely online venues, it had – in 2019 – succeeded in reaching 18,000 students across sub-Saharan Africa.[xlix] It hopes to enrol 100,000 by 2023. Priced at $4,000, Unicaf provides a service which – though it is not cheap – is within reach of the region's growing middle class. Its degrees are recognized in Malawi and Zambia, and are due to be accredited in Rwanda and Zimbabwe in the near future.

Unicaf constitutes but one of many examples of institutions looking to digital education as an opportunity for expanding education on the continent. Over 500,000 learners accessed African Teen Geeks' (ATG) Digital Lockdown course, hosted through the MsZora platform (an OPM), in 2020.[l] Support for (and acceptance of) e-learning is high among African consumers, and has enjoyed a significant boost

in support as a result of COVID-19. The Global University Network for Innovation found in 2020 that as many as 83% of Africans are in favour of adapting national curriculums to enable more effective distance learning in the future.[li] OPMs are not the only online venues to support e-learning in sub-Saharan Africa – though, due to the data harvesting capacities unlocked through their scale, their market share within the continent is likely to grow in the near future. Many institutions which offer tertiary education choose – whether as a business consideration or out of their view that controlling a platform will allow them to offer better education – not to partner with OPMs, opting instead to host their courses through boutique platforms, their own intranets, or the platforms made available to them by national governments.[lii]

3.5.1. Digitalization as a barrier to digital Education in sub-Saharan Africa

Digital education's potential to improve access to (tertiary) education notwithstanding, deploying it within the sub-Saharan Africa region is challenging. Deploying it in a way that succeeds not only at reaching disadvantaged individuals within the region but also at providing learners with a level of education that rivals what is available through traditional means, even more so. Digitalization – a term which, within the context of this research, refers to a process in which individuals and institutions gain access to the knowledge, infrastructures, technologies, and services they need to offer and pursue tertiary educations online – has, in sub-Saharan Africa, not progressed to a degree where (as is the case in most high-income countries) the main factor limiting individuals' access to it is educators' laziness when it comes to implementing it. Whereas consumers in most high-income countries can take access to a computing device (and, in many cases, several computing devices) and to a stable internet connection for granted, learners looking to access digital courses – if, indeed, they are available – in sub-Saharan Africa oftentimes lack the basic means for doing so.

A comprehensive overview of factors limiting access to digital education in sub-Saharan Africa, hereafter referred to as the region's digitalization status, is outlined in Table 9 below. In line with the factors

outlined in this study's definition of digitalization, Table 9 distinguishes between individual and/or institutional ability to access and offer digital learning resources, access to technology, and – finally – the quality and availability of digital learning resources.

Table 9 - Factors contributing to digitalization status, sub-Saharan Africa

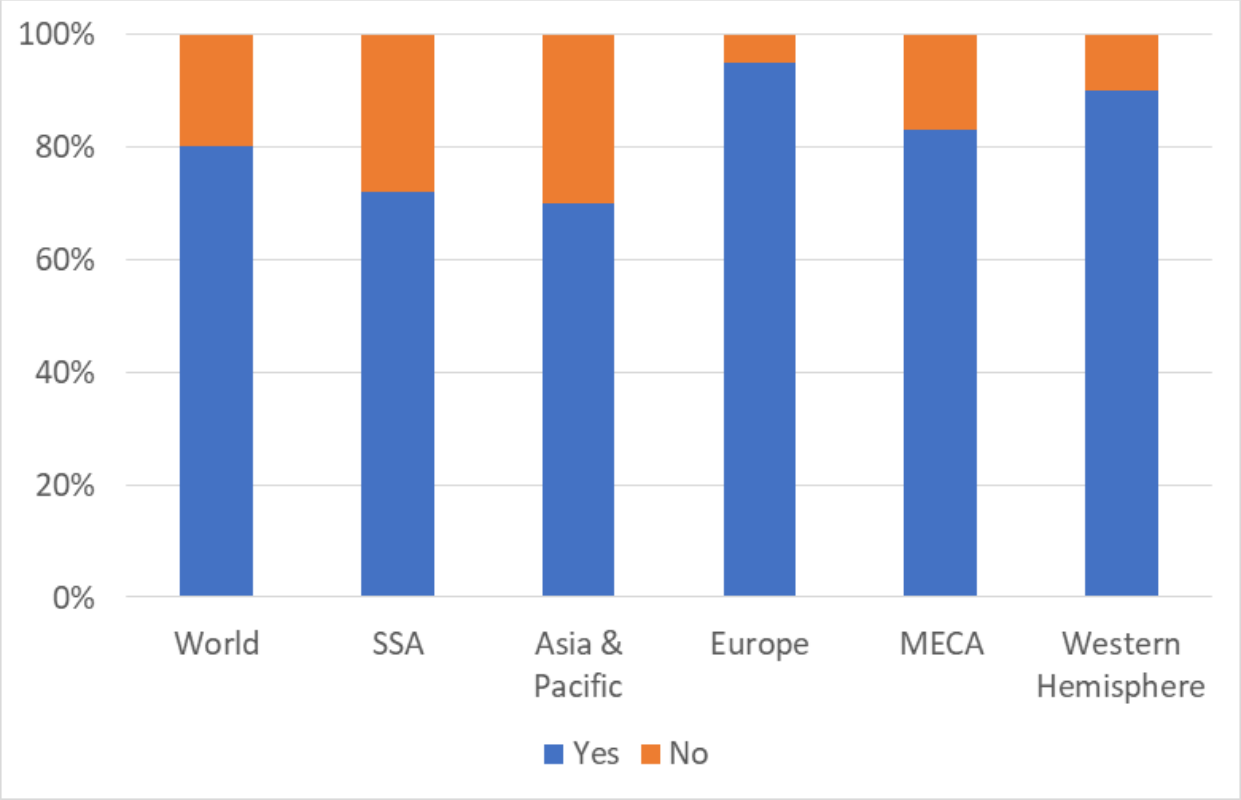
Status category	Variable
Ability	Digital skills (individual)
	Digital skills (institutional)
Access	Access to computing devices
	Access to internet
	Quality of internet
	Access to working electricity
Quality & availability	Demand (perceived quality of) for digital education (individual)
	Availability of digital education (institutional)

Ability, access, and quality & availability's respective contribution to furthering digitalization are, by and large, self-evident. On the ability side, it pays to note that accessing and deriving educational value from online resources is contingent on individuals' ability to interface with such content on the one hand, and on institutions' ability to provide and maintain it on the other. While such skills are unlikely to emerge in the absence of access to computing devices, internet, and stable electricity, ability and access need not be mutually enforcing, with a lack of access to electricity having been cited as a major roadblock to the widespread deployment of digital education initiatives in sub-Saharan Africa specifically. Patchy and/or inconsistent access to the internet or electricity undermine learners' ability to follow online courses, attend online meetings, or to submit assignments in a timely manner. While this is less of an issue for students engaging in CML, those engaging in CAI – a solution that, especially during COVID-19, has continued to account for a significant share of digital education in sub-Saharan Africa. Quality & availability are included because these constitute prerequisites for digital education playing a role in expanding access to education in sub-Saharan Africa. Institutional and individual ability to

interface with and to access web-based graphical user interfaces (GUIs) does not guarantee they are doing so. Demand for digital education – something which, within the context of this study, is conceptualized as being deeply rooted in consumer demand for (and, by extension, the quality of) web-based learning solutions – constitutes another important part of this puzzle. It is also one which requires the implementation of a different set of measures to address than do factors such as a lack of access to working internet.

While digitalization in sub-Saharan Africa has lagged behind much of the rest of the world, the gaps between the region and the rest of the world are narrowing. The International Communications Union (ITU) in 2017 showed that the region had experienced a tenfold increase in internet penetration since the early 2000s, relative to a threefold increase in most of the rest of the world. A 2020 study on organizations' ability to switch to telework during COVID-19 found that 28% of countries in sub-Saharan Africa – a comparatively huge amount – reported issues engaging in telework as a result of organizations' inability to access reliable internet and/or electricity, something which speaks to the magnitude of the opportunities associated with expanding digitalization in the region (Figure 6).[liii]

Figure 6 - Regional ability to switch to telework during COVID-19



4. Measuring Barriers

The following chapter outlines a methodology for measuring the variables identified in the previous chapter – namely: barriers to tertiary education and the state of digitalization in sub-Saharan Africa. It also presents and provides an analysis of the results of applying this methodology, with the ultimate result being a discussion of countries which, on paper, are most in need of the implementation of measures designed to expand digitalization. For an overview of the caveats which apply to this method. See Annex VI.

4.1. Methodology

This study leverages various open-source datasets to arrive at overviews of a.) which countries in sub-Saharan Africa offer the highest quality education, b.) which countries in the sub-Saharan Africa region face the most significant barriers to tertiary education, and c.) which countries in the sub-Saharan Africa region have progressed the furthest in their digitalization. The datasets leveraged to quantify the featured in this study, as well as the steps applied to aggregate them into composite measurements, are outlined in the sections below and in Annex II.

4.1.1. Quality of and barriers to tertiary education

In line with this research's overarching goal of identifying opportunities to leverage digital education not only to improve access to tertiary education, but also to improve its quality, we measure two distinct composite variables under tertiary education. The first, unsurprisingly, has to do with quality (Table 10). The second has to do with barriers (Table 11). These align with the barriers described in the previous chapter (Table 3), and are used to generate a comparative overview of sub-Saharan African countries' barriers to accessing tertiary education on the one hand, and to the region's barriers to improving the quality of tertiary education on the other. The second has to do with allowing for a differentiation between the quality of education on offer in these countries.

We measure quality individually because measuring barriers to improving the quality of education in a specific country speaks little to the actual quality of education in that country. This is particularly the case in sub-Saharan Africa, where – as previously outlined – private-sector institutions have made consecrated efforts to offer education through various for-profit models. The quality measurement differs significantly from the access measurement in this regard. Whereas the variables used to measure barriers to access do – by and large – grant insight as to the degree to which individuals are able to access tertiary education in a specific country, those used to measure barriers to improving the quality of education do not. Measuring the quality of tertiary education through means which are divorced from the limitations of measuring state commitment to supporting education is therefore of significant importance to addressing the study's overarching research question.

Table 10 outlines the variables leveraged to measure quality of education. The variables leveraged to quantify barriers to improving the quality of tertiary education, barriers to accessing tertiary education, and (by extension and as outlined above) access to tertiary education are outlined in Table 11.

Table 10 - Indicators, quality of tertiary education in sub-Saharan Africa

Variable	Dataset	Variable
Quality of secondary education	Global Competitiveness Index (GCI)	5
Extent of staff training	Global Competitiveness Index (GCI)	5.08
TVET availability	Global Competitiveness Index (GCI)	5.07
Quality of math and science	Global Competitiveness Index (GCI)	5.04
Quality of business schools	Global Competitiveness Index (GCI)	5.05

Each of these variables is normalized between 0 and 1. This results in the country with the best performance within each variable receiving a 1 and country with the worst performance receiving a 0. All other countries are clustered proportionally between 0 and 1. Scores from all four variables are added together to calculate a country's overall (comparative) quality of education, resulting in a theoretical score range of 0 to 5.

Table 11 - Indicators, barriers to accessing tertiary education in sub-Saharan Africa (Annex II)

Component	Barrier	Dataset	Variable
Costs	Direct costs	Manually coded (HCSS)	Average cost of tuition fees
	Indirect costs	World Bank	Rural population (% of total)
	Local attitudes	Varieties of Democracy (V-DEM)	v2pepwrgen
Environment	Health and nutrition	Institute for Health Metrics and Evaluation	DALY (annual disease burden)
	Crisis and instability	Fragile States Index (FSI)	Aggregate score (2019)
		Varieties of Democracy (V-DEM)	v2X_rule
	Infrastructure	Global Competitiveness Index (GCI)	2.01
Institutional capacity	Government funding	World Bank	GDP Per Capita
	Government support (other)	Doing Business Index (DBI)	Starting a business score
Population Pressure	Population	World Bank	Population, total
		World Bank	Population growth, last 5 years

A country's final score reflects its aggregate score across categories. This means that countries' final scores can theoretically range between 0 and 11 (each variable is assigned equal weight). Population is included to correct for the fact that the challenge of overcoming barriers grows more severe as a country's population size increases.

4.1.2. State of digitalization

As previously outlined, this research measures the state of digitalization in sub-Saharan Africa rather than measuring barriers to digitalization. This is because this study conceptualizes digitalization as a tool for overcoming barriers to accessing and increasing the quality of tertiary education (see previous sections). In line with this thinking, a country's intervention need increases as its barriers to

education become more formidable and its path towards digitalization is less progressed. Barriers to digitalization are proxied for (though not measured directly) in the following step, which gauges the feasibility and potential impact of implementing a comprehensive list of possible interventions on a country-by-country basis.

The methodology for operationalizing the state of digitalization in sub-Saharan Africa (applied on a country-by-country basis) is outlined in Table 12 below. In line with previous sections, it yields separate scores for ability, access, and quality & availability.

Table 12 - Indicators, state of digitalization in sub-Saharan Africa (Annex II)

Compo-nent	Variable	Dataset	Variable
Ability	Digital skills (individual)	Global Competitiveness Index (GCI)	Mobile broadband subscriptions (per 100)
	Digital skills (institutional)	Global Competitiveness Index (GCI)	Internet use by schools (5.06)
Access	Access to computing devices	Global Competitiveness Index (GCI)	Presence of modern technology (9.01)
			Business access to technology (9.02)
	Access to internet	International Communications Union (ITU)	Individuals using the internet (% of population)
		Visual Capitalist	Price of 1GB (USD)
	Quality of internet	Global Competitiveness Index (GCI)	Internet bandwidth (kb/s) per internet user
	Access to working electricity	Global Competitiveness Index (GCI)	Quality of electricity supply (2.07)

Component	Variable	Dataset	Variable
Quality & availability	Availability of distance education	Manually coded (HCSS)	Number of universities offering distance learning
	Availability of digital education	Manually coded (HCSS)	Number of universities offering some form of online education.

A country's final score reflects its aggregate score across categories. This means that countries' final scores can theoretically range between 0 and 10. The number of languages offered at universities, while a relevant variable, is not included due to challenges associated with building a comprehensive (and accurate) dataset for measuring it.

Countries that suffer from a lack of data coverage in one or more of the indicators outlined in the tables above are removed from the analysis. This is because, in the absence of full data availability, it is impossible to conduct a rigorous comparative analysis of results. Indicators have been selected with the explicit goal of ensuring maximum geographical coverage, with the result being that this study covers 22 sub-Saharan African countries in total.[2]

For an in-depth overview of the datasets leveraged and data transformations applied to operationalize quality of education, barriers to education, and state of digitalization, please refer to Annex II.

[2] The 22 countries included in this study are Benin, Botswana, Burundi, Cameroon, Chad, Ethiopia, Gabon, Ghana, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Uganda, Zambia.

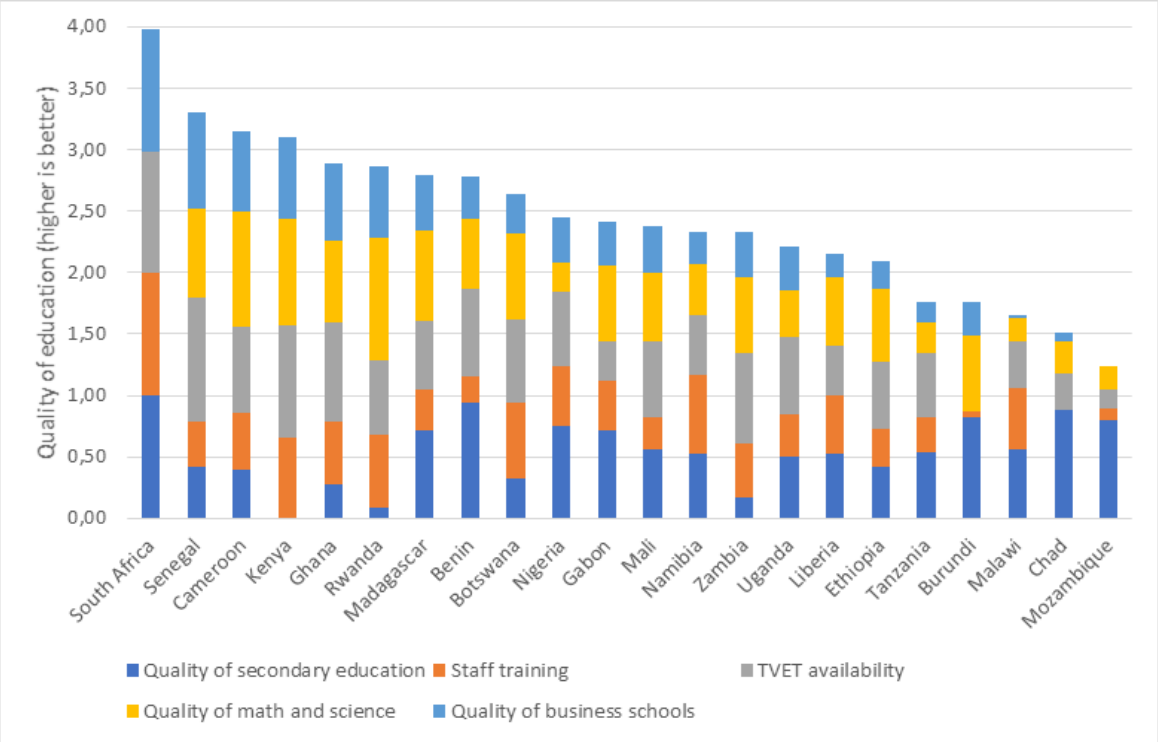
4.2. Findings

4.2.1. Quality of education

The quality of sub-Saharan African countries' education systems is showcased in Figure 7 below. Figure 7 provides a high-level overview of countries' performance within the quality of education (aggregate) metric; for a full overview of the component scores within quality of education, see Annex III.

South Africa emerges as presiding over by far the most robust education system in the region. The country scores highest on virtually all variables (quality of secondary education, staff training, TVET availability, quality of math and science, quality of business schools). Senegal, Cameroon, and Kenya are the closest runners up. An important caveat here is that none of these countries scores particularly high within the quality of secondary education variable. Instead, they derive a large share of their overall performance from TVET availability, quality of math and science, and quality of business schools. These countries' underperformance within the quality of secondary education metric arguably undermines their overall performance from an intervention feasibility standpoint. Quality secondary education is a facilitating factor for many of the interventions identified within the context of this study (see section 4.2).

Figure 7 - Quality of education (aggregate scores)



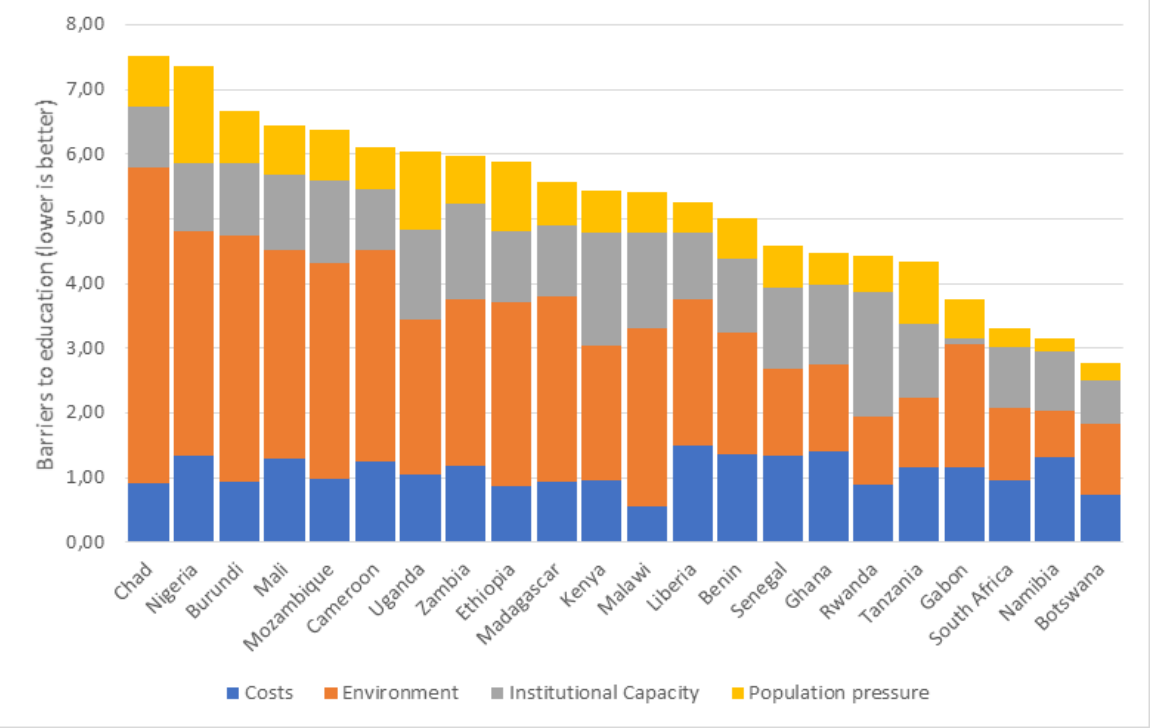
The image is similar for Ghana and Rwanda. Madagascar and Benin both preside over relatively high-quality secondary education systems. They fall behind on virtually all other indicators – something which speaks to a (lack of) quality in their tertiary education systems. Botswana, Nigeria, Gabon, Namibia, Zambia, Uganda, Liberia, and Ethiopia all emerge as (relative) laggards throughout indicators. Zambia performs particularly poorly on the quality of secondary education metric. Tanzania, Malawi, Chad, and Mozambique perform worst in the region, with Mozambique scoring bottom of the barrel. These countries universally score relatively poorly on tertiary education metrics (staff training, TVET availability, quality of math and science, quality of business schools). Conversely, they perform well on the quality of secondary education metric. This makes them potentially attractive countries to target interventions at because their tertiary education systems require improvement, and because they pre-

side over the (secondary) education infrastructure for facilitating some of the potentially high-impact ICT programs.

4.2.2. Barriers to education

The magnitude of sub-Saharan African countries' barriers to education is showcased in Figure 8 below. Figure 8 provides a high-level overview of countries' performance within the quality of education (aggregate) metric; for a full overview of the component scores within barriers to education, see Annex III. An important point to note is that, as barriers to education – and, by extension, countries' scores within this measurement – increase, their "performance" is conceptualized as worse. This means that, in Figure 8, Chad faces the greatest barriers to education and Botswana faces the least.

Figure 8 - Barriers to education (aggregate)



One important observation to derived from Figure 8 is that the score distribution – that is to say, the difference between the "best" (Botswana) and "worst" (Chad) performing countries – is relatively less pronounced within the barriers to education metric than it is within the quality of education metric (Figure 7). Because these scores are derived from, and normalized on the basis of, only sub-Saharan African countries' (rather than global) scores, this implies that all countries within the region likely face sizable barriers to tertiary education.

This observation notwithstanding, Chad and Nigeria face more significant barriers than either of their counterparts. Importantly, these countries – and Chad in particular – derive large shares of their barriers from their performance within the environmental component, which contains variables such as local attitudes, health & nutrition, crisis & instability, and infrastructure. Their relative overperformance

within this category is significant because environmental barriers are arguably some of the most difficult to overcome. Nigeria also derives an outsized share of its score from the population pressure variable, something which speaks to the difficulty it is likely to have as far as tackling environmental barriers in the future is concerned.

Mali, Mozambique, Cameroon, Uganda, Zambia, and Ethiopia make up the second least performant country cluster. These countries don't derive low performance from any particular barrier component. Rather, they underperform across the board. The view is similar in their follow-up category, which is comprised of Senegal, Ghana, Rwanda, and Tanzania.

Gabon, South Africa, Namibia, and Botswana are the best performing countries in the region. Important to note here is that – despite its high performance – Gabon suffers from relatively high environmental and cost-related barriers. Namibia also stands out as facing significant cost-related barriers.

Figure 9 - Barriers to education vs. quality of education

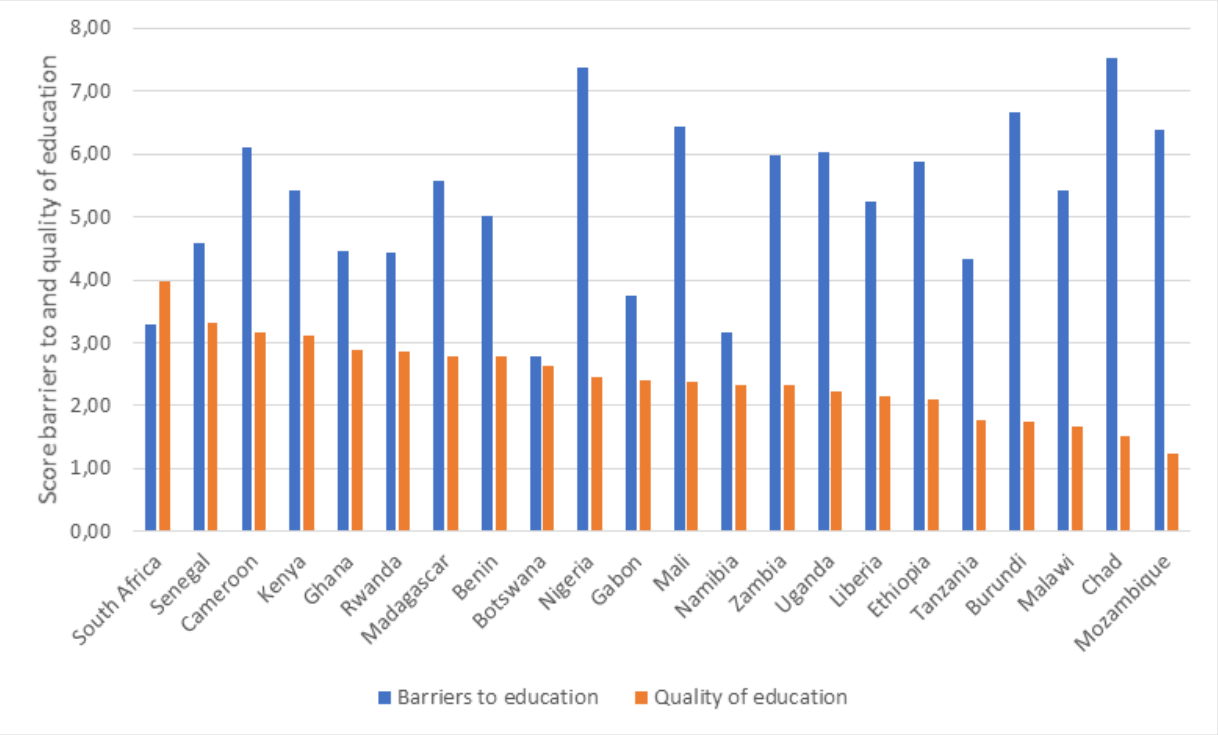


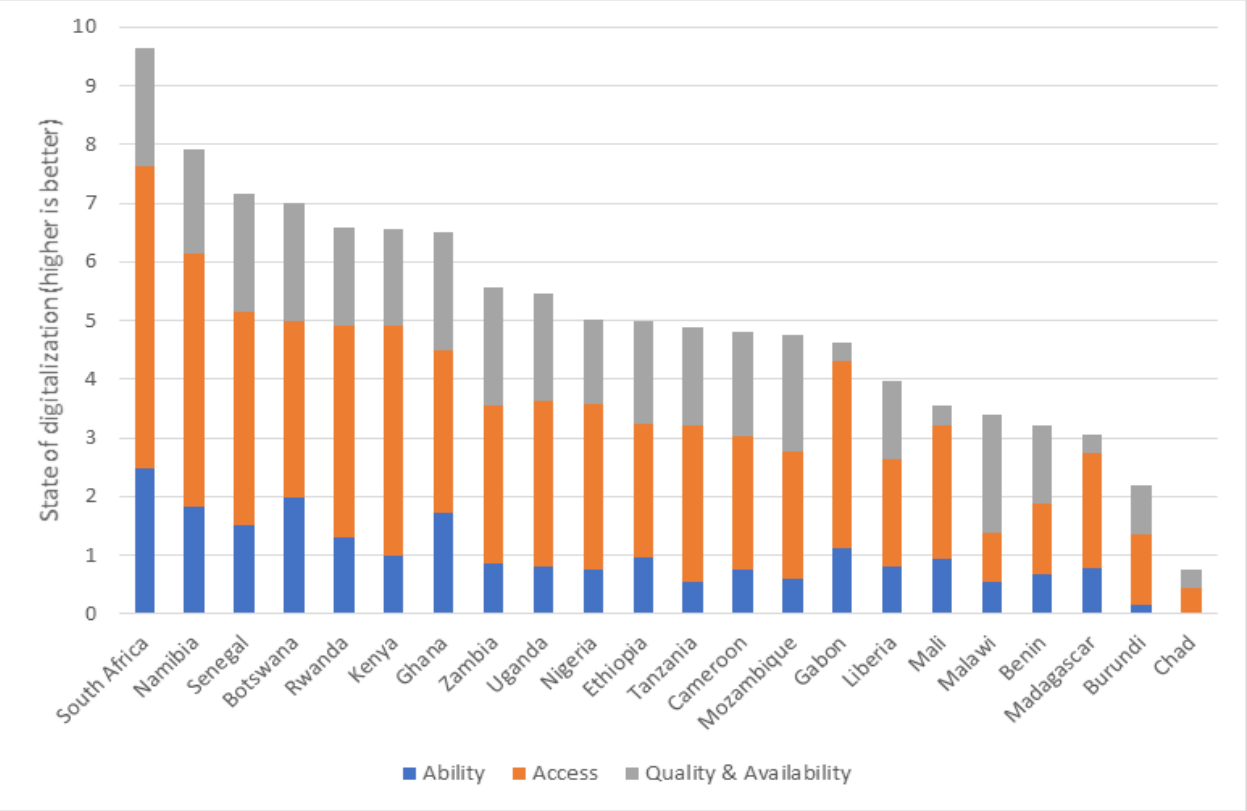
Figure 9 plots countries' aggregate performance within the quality of education metric (Figure 7) against the aggregate magnitude of their barriers to tertiary education (Figure 8). Though there is a high degree of correlation between these two variables – quality of education generally goes up as barriers to education go down – there are some notable exceptions to this rule. Most significant here are Cameroon, Kenya, Mali, and Nigeria. Despite scoring second-highest on barriers to education, Nigeria succeeds at offering a relatively high quality of education relative to its regional counterparts. An important possible explanation for this phenomenon is that Nigeria – though it suffers from significant environmental barriers to education – is slightly less affected by this barrier type than are high-barrier peers such as Chad, Burundi, and Mozambique. These countries also score relatively much higher than Nigeria on crisis and instability (1.99, 1.77, and 1.06 compared to Nigeria's 1.39 respectively) and health & nutrition (0.91, 0.62, and 1.00 compared to Nigeria's 0.54). This implies that these environmen-

tal barriers have an outsized impact on countries' quality of education. The relevance of health and local attitude-related factors can also be observed clearly in Cameroon, which scores 0.48 and 0.27 on these variables respectively and – despite needing to contend with the 6th most severe barriers to education in the region – succeeds at offering the 3rd best quality of education.

4.2.3. State of digitalization

The state of sub-Saharan African countries' digitalization is showcased in Figure 10 below. Figure 10 provides a high-level overview of countries' performance within the quality of education (aggregate) metric; for a full overview of the component scores within state of digitalization, see Annex III.

Figure 10 - State of digitalization, sub-Saharan Africa



Unlike what was the case in barriers to education (Figure 8), the score distribution within the state of digitalization metric is relatively pronounced, with aggregate scores ranging from 0.76 (Chad) to 9.63 (South Africa). The difference between South Africa (9.63) and the runner up – Namibia (7.93) – is also significant. Outside of indicating that South Africa is significantly more digitalized than its regional counterparts, this indicates that – as far as furthering digitization is concerned – the region likely offers a significant amount of low-hanging fruit.

Outside of a few outliers, country scores across components (ability, access, quality & availability) are generally distributed evenly. One clear exception is Gabon. Gabon performs relatively well (and in the case of access, even disproportionately well) on both ability and on access. It stutters on quality &

availability – a metric which proxies for the degree to which tertiary education institutions offer content through online venues. A similar view emerges in Mali and in Madagascar, though neither of those countries attain particularly high scores access – just proportionally higher than they do on quality & availability. Tanzania, Mozambique, Burundi, and (to a lesser degree) Chad all underperform on ability. This potentially makes them high-impact targets for many of the interventions assessed in the following section.

4.2.4. **Overall**

Figure 11 provides a high-level overview of countries' performance within the quality of education, barriers to education, and state of digitalization metrics. Barriers to education are plotted on the horizontal (X) axis, while quality of education is plotted on the vertical (Y) axis. State of digitalization is used to determine the size of each country's bubble, with larger sizes indicating a higher degree of digitalization.

Figure 11 - Relationship quality of education, barriers to education, and digitalization by country

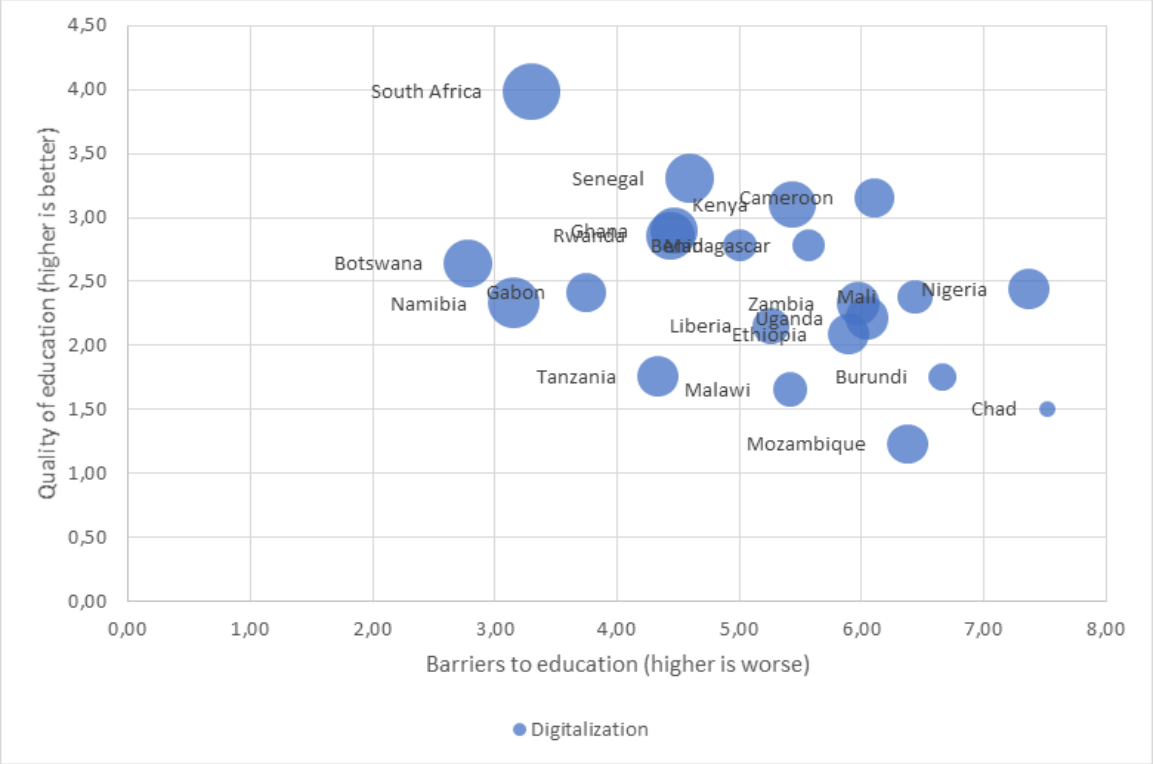


Figure 11 shows a relatively high degree of correlation between degree of digitalization, barriers to education, and quality of education. South Africa – which also has the highest level of education and among the lowest barriers to education – is the most digitized. Chad, which scores poorly on both quality and barriers to education, has made the least progress towards full digitalization. More interesting cases emerge in the center. Benin, Gabon, Ghana, Rwanda, and Tanzania are all examples of countries that combine a relatively high degree of digitalization with above-baseline levels of education quality, while still facing significant barriers to tertiary education. Nigeria and Mozambique fall into this category as well.

5. Interventions

In line with this study's overarching research goal, this section outlines and appraises – on a country-by-country basis – the feasibility and potential impact of several possible interventions to expand digitalization in sub-Saharan Africa. In expanding digitalization, these interventions are conceptualized as vectors for improving individuals' ability to access digital education resources and – by extension – for improving quality and access to tertiary education in sub-Saharan African more generally. The section initiates with a short overview of the methodology which has been applied in the identification and assessing of interventions. It then dives into an analysis of the interventions' feasibility and potential impact.

5.1. Methodology

5.1.1. Intervention choice and distribution

In order facilitate this research's overarching goal of allowing for a comparative analysis between interventions, it identifies a curated list of interventions which have the potential to positively impact the previously outlined components of digitalization in sub-Saharan Africa (ability, access, and quality & availability). Because the number of potential interventions which might be considered within the context of this chapter are, for all intents and purposes, infinite, this study focuses on a shortlist of interventions which, when viewed through the lens of the following parameters, are likely to be of highest relevance:

The intervention is relatively high level. Many possible interventions identified within existing literature (read: other countries' IT strategies, digitalization strategies published by the UN and the African Union Commission (AU), reports published by NGO's, etc.) are extremely specific. In concrete terms, this means that an initiative to expand access to internet in schools might be described as "the deployment of StarLink satellites in ten rural communities in Niger" rather than "improve internet access

through nontraditional means". This study clusters specific interventions into high-level buckets such as the previously outlined "improve internet access through nontraditional means," something which significantly reduces the number of interventions in need of in-depth analysis in the process. This improves not only the rigor of the analysis by allowing for a more focused research design, but also the actionability of the results. To correct for the danger that intervention "buckets"' may come across as non-actionable and/or vague to decisionmakers, each bucket is provided with an in-depth explanation of background information and examples in the following section.

A reasonable expectation exists that the intervention might be feasibly implemented. A defining characteristic of this list is that interventions which are geared towards improving access to internet, computing devices, and electricity (or the previously outlined access category more generally) are underrepresented. This is partially because the intervention options for addressing shortcomings in access are relatively limited, and partially because access to internet, quality of internet, and access to working electricity are all factors whose improvement – though they arguably drive a significant share sub-Saharan Africa's (lack of) progress towards realizing widespread digitalization – is contingent on structural change and on sizable investments into infrastructure. While this does not mean that there is nothing that an actor such as Nuffic can do to contribute to these problems – as an example, expanding access to internet in rural communities is something which projects such as Elon Musk's StarLink might feasibly offer relatively low-cost solutions to within the next few years, at least at the local level – it does mean that many of them can be eliminated on the grounds of their low feasibility from the get-go.

A reasonable expectation exists that the intervention might be high impact. This study also favors interventions which have the potential of being highly impactful when viewed from an impact per Euro spent perspective (ROI). Outside of choice initiatives – some of which are shortly touched on in the pages below – Nuffic is simply less likely to move the needle by focusing on initiatives to improve access to internet, computing devices, and electricity (or the previously outlined access category more generally) than it is by focusing on initiatives which are geared towards improving sub-Saharan African populations' digital skills. This can, on the one hand, be attributed to the fact that the mechanics surrounding their implementation align more closely with Nuffic's organizational footprint. The initia-

tives this research identifies as holding potential as far as improving sub-Saharan African populations' digital skills almost universally concern the design and implementation of (re)training programs and/or the fostering of public-private partnerships, both activity areas which lend themselves better to the instruments – grants, training projects, etc. – at Nuffic's disposal. On the other, it can be attributed to the fact that these initiatives – hereafter referred to as "ecosystem building initiatives" – facilitate structural change indirectly by increasing familiarity with digital infrastructures and technologies at all levels of society (government, businesses, consumers, etc.).

The initiatives outlined in the pages below are derived from the IT strategies published by several sub-Saharan countries – Kenya, Nigeria, and South Africa included. They have been cross-referenced with goals formulated by (among others) the UN and the African Union Commission (AU). For an overview of the interventions identified through this process, please refer to Table 13.

5.1.2. Establishing Feasibility and Potential Impact

The previous section provides a high-level overview of those countries which face the greatest barriers to tertiary education, and which have made the least progress as far as digitalization is concerned. While this facilitates an initial estimation of where to implement initiatives, it is nonetheless useful to introduce – and correct for – the fact that there is no such thing as a "one size fits all" approach to furthering digitalization.

This is because digitalization is difficult – and oftentimes costly – to implement. Meaningful distinctions can be drawn between the necessary preconditions for implementing different interventions, with many requiring that digitalization have progressed past a certain point to be effective. This has significant implications as far as allocating resources to interventions in sub-Saharan Africa is concerned. Chad may, by virtue of its high barriers to education and its relative lack of progress towards digitalization, appear to offer the best real-world impact per Euro spent potential in the region, but – in practice – conditions within its borders are far from conducive to the successful implementation of the interventions identified within the context of this study. This means that, while implementing these in-

terventions in Chad has a potentially large upside, the feasibility of doing so is low. Chad can therefore be regarded as a high-risk investment as far as implementing interventions geared towards furthering digitalization is concerned.

This information is of high relevance to implementing organizations. It allows for not only a clear overview of which types of interventions to pursue in which countries (and why), but also – in generic terms – of the risks and opportunities associated with doing so. Within the context of this report, these variables (read: the feasibility and potential impact of interventions at the intervention-country level) are operationalized by means of a methodology which measures, for each country in sub-Saharan Africa, the degree to which conditions within the country are conducive to the success of each individual intervention. The methodology underpinning the process is implemented as follows:

Literature review. A literature review is conducted to establish, on an intervention-by- intervention basis, those factors which positively or negatively impact the feasibility and potential impact of each intervention's implementation. Within the context of this study, factors which impact an intervention's feasibility are conceptualized as factors which increase or decrease the ease of implementing said intervention within a given country. Factors which impact an intervention's potential impact place a heavy emphasis on the facets of digitalization which a specific intervention might facilitate an improvement in. The interventions explored within the context of this study almost universally further digitalization by increasing know-how or demand within a specific subsection of the population, meaning that their potential impact increases as variable such as the size of the stakeholder group they target and/or affect increase in magnitude.

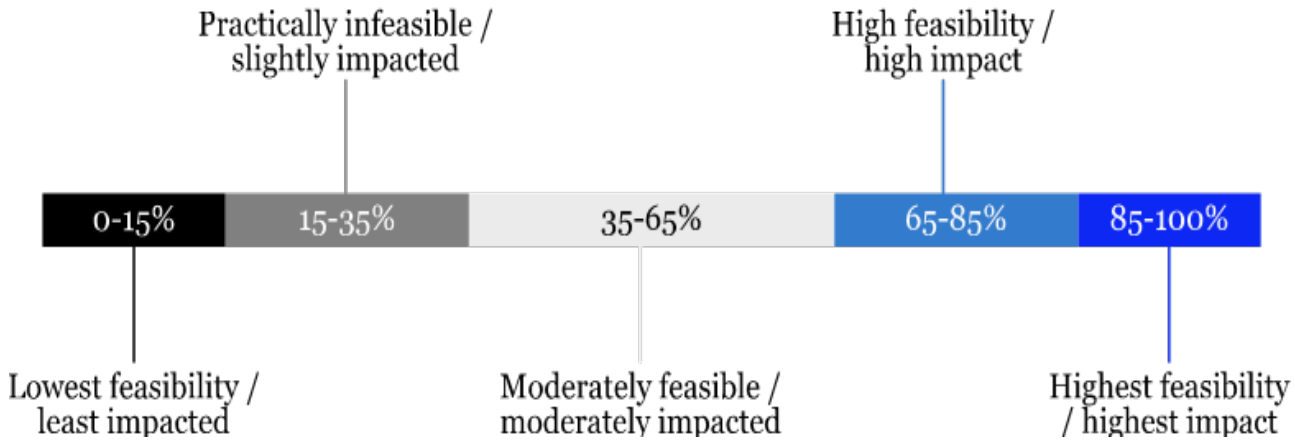
Variable identification. The factors identified on the basis of the previous step are matched to measurement variables. In many cases, these are variables which correspond to variables incorporated into either the previous chapter's "barriers to tertiary education" analysis, or into the previous chapter's "state of digitalization" analysis (see Annex IV).

Performance measurement. The previous two steps allow for the formulation of variable-based parameters denoting circumstances under which an intervention's implementation is likely to be feasible and high impact. This allows the research team to establish that (for example) the feasibility of imple-

menting an intervention which aims to do away with laws that discourage internet, decreases as its level of corruption – as measured through the corruption perception index – increases. The performance measurement step transposes the aforementioned knowledge of a measurable relationship between two phenomena into a tool for conducting a comparative analysis by assigning countries performance labels within each of the variables identified in step two.

The use of performance labels allows for the identification of clusters. It also facilitates the intuitive communication of study results. Countries are assigned performance scores within particular variables on the basis of their performance relative to other countries in the region. Performance labels range from low to high, with medium-low, medium, and medium-high falling in-between. Performance labels are assigned on the basis of the percentile scores outlined in Figure 12 below:

Figure 12 - Performance labels percentile ranges



The chosen breakdown for labeling the percentiles resembles a normal distribution. As countries move away from the medium category, it becomes progressively more difficult to score low or high. Countries only obtain a low or high label if they fall above the 85th percentile or below the 15th percentile within any given variable, meaning that – if they do so – their performance within these variables is meaningfully higher or lower than that of other countries in the region.

This approach also has the benefit of returning conceptually sound results when viewed within the scope of the wider research design. While they are described in generic terms, many of the measurable relationships formulated and attributed to interventions within the following section are subject to diminishing returns, cutoff points, or other complexities which undermine their validity when subjected to granular analyses. The use of percentage cutoff points corrects for this problem by eliminating un-

warranted granularity from the results. By conveying results through categories which a.) are relatively macro level, and b.) speak to relative rather than absolute feasibility and potential impact (highest feasibility or impact rather than high feasibility or impact), it provides results which are accurate, actionable, and which constitute a good basis for further analysis.

For a full overview of the datasets leveraged to assert countries' per-intervention performance on feasibility and potential impact, please see Annex IV. For an overview of the caveats that apply to this methodology, please see Annex VI.

5.2. Initiative descriptions

For the purposes of this research, initiatives have been clustered into several categories; namely digital skills & demand for digital education, access to computing devices, and access to internet & electricity. These categories by-and-large – but do not entirely – align with the ability, access, and quality & availability components of this study's "state of digitalization" metric. The reason for this disconnect is that, while it makes conceptual sense to cluster access-related factors such as access to internet and access to electricity within one category within the context of measuring the state of digitalization, the fact that they require diverging interventions to address means that clustering them together within the context of this section's research design does not. Conversely, the high degree of overlap and/or interrelation between interventions which improve ability and quality & availability means that clustering interventions which target them within a single bucket does. An overview of the initiatives identified and addressed in this section, as well as of the category they have been assigned to, is provided in Table 13 below.

Table 13 - Overview of intervention clusters

Category	#	Intervention
Digital skills & demand for digital education	1	Integrate ICT subjects in the curriculum at all levels of education.
	2	Incentivize return, retention, attraction (commercial).
	3	Incentivize return, retention, attraction (academic).
	4	Government retraining programs
	5	Incentivize nonstate actors to conduct digital training programs and to contribute to state-funded (re)training programs.
	6	Mobilize resources in order to support e-learning initiatives.
	7	Encourage close collaboration and the exchange of personnel.
	8	Create opportunities and provide assistance to disadvantaged groups.
	9	Do away with laws which discourage internet use.
Access to computing devices	10	Leverage fiscal and/or monetary tools to reduce the cost of devices.
	11	Supply computing devices.
Access to internet & electricity	12	Invest in affordable alternatives to broadband.

The following section provides a short overview and explanation of the pathways through which each intervention's impacts and/or improves digitalization, and under what circumstances. To facilitate ac-

tionability, it also showcases examples and other relevant information for each intervention.

5.2.1. Digital skills & demand for digital education

As previously outlined, the digital skills & demand for digital education bucket is relatively overrepresented within this research, largely because improving access to internet or electricity requires outsized investments into infrastructure – something which makes their implementation infeasible for an organization such as Nuffic. Interventions falling within this bucket can, by and large, be understood as "ecosystem building initiatives". They foster demand for digitalization at all levels of society, thus facilitating improvements in access. They are outlined in further detail below.

5.2.1.1. Integrate ICT subjects in the curriculum at all levels of education

Integrating ICT subjects in the curriculum at all levels of education – and at the primary and secondary levels particular – offers a meaningful pathway to improving tertiary-level access to digital education. This improves access to tertiary education by empowering individuals to access online learning resources, whether these take the form of MOOCs or institutionally administered courses (Table 14).

Table 14 - Integrate ICT subjects in the curriculum at all levels of education

Intervention number	**1**
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (consultation on course design, lobbying, offering courses themselves, etc.)
Implementation (tools)	Institutional cooperation (project-based), supplemented by grants.
Effect horizon	Medium-short term.
Feasibility facilitators	Feasibility improves as overall quality of education increases.
Potential impact modifiers	Potential impact increases as (individual) digital skills decrease.

UNESCO's Institute for Statistics posited in 2015 that introducing ICT subjects in primary and sec-

ondary' education curricula is of vital importance to develop digital literacy and guarantee ICT skills development in post-secondary and tertiary education.[liv] It also found that – in 2015 – Burkina Faso, Comoros, Guinea, Madagascar and Niger did not have basic ICT courses in their primary or secondary education.[lv]

An example of this initiative being implemented successfully can be observed in Mauritius, where the government introduced mandatory ICT subjects at the primary and secondary level under the Education and Human Resources Strategy Plan2008-2020. Educational policies were changed to favor the teaching of basic ICT skills, and programming subjects were introduced in five state schools in 2013. The integration of ICT subjects in schools' curriculum spurred a series of other measures such as the improvement of ICT infrastructures, the provision of ICT courses and training for teachers, and the equipment of schools with ICT materials that overall benefited the operations and service delivery of the Education sector. The success of this intervention can be partially attributed to the (re)election of the sitting government, something which contributed to the Ministry's ability to properly implement the Education and Human Resources Strategy Plan 2008-2020.[lvi]

One way to achieve this is to develop and deploy a nationwide e-education system. If implemented well, such an arrangement benefits educational institutions and students alike. It benefits students by (among others) introducing some degree of standardization within a country's e-education system (this increasing the national "reach" of any certificates they earn by following online courses). Educational institutions see a benefit not only because they potentially gain access to more students, but also because such a system facilitates knowledge sharing between institutions within a country, something which levels the playing field. Within the context of sub-Saharan Africa, the introduction of some sort of ICT certificate for primary or secondary schools to work towards being able to award students is a thinkable incarnation of such an initiative.

Another way to work towards integrating ICT subjects throughout levels of education, is to leverage the know-how of 3rd parties, meaning that incentivizing countries' active engagement with platforms such as these, constitutes a potentially useful way for NGOs to become involved. eLearning Africa is an international conference that aims to pool knowledge and resources to promote progress in

e-learning in Africa.[lvii] The Research and Education Networking Unit (RENU) is a unit from the Association of African Universities that focuses on initiatives related to ICT in African education. RENU was instrumental in the creation of UbuntuNet Alliance, the regional Research and Education Networking organization for Eastern and Southern Africa. UbuntuNet Alliance promotes broadband access and ICT tools for education.[lviii] Africa Virtual University (AVU) is an innovative education institution based in Nairobi, Kenya, that services 57 learning centers in 27 African countries. AVU provides academic programs and classes through open and distance e-learning. The AVU has a digital library as well that shares resources with African academics and students.[lix]

While NGOs could feasibly contribute to the implementation of this intervention at the local level and/or at individual schools, they cannot feasibly implement an intervention such as this at the national level. This notwithstanding, they can contribute to their large-scale implementation by (among others) designing criteria and advising government ministries. Because the likelihood that these efforts will produce positive effects increases as a country's education infrastructure grows more robust, this intervention's feasibility is conceptualized as increasing with quality of education. Potential impact increases as (individual) digital skills decrease.

5.2.1.2. Incentivize the return, retention, and attraction of highly educated, tech-savvy individuals

The inability to attract – or to retain – highly skilled individuals constitutes perhaps one of the largest obstacles to facilitating the digitalization of sub-Saharan Africa. As previously outlined, many sub-Saharan African countries have a brain drain problem. Approximately 375,000 – more than double of 1997's 156,000 – individuals studied overseas in 2017.[lx] Sub-Saharan African countries can leverage a combination of commercially (Table 15) and academically-oriented (Table 16) policies to work towards remedying this situation.

Table 15 - Incentivize return, retention, attraction (commercial)

Intervention number	2
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (Lobbying, offering policy recommendations, offering grants to startups, etc.)
Implementation (tools)	Institutional cooperation (project-based).
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as ease of doing business increases and as corruption decreases.
Potential impact modifiers	Potential impact increases as societal ability to engage with technology decreases.

Table 16 - Incentivize return and retention, attraction (academic)

Intervention number	3
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (Lobbying, offering policy recommendations, offering grants to universities, etc.)
Implementation (tools)	Institutional cooperation (project-based), supplemented by grants.
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as quality of tertiary education increases.
Potential impact modifiers	Potential impact increases as societal ability to engage with technology decreases.

Though brain drain offers some opportunities from the African perspective (remittances, diaspora options, technology transfer, etc.), emigrees often represent significant losses in government investment in education – and their loss is harmful to digitalization prospects. Highly educated, tech-savvy individuals have a deep understanding – and often build businesses which rely on – the modern internet. This means not only that they have a potential role to play in fomenting bottom-up demand for improvements in national infrastructures, but in many cases also that they preside over knowledge bases which might allow them to recommend non-superfluous courses of action for doing so.

Incentivizing the return, attraction, or retention of highly skilled individuals is no easy task. One potentially viable (commercial) strategy for doing so is to offer sub-Saharan African diaspora financial incentives to expand companies they have started abroad to cover their countries of origin. This strategy has been successfully employed by Greece – which also suffered significant brain drain as a result of its economic crisis – in recent years.[lxi] The Greek model is far from comprehensive, but it offers some useful insights as far as maximizing the impact of these financial incentives is concerned. Specifically, Greece offered Greek entrepreneurs abroad significant investments on the condition that half of any funds awarded be spent within the country and that these individuals build part of their teams and companies there. Strategies such as these are not uncommon. Lockheed Martin's successful bid to supply India with F-16 fighter jets – while very different in nature than Greece's initiative to invest in Greek entrepreneurial ventures abroad – was also conditional on the company's willingness to produce the jets in India, using Indian labor. Initiatives such as these have the potential of benefiting digitalization in several ways. First, they have the potential of creating medium-high skilled employment opportunities within the region's countries, thus helping to retain high skilled workers, improving the ROIs of government investments into education, and contributing to bottom-up demand to invest into digital infrastructure and to improve the quality of (digital) education. Second, they ensure that entrepreneurial diaspora remain financially invested in the realization of (digital) progress within their countries of origin.

Solutions can also be identified within academia. Part of the reason why post-doctoral research in African countries is scarce is the lack of mentorship for post-doctoral scholars. Encouraging universities to establish post-doctoral research fellow positions entails providing consistent mentorship programs for post-doctoral scholars. Because the supply of eligible mentors is low, universities are discouraged from establishing such positions. Institutional partnerships offer potential solutions. A successful example can be observed in the partnership between the University of Zimbabwe and the University of Buffalo (US). The equal contribution toward grant writing and mentored training of both institutions allowed for the successful formation of a group of post-doctoral scholars. The fact that most of the program was carried on at Zimbabwean premises reduced the risk of brain drain.[lxii] Another way to encourage universities to establish post-doctoral research fellow position is to provide them with financial incentives. If governments or NGOs were to allocate funds specifically to the establishing and

expansion of post-doctoral research programs, the impact on digitalization – and on the retention of high-skilled individuals – would likely be positive.[lxiii]

The implementation of commercial solutions – including the implementation of initiatives such as the introduction of tax laws which favor technology entrepreneurs (not outlined) – is unlikely to be successful in countries in which corruption is prevalent or in which the barriers to starting a business are high. This is because operating in countries such as these incurs significant indirect costs (financial, other), something which reduces the attractiveness of doing so. The implementation of academic solutions is unlikely to be successful in countries which do not offer robust tertiary education. Because the impact of retaining or introducing training opportunities increases as a country's overall ability to engage with technology decreases, potential impact increases as societal ability to engage with technology decreases

5.2.1.3. Expand and improve adult education, life-long learning, and both general and digital literacy programs, notably for retraining and reskilling the existing workforce

Sub-Saharan Africa faces high demand for skilled labor, with over 230 million jobs in the region being projected to require digital skills by 2030.[lxiv] Only training youth is not sufficient; adult reskilling and life-long learning are also necessary. This can be offered by government entities (Table 17) and nonstate actors alike (Table 18). In addition to being targeted at under-skilled workers, this form of education should ideally also be provided and/or targeted at decision makers and civil society leaders.

Table 17 - Government retraining programs

Intervention number	**4**
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (consultation on course design, lobbying, offering courses themselves, etc.)
Implementation (tools)	Institutional cooperation (project-based), supplemented by grants and training programs
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as the magnitude of environmental barriers decreases.
Potential impact modifiers	Potential impact increases as (individual) digital skills decrease.

Table 18 - Incentivize nonstate actors to conduct digital training programs and to contribute to state-funded (re)training programs

Intervention number	**5**
Implementation (actors)	Government, but open to ad-hoc support.
Implementation (tools)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to businesses, etc.)
Effect horizon	Medium-short term.
Feasibility facilitators	Feasibility improves as business access to technology increases.
Potential impact modifiers	Potential impact increases as (individual) digital skills decrease.

Several examples of African countries benefiting from the implementing policies (whether by themselves or by 3rd parties) geared towards the promotion of adult education and reskilling exist. Intel – an American chip manufacturer – offers its Intel Tech program in Ghana, Egypt, Nigeria, and South Africa. The program aims to enhance teaching and learning for subjects such as mathematics, science, engineering through ICT, meaning it provides education to teachers while familiarizing them with ICT tools.[lxv] UNESCO's Teacher Training Initiative for Sub-Saharan Africa (TTISSA) and the African Virtual University (AVU) Teacher Education Project are multi-country regional programs which promote teachers' professional development and ICT integration. Both projects aim to boost teaching quality

while reskilling teachers to be able to work with digital tools.[lxvi] Microsoft 4Africa promotes upskilling within the continent through Skills Labs which offer courses geared towards promoting ICT skills. The project has had noticeable success, with high rates of employment for professional following the program, as demonstrated by examples in Ghana and Nigeria.[lxvii] SangoNet and WomensNet in South Africa, WougNet in Uganda, Kubatana.Net in Zimbabwe, the Community Education Computer Society (CECS) in South Africa, and AngoNet in Angola all constitute examples of civil society networks organizing and promoting programs which improve digital literacy in adults.[lxviii]

Whether government-funded or provided by nonstate actors, retraining programs can – if well designed – generally be understood as having a high potential of contributing to digitalization, because they allow groups of individuals which no longer benefit from changes in primary or secondary curricula to engage in the digital economy, thus furthering digitalization by positively impacting societal ability. In line with this logic, the potential impact of both forms of retraining initiatives increases as individual digital skills decrease at the societal level. Because government actors need access to preexisting infrastructure to implement these initiatives, the feasibility of implementing them decreases as the magnitude of environmental barriers increases. On the nonstate side, feasibility increases as business access to technology increases.

5.2.1.4. Facilitate public-private partnerships

In addition to being potentially productive partners as far as offering (re)training, retaining and attracting high-skilled personnel is concerned, several partnership configurations in which private sector actors cooperate with and/or bolster public sector efforts are thinkable. These partnerships can take the form of resource mobilization on the one hand, and of the exchange of personnel on the other.

Table 19 - Mobilize resources in order to support e-learning initiatives

Intervention number	**6**
Implementation (actors)	Government, but open to ad-hoc support.
Implementation (tools)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to businesses, etc.)
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as business access to technology increases.
Potential impact modifiers	Potential impact increases as overall digitalization decreases.

Table 20 - Encourage close collaboration and the exchange of personnel

Intervention number	**7**
Implementation (actors)	Government, but open to ad-hoc support.
Implementation (tools)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to businesses and universities, etc.)
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as quality of education increases.
Potential impact modifiers	Potential impact increases as overall digitalization decreases.

At the broadest level, public-private partnerships within the education space are partnerships that include (usually ICT based) private companies, one or more government ministries, educational institutions, donor and development agencies, and civil society organizations working together to garner resources and set priorities for ICT in education projects.[lxix] Examples include the Kenya ICT Trust Fund, the Egyptian Education Initiative, and the Information Society Partnership for Africa's Development (ISPAD).[lxx] Though the precise configuration of these partnership initiatives differs, they are typically geared toward either securing government funding for private sector initiatives (or vice versa), or to facilitate exchange programs between the private sector and government and/or academia. Contrib-

uting to the initiation of these partnerships furthers digitalization by ensuring knowledge transfer between private and public sector actors on the one hand, and by improving project funding on the other.

Another possible configuration for facilitating this form of knowledge, financial, and personnel transfer is to explore the feasibility of establishing ICT centers of excellence within sub-Saharan Africa. Centers of excellence vary significantly in their characteristics, but are generally shared facilities or entities that provide leadership, best practices, research, or support within their specified focus areas. An ICT center of excellence could play a central role in facilitating the implementation of several of the initiatives outlined within this section, including (among others) government retraining programs and the exchange of personnel.

The feasibility of leveraging these types of partnerships to mobilize resources increases as business access to technology increases. This is because higher business access to technology is conceptualized as correlating with greater technological know-how within business communities, something which increases the likelihood that a measurable impact will manifest. Because exchange of personnel between public and private sectors is at least partially geared towards improving knowledge technical know-how within academia, the feasibility of organizing those types of partnerships increases as the quality of tertiary education increases. This is because private sector organizations' interest in forming such partnerships is likely to increase as the quality of the education offered increases. Potential impact increases as the overall state of digitalization decreases within both variables.

5.2.1.5. Create opportunities and provide assistance to disadvantaged groups

Having access to ICT technology and skills allows people to improve their lives and, in many cases, to make positive contributions to their communities. However, in many developing countries, living in rural areas means being excluded from the benefits of ICT. Providing assistance to this disadvantaged groups means giving them the opportunity to familiarize themselves with ICT and digital means.[lxxi]

Table 21 - Create opportunities and provide assistance to disadvantaged groups

Intervention number	**8**
Implementation (actors)	Government, but open to ad-hoc support.
Implementation (tools)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to businesses and universities, etc.)
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as quality of education increases.
Potential impact modifiers	Potential impact increases as inequality increases.

There is no one way of improving rural and/or underprivileged communities' ability to engage with technology. South Africa successfully implemented a community-development project revolving around ICT and digital inclusion in the province of Mpumalanga. More precisely, the University of Pretoria's Department of Informatics and a private company established a computer facility with 27 computers and digital literacy courses in Siyabuswa, a small town in the rural area. The facility has since come under local ownership and has become self-sufficient, with the graduates of the facility's courses opening small businesses and finding jobs in tech-related fields.[lxxii] Egypt has a video-conference distance learning center that links 27 sites across the country to provide learning facilities in remote areas.[lxxiii] Mauritius has introduced a Cyber Caravan Project which goal is making ICT facilities available in the most isolated and disadvantaged areas in Mauritius. There are two caravans with several PCs and Internet connection. Zimbabwe also developed a similar project thanks to mobile internet buses.[lxxiv]

These are all possible models for directly targeting rural communities and for providing them with the tools to improve their digital skills. Because none of these initiatives are likely to have any sizeable impact whatsoever in communities in which there is little to no prior access to (or even knowledge of) education and technology, feasibility is conceptualized as increasing along with a country's average quality of education. Potential impact increases as inequality increases.

5.2.1.6. Do away with laws which discourage internet use

Several countries in the sub-Saharan Africa region have implemented laws which discourage internet use, something which significantly reduces both the feasibility and the potential impact of pursuing interventions within their borders. These countries actions can often be understood as being motivated by regime survival rather and/or kleptocracy rather than by a genuine concern over their populations' welfare.[lxxv]

Table 22 - Do away with laws which discourage internet use

Intervention number	9
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to key local partners, etc.)
Implementation (tools)	Institutional cooperation (project-based).
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as freedom increases.
Potential impact modifiers	Potential impact increases as degree of digitalization decreases.

Uganda, Benin, and Zambia are all examples of African countries which have implemented policies designed to stifle internet use (and, by extension, individual-level ability). More concretely, these countries have all introduced social media taxes. These make access to internet much more expensive, something which discourages use. In Uganda, the introduction of such a policy resulted in 2,5 million people abandoning social media. It also reduced internet saturation to a measly 30% of the population.[lxxvi] In the case of Benin – which implemented a 5% tax on texting and calls via web in 2018 – the government faced significant resistance, and was compelled to repeal the policy ten days after its initial introduction.[lxxvii]

Autocrats may also disincentivize internet use by combining the capacity to monitor and police online

communications with ambiguously phrased national security or cybersecurity laws. These allow autocrats to crack down on online speech, something which puts internet users on high alert and – in many cases – may cause them to avoid using the internet altogether.

5.2.1.7. Access to computing devices

Access to computing devices (whether smartphones, tablets, laptops, or desktop computers) constitutes a prerequisite for accessing the internet. As a consequence, access to these devices can also be understood as being a prerequisite to expanding digitization in sub-Saharan Africa and for accessing digital education. While these devices have become cheaper across the board in sub-Saharan African broadly,[lxxviii] poverty and unequal opportunities mean that – particular in the region's rural areas – they remain largely inaccessible. The GSMA estimates that the average entry-level, internet-enabled handset costs more than 120% of the monthly earnings of the poorest 20% of the region. Even after correcting for exacerbating factors such as Zimbabwe's 25% import duty tax on mobile handsets,[lxxix] this makes these devices practically inaccessible to a large share of sub-Saharan Africa's population.

Table 23 - Leverage fiscal and/or monetary tools to reduce the cost of devices

Intervention number	10
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to key local partners, etc.)
Implementation (tools)	Institutional cooperation (project-based), supplemented by grants.
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as degree of corruption decreases.
Potential impact modifiers	Potential impact increases as access to computing devices decreases.

Table 24 - Supply computing devices

Intervention number	11
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to key local partners, providing devices autonomously, etc.)
Implementation (tools)	Institutional cooperation (project-based), supplemented by grants.
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as degree of corruption decreases.
Potential impact modifiers	Potential impact increases as access to computing devices decreases.

Contrary to the challenges outlined within the previous (digital skills & demand for digital education) category – which require, in no small part, changes in behavior and in human systems, options for addressing sub-Saharan Africa's (lack of) access to computing devices are relatively sparse. Device manufacturers have actively explored – and are engaging in – efforts to tap into low-income markets (see for example Huawei and Oppo's expansion in India), but even access to larger economies of scale is unlikely to reduce their per-unit cost by hundreds of US dollars. As a result, feasible options are limited to efforts to convince national governments to do away with financial disincentives (see Zimbabwe's import tax, previously referenced, as an example – and to introduce financial incentives (Table

23), or to outright supply them to in-need populations (Table 24).

Neither of these solutions is likely to produce impact at the scale of those outlined in the previous section. In the case of outright supplying computing devices, this is because the financial feasibility of implementing such an intervention at scale is low. Given the fact that much of sub-Saharan Africa's (lack of) digital skills can be attributed to lack of access to computing devices during primary and secondary phases of education, the highest impact configuration for such an intervention would likely target primary and secondary educators in rural areas. Modifying government behavior as it relates to incentives is challenging because government decision making – as is also the case with, for example, a social media tax – has likely been informed by priorities other than maximizing citizen welfare.

The feasibility of implementing either of these interventions increases as corruption decreases. This is because government incentives to introduce beneficial policy are likely to be stronger within more democratic contexts, and because previous initiatives to supply computing devices to schools and/or individuals in rural areas have explicitly identified petty corruption and theft as barriers. Potential impact increases as access to computing devices decreases.

5.2.1.8. Access to internet & electricity

Much as is the case with the challenges addressed by interventions outlined in the previous section (Table 23, Table 24), addressing shortcomings in access to internet and electricity is something which cannot feasibly be realized at scale by nonstate actors. Expanding internet to sub-Saharan Africa's rural areas would require the deployment of new 4G base stations (mobile internet) or the installation of hundreds of kilometers of fiber (broadband, wired).[lxxx] Expanding access to working electricity similarly requires the expansion of existing energy grids and other substantive investments into electrification.[lxxxi]

Table 25 - Invest in affordable alternatives to broadband

Intervention number	12
Implementation (actors)	End responsibility falls to governments, but 3rd parties can play a variety of roles (lobbying, offering policy recommendations, offering grants to key local partners, providing satellite dishes, etc.)
Implementation (tools)	Institutional cooperation (project-based), supplemented by grants.
Effect horizon	Medium-long term.
Feasibility facilitators	Feasibility improves as degree of corruption decreases.
Potential impact modifiers	Potential impact increases as access to internet decreases.

Due to the relative infeasibility of these large scale (structural) solutions – support for whose implementation is likely to gain momentum as progress is made in digital skills & demand for digital education-related initiatives (see previous section) – this study does not consider them within its comparative analysis. Instead, it focuses on small-scale, localized initiatives – most concretely, the purchase and deployment of high-speed satellite internet dishes. These are manufactured by (among others) SpaceX (StarLink) and Amazon (Kuipers) and offer speeds which match or exceed average broadband connections (100+ MB/s). The deployment of this type of internet is contingent on the negotiation of agreements between operating companies (SpaceX, Amazon, etc.) and national communications authorities,[lxxxii] something which may reduce this implementation's feasibility in authoritarian countries. They are also likely to be prohibitively expensive. SpaceX's StarLink dish costs €499, with access to its internet serving being priced at an additional €100 per month.

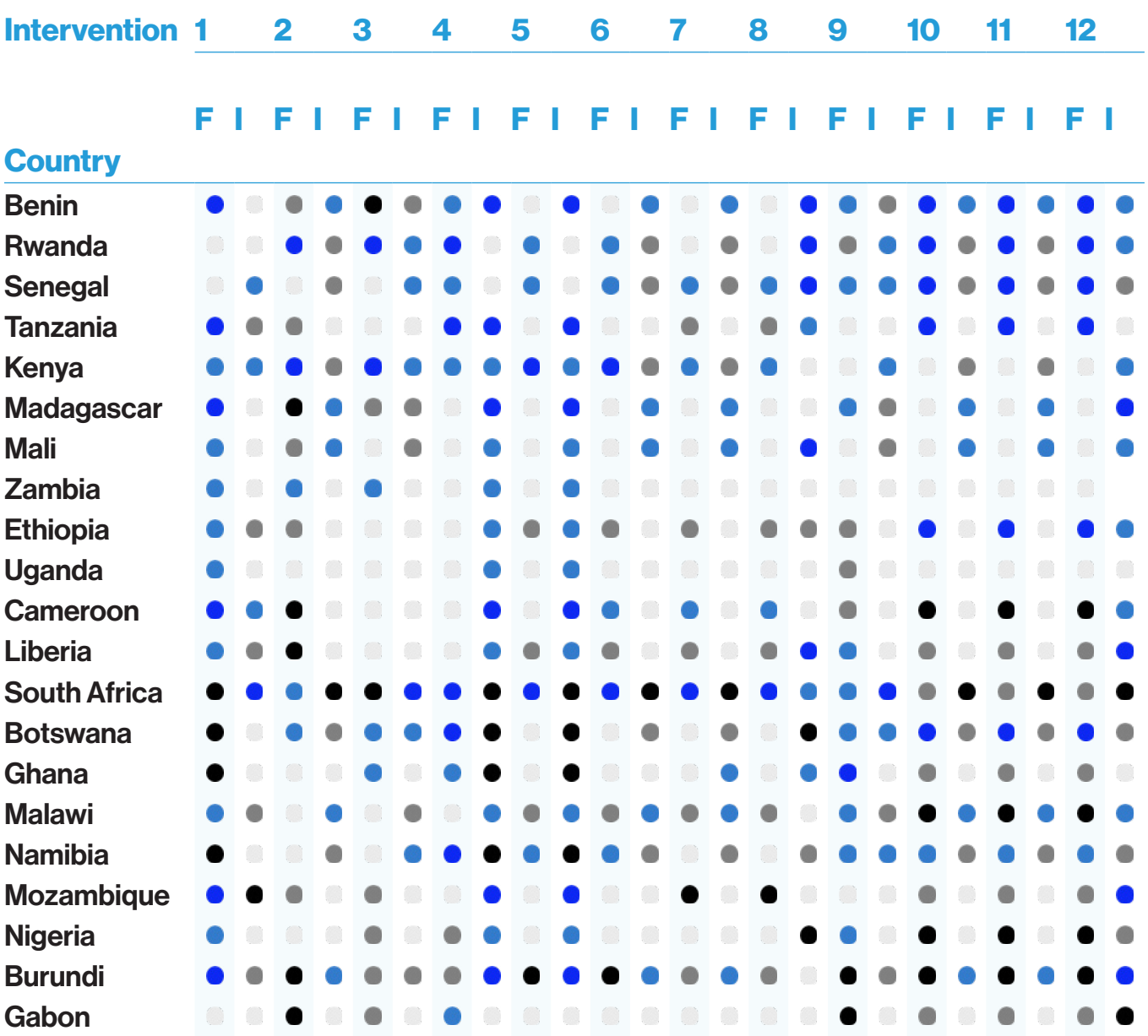
These dynamics mean that, much as was the case with the interventions introduced in the previous section, an optical configuration for such an intervention would likely involve the identification and lobbying of likely-to-be-agreeable national communications authorities on the one hand, and the installation of satellite dishes as primary and/or secondary education institutions on the other. As was also the case with the previous section's interventions, the feasibility of such an initiative increases as corruption decreases. Potential impact increases as access to computing devices decreases. This interven-

tion is proposed as a single (rather than two) interventions because securing government support for these technologies' deployment is a prerequisite for realizing their potential impact.

5.3. Findings feasibility and potential impact assessment

This section provides a high-level analysis of the previously outlined country-intervention level feasibility and potential impact assessment (Figure 13). For an in-depth insight into the results of this exercise, see Annex V.

Figure 13 - Intervention-level feasibility and potential impact analysis by country



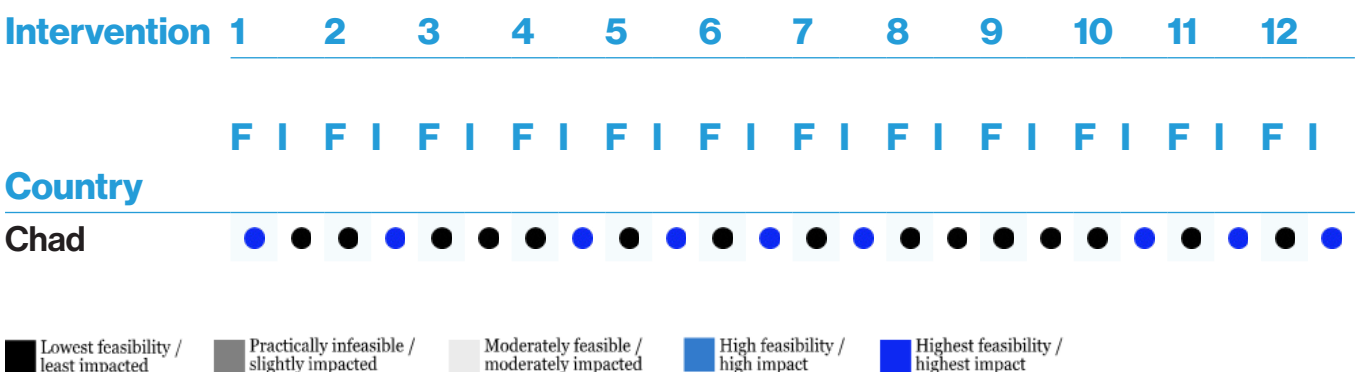


Figure 13 showcases an overview of each intervention's feasibility and potential impact in each of the countries covered by this study. Countries have been sorted based on their average feasibility and potential impact scores across interventions. This analysis identifies Benin, Rwanda, Senegal, Tanzania, and Kenya as the five most high-potential countries to organize interventions in, with interventions 1, 4, 5, 8, 10, 11, and 12 (integrate ICT subjects at all levels of education, government retraining programs, incentivize nonstate actors to conduct digital training programs, create opportunities for disadvantaged groups, supply computing devices, and invest in affordable alternatives to broadband) emerging – by virtue of the frequency with which they receive highest feasibility or highest impact scores within the aforementioned 5-country sample – as being most relevant at the macro level.

Figure 14 - Overall intervention feasibility and potential impact per country

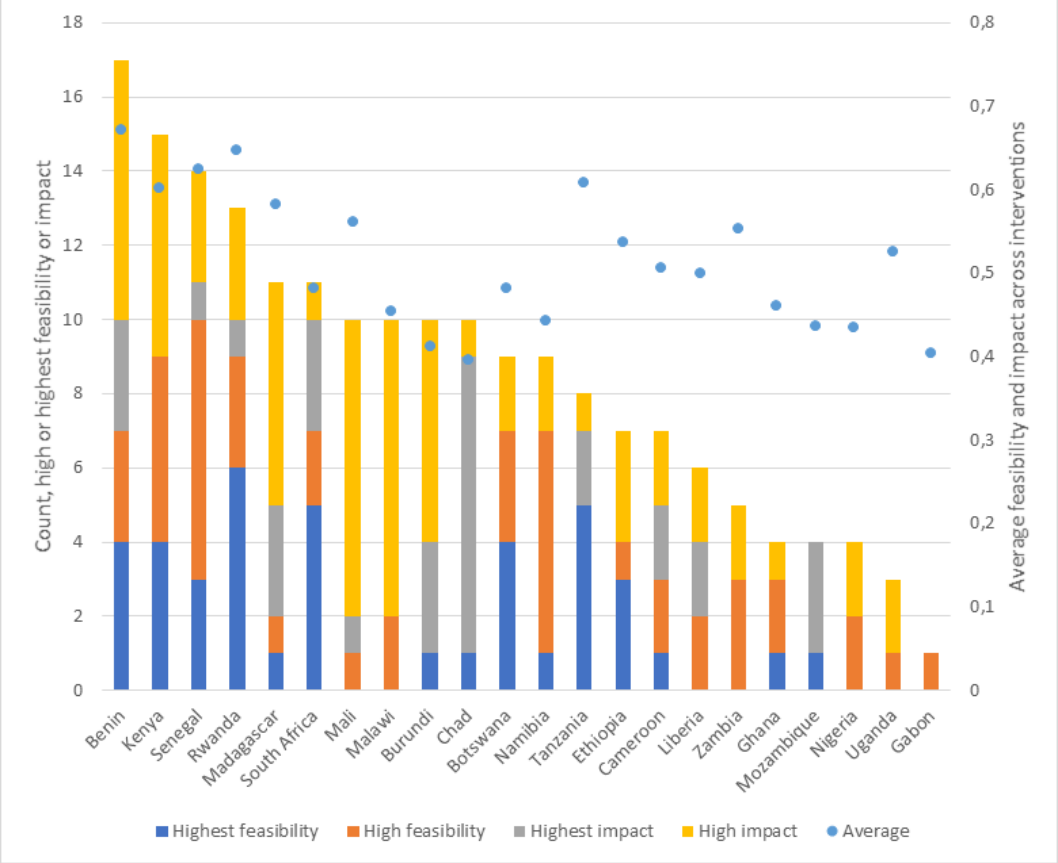
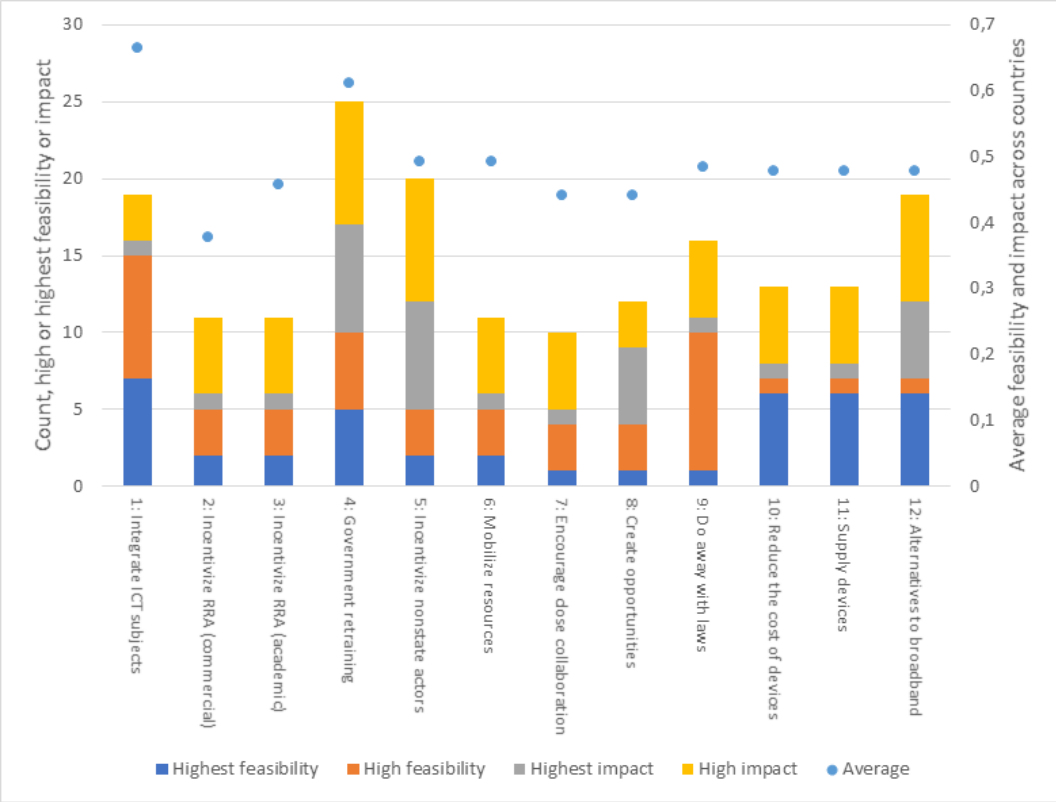


Figure 14 visualizes how often interventions receive highest or high feasibility or potential impact labels across all interventions. This method of showcasing data differs from the method applied in Figure 13 in that it reduces the relevance of countries which consistently receive medium scores within either performance metric. This is the case in (for example) Tanzania, which receives a relatively high across-interventions score of 0.6, but which only receives highest or high feasibility or potential impact scores eight (8) times. Because high or highest scores in either performance metric (and, preferably, in both) can generally be viewed as strong indicators that an intervention is, relatively speaking, of high potential, Figure 14 arguably offers a useful springboard for further analysis.

Figure 14's top-5 list diverges from that of Figure 13 in several ways. Benin retains its number one spot, but Kenya – formerly at number 5 – ascends to number two. Senegal retains its number three spot; Rwanda drops from two (formerly) to four. Madagascar enters the top-5, while Tanzania drops to 13. Figure 14 also draws clear attention to the fact that many countries derive a large share of their implementation potential – a measurement which is arguably reflected in the averaged performance outlined in Figure 13 – from either high or highest feasibility or potential impact. A clear example is Chad. Chad performs poorly on virtually all of the previously explored quality of education, barriers to education, and state of digitalization metrics. It is therefore unsurprising – but important to note – that it attains nine out of its ten points through impact-related performance, with only one point being derived from feasibility benchmarks.

Figure 15 - Overall feasibility and potential impact per intervention



A similar picture can be gleaned from Figure 15, which applies the counting method on-display in Figure 14 to the 12 proposed interventions. This results in interventions 1, 4, 5, 9, and 12 (integrate ICT subjects at all levels of education, government retraining programs, incentivize nonstate actors to conduct digital training programs, do away with laws which discourage internet use, and invest in affordable alternatives to broadband) emerging – at first sight – as holding the highest-potential. While intervention 4 (government retraining programs) receives relatively high marks across the board, the results are less universally positive for the remaining four interventions. Interventions 1 and 9 (integrate ICT subjects at all levels of education and do away with laws which discourage internet use) are relatively low in their potential impact, and intervention 12 (invest in affordable alternatives to broadband) registers as being relatively low in its feasibility.

Looking at only country-intervention combinations in which both feasibility and potential impact register as highest or high yields the following list (Table 26):

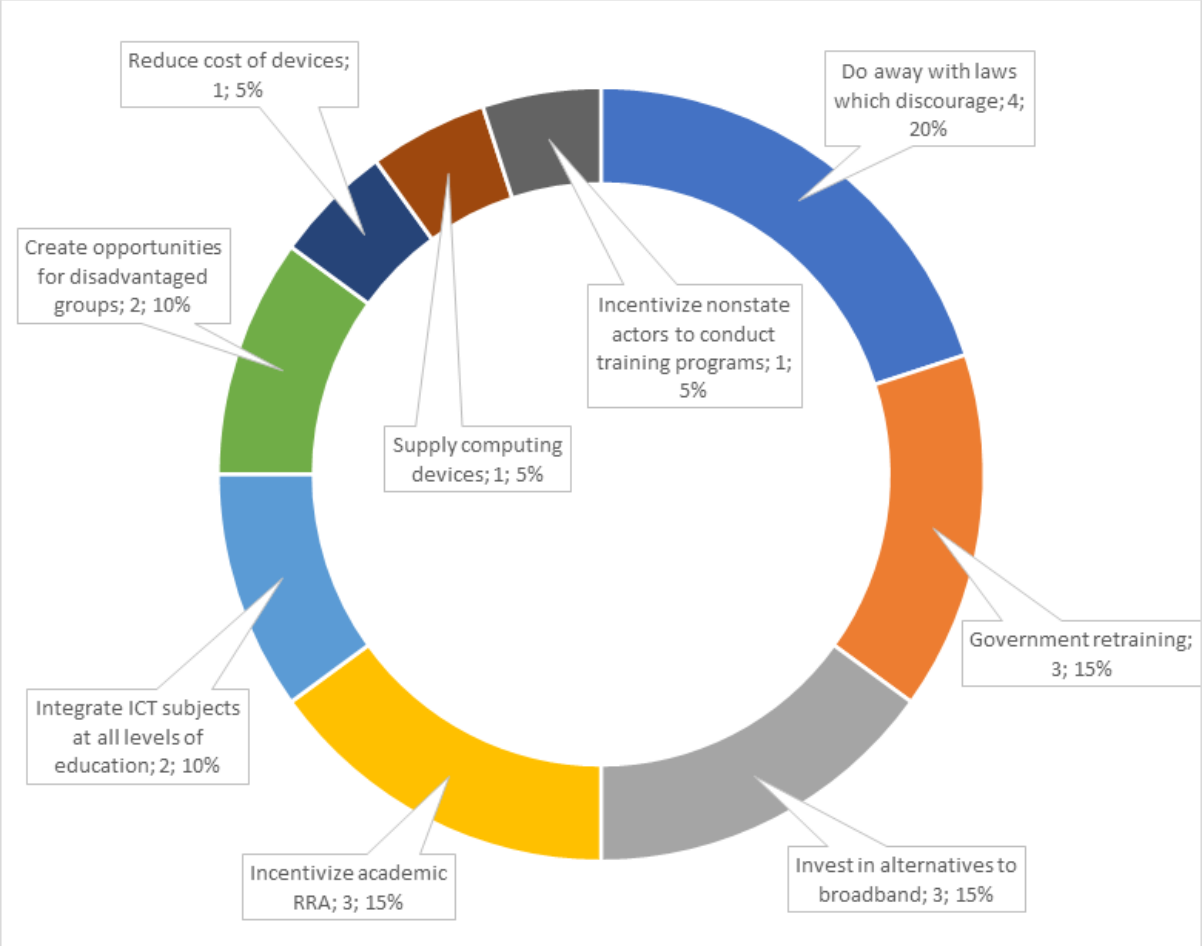
Table 26 - Overview of highest or high feasibility & potential impact country-intervention combinations

Country	Intervention
Benin	Government retraining programs (4). Leverage fiscal and/or monetary tools to reduce the cost of devices (10). Supply computing devices (11). Invest in affordable alternatives to broadband (12). Integrate ICT subjects in the curriculum at all levels of education (1).
Kenya	Incentivize return, retention, attraction (academic) (3). Government retraining programs (4). Incentivize nonstate actors to conduct digital training programs and to contribute to state-funded (re) training programs (5).
Botswana	Incentivize return, retention, attraction (academic) (3). Do away with laws which discourage internet use (9).
Rwanda	Incentivize return, retention, attraction (academic) (3). Invest in affordable alternatives to broadband (12).
Senegal	Create opportunities and provide assistance to disadvantaged groups (8). Do away with laws which discourage internet use (9).
South Africa	Create opportunities and provide assistance to disadvantaged groups (8). Do away with laws which discourage internet use (9).
Cameroon	Integrate ICT subjects in the curriculum at all levels of education (1).
Ethiopia	Invest in affordable alternatives to broadband (12).
Namibia	Do away with laws which discourage internet use (9).
Tanzania	Government retraining programs (4).

Within this sample, intervention 9 recurs four times, interventions 4, 12, and 3 recur three times, in-

terventions 1 and 8 recur twice, and interventions 5, 10, and 11 recur once (Figure 16).[3] Benin, Kenya, Botswana, Rwanda, Senegal, South Africa, Cameroon, Ethiopia, Namibia, and Tanzania all emerge as countries with high intervention potential.

Figure 16 – Number of times interventions are found to be highest or high feasibility and potential impact across countries, Table 26



[3] The decision making surrounding these results is open to interpretation, preference, and prioritization. These results indicate that the country-intervention combinations outlined in Table 23 are optimal due to their combined high or highest rankings in both feasibility and potential impact, but users are welcome and encouraged to draw their own conclusions – and to apply their own insights and value systems – to the data presented in Figure 14 and in the rest of this section more generally.

6. Conclusion

As the number of sub-Saharan Africans rounding off secondary school is set to increase substantially in the coming years,[lxxxiii] so, too, is the region's demand for high-quality tertiary education. Keeping up with this increase in demand is already proving itself a challenge for the region's (largely publicly-funded) tertiary education system. African universities have a 50% higher pupil-student ratio than the global average,[lxxxiv] something which had already contributed to approximately 375,000 – more than double of 1997's 156,000 – opting to pursue their studies overseas as early as 2017.[lxxxv] For many of those which succeed at completing secondary educations, the challenges associated with educators' (lack of) institutional capacity is compounded by cost and environment-related hurdles. The region's private sector has seized on the opportunities created by traditional educator's inability to meet growing demand by designing and offering a wide range of for-profit alternatives, but – within the context of sub-Saharan Africa, where a staggering 38% of the population lived on less than $1.90 a day as recently as 2018 – these remain out of reach for most. The costs of relocating to and funding a lifestyle in metropolitan areas (where the majority of tertiary education is offered) are also substantial. Environmental factors – from gender inequality to the stigmas (and shame) associated with disease to, in many sub-Saharan African countries, the uncertainty brought on by widespread conflict and political instability – mean that many miss out on at least parts of their tertiary educations.

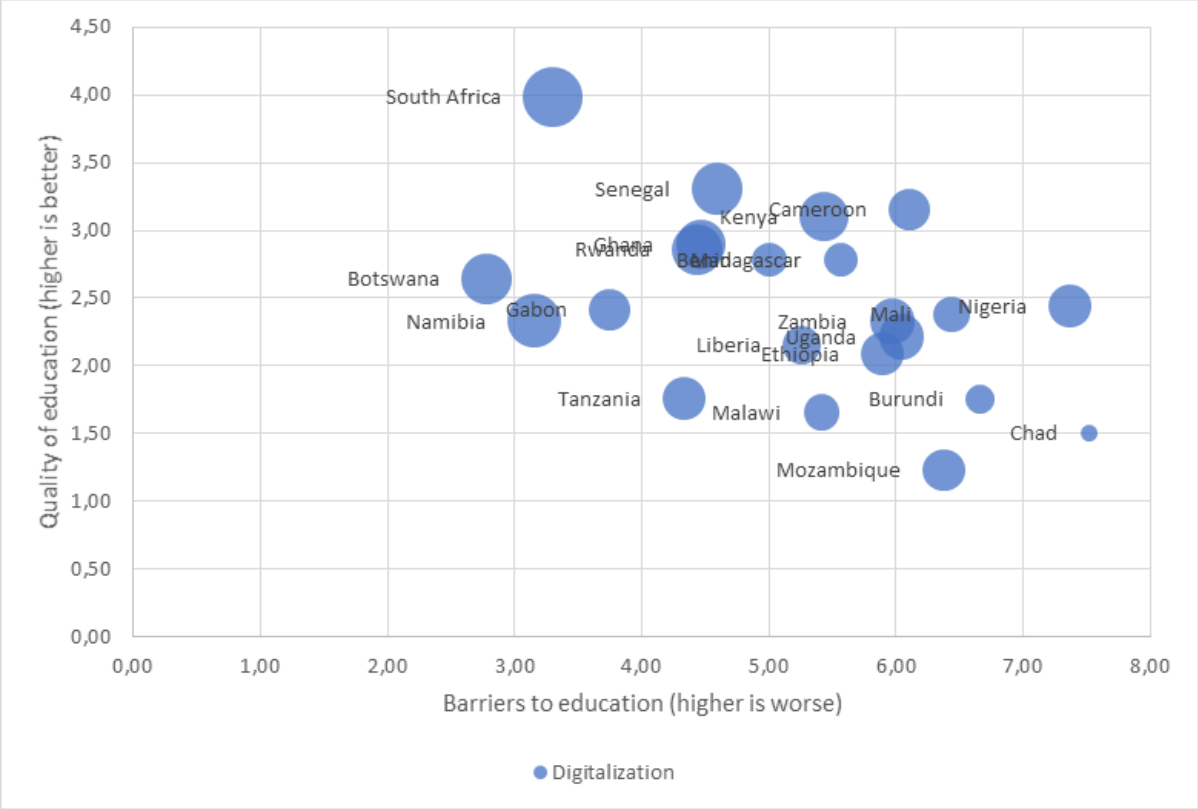
These shortcomings have significant (negative) implications for the region as a whole. Though brain drain offers some opportunities from the African perspective (remittances, diaspora options, technology transfer, etc.), emigration means that many of sub-Saharan Africa's brightest individuals are building lives – and making significant contributions to societies – far from home. This negatively impacts sub-Saharan African countries' economic competitiveness, thus "locking in" and perpetuating many of the negative trends which have contributed to the underlying problem in the first place. An improvement in the region's education system would likely also contribute to a tangible alleviation of misery at the individual and/or community levels. With the exception of Sustainable Development Goals (SDGs) 13 (climate action) and 15 (life on land), progress towards achieving SDGs in the sub-Saharan Africa region can be understood as facing either significant or major challenges – something which, particularly in the case of goals 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), 5 (gender equality), 6 (clean water and sanitation), 10 (reduced inequalities), 16 (peace, justice, and strong institutions) – equates to a not-insignificant degree of human suffering. Access to an education (and to a higher

education in particular) has consistently been shown to positively impact health and wellbeing,[lxxxvi] gender equality,[lxxxvii] and poverty rates at the macro level. "Knowledge" has been identified by several UN agencies as playing a key role in achieving sustainable development.[lxxxviii]

Digital education offers a potential pathway for improving access to and increasing the macro-level quality of tertiary education. Students enjoy increased information retention, education can (on paper) scale better and be offered at lower costs, and – perhaps most importantly – the flexibility it offers means that students need not, in many cases, foot the direct or indirect bills that they might normally associated with a relocation to metropolitan areas. All of this means that – digital education offers, on paper, a possible (partial) solution to sub-Saharan Africa's (tertiary) education woes. Because it bypasses or partially mitigates several of the challenges facing the region's education system, and because it creates financial opportunities for both students and educators – oftentimes without compromising on quality – it promises to make a positive contribution to both access to and macro-level quality of tertiary education in the region – at least in those countries which preside over the digital infrastructure (or state of digitalization) to allow for its in-earnest rollout and applicability.

This is, unfortunately, not the case in most sub-Saharan African countries. This study quantifies quality of education, barriers to tertiary education, and the state of digital education. It finds that those countries which face the most significant barriers to tertiary education and which are in greatest need of improving their education systems, also tend to be the countries which have made the least progress towards digitalization – though some notable exceptions (see Benin, Gabon, Ghana, Nigeria, Mozambique, Rwanda, and Tanzania) apply (Figure 17).

Figure 17 - Relationship quality of education, barriers to education, and digitalization by country



It also conducts feasibility and potential impact analyses of 12 interventions geared towards improving digital skills & demand for digital education, access to computing devices, and access to internet & electricity in the region – all factors which are key to furthering digitalization and (by extension) to improving countries' ability to improve their tertiary education systems by integrating or further democratizing digital components. This study's intervention-specific (read: unique feasibility and potential impact parameters have been defined and measured for each country-intervention combination) feasibility and potential impact analysis somewhat aligns with the previously outlined findings. It identifies Benin, Kenya, Botswana, Rwanda, Senegal, South Africa, Cameroon, Ethiopia, Namibia, and Tanzania as countries with high intervention potential (Table 27).

Table 27 - Overview of highest or high feasibility & potential impact country-intervention combinations

Country	Intervention
Benin	Government retraining programs.
	Leverage fiscal and/or monetary tools to reduce the cost of devices.
	Supply computing devices.
	Invest in affordable alternatives to broadband.
	Integrate ICT subjects in the curriculum at all levels of education.
	Incentivize return, retention, attraction (academic).
Kenya	Government retraining programs.
	Incentivize nonstate actors to conduct digital training programs and to contribute to state-funded (re) training programs.
Botswana	Incentivize return, retention, attraction (academic).
	Do away with laws which discourage internet use.
Rwanda	Incentivize return, retention, attraction (academic).
	Invest in affordable alternatives to broadband.
Senegal	Create opportunities and provide assistance to disadvantaged groups.
	Do away with laws which discourage internet use.
South Africa	Create opportunities and provide assistance to disadvantaged groups.
	Do away with laws which discourage internet use.
Cameroon	Integrate ICT subjects in the curriculum at all levels of education.
Ethiopia	Invest in affordable alternatives to broadband.
Namibia	Do away with laws which discourage internet use.
Tanzania	Government retraining programs.

Though they are open to interpretation, these results imply that doing away with laws which discourage internet use, the design and deployment of government retraining programs, the rollout of alternatives to wired broadband, and the incentivization of academic return, retention, and attraction programs constitute the most feasible and high-impact interventions to pursue in the near term.

Because they can be implemented in relatively low-risk countries (Benin, Kenya, Botswana, Rwanda), the implementation process is likely to result in the identification of best practices. This will aid in their wider regional implementation going forward. A set of concrete suggestions for these interventions' implementation are outlined below:

Do away with laws which discourage internet use

- This intervention is of high potential in Botswana, Senegal, South Africa, and Namibia.
- Due to time constraints, this study has not assessed the degree to which these countries have discouraging laws in place. As such, this intervention – which places a heavy emphasis on countries' levels of freedom – should be viewed more as an indication that the countries it is recommended for are countries which are likely to be most agreeable as far as regulatory overhauls are concerned.
- These countries are not likely to feature laws which are explicitly discouraging. Rather, they are likely to maintain regulatory frameworks which "lock in" existing inequalities. The focus should therefore be on policies which artificially inflate the cost of internet, which increase the cost of devices, or which limit access to social media.

Design and deploy government retraining programs

- This intervention is of high potential in Benin, Kenya, and Tanzania.
- This intervention has a wider societal effect because it is geared towards creating an environment in which individuals which have been working for many years (read: they are perhaps halfway through their career) receive training which provides them with basic or moderate digital skills. In sub-Saharan Africa, these trainings should ideally be offered to tertiary-level students and working individuals alike. The specifics of these courses will likely differ significantly between countries and focus groups, but should generally focus on imparting skills such as the basics of using a smartphone, surfing the web, and using programs such as Microsoft Word and Excel.
- These trainings could feasibly be offered by NGOs, but their highest impact configurations feature a high degree of government support. As such, a useful first step presents in the identification of programs already offered by these countries Ministries of Education and (where applicable) of these Ministries current implementation partners.
- This intervention has a high degree of synergy with intervention 5 (the incentivization of nonstate actors to conduct digital training programs and to contribute to state-funded (re)training programs.

Incentivize return, retention, and attraction within academia

- This intervention is of high potential in Kenya, Botswana, and Rwanda.
- The premise behind this intervention is that improving the standing of sub-Saharan African universities has a positive trickle-down effect on the rest of society. This is partially because retaining innovative students – and giving them the opportunity to pursue their research domestically – increases the likelihood that they will make positive contributions to their communities of origin, and partially because hosting R&D of this kind has "soft power" value. To maximize this intervention's impact on digitization, research programs in areas relating to computer science, artificial intelligence, and advanced mathematics should be prioritized.
- A first step involves the identification of potential partner universities, and an analysis of their capacity to expand existing or host new advanced research programs.
- This intervention has a high degree of synergy with intervention 7 (encourage close collaboration with and the exchange of personnel).

Invest in affordable alternatives to wired broadband

- This intervention is of high potential in Benin, Rwanda, and Ethiopia.
- This intervention focuses on the small-scale, localized purchase and deployment of high-speed satellite internet dishes. These are manufactured by (among others) SpaceX (StarLink) and Amazon (Kuipers) and offer speeds which match or exceed average broadband connections (100+ MB/s).
- Because he deployment of this type of internet is contingent on the negotiation of agreements between operating companies (SpaceX, Amazon, etc.) and national communications authorities, a first (prerequisite) step entails the approaching of the aforementioned authorities.
- It is also important to note that, when viewed within the context of this research's overall goal of identifying opportunities to expand digitalization in sub-Saharan Africa, this intervention's optimal configuration involves the provision of this type of internet to primary and/or secondary schools in rural communities.
- This intervention has a high degree of synergy with interventions 1 and 11 (Integrate ICT subjects in the curriculum at all levels of education and supply computing devices).

7. Annex

7.1. Annex I – Overview of barrier-centric mitigation potential, digital education

Table 28 - Overview barrier-centric mitigation potential, digital education

Component	Barrier	Mitigation potential	Explanation
Costs	Direct costs	High	Reductions in cost of admission result in reduced tuition fees; ability to follow courses remotely reduces costs associated with paying for life in or commuting to metropolitan areas.
	Indirect costs	High	Ability to follow courses remotely at one's own leisure reduces indirect (opportunity) costs.

Component	Barrier	Mitigation potential	Explanation
Environment	Local attitudes	Low	Empowers individual agency: individuals wishing to pursue an education regardless of circumstances now face fewer obstacles to doing so.
	Health & nutrition	Low	Empowers individual agency: individuals wishing to pursue an education regardless of circumstances now face fewer obstacles to doing so.
	Crisis & instability	Medium	Offers alternative venue for offering education to educators; individuals unaffected by the conflict can continue to access learning materials.
Institutional Capacity	Infrastructure	High	Ability to follow courses remotely reduces costs associated with overcoming obstacles deriving from low infrastructure investment.
	Funding for tertiary education	High	Course scalability and automation reduces educators' operating costs, making them less dependent on government support.
	Government support (other)	High	Course scalability and automation increase educators' profitability, allowing them to invest in resources which they would otherwise have depended on state funding for to access.

7.2. Annex II – Variable descriptions, quality of education, barriers to education, state of digitalization

7.2.1. Barriers to education

7.2.1.1. Costs

Box 1 - Direct costs

Measurement	Direct costs
Description	This measurement is manually coded, with data being extracted from individual universities' websites. We synthesized a list of sub-Saharan universities using Webometrics Ranking of World Universities. We then identified the 5 highest-ranked universities on a per-country basis and manually extracted data pertaining to their average annual costs of tuition.
Processing methodology	A country's final score reflects the average of available data points, adjusted for PPP (US$). Averages were multiplied by -1 and then normalized between 0 and 1. This results in the cheapest country (in terms of mobile broadband subscriptions) receiving a 0 and the best performing country receiving a 1. All other countries are clustered proportionally between 0 and 1.

Box 2 - Indirect costs

Measurement	Indirect costs
Description	This measurement is derived from the World Bank. It leverages the "Rural population (% of total)" variable. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results the country with the smallest rural population receiving a 0 and the country with the largest rural population receiving a 1. All other countries are clustered proportionally between 0 and 1.

A country's overall score within the costs category represents the sum of its performance within the direct costs and indirect costs variables. This means countries can theoretically score anywhere between 0 and 2 on costs.

7.2.1.2. Environment

Box 3 - Local attitudes

Measurement	Local attitudes
Description	This measurement is derived from the Varieties of Democracy (V-DEM). It leverages the "v2pepwrgen" variable for the year 2017. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study, inverted them, and then normalized them between 0 and 1. This results in the best performing country in the region (in terms of gender inequality) receiving a 0 and the worst performing country receiving a 1. All other countries are clustered proportionally between 0 and 1.

Box 4 - Health and nutrition

Measurement	Health and nutrition
Description	This measurement is derived from the Institute for Health Metrics and Evaluation (IHME). It leverages IHME's DALY scores for the year of 2017 variable. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in countries with the lowest disease burden receiving a 0 and countries with the highest disease burden receiving a 1. All other countries are clustered proportionally between 0 and 1.

Box 5 - Crisis and instability

Measurement	Crisis and instability
Description	This measurement is derived from the Fragile States Index (FSI) and from Varieties of Democracy (V-DEM). It leverages the FSI's aggregate scores for 2019 V-DEM's "v2x_rule" (year) variable. These are scale variables.
Processing methodology	We extracted the values for all the countries included in this study for both variables and normalized each of them between 0 and 1 individually. The v2x_rule variable is inverted (multiplied by -1) prior to normalization. This results in two variables in which the worst performing country receives a 0 and the best performing country receives a 1. All other countries are clustered proportionally between 0 and 1. These values were added together, resulting in country scores ranging between +/- 0 and +/- 2.

Box 6 - Infrastructure

Measurement	Infrastructure
Description	This measurement is derived from the Global Competitiveness Index (GCI), which utilizes a survey-based methodology to rank variables relating to a country's competitiveness. This measurement leverages the GCI's "Quality of Overall Infrastructure" variable. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in countries with the best logistics performance receiving a 0 and countries with the worst logistics performance receiving a 1. All other countries are clustered proportionally between 0 and 1.

A country's overall score within the environment category represents the sum of its performance within the local attitudes, health and nutrition, crisis and instability, infrastructure, and quality of secondary education variables. This means countries can theoretically score anywhere between 0 and 5 on environment.

7.2.1.3. Institutional capacity

Box 7 – Government funding

Measurement	Government funding
Description	This measurement is derived from the World Bank's GDP per Capita index This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study, inverted them, and normalized them between 0 and 1. This results in the country with the fewest barriers receiving 0 and the country with the greatest barriers receiving a 1. All other countries are clustered proportionally between 0 and 1.

Box 8 - Government support (other)

Measurement	Government support (other)
Description	This measurement is derived from the World Bank's Doing Business Index (DBI). It leverages the DBI's starting a business score. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in the country with the fewest barriers receiving 0 and the country with the greatest barriers receiving a 1. All other countries are clustered proportionally between 0 and 1.

A country's overall score within the institutional capacity category represents the sum of its performance within the government funding and government support (other) variables. This means countries can theoretically score anywhere between 0 and 2 on institutional capacity.

7.2.1.4. Population pressure

Box 9 - Population

Measurement	Population
Description	This measurement is derived from the World Bank. It utilizes the "Population, total" and "Population growth, last five years" variables. These are scale variables.

Measurement	Population
Processing methodology	We extracted the values for all the countries included in this study for both variables and normalized each of them between 0 and 1 individually. This results in two variables in which the worst performing country receives a 0 and the best performing country receives a 1. All other countries are clustered proportionally between 0 and 1. These values were added together, resulting in country scores ranging between +/- 0 and +/- 2.

7.2.2. State of digitalization

7.2.2.1. Ability

Box 10 - Digital skills (individual)

Measurement	Digital skills (individual)
Description	This measurement is derived from the Global Competitiveness Index (GCI), which utilizes a survey-based methodology to rank variables relating to a country's competitiveness. This measurement leverages the GCI's "Mobile broadband subscriptions (per 100)" variable. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in the worst performing country (in terms of mobile broadband subscriptions) receiving a 0 and the best performing country receiving a 1. All other countries are clustered proportionally between 0 and 1.

Box 11 - Digital skills (institutional)

Measurement	Digital skills (institutional)
Description	This measurement is derived from the Global Competitiveness Index (GCI), which utilizes a survey-based methodology to rank variables relating to a country's competitiveness. This measurement leverages the GCI's "Internet use by schools" variable. This is an ordinal variable.

Measurement	Digital skills (institutional)
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in the worst performing country (in terms of internet use by schools) receiving a 0 and the best performing country receiving a 1. All other countries are clustered proportionally between 0 and 1.

A country's overall score within the ability category represents the sum of its performance within the digital skills (individual) and individual skills (institutional) variables. This means countries can theoretically score anywhere between 0 and 2 on ability.

7.2.2.2. Access

Box 12 - Access to computing devices

Measurement	Access to computing devices
Description	This measurement is derived from the Global Competitiveness Index (GCI), which utilizes a survey-based methodology to rank variables relating to a country's competitiveness. This measurement leverages the GCI's "Presence of modern technology (9.01)" and "Business access to technology (9.02)" variables. These are ordinal variables.
Processing methodology	We extracted the values for all the countries included in this study for both variables and normalized each of them between 0 and 1 individually. This results in two variables in which the worst performing country receives a 0 and the best performing country receives a 1. All other countries are clustered proportionally between 0 and 1. These values were added together, resulting in country scores ranging between +/- 0 and +/- 2.

Box 13 - Access to internet

Measurement	Access to internet
Description	This measurement is derived from the Global Competitiveness Index (GCI) and from Visual Capitalist. This measurement leverages the GCI's "Individuals using the internet (% of the population)" and Visual Capitalist's "Price of 1GB (USD)" variables. These are scale variables.

Measurement	Access to internet
Processing methodology	We extracted the values for all the countries included in this study for both variables and normalized each of them between 0 and 1 individually. This results in two variables in which the worst performing country receives a 0 and the best performing country receives a 1. All other countries are clustered proportionally between 0 and 1. These values were added together, resulting in country scores ranging between +/- 0 and +/- 2. Countries' scores were subsequently normalized between 0 and 1.

Box 14 - Quality of internet

Measurement	Quality of internet
Description	This measurement is derived from the Global Competitiveness Index (GCI), which utilizes a survey-based methodology to rank variables relating to a country's competitiveness. This measurement leverages the GCI's "Internet bandwidth (kb/s) per internet user" variable. This is a scale variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in the worst performing country (in terms of bandwidth per internet user) receiving a 0 and the best performing country receiving a 1. All other countries are clustered proportionally between 0 and 1.

Box 15 - Access to working electricity

Measurement	Access to working electricity
Description	This measurement is derived from the Global Competitiveness Index (GCI), which utilizes a survey-based methodology to rank variables relating to a country's competitiveness. This measurement leverages the GCI's "Quality of electricity supply" variable. This is an ordinal variable.
Processing methodology	We extracted the values for all the countries included in this study and normalized them between 0 and 1. This results in the worst performing country (in terms of quality of electricity supply) receiving a 0 and the best performing country receiving a 1. All other countries are clustered proportionally between 0 and 1.

A country's overall score within the access category represents the sum of its performance within the access to computing devices, access to internet, quality of internet, and access to working electricity

variables. This means countries can theoretically score anywhere between 0 and 6 on access.

7.2.2.3. Quality & availability

Box 16 - Availability of distance education

Measurement	Availability of distance education
Description	This measurement is manually coded, with data being extracted from individual universities' websites.
Processing methodology	We synthesized a list of sub-Saharan universities using Webometrics Ranking of World Universities. We then identified the highest-ranked universities on a per-country basis and manually extracted data on whether the higher education institutions offer a way of studying in which the student does not have to attend the course physically, but study from home, usually being taught and given work to do over the internet.

Box 17 - Availability of digital education

Measurement	Availability of digital education
Description	This measurement is manually coded, with data being extracted from individual universities' websites.
Processing methodology	We synthesized a list of sub-Saharan universities using Webometrics Ranking of World Universities. We then identified the highest-ranked universities on a per-country basis and manually extracted data on whether the higher education institutions offer digital tools and technologies to facilitate the teaching and learning process.

A country's overall score within the quality & availability category represents the sum of its performance within the availability of distance education and availability of digital education variables. This means countries can theoretically score anywhere between 0 and 2 on quality & availability.

7.3. Annex III – Score overview: quality of education, barriers to education, state of digitalization

Table 29 - Quality of education (component scores)

Country	Quality	Quality of secondary education	Staff training	TVET availability	Quality of math and science	Quality of business schools
South Africa	3,99	1,00	1,00	0,99	0,00	1,00
Senegal	3,31	0,41	0,38	1,00	0,73	0,79
Cameroon	3,16	0,40	0,45	0,71	0,94	0,66
Kenya	3,10	0,00	0,66	0,91	0,87	0,67
Ghana	2,89	0,27	0,52	0,80	0,66	0,64
Rwanda	2,86	0,09	0,59	0,60	1,00	0,58
Madagascar	2,79	0,71	0,34	0,56	0,74	0,45
Benin	2,78	0,94	0,21	0,72	0,57	0,35
Botswana	2,64	0,33	0,62	0,67	0,70	0,33
Nigeria	2,45	0,75	0,49	0,60	0,23	0,37
Gabon	2,41	0,72	0,40	0,32	0,62	0,36
Mali	2,38	0,56	0,27	0,61	0,57	0,38
Namibia	2,33	0,52	0,65	0,49	0,41	0,26
Zambia	2,33	0,17	0,45	0,73	0,61	0,37
Uganda	2,22	0,51	0,34	0,63	0,38	0,36
Liberia	2,15	0,53	0,48	0,40	0,55	0,19
Ethiopia	2,09	0,42	0,32	0,54	0,59	0,22
Tanzania	1,76	0,54	0,28	0,53	0,25	0,16
Burundi	1,76	0,82	0,05	0,00	0,62	0,27
Malawi	1,66	0,56	0,50	0,37	0,20	0,02
Chad	1,51	0,88	0,00	0,29	0,26	0,07

Country	Quality	Quality of secondary education	Staff training	TVET availability	Quality of math and science	Quality of business schools
Mozambique	1,23	0,80	0,09	0,16	0,18	0,00

Table 30 - Barriers to education (component scores)

Country	Barriers to education	Costs	Environment	Institutional Capacity	Population pressure
Chad	7,51	0,91	4,89	0,93	0,78
Nigeria	7,37	1,35	3,46	1,05	1,51
Burundi	6,66	0,93	3,82	1,11	0,80
Mali	6,44	1,29	3,23	1,15	0,77
Mozambique	6,37	0,97	3,35	1,27	0,78
Cameroon	6,10	1,24	3,28	0,93	0,64
Uganda	6,04	1,05	2,40	1,39	1,21
Zambia	5,97	1,18	2,58	1,48	0,74
Ethiopia	5,89	0,86	2,85	1,09	1,09
Madagascar	5,57	0,92	2,88	1,10	0,67
Kenya	5,43	0,96	2,09	1,73	0,66
Malawi	5,41	0,55	2,76	1,48	0,62
Liberia	5,25	1,50	2,26	1,02	0,47
Benin	5,00	1,37	1,88	1,14	0,62
Senegal	4,59	1,33	1,35	1,24	0,67
Ghana	4,47	1,41	1,34	1,23	0,49
Rwanda	4,43	0,88	1,06	1,92	0,58
Tanzania	4,33	1,15	1,08	1,15	0,96
Gabon	3,75	1,16	1,90	0,09	0,59
South Africa	3,30	0,95	1,13	0,93	0,29
Namibia	3,16	1,31	0,71	0,93	0,20
Botswana	2,78	0,73	1,10	0,66	0,28

Table 31 - State of digitalization (component scores)

Country	Digitalization total	Ability total	Access total	Q&A total
South Africa	9,63	2,48	5,15	2,00
Namibia	7,93	1,82	4,33	1,78
Senegal	7,15	1,51	3,65	2,00
Botswana	6,99	1,98	3,01	2,00
Rwanda	6,59	1,30	3,62	1,67
Kenya	6,57	1,00	3,90	1,67
Ghana	6,51	1,73	2,77	2,00
Zambia	5,56	0,85	2,71	2,00
Uganda	5,45	0,80	2,82	1,83
Nigeria	5,02	0,77	2,81	1,44
Ethiopia	4,98	0,95	2,30	1,73
Tanzania	4,88	0,56	2,66	1,67
Cameroon	4,81	0,75	2,28	1,78
Mozambique	4,76	0,61	2,15	2,00
Gabon	4,63	1,12	3,18	0,33
Liberia	3,96	0,80	1,82	1,33
Mali	3,54	0,93	2,28	0,33
Malawi	3,39	0,56	0,84	2,00
Benin	3,20	0,68	1,18	1,33
Madagascar	3,06	0,77	1,96	0,33
Burundi	2,20	0,17	1,20	0,83
Chad	0,76	0,02	0,41	0,33

7.4. Annex IV – Feasibility and potential impact assessment matrix

Each intervention's feasibility and potential impact is calculated at the country level. Each country is assigned a percentile score based on its per-indicator (Table 32)performance within relative to other counties within the sub-Sahara African region.

Table 32 - Feasibility and potential impact assessment matrix

#	Intervention	Metric	Indicator	Improvement direction
1	Integrate ICT subjects in the curriculum at all levels of education.	Feasibility	Quality of education (KPI) metric.	Increase
		Potential Impact	Mobile broadband subscriptions (per 100) – GCI	Decrease
2	Incentivize return, retention, attraction (commercial).	Feasibility	Doing Business Index (DBI)	Increase
		Potential Impact	Digitalization component: ability (aggregate score)	Decrease
3	Incentivize return, retention, attraction (academic).	Feasibility	Quality of education GCI	Increase
		Potential Impact	Digitalization component: ability (aggregate score)	Decrease
4	Government retraining programs	Feasibility	Barriers to education component: environment (aggregate score)	Decrease
		Potential Impact	Mobile broadband subscriptions (per 100) – GCI	Decrease
5	Incentivize nonstate actors to conduct digital training programs and to contribute to state-funded (re)training programs.	Feasibility	Business access to technology (9.02) – GCI	Increase
		Potential Impact	Mobile broadband subscriptions (per 100) – GCI	Decrease

#	Intervention	Metric	Indicator	Improvement direction
6	Mobilize resources in order to support e-learning initiatives.	Feasibility	Business access to technology (9.02) – GCI	Increase
		Potential Impact	State of digitalization (aggregate) metric	Decrease
7	Encourage close collaboration and the exchange of personnel.	Feasibility	Quality of education (KPI) metric.	Increase
		Potential Impact	State of digitalization (aggregate) metric	Decrease
8	Create opportunities and provide assistance to disadvantaged groups.	Feasibility	Quality of education (KPI) metric.	Increase
		Potential Impact	Power Inequality Index (v2pepwrgen) – V-DEM	Increase
9	Do away with laws which discourage internet use.	Feasibility	Freedom in the World	Increase
		Potential Impact	State of digitalization (aggregate) metric	Decrease
10	Leverage fiscal and/or monetary tools to reduce the cost of devices.	Feasibility	Executive Corruption Index (e_v2x_execorr) – V-DEM	Decrease
		Potential Impact	Digitalization component: access (aggregate score)	Decrease
11	Supply computing devices.	Feasibility	Executive Corruption Index (e_v2x_execorr) – V-DEM	Decrease
		Potential Impact	Digitalization component: access (aggregate score)	Decrease
12	Invest in affordable alternatives to broadband.	Feasibility	Executive Corruption Index (e_v2x_execorr) – V-DEM	Decrease
		Potential Impact	Individuals using the internet (% of population)	Decrease

Percentile scores (and, by extension, performance labels) are assigned in accordance with the cutoff points outlined in Figure 18 below.

Figure 18 - Performance labels percentile range breakdown

7.5. Annex V – Full results, intervention analysis

Table 33 - Results intervention 1

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility			Namibia, Ghana, Botswana		South Africa
Practically infeasible					
Moderately feasible			Rwanda, Gabon	Senegal	
High feasibility		Malawi, Liberia, Ethiopia	Zambia, Uganda, Nigeria, Mali	Kenya	
Highest feasibility	Mozambique, Chad	Tanzania, Burundi	Madagascar, Benin	Cameroon	

Table 34 - Results intervention 2

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility			Liberia, Gabon, Cameroon	Madagascar, Burundi	Chad
Practically infeasible			Tanzania, Mozambique, Ethiopia	Mali, Benin	
Moderately feasible		Senegal, Namibia	Uganda, Nigeria, Ghana	Malawi	
High feasibility	South Africa	Botswana	Zambia		
Highest feasibility		Rwanda, Kenya			

Table 35 - Results intervention 3

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility	Chad	Benin			South Africa
Practically infeasible		Madagascar, Burundi	Nigeria, Mozambique, Gabon		
Moderately feasible		Mali, Malawi	Uganda, Tanzania, Liberia, Ethiopia, Cameroon	Senegal, Namibia	
High feasibility			Zambia, Ghana	Botswana	
Highest feasibility				Rwanda, Kenya	

Table 36 - Results intervention 4

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility					Chad
Practically infeasible				Nigeria	Burundi
Moderately feasible				Zambia, Uganda, Mali, Malawi, Liberia, Ethiopia	Mozambique, Madagascar, Cameroon
High feasibility	Ghana		Senegal, Gabon	Kenya	Benin
Highest feasibility	South Africa, Namibia, Botswana		Rwanda		Tanzania

Table 37 - Results intervention 5

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility					Chad, Burundi
Practically infeasible				Malawi, Liberia, Ethiopia	
Moderately feasible	Ghana, Botswana		Gabon	Zambia, Uganda, Nigeria, Mali	Tanzania, Mozambique, Madagascar, Cameroon, Benin
High feasibility	Namibia		Senegal, Rwanda		
Highest feasibility	South Africa			Kenya	

Table 38 - Results intervention 6

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility				Burundi	Chad
Practically infeasible			Liberia, Ethiopia	Malawi	
Moderately feasible		Botswana	Zambia, Uganda, Tanzania, Nigeria, Mozambique, Ghana, Gabon, Cameroon	Mali, Madagascar, Benin	
High feasibility		Senegal, Rwanda, Namibia			
Highest feasibility	South Africa	Kenya			

Table 39 - Results intervention 7

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility			Mozambique		Chad
Practically infeasible			Tanzania, Liberia, Ethiopia	Malawi, Burundi	
Moderately feasible		Rwanda, Namibia, Botswana	Zambia, Uganda, Nigeria, Ghana, Gabon	Mali, Madagascar, Benin	
High feasibility		Senegal, Kenya	Cameroon		
Highest feasibility	South Africa				

Table 40 - Results intervention 8

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility	Chad		Mozambique		
Practically infeasible		Ethiopia	Malawi, Burundi	Tanzania	Liberia
Moderately feasible	Nigeria, Botswana	Namibia	Zambia, Uganda, Madagascar, Gabon	Ghana	Rwanda, Mali, Benin
High feasibility			Kenya, Cameroon		Senegal
Highest feasibility				South Africa	

Table 41 - Results intervention 9

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility	Chad	Burundi	Gabon		

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Practically infeasible			Uganda, Ethiopia, Cameroon	Rwanda	
Moderately feasible		Mali	Zambia, Tanzania, Mozambique	Kenya	
High feasibility		Malawi, Madagascar, Benin	Nigeria, Liberia	Senegal, Namibia, Botswana	South Africa
Highest feasibility			Ghana		

Table 42 - Results intervention 10

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility			Nigeria, Cameroon	Malawi, Burundi	Chad
Practically infeasible	South Africa		Mozambique, Liberia, Ghana, Gabon		
Moderately feasible		Kenya	Zambia, Uganda	Mali, Madagascar	
High feasibility		Namibia			
Highest feasibility		Senegal, Rwanda, Botswana	Tanzania, Ethiopia	Benin	

Table 43 - Results intervention 11

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility			Nigeria, Cameroon	Malawi, Burundi	Chad
Practically infeasible	South Africa		Mozambique, Liberia, Ghana, Gabon		
Moderately feasible		Kenya	Zambia, Uganda	Mali, Madagascar	
High feasibility		Namibia			

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Highest feasibility		Senegal, Rwanda, Botswana	Tanzania, Ethiopia	Benin	

Table 44 - Results intervention 12

	Least impacted	Slightly impacted	Moderately impacted	High impact	Highest impact
Lowest feasibility		Nigeria		Malawi, Cameroon	Chad, Burundi
Practically infeasible	South Africa, Gabon		Ghana		Mozambique, Liberia
Moderately feasible			Zambia, Uganda	Mali, Kenya	Madagascar
High feasibility		Namibia			
Highest feasibility		Senegal, Botswana	Tanzania	Rwanda, Ethiopia, Benin	

Figure 19 - Results intervention 1

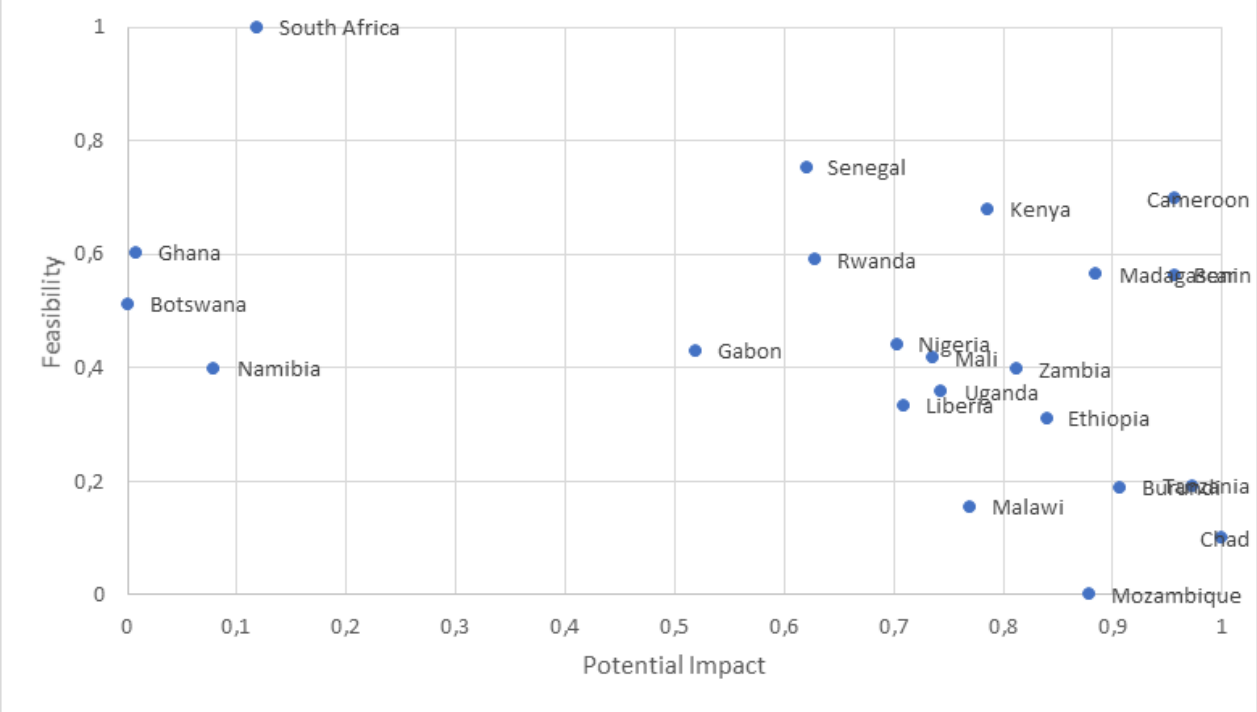


Figure 20 - Results intervention 2

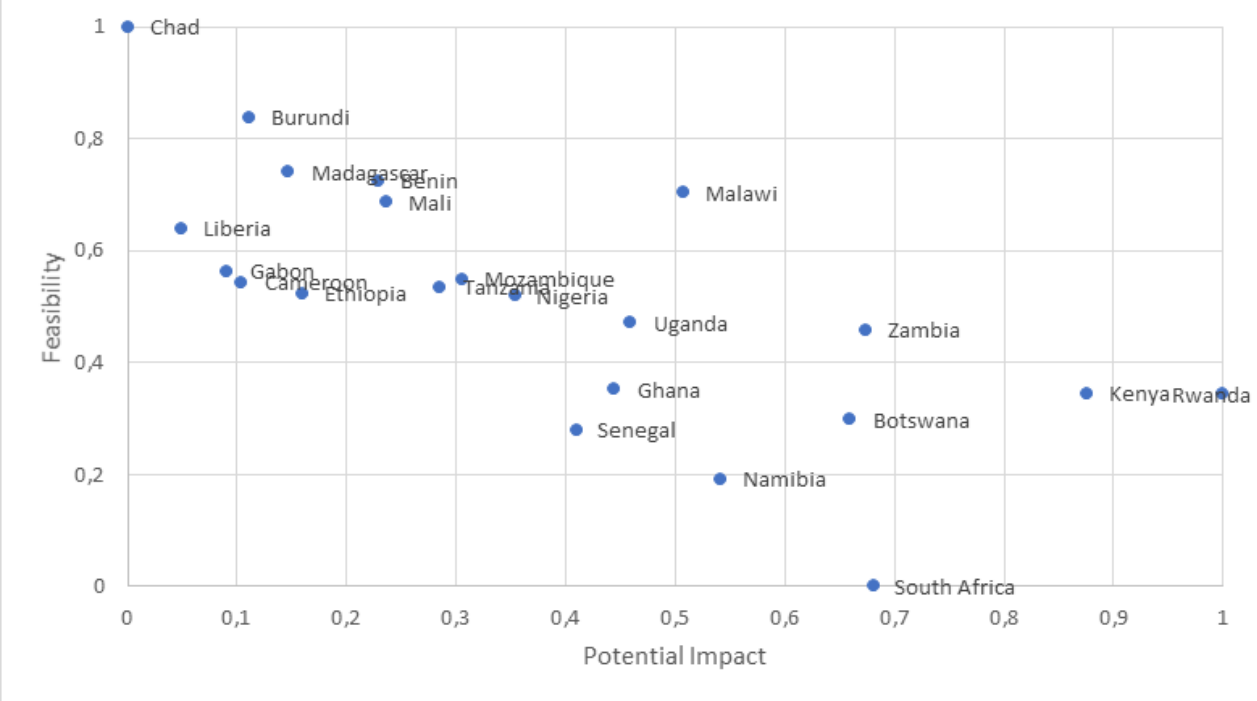


Figure 21 - Results intervention 3

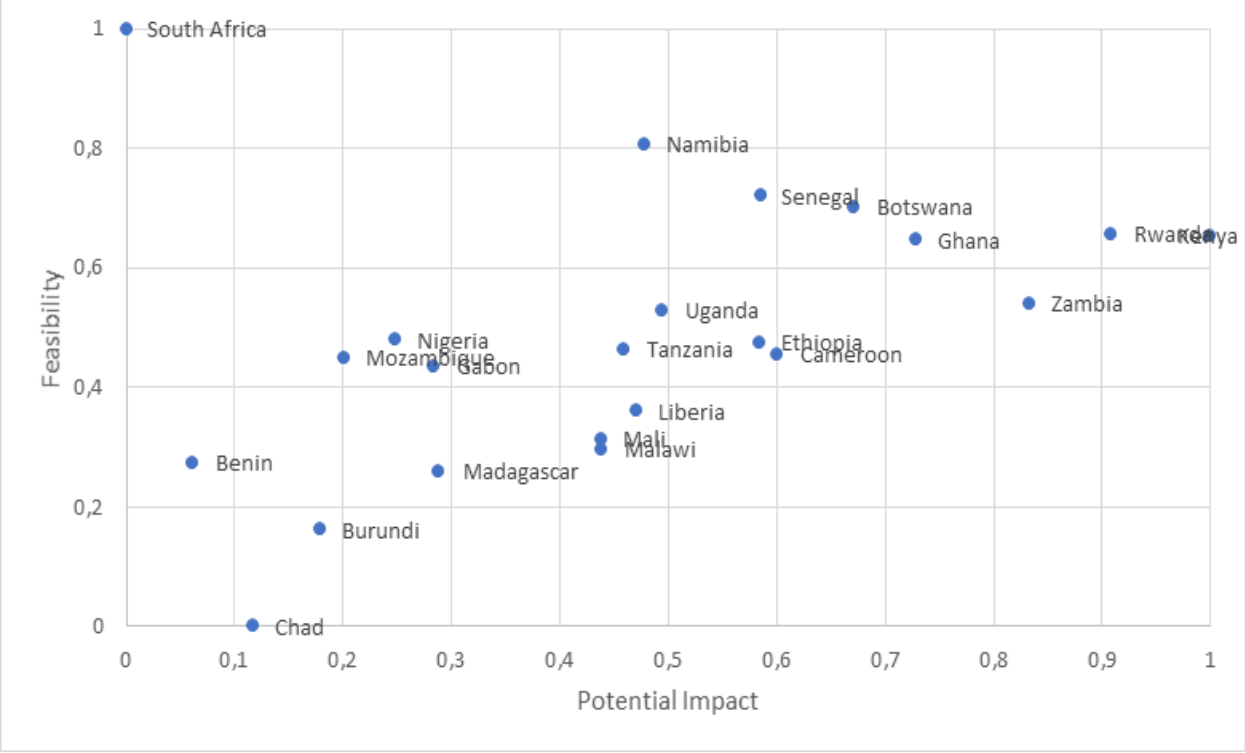


Figure 22 - Results intervention 4

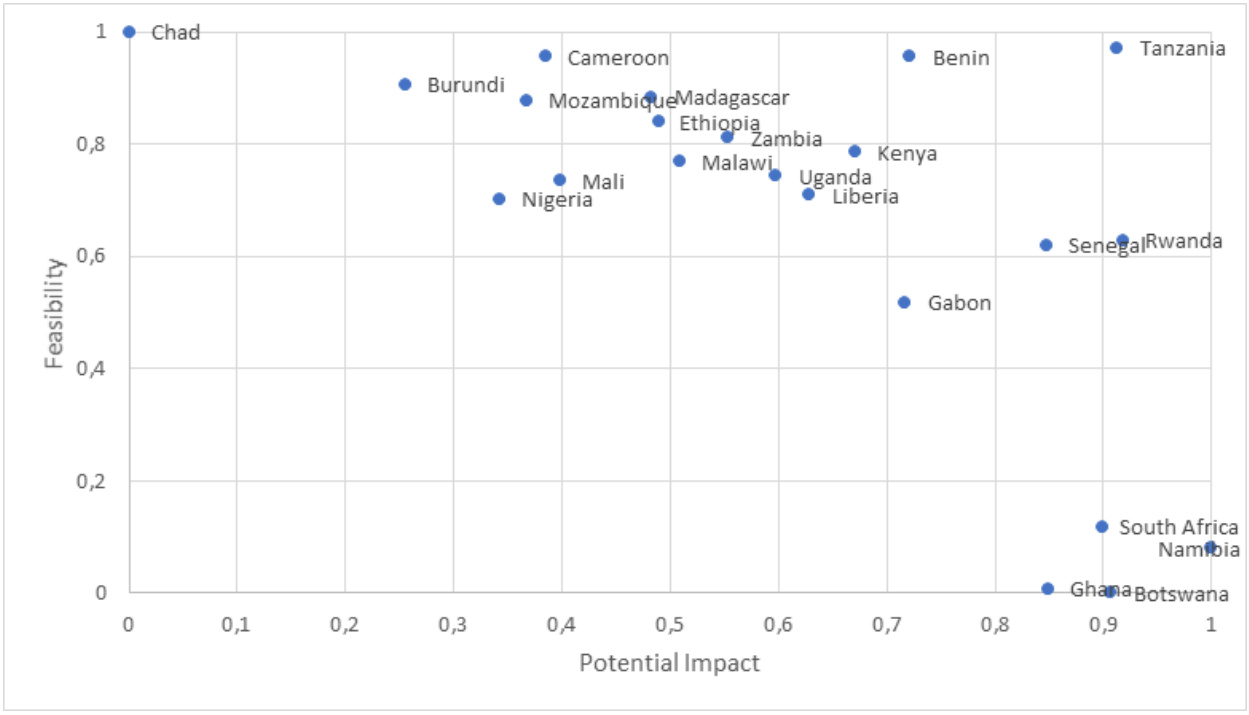


Figure 23 - Results intervention 5

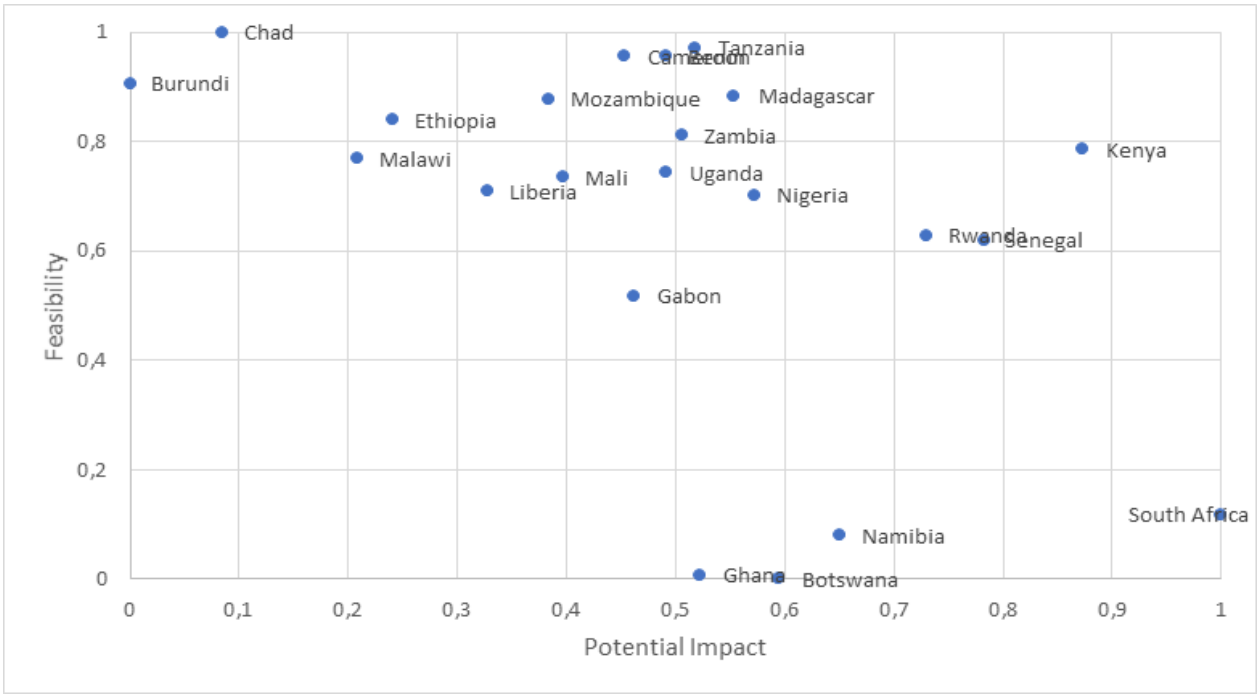


Figure 24 - Results intervention 6

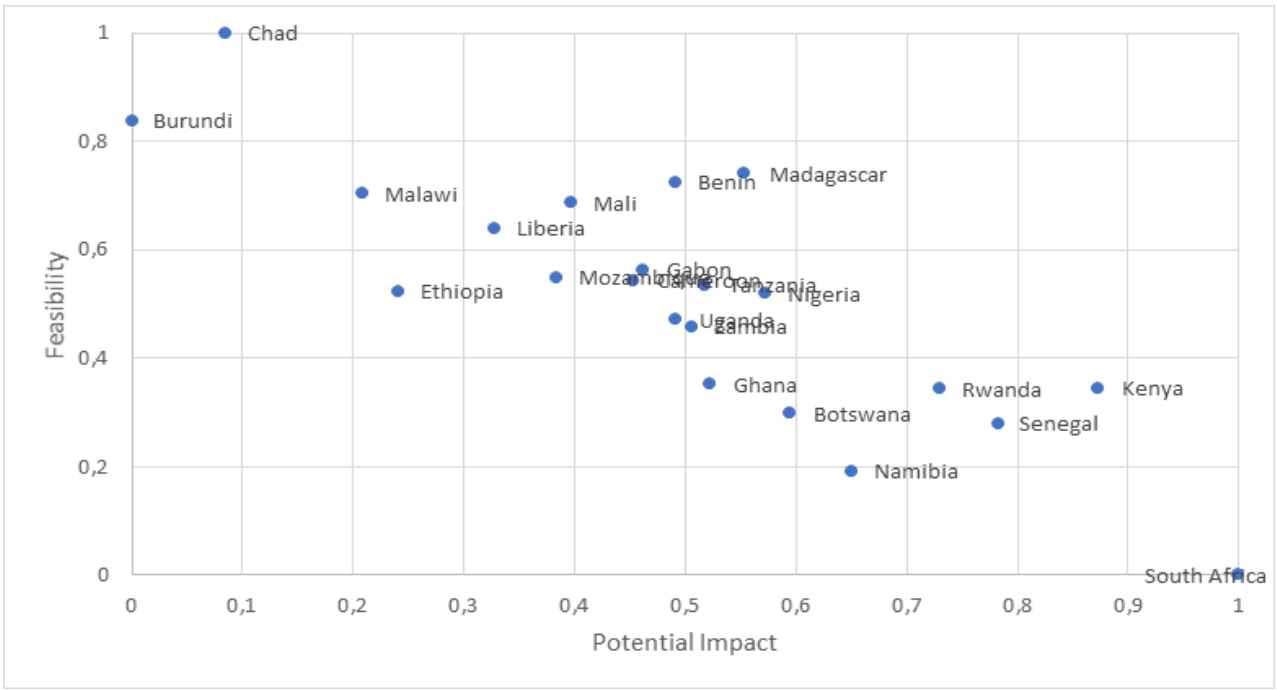


Figure 25 - Results intervention 7

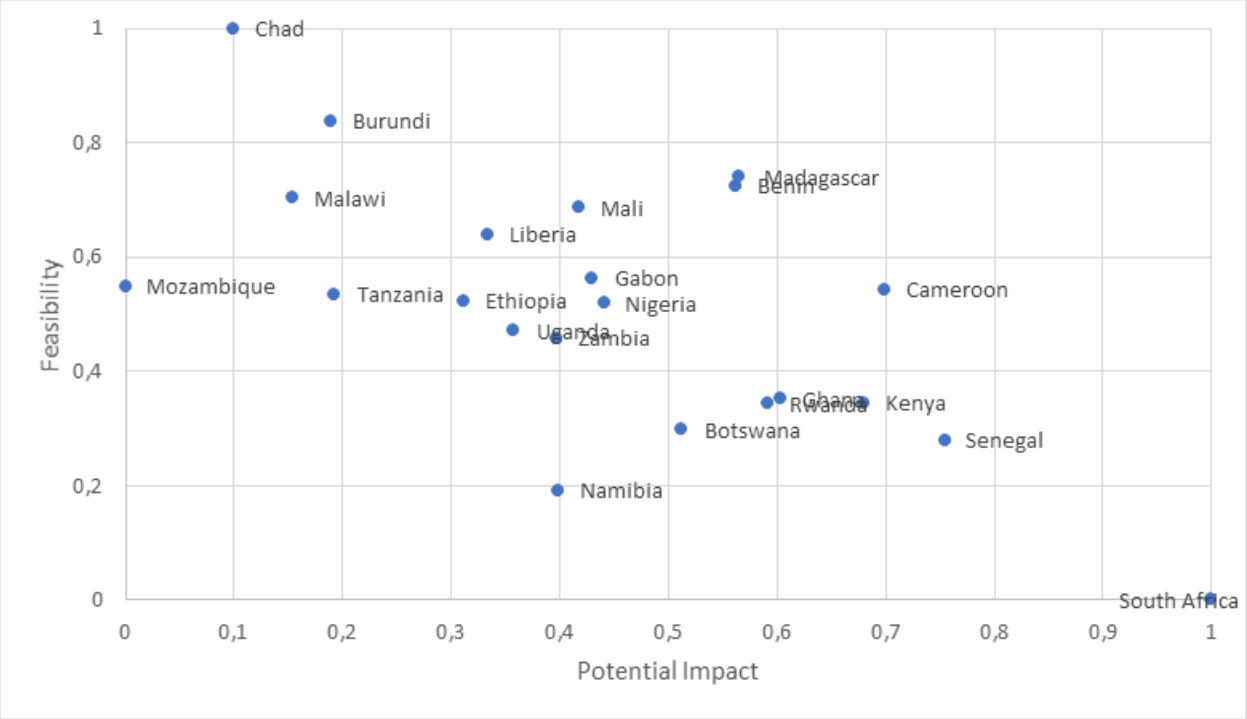


Figure 26 - Results intervention 8

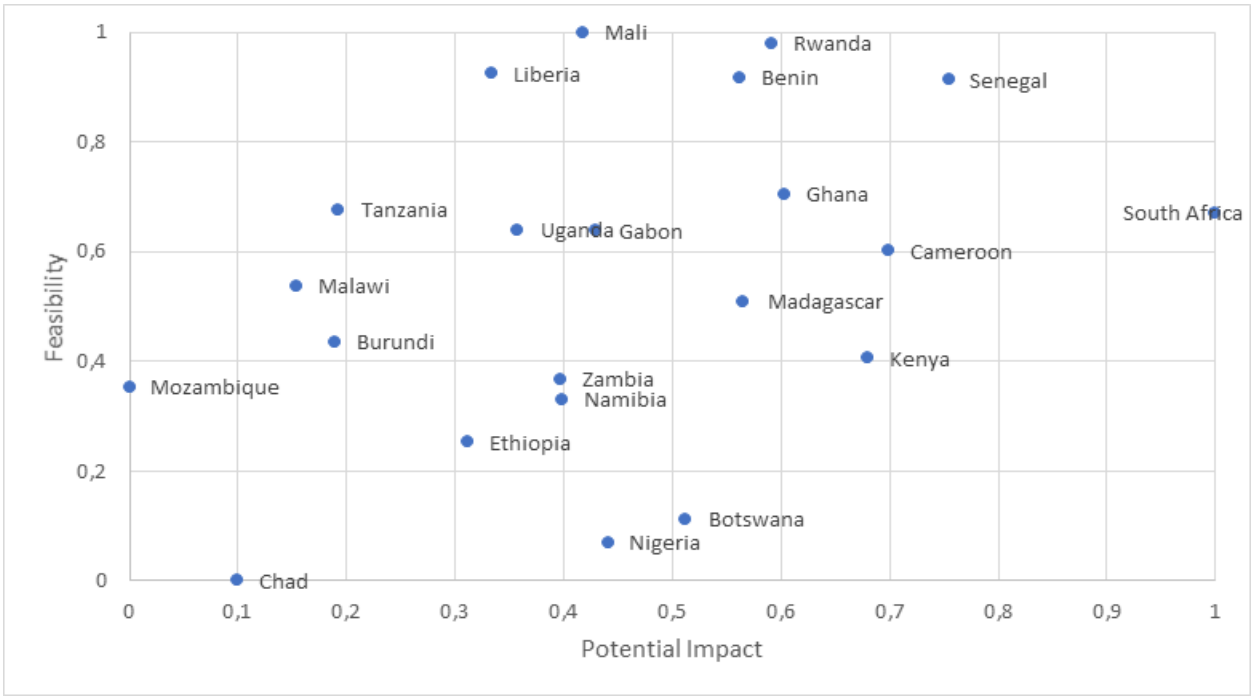


Figure 27 - Results intervention 9

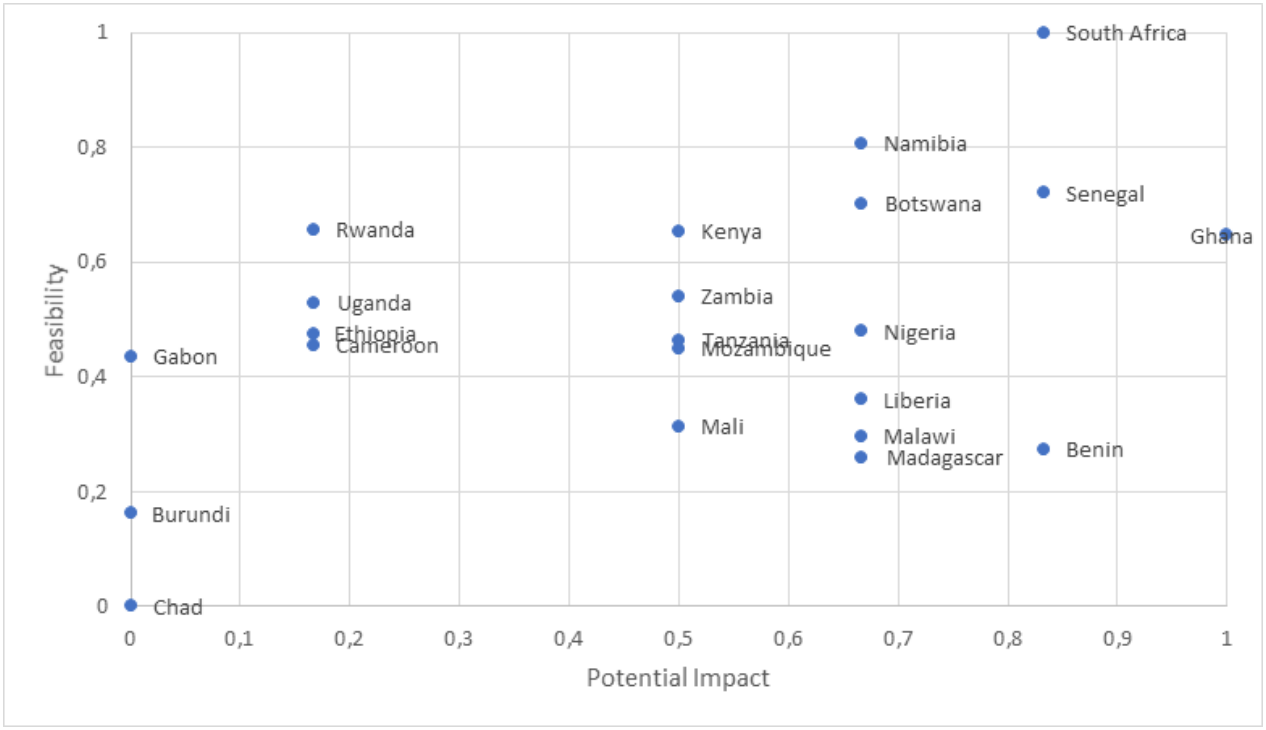


Figure 28 - Results intervention 10

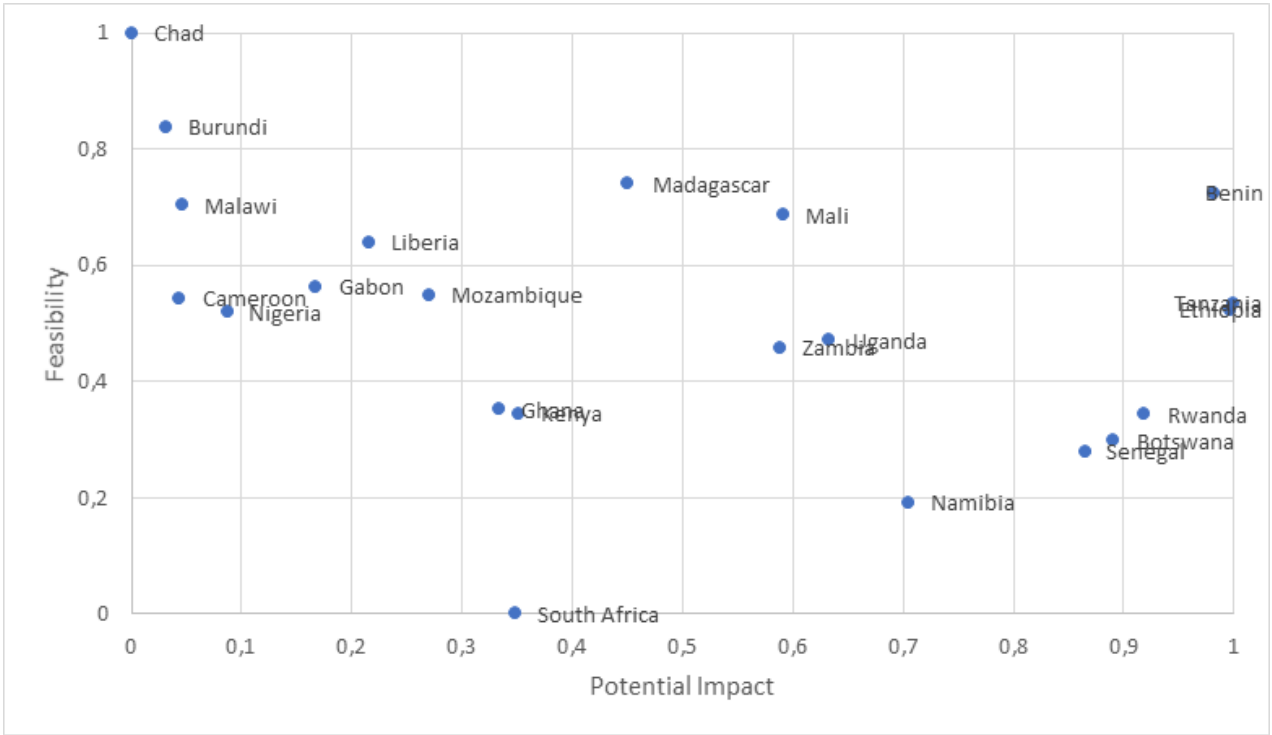


Figure 29 - Results intervention 11

Figure 30 - Results intervention 12

7.6. Annex VI – Methodological caveats & shortcomings

The Hague Centre for Strategic Studies (HCSS) stands behind the results outlined within this report. The methodologies applied towards the quantification of country-level quality of education, barriers to education, and state of digitalization, as well as towards the country-intervention level analysis of feasibility and potential impact, serve their intended function. They provide the reader with a high-level overview of countries' and/or country-intervention combinations' feasibility and potential impact relative to one another. The results – and particularly those presented within the Comparing interventions section – are open to interpretation, with the reader being cautioned to apply the previously outlined "high-level overview" caveat while doing so.

It is important to note that the methodologies applied towards their identification – and, by extension, the results themselves – are subject to several shortcomings and/or caveats. These – along with their implications for the study's overall integrity – are shortly outlined in the sections below. Shortcomings and/or caveats specific to the Barriers to education and the state of digitalization in sub-Saharan Africa and Comparing interventions are outlined in their respective sections below. Shortcomings and/or caveats that apply to both phases of the research are outlined under General.

7.6.1. Shortcomings and/or caveats – general

This study's results are based on methodologies which have had to contend with or correct for the following shortcomings:

- Data availability is spotty. Many of the indicators incorporated within the Barriers to education and the state of digitalization in sub-Saharan Africa and Comparing interventions sections have spotty geographical coverage. Within the context of this research, this has resulted in several countries being removed from consideration.[4] The choice that has been made here is that, in cases where the data from all the datasets leveraged to measure quality of education, barriers to education, and state of digitalization is not available, the country is removed from the analysis altogether, some-

[4] The 22 countries included in this study are Benin, Botswana, Burundi, Cameroon, Chad, Ethiopia, Gabon, Ghana, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Uganda, Zambia.

thing which arguably erodes the study's utility because it limits its scope.

- Data is subject to time lag. In addition to having limited geographical coverage, many of the indicators incorporated within the Barriers to education and the state of digitalization in sub-Saharan Africa and Comparing interventions sections are subject to time lag. This can take two forms. The first is where an index has not been updated for several years, whether for a given country or region or otherwise, meaning that the data which is leveraged is a reflection of the status quo as it existed several years ago. The second occurs when an index's results lag behind their publication date by a specific amount of time. This occurs in many indices which publish updated results on an annual basis; the 2020 iteration might capture the 2019 status quo. While the first of these types of time lag is arguably more detrimental, both are problematic. Many of the indicators incorporated in this index are volatile (meaning they are subject to "sudden" changes stemming from political unrest, etc.), with the result being that the results they yield do not necessarily reflect the status quo that exists at the time of this report's consumption. This research compensates for this shortcoming by providing readers with a clear overview of the year which has been leveraged for each indicator on the one hand, and by ensuring that no one indicator "defines" a country's quality of education, barriers to education, or state of digitalization on the other.
- Many variables used are proxy measurements. This study relies heavily on proxy measurements. This means that HCSS has relied on datasets which measure phenomena and/or developments which correlate with or are similar to – but do not measure exactly – the variables it introduces as being in need of exploration within the Barriers to education and the state of digitalization in sub-Saharan Africa and Comparing interventions sections. In all cases, this is because datasets which measure these phenomena exactly do not exist. As an example, the local attitudes measurement under barriers to education's "local attitudes" variable does not offer a comprehensive overview of all local attitudes that might hamper access to education. Instead, it measures gender inequality. Proxy measurements have been used because conducting this research would be impossible without them. This notwithstanding, it is useful to remember that – as far as looking at individual components and/or measurements within quality of education, barriers to education, and state of digitalization is concerned, the fact that proxy measurements have been used means that the degree to which each component measures exactly what it describes varies by component. This has repercussions for policymaking which targets specific components but does little to detract from the study's high level (aggregate) results.

7.6.2. Shortcomings and/or caveats – barriers to education the state of digitalization

In addition to the shortcomings and/or caveats outlined in the previous section, the research steps outlined in the Barriers to education and the state of digitalization in sub-Saharan Africa section are subject to the following:

- Variable and component makeup is based on literature review. Qualitative (literature review-based) methods were applied to arrive at final component-variable "taxonomies" for quality of education, barriers to education, and state of digitalization. While HCSS is confident in the thoroughness of this

(peer-reviewed) process, concerns over comprehensiveness are endemic to qualitative methods. The potential impact of this concern is amplified by the research team's relative lack of prior knowledge concerning the research subjects. External experts were consulted to minimize the impact of these so-called "blind spots," but it is nonetheless entirely possible that some components and/or variables were omitted. This may skew results slightly but is unlikely to result in large shifts in countries' rankings or their relative performance.

- All variables are assigned equal weight. One of the most important decisions made within the context of the Barriers to education and the state of digitalization in sub-Saharan Africa section is that each variable has been assigned equal weight. This means that each variable is granted equal "opportunity" to influence a country's overall score within the quality of education, barriers to education, and state of digitalization measurements. This decision has been taken because no comprehensive preexisting research exists which provides regression coefficients for the variables included within these models (for example: "local attitudes predict 50% of reductions in quality of education"). The study's implementation timeline and budget also did not allow for the comprehensive deep-dive into each variable which would have been required to ascertain said regression coefficients. This has two important implications, both of which speak to the importance of viewing this study's results through a high-level lens. First, while the study's aggregate results are likely close to reflect reality, they likely diverge from it slightly. It is – unfortunately – impossible to ascertain by how much. Second, some components (i.e.: ability, access, quality & availability under state of digitalization), end up having more weight than others simply by virtue of their being made up of more variables. As an example, the access component of the state of digitalization metric accounts for 60% of countries' overall scores within that metric. Users are recommended to be mindful of this caveat when interacting with and/or assigning meaning to country scores. HCSS has considered this caveat in the formulation of its recommendations.
- Normalization methods. This study uses a normalization method in which countries are compared, on an indicator-by-indicator basis, with peers for which data is available. This method constitutes a conscious decision on the part of the research team to a.) not compare sub-Saharan African countries' performance to countries outside of the region, and b.) allow for the "floor creation" effect which derives from this methodology's combination with countries' exclusion from the index on the basis of data unavailability. The first point means that, because countries from outside of sub-Saharan Africa are not included, the user cannot compare (and relativize) country results to non-sub-Saharan countries. This does not detract from the study's results but arguably detracts from the indexes' utility outside of this report. The second point means that, because data coverage is typically better in more developed countries, some countries – and countries which perform worse in particular – are "punished" because they receive scores that are lower than what they might have achieved had more countries been included in the study. Readers are recommended to read this study's results carefully as a result of this caveat. The measurements presented are relative rather than absolute. A high score in quality of education does not mean quality of education is high – it simply means that it is high relative to other (sub-Saharan African) countries included in the study.
- Manual coding methods. Several of the variables within barriers to education and state of digitalization were hand-coded. While Annex II provides some insight into how these were coded, they are likely to be difficult and time-intensive to replicate. Challenges associated with correcting for variables such as the subjects, quality, and length of courses between different universities – brought on partially by their websites being difficult to navigate and partially by language barriers – means that some of these results are likely to deviate (if only slightly) from reality.

7.6.3. Shortcomings and/or caveats – comparing interventions

In addition to the shortcomings and/or caveats outlined in the Shortcomings and/or caveats – general section, the research steps outlined in the Comparing interventions section are subject to the following:

- Intervention choice is based on literature review. Qualitative (literature review-based) methods were applied to arrive at the final intervention shortlist. While HCSS is confident in the thoroughness of this (peer-reviewed) process, concerns over comprehensiveness are endemic to qualitative methods. The potential impact of this concern is amplified by the research team's relative lack of prior knowledge concerning the research subjects. External experts were consulted to minimize the impact of these so-called "blind spots," but it nonetheless entirely possible that some interventions were omitted. This may skew results slightly but is unlikely to result in large shifts in country rankings or their relative performance.
- Limited data use. Feasibility and potential impact have been measured using a single indicator for each intervention. This is due to limited time availability and because more granular data was, in many cases, not available. Building indexes to measure each feasibility/potential impact-intervention combination was not feasible. As a result, these results are subject to a large caveat – they have been measured using extremely rough proxy measurements. While they likely reflect relative performance well, they are open to interpretation.
- Feasibility and potential impact do not reflect Nuffic's competencies. This study assigns each country-intervention combination a score for feasibility and potential impact. These measurements – and feasibility in particular – reflect generic feasibility and impact rather than Nuffic-specific feasibility and potential impact. Factoring for variables such as Nuffic's area of expertise, its existing infrastructure, and its relationship with communities and policymakers in each of the studied countries would likely have yielded different (and potentially more actionable) results.
- Country classification methods are open to interpretation. This study opts to leverage a methodology in which country-intervention combinations are assigned performance labels (highest feasibility / highest potential impact, etc.) which reflect – as is also the case with country results presented in the Barriers to education and the state of digitalization in sub-Saharan Africa section – their relative rather than absolute performance. This approach constitutes a conscious choice not to mark cluster countries in accordance with the "boxes" they fall into in Table 33 to Table 44. This approach is open to interpretation. This study only describes and applies a method and presents a variety of approaches to interpreting the results. It derives its findings by looking at country-intervention combinations where both feasibility and potential impact are high or highest. This is a logical approach that should be viewed as a guideline rather than as an absolute truth. The results are open to interpretation, and exhaustive efforts have been made – from outlining the methods, to outlining their caveats, to presenting several alternate methods of analysis (see the Findings feasibility and potential impact assessment; Table 33 to Table 44; and Figure 19 to Figure 30) – to provide the reader with the tools to draw well-informed conclusions of his or her own.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