Are Mobile Phones the Future for Education in Africa?

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Abstract

Mobile phone usage is rapidly expanding and is now being considered a fundamental tool to help improve educational outcomes in Africa. This paper examines the effects of mobile phones on test scores including their short and long-term impacts. Using results from a randomised experiment in Niger, pooled ordinary least squared methods were applied. Students who had access to a mobile phone in a teaching programme (ABC) scored higher marks than those on a regular teaching programme. For maths scores, the effects of mobile phones were more significant in seventeen months than in five months. However, for writing scores, the effects of mobile phones diminish between five months and seventeen months. It becomes evident from these results that mobile phones enhance educational outcomes and, hence, can be considered a tool to improve the lack of education in Africa.

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Chapter 1: Introduction and Literature Review

1.1: Introduction

Education plays a crucial role in economic development through human capital, productivity, and unemployment. Many studies have found a positive causal correlation between economic growth and additional years of education [Gyimah-Brempong, Paddison and Mitiku, (2006), Kobzev Kotásková et al., (2018) and Hanushek and Wößmann (2010)]. Moreover, research papers have found that the marginal benefits of education are more significant in developing countries. Consequently, education is becoming a key instrument in stimulating growth in developing countries.

Africa has very little access to education, despite its sizeable public spending. In Sub-Saharan Africa in 2019, approximately 34.7% of adults over 15 years old were illiterate (Statista, 2022). A lack of education stems from barriers to education at a young age. Approximately 40% of children in Eastern and Southern Africa are not in school (UNICEF, 2021). Barriers include the high costs of education, low accessibility, low engagement in learning, irrelevant curriculum, and many more. Overall, this causes high dropout rates and low engagement in education, particularly for females. Gender disparities in education are also a significant factor as it is the norm to send boys to school over girls. Due to these factors, Africa needs to consider implementing a relevant policy, such as increasing government spending on technology, to incentivise and increase accessibility within the education sector.

Mobile phones, a relatively new technology, are popular worldwide, especially in Africa. GSMA (2021) predicts that 50 percent of Sub-Saharan Africa's population will have a mobile phone by 2025. Due to mobile phones' cheap costs and extensive benefits, recently, policymakers have considered mobile phones to improve education. M-learning, or mobile-based learning, can be applied in Africa to help increase engagement in education, provide more opportunities to learn and make education more accessible. Previous studies, such as Kaliisa and Picard (2017) and Aker, Ksoll, and Lybbert (2012), research whether mobile phones can improve education in Africa. This paper hopes to add to the existing literature by using pooled OLS methods on panel data.

Furthermore, this paper seeks to explain the impacts of mobile phones over time, which minimal studies in this area research further. Specifically, it looks at the effects of mobile phones over five months and seventeen months. The research question analyses whether the impact of mobile provides a short-term boost on test scores or whether it is more effective over a more extended period. The significance of this question lies in its implications for the way mobile phones integrate into education in Africa.

The following section explores previous literature found when applying mobile phones to economic development and education. The second chapter discusses the barriers to education in Africa and the importance of education. Chapter 3 explains the data used to test the research questions. Then pooled OLS methods are explained (Chapter 4) alongside descriptive analysis. A discussion of the results and implications follows in Chapter 5. Finally, Chapter 6 outlines the limitations, further research, and concluding comments.

1.2: Literature Review

1.2.1: Impact of Mobile Phones for Economic Development

The usage of mobile phones has been growing exponentially since the 2000s, as the world economy is technologically advancing. According to Turner (2021), 91.54% of people will own mobile phones worldwide in 2022, and by 2025, the forecasted number of people who own a mobile phone will increase by 39 million. Consequently, opportunities for mobile phones to aid economic development are rapidly expanding, especially in developing countries. Previous literature, such as Lee and Gardner (2011), found that mobile phones positively correlate with economic growth. Additionally, the marginal benefits of mobile phones are more significant in countries with poor infrastructure.

Mobile phones provide many benefits to economic growth, such as communication benefits and accessibility benefits. A study by Abraham (2006) shows that mobile phones increased fisheries' productivity through improved communication and the free flow of information. The research paper highlights that communication is a vital tool for mobile phones in enhancing economic development as fisheries were able to communicate and gain access to market opportunities efficiently. However, this study is outdated and only observed the initial effects of mobile phones as they were being integrated into society; thus, the consequences could be quite different today. A supporting study by Mittal, Gandhi, and Tripathi (2010) concludes that access to information showed productivity improvements in Indian agriculture. The key conclusion of these studies is that mobile phones provide ease of access to information, leading to an increase in education and communication, which increases productivity and economic growth. Despite this, these studies only measure the effects of mobile phones on economic development through correlations. In other words, mobile phones do not necessarily contribute directly to economic growth; there may be involvement of confounding.

Existing literature also explains that mobile phones can help to improve equity and equality in an economy. Access to mobile phones reduces the need to travel to areas where services, such as banking or education, are provided. Thus, in developing countries, the poor can access services online without travelling (Scott et al., 2004). As more people can benefit from services equally, it may increase efficiency, leading to economic growth.

Overall, policymakers emphasize mobile phones as an instrument to improve economic development due to their tools. Moreover, this phenomenon amplifies because technological change has made mobile phones cheaper and more accessible. Therefore, it is easier to implement a mobile phone policy to increase economic development in developing countries.

1.2.2: Implications of Mobile Phones on Education

Several existing studies in the broader literature have examined the benefits of applying mobile phones to education. One such way is through M-learning, where students can use mobile phones to learn the curriculum from their phones, meaning no school infrastructure is needed. As suggested by Brown (2003), mobile learning brings many benefits to developing countries lacking good quality education, such as countries in Africa. M-learning is more accessible, allows more communication between students and lecturers, and provides more motivation. All of these benefits are discussed further in this chapter.

Free-Access

One main benefit is the free access to information sources that can be reached independently and at any point. For example, Derksen, Leclerc, and Souza (2020) found that students who had access to Wikipedia in Malawi could improve their English exam results, especially those who were low achieving, which narrowed the achievement gap between high and low-achieving students. Additionally, there is a scarce resource for up-to-date textbooks in Africa due to the relatively high cost. According to Ross' (2010) study (cited in Goundar, 2011), "half of the classrooms across six countries studied in Sub-Saharan Africa have no textbooks at all, because of cost and logistical issues." Applying mobile phones to education will allow students to access up-to-date information related to their curriculum (Porter et al., 2015). Demonstrating how mobile phones can help individuals access information to facilitate their learning.

Motivation

Mobile phones also provide an innovative and personalised learning approach to education through mobile apps. Mobile apps are a powerful tool that is often affordable and easy to access, many of which are suitable for education (Goundar, 2011). For instance, gamification involves students learning through educational games. Studies have shown that using games as a critical learning tool to retain knowledge has provided positive results. (Putz, Hofbauer and Treiblmaier, 2020). On the contrary, Hwang et al. (2014) found that mobile phones motivated students to practice English speaking and listening skills but found only minor education improvements. Overall, existing literature shows that mobile phone learning helps to encourage students to learn; however, whether apps lead to an increase in educational outcomes is still debated.

Communication

Some authors have also reported that mobile phones enable students to communicate with each other to enhance their learning. For example, Chipps et al. (2015) conducted a study analysing the use of mobile phones to support learning for rural-based midwives in South Africa. They concluded that mobile phones were most beneficial for allowing students to discuss topics and tasks from the course and searching for topic information in the clinical context. The result from this study supports the idea that mobile phones could allow students to communicate and further discuss their curriculum without the need to travel. Furthermore, more communication will allow students to develop social skills, which will help to improve their language skills. On the other hand, this is difficult to imply as this study does not show whether educational outcomes increase due to increased communication.

1.2.3 Summary of Literature review

Due to the recent development of mobile phones, there is little research about whether mobile phones' effects can help improve education in Africa. However, many studies have found various benefits attached to mobile phones, such as accessibility which could help stimulate economic growth. Mobile phones could be considered an inexpensive, crucial tool for economic development in developing countries, such as countries in Africa. As discussed previously, mobile phones could allow students to learn on the go and more in-depth, tackling the barriers to high-quality education in Africa. Which raises the question of whether investing in mobile phones would be beneficial?

On the contrary, many studies fail to acknowledge the impacts of mobile phones over time. For example, many studies such as Derksen, Leclerc, Souza (2020) and Aker, Ksoll, and Lybbert (2012) show a positive correlation between mobile phones and educational outcomes however do not go into depth about the short- and long-term impacts of mobile phones on education. For example, are there any optimal points where mobile phones produce the most benefit? Are mobile phones a short-term or long-term policy?

Chapter 2: Background and Theory

2.1: Background

2.1.1: Education in Africa

Education in Sub-Saharan Africa is substandard. "Over one-fifth of children between the ages 6 and 11 are out of school, followed by one-third of youth between the ages 12 and 14" UNESCO (2016). As a result, low schooling negatively affects their literacy and mathematics abilities, which stifles economic development. For example, in 2018, one in three people aged 25 to 64 were illiterate (UNICEF and African Union Commission, 2021). Additionally, the number of children and adolescents not achieving minimum proficiency in mathematics in Sub-Saharan Africa reached 84% in 2015 (United Nations Statistics Division, 2019). These statistics show that Africa needs to prioritise education levels.

2.1.2: Barriers to Education in Africa

According to Guardian News (2011), "Sub-Saharan Africa spends 5% of its gross domestic product on education which is only shortly behind Europe at 5.3%.". This statistic suggests an inefficient allocation of spending on educational resources, given the higher education standards that Europe provides compared to Africa. Moreover, it points out that education spending in an economy does not correlate with a good education. Additionally, in 2019, the world average public expenditure on education was approximately 3.7% (UNESCO Institute for Statistics, 2019). On the contrary, in 2019, the average public expenditure across 37 countries in Africa was 4.28% (The Global Economy, n.d.). These statistics highlight that public expenditure on education is inefficient and that their other challenges, rather than low spending, in Africa must lead to a lack of education.

Costs

One main challenge to the lack of education in Africa is the high costs resulting in increased dropouts and low attendance. Despite Africa's high educational spending, only 37% of Sub-Saharan countries offer fee-free education (Kerr, 2020). However, even in countries where education is free, other direct costs, such as books, equipment, and travel, are extortionate. As a result, many families in Africa cannot afford tuition fees for their children, increasing exclusion in education. Furthermore, even when families can afford some schooling, they often prioritise boys over girls because girls are expected to perform a wider variety of tasks to support households (for example, household work and farming work). As a result, the opportunity cost of sending girls to school is greater than for boys. (Colclough, Rose, and Tembon, 2000). Consequently, girls are often the first ones to drop out of school. According to Musau (2017), "A girl can expect to receive only nine years of schooling while boys can expect ten years.". Since girls have fewer educational opportunities than boys, gender inequality worsens.

On the positive side, improvements with exclusion and dropout rates have improved in recent years, with a gain of 3% of students completing secondary school between 2010 and 2019 (United Nations, 2021). However, significant gender disparities remain in Africa. In their fourth sustainable target, the United Nations emphasizes the importance of gender disparities in education by ensuring equal access to all levels of education by 2030.

Shortage of Teachers

Africa's shortage of teachers represents another barrier. It is common for some countries such as Burkina Faso, Chad, and Niger to have average class sizes of over 50 students per class, highlighting the need for more teachers. According to Commonwealth of Learning (2016), Sub-Saharan Africa needs 6.2 million teachers by 2030, of which around a third are newly created positions. The standards of teachers are equally as important. Many teachers do not have sufficient qualifications and training, resulting in their students not receiving a good enough education. Training teachers is a long-term solution, and hence a generalised solution that can apply to each country in Africa should be prioritised.

Shortage of Textbooks

Additionally, much of the educational content is outdated, with old textbooks that do not necessarily align with the curriculum nor add value in present-day society. As a result, many students find learning the curriculum challenging. The lack of textbooks also prevents students from researching further into their interests. Charities such as "Books2Africa" and "Book Aid for Africa (BAFA)" help with providing books to Africa; however, these are of limited use as demand far outweighs supply.

Infrastructure

Another barrier in Africa is the poor infrastructure. For example, many classrooms are not large enough to fit every student resulting in cramped classrooms. Additionally, many schools are without toilets and a canteen, affecting the nutrition and wellbeing of students. These factors discourage students from attending school, causing high exclusion and dropout rates.

Despite increased public expenditure, building more schools or hiring additional teachers will not be enough to overcome these barriers (Internet Society, 2017). Other solutions, such as technology, must also be considered. Additionally, solutions must incentivize minority groups (such as girls or students with disabilities) to support those disadvantaged in education participation to reduce inequalities in education.

2.2: Theory

2.2.1: The Importance of Education

Human Capital

Education and training are instruments for economic growth through the human capital theory initially formulated by Becker (1962). Human capital is the economic value of each worker's skill level through tools such as productivity and labour costs. Economic growth increases when human capital (productivity per worker) increases, leading to economic development.

In other words, education produces positive externalities when consumed, such as knowledge and skills. These skills produce a more significant marginal social benefit than the marginal private benefit of attending school. When a person has an additional year of schooling, they are considered higher skilled than those who dropped out early. As higher-skilled workers have more skills and knowledge, they are more likely to work more efficiently and productively. Consequently, firms will be more productive because they can increase output while maintaining exact costs. Thus, total output and revenue will increase, incentivising firms to invest in education. In an economy, a higher total output per firm translates into a higher gross domestic product (GDP), which is the basis for economic growth. Overall, the human capital theory shows the significance of education as it causes a ripple impact on economic growth.

Innovation

High-quality education may also stimulate innovation and invention in an economy. If more people are higher educated, it will raise creativity in the economy. Creativity will help firms find more innovative solutions to their problems, for example, inventing new technology. More innovative solutions may increase consumer welfare and influence consumers to buy more goods. As a result, consumption will increase and positively affect aggregate demand in an economy, which will cause an increase in economic growth. Furthermore, firms are more likely to increase their productivity if they invest in more technology. Consequently, GDP will increase, which shows a surge in economic growth.

A well-designed curriculum and a creative environment can help foster habits where students become more innovative in school and throughout their working lives. A more innovative society may lead to a greater invention of new technologies. Therefore, also leading to an increase in economic growth.

Unemployment

An educated society may also result in lower unemployment levels in the economy because people receiving good education are more likely to find a higher-paid job. Unemployment measures how many people are currently out of work but are actively searching for a job. Lower unemployment levels lead to a variety of benefits in an economy. The first advantage is that more people are likely to earn a sustainable income, decreasing poverty levels in an economy. Moreover, those not in poverty will likely have a happier and healthier lifestyle, increasing the individual's life span. A supporting study by Raghupathi and Raghupathi (2020) found a positive correlation between education and lifespans. A higher lifespan per individual will increase the overall life expectancy in an economy. Additionally, if life expectancy has increased, it will increase the human development index in an economy.

Furthermore, a lower unemployment level means a reduced crime rate. Many studies, such as Edmark (2005), have found a positive correlation between unemployment and crime rates. A lower crime rate occurs as the opportunity cost reduces when a person is employed. However, studies have only found a correlation between these two variables meaning that other confounding factors may be involved.

Chapter 3: Data Source

The following analysis of whether mobile phones affect education uses data from a similar research paper (Aker, Ksoll, and Lybbert, 2012). The researchers conducted a field experiment in Niger through a randomised experiment to test whether mobile phones affected learning.

3.1: Background on Niger

Niger is a landlocked country in West Africa, with an estimated population of 26 million in 2022 (Worldometers, 2019). Niger's GDP per capita in 2020 is US$567.67 (The World Bank Group, 2010), placing it as one of the world's poorest nations. On the contrary, in 2017, public education spending in Niger was approximately 13.2% of its government budget (Giovetti, 2019). Niger's public spending budget provides free schooling to students, but many are out of education due to the lack of school infrastructure and out-of-date textbooks. As a result, literacy rates in Niger are meager. According to Giovetti (2019), literacy rates for males aged 15-25 were 48.5%, whereas it is 31.6% for females. The stark contrast in literacy rates between males and females highlights the gender inequality in Niger's education system.

3.2: Data Source

In Aker, Ksoll, and Lybbert's (2012) study, the researchers randomly allocated 113 villages to one of the following programmes: "ABC" or "non-ABC." Both programmes followed the same adult teaching curriculum, which involved teaching students literacy and numeracy skills over two years. However, students assigned to ABC were the treatment group, and they had access to mobile phones. In the ABC programme, students received training on how to use the essential functions of a mobile phone (for example, recognising numbers and letters on the handset, sending and receiving messages and calls. Every group of five students also had a mobile phone to share. For the non-ABC programme, the control group, students did not have access to a mobile phone and followed the regular teaching curriculum.

Additionally, participants were also randomly assigned into two cohorts which started on different dates (2009 and 2010). However, the forthcoming analysis only studies data from the 2009 cohort for simplicity.

Randomisation of villages for each programme is crucial for this data as it prevents selection bias, ensuring that the sample accurately represents the population. Moreover, it balances each group according to known and unknown confounding variables. Hence, the variables will be uncorrelated with the error term, which is an assumption required for simple linear regression. Furthermore, only the experimenters knew what villages were following what programmes to prevent biases from occurring. For example, students change their behaviours based on their knowledge of their assigned program, which increases the validity of the results.

In January 2009, students for both programmes first sat baseline mathematics and writing tests. Scores for each test varied between level 0 and level 7. For writing, level 0 represented "completely illiterate," and level 7 represented that the student could form two complete sentences. For maths scores, students ranking level 0 were complete "innumeracy," and level 7 represented that the student could work out maths word problems. Four further tests were recorded approximately every six months in January and June.

Chapter 4: Methodology and Initial Analysis

4.1: Methodology

Aker, Ksoll, and Lybbert's (2012) research paper explain the central question about whether mobile phones impact learning in Niger. The paper finds a positive effect of mobile phones on writing and mathematics scores. However, the paper does not elaborate on the difference between mobile phones' short- and long-term effects and the implications. The results discuss the following research questions:

1. Do mobile phones have an impact on learning?
2. What are the short- and long-term implications of mobile phones on learning?

A pooled ordinary least squares regression is applied to the panel data to answer these questions. Stata was used to formulate these results. The methodology below is split into two parts to explain the methodology for either question.

4.1.1: Do Mobile Phones have an Impact on Learning?

Below is the multiple linear regression model used to examine if mobile phones impact learning:

$$Score = \beta_0 + \delta_0 ABC + \delta_1 young + \delta_2 female + \delta_3 dosso + \beta_1 age + \beta_2 age^2 + \alpha_0 round1 + \alpha_1 round3 + \alpha_2 round4 + u$$

The dependent variable *score* splits into two sections; maths and writing. The score represents the mark each student got in maths and writing. *ABC* is an indicator variable, which takes the value of 1 (when the student has access to a mobile phone) or 0 otherwise. The alternative hypothesis states that the ABC programme positively affects scores. Hence, the ABC coefficient should be greater than zero. In contrast, the null hypothesis states that the ABC coefficient is equal to zero, so mobile phones do not affect test scores.

The regression includes several control variables. Their coefficients are represented by β_i for linear variables, δ_i for dummy variables and α_i for seasonal dummy variables.

Firstly, the dummy variable *young* indicates whether a student is under nineteen years old (takes the value of 1) or not. Similarly, to indicate the gender of each student, the dummy variable *female* has been used to analyse the gender disparities in education. The final dummy variable is *dosso*, which takes the value of 1 when the student lives in Dosso. Dosso is a city in the South-West of Niger with exceptionally high poverty rates and poor education, making it an interesting area to study.

The variable age gives the age of each student in the programme. As this is a linear variable, it will have a linear effect on the scores of each participant. However, adding the variable age squared can improve the goodness of fit; hence it was added to the model. Figure 5.1 (in Chapter 5) shows that the standard error for age squared is much smaller than age, thus proving that age squared is beneficial in the model.

Finally, four seasonal dummy variables are included in the model to show the seasonal variation in each round (round one to four) on the dependant variable. These rounds only consider the time when the programmes were implemented, excluding the baseline round. Furthermore, round two is omitted to prevent multicollinearity in the estimates. Multicollinearity occurs when there is a high correlation between two or more independent variables. For example, students who perform better in round one is likely to perform better in round two, causing these variables to be positively correlated. However, if variables are correlated, they are not independent, violating one of the Gauss-Markov assumptions and causing the coefficients to be biased. Hence, the second round is excluded from the model to prevent multicollinearity.

4.1.2: Short and Long-Term Impacts of Mobile Phones on Education

To analyse further the short- and long-term effects of mobile phones on education, a similar multiple linear regression model is formed:

$$Score_t = \beta_0 + \delta_0 ABC_t + \delta_1 female_t + \delta_2 dosso_t + \beta_1 age_t + \beta_2 age_t^2 + \beta_3 baseline_t + \beta_4 attendance_t + u_t; \text{ where t} = 5 \text{ months or } 17 \text{ months}$$

Four multiple linear regression models are tested: mobile phones' short- and long-term impacts on each subject score (mathematics and writing). The analysis explores the effects of mobile phones for five months (short-term) and seventeen months (long-term). Examining the effects of mobile phones over time is critical because it reveals whether mobile phones continue to positively affect test scores in the long run and the magnitude of any change. It also enables us to look at the marginal impacts of mobile phones on test scores. The results will then further imply whether the implementation of mobile phones in education should be a longer-term policy or a shorter-term policy. It is important to investigate this as it affects the costs associated with the implementation of mobile phones to improve education.

The model has similar control variables as above; however, it excludes the seasonal dummy variables as this is no longer needed to identify the round. Instead, the subscript, t, represents whether the scores are from the five months test or the seventeen months test. Additionally, the model excludes the variable *young*. Finally, the variable *attendance* as a control variable was included, which shows the percentage of classes a student attended.

The model incorporates individual baseline scores by calculating the average baseline score for each class. There was no access to individual codes, so calculating the average score of baseline scores was the class average. Baseline scores are positively correlated with scores, as shown in Appendix A in Figure 4.1a. Thus, it is significant to put baseline scores into the model.

The command *robust* was used for each model to adjust for robust standard errors. Robust standard errors are critical in these models as it obtains unbiased standard errors of ordinary least squares coefficients under heteroscedasticity. Heteroscedasticity occurs when the variability of the variance of the residual term is immense. A Gauss Markov assumption for multiple linear regression is that errors should be homoscedastic. Hence using robust standard errors prevents the violation of this assumption.

As part of panel data analysis, the standard errors are clustered for each village. Clustered standard errors group students into each village but ensures that villages in Niger are not correlated. Clustering prevents correlation between observations in each village. A correlation between villages could cause homoscedasticity, which would violate a Gauss Markov assumption and make the coefficients biased.

4.1.3: Evaluation of Data

The lack of individual codes in this data meant that other panel data methods were unavailable. With this type of data, the difference in difference approach (as shown in Aker, Ksoll, and Lybbert's (2012) paper) would have been more beneficial as it would eliminate unobserved variables and biases with coefficients. Thus, it indicates whether mobile phones impacted education by looking at the pre-intervention and the post-intervention outcomes. Nevertheless, the outcomes for pooled OLS and differences and differences should be similar, and it still allows comparison between these results and previous literature.

Furthermore, another challenge to consider is the time difference between each model. It could be argued that seventeen months is a short period, and hence the results may not show the full long-term effect of mobile phones on education. On the contrary, the analysis will allow us to see the impact mobile phones had on test scores in a year.

4.2: Initial Analysis

Descriptive statistics for each variable are in Appendix A (Figure 4.1b). There are approximately fifteen thousand pieces of data which account for approximately three thousand students in the sample. However, both maths and writing scores only have approximately twelve thousand scores due to absenteeism and missing data. Alternatively, the percentage of classes attended variable has fewer data because data is only present in months five and seventeen.

Due to a lack of data on the percentage of classes attended, the variable was only included in the second model. Furthermore, the average percentage of classes attended was 66%, highlighting high absenteeism across Niger. As specified earlier, students often do not attend school regularly due to travel costs. The average for this variable supports the hypothesis that students often do not attend school due to these facts. On the contrary, the standard deviation for this variable is 0.39, which shows that the range of percentage of classes attended varies a lot.

The descriptive statistics also show that the average maths score (2.61) is greater than the average writing score (1.93). The following reasons could explain the difference in means:

students observed were more capable with maths scores before the programme's implementation, or the ABC programme affected maths scores more than writing scores. As the baseline scores average for maths is 0.15, and for the writing scores, it is 0.09, it shows that maths scores are higher overall than writing scores. The standard deviations for both scores are relatively large, maths scores (2.20) and writing scores (2.32). As standard deviations are large, the sample means disperse widely across the population mean.

As stated previously, the variable *ABC* is a dummy variable that takes the value of one and zero. The mean of ABC is 0.495. The mean shows an equal allocation of those on the programme and those who were not.

The average age of participants in this study was 36 years of age, with the youngest student being nine years old and the oldest student being 79 years old. However, the standard deviation (12.4) is large, suggesting that the population ages were equally distributed, and the study includes a broad sample of ages.

Chapter 5: Results

5.1: Impact of Mobile Phones on Education

Figure 5.1 and 5.2 discusses the clustered and non-clustered results for the impact on mobile phones on test scores. These models are testing the first research question with the following model:

$$\text{Score} = \beta_0 + \delta_0\text{ABC} + \delta_1\text{young} + \delta_2\text{female} + \delta_3\text{dosso} + \beta_1\text{age} + \beta_2\text{age}^2 + \alpha_0\text{round1}$$
$$+\alpha_1\text{round3} + \alpha_2\text{round4} + \text{u}$$

The hypotheses for this research question are:

$H_0: ABC = 0$ → Mobile phones don't have an effect on test scores.

$H_1: ABC > 0$ → Mobile phones have a positive effect on test scores.

5.1.1: Non-Clustered Scores

Lu (2008) found that introducing mobile phones through phone messaging lessons to a student's education improves vocabulary. Similar to Lu (2008), these findings in Figure 5.1 show that mobile phones positively affect literacy scores because the coefficient for ABC (where students had access to mobile phones) is positive. Students who had access to mobile phones scored approximately 0.0863 marks higher in writing scores than those who did not have mobile phones. Furthermore, the coefficient for the ABC programme is statistically significant at the 10% significance level. Therefore, the results show that there is sufficient evidence to reject the null hypothesis at the 10% significance level. The rejection suggests that the ABC programme does have a positive impact on test scores.

Additionally, Figure 5.1 shows that mobile phones also positively affect maths scores. Students assigned to the ABC programme had access to mobile phones and scored approximately 0.169 marks higher than those who did not have mobile phones. The coefficient is statistically significant at the 1% significance level, as the P-value is less than 0.01. These results also support the rejection of the null hypothesis. Thus, we accept the alternative hypothesis that mobile phones can be used as an instrument to help improve education in Africa.

These findings align with previous literature and theories discussed in Chapters 1.1 and 1.2. The results suggest a correlation between mobile phones and improving educational outcomes in Africa. The results also highlight that having access to a mobile phone overall has a more prominent positive effect on mathematics scores than writing scores. The increase in scores could perhaps be due to students having more access to learning opportunities. For example, a student who had a mobile phone became more familiar with numbers and letters, affecting their scores. Alternatively, another factor that could have caused the increase is that mobile phones perhaps incentivised students to learn. These findings are similar to those of Ford and Batchelor (2007), as these researchers found that mobile phones motivated learners since they enjoyed learning how to use them.

Moreover, the results in Figure 5.1 show the gender disparities in education. Females scored at least one mark less in maths and writing scores than males in Niger. In Sub-Saharan Africa, especially in Niger, girls are disadvantaged when attending school (UNICEF, 2020) mainly due to the high education costs. As a result, many girls in Africa often drop out of school or are discouraged from attending, which affects their educational outcomes. The negative coefficient for females in Figure 5.1 supports the scenario that girls in Niger do not achieve high scores due to being disadvantaged previously. Thus, it shows the importance of finding a policy to encourage female education in Africa.

In both subjects, the coefficient for the rounds increases significantly between round one and round three. Since students are still on a teaching curriculum without mobile phones, results should improve as they learn skills. On the contrary, between round three and round four, for both subjects, the coefficients decrease, suggesting that either the marginal benefits of teaching are not as great or perhaps other factors influenced these scores, such as a more difficult test.

Figure 5.1: *Non-Clustered Impact of Mobile Phones on Test Scores*

Variables	Maths	Write
	(1)	(2)
ABC	0.169 ***	0.0863 *
	(0.0378)	(0.0462)
Young	0.211 ***	0.165 **
	(0.070)	(0.0838)
Female	-1.09 ***	-1.60 ***
	(0.0382)	(0.0478)
Age	0.00112	-0.0127
	(0.00729)	(0.00883)
Age squared	-0.000289 ***	-0.000270 **
	(0.0000921)	(0.000107)
Dosso	0.127 ***	-0.596 ***
	(0.0389)	(0.0491)
Round 1	0.468***	0.876 ***
	(0.051)	(0.061)
Round 2	*Omitted*	*Omitted*
Round 3	1.22 ***	1.266 ***
	(0.0561)	(0.0639)
Round 4	1.20 ***	1.158 ***
	(0.0561)	(0.0680)
Number of observations	8390	8365

Notes: This table is estimating the model:

$$Score = \beta_0 + \delta_0 ABC + \delta_1 young + \delta_2 female + \delta_3 dosso + \beta_1 age + \beta_2 age^2 + \alpha_0 round1 + \alpha_1 round3 + \alpha_2 round4 + u$$

Column 1 presents the results of mobile phones affecting maths scores whereas column 2 presents the results for writing scores. The results include robust standard errors but are not clustered. Robust standard errors are shown in parentheses.

*** = 1% significance level where the P value <0.01

** = 5% significance level where the P value <0.05

* = 10% significance level where the P value <0.1

5.1.2: Clustered Scores

The following figure, Figure 5.2, estimates results using the same model and hypotheses as Figure 5.1. However, this table includes clustered standard errors.

In Figure 5.1, villages are clustered to prevent them from being correlated. Due to panel data, this is a crucial step as it prevents homoscedasticity (explained further in Section 4.1.2) and ensures the coefficients are unbiased. As a result, the coefficients are more precise when clustering the standard errors. Figure 5.2 shows that the standard errors have increased by clustering the villages. An increase in standard errors shows that the sample mean's accuracy has reduced compared to the population mean. Therefore, the distribution of results is more varied. Additionally, the statistical significance for most variables has changed.

For the coefficients of ABC, the process of clustering has affected the significance of the coefficients. In the previous table, the significance for ABC was 1% significance level and 10% significance level for maths and writing retrospectively. Clustered standard errors have made the ABC coefficients statistically insignificant at the 5% significance level. Therefore, the null hypothesis is accepted as there is insufficient evidence to show otherwise. In other words, it highlights that this data does not support the idea that mobile phones affect test scores and that other confounding variables influenced the scores.

On the contrary, the standard error has included fifty-seven clusters for each village in this data. The number of clusters may be too large since the more clusters added to the model, the larger the standard error becomes. The larger the standard error, the less accurate the sample mean is to the population mean. Therefore, implying that the sample does not closely match the population. Additionally, too many clusters widen the confidence intervals meaning that there is a higher chance that the null hypothesis is accepted. Therefore, a large cluster sample could explain the change in the statistical significance of the coefficients.

Figure 5.2: *Clustered Impact of Mobile Phones on Test Scores*

Variables	Maths	Write
	(1)	(2)
ABC	0.169	0.0863
	(0.151)	(0.179)
Young	0.211 **	0.165
	(0.0989)	(0.119)
Female	-1.09 ***	-1.60 ***
	(0.0938)	(0.126)
Age	0.00112	-0.0127
	(0.0142)	(0.197)
Age^2	-0.000289 *	-0.000270
	(0.000167)	(0.000234)
Dosso	0.127	-0.596 ***
	(0.147)	(0.183)
Round 1	0.468***	0.876 ***
	(0.137)	(0.144)
Round 2	*Omitted*	*Omitted*
Round 3	1.22 ***	1.266 ***
	(0.148)	(0.127)
Round 4	1.20 ***	1.158 ***
	(0.113)	(0.112)
Number of observations	8390	8365

Notes: This table is estimating the model:

$$Score = \beta_0 + \delta_0 ABC + \delta_1 young + \delta_2 female + \delta_3 dosso + \beta_1 age + \beta_2 age^2 + \alpha_0 round1 + \alpha_1 round3 + \alpha_2 round4 + u$$

Column 1 presents the results of mobile phones affecting maths scores whereas column 2 presents the results for writing scores. The results include robust standard errors and are clustered by villages. Robust standard errors are shown in parentheses.

*** = 1% significance level where the P value <0.01

** = 5% significance level where the P value <0.05

* = 10% significance level where the P value <0.1

5.2: Short and Long-term Impacts

Figure 5.3 uses robust standard errors to test the research question about the effects of mobile phones in the short and long term. The model is as follows:

$$Score_t = \beta_0 + \delta_0 ABC_t + \delta_1 female_t + \delta_2 dosso_t + \beta_1 age_t + \beta_2 age_t^2 + \beta_3 baseline_t + \beta_4 attendance_t + u_t; \text{ where t} = 5 \text{ months or } 17 \text{ months}$$

The same hypotheses (from Chapter 5.1) are used in this model:

$H_0: ABC = 0$ → Mobile phones don't have an effect on test scores.

$H_1: ABC > 0$ → Mobile phones have a positive effect on test scores.

Figure 5.3: *Short and Long-Term Impacts of Mobile Phones on Education*

Variables	Maths 5 months (1)	Maths 17 months (2)	Writing 5 months (3)	Writing 17 months (4)
ABC	0.276 ***	0.395 ***	0.210 ***	0.155 *
	(0.069)	(0.0680)	(0.080)	(0.090)
Baseline classes scores	0.836 ***	1.62 ***	1.56 ***	1.91 ***
	(0.163)	(0.167)	(0.313)	(0.291)
Female	-0.511 ***	-0.610 ***	-1.00 ***	-1.68 ***
	(0.758)	(0.0719)	(0.0854)	(0.939)
Dosso	0.142 *	0.152 **	-0.843 ***	0.101
	(0.0735)	(0.0700)	(0.0851)	(0.0947)
Age	0.00770	-0.00948	-0.00137	-0.0144
	(0.142)	(0.0126)	(0.0160)	(0.165)
Age squared	-0.000373 **	-0.000257	-0.000331 *	-0.000392 *
	(0.000178)	(0.000162)	(0.000201)	(0.000205)
Percentage of classes attended	1.19 ***	-0.0968	1.14 ***	0.0689
	(0.151)	(0.0807)	(0.174)	(0.105)
Number of observations	2314	2322	2312	2319

Notes: This table is estimating the model:

$$Score_t = \beta_0 + \delta_0 ABC_t + \delta_1 female_t + \delta_2 dosso_t + \beta_1 age_t + \beta_2 age_t^2 + \beta_3 baseline_t + \beta_4 attendance_t + u_t;\ \text{where t = 5 months or 17 months}$$

Column 1 presents the regression results for maths results in 5 months whereas column 2 presents maths results in 17 months. Column 3 presents the writing results in 5 months and column 4 presents the writing results in 17 months. Robust standard errors are shown in parentheses.
*** = 1% significance level where the P value <0.01
** = 5% significance level where the P value <0.05
* = 10% significance level where the P value <0.1

5.2.1: Maths Scores

Figure 5.3 shows that the ABC coefficient increases from 0.276 to 0.395. The increase in coefficient implies that mobile phones had approximately a 0.12 mark difference in maths scores between five months and seventeen months. Additionally, the long-term results show that mobile phones had a more significant effect on test scores than those not on the programme. Students who had access to mobile phones scored an additional 0.395 marks higher than those who did not have mobile phones for seventeen months. However, those who had access to mobile phones only scored 0.276 marks higher than those who did not have a mobile phone for five months.

In addition, both coefficients for the ABC programme are significant at the 1% significance level, supporting the null hypothesis' rejection. Therefore, the alternative hypothesis is correct and that mobile phones affect education.

5.2.2: Writing Scores

On the other hand, the ABC coefficient decreases from 0.210 to 0.155 between month five and month seventeen for the writing results. Since there was a decrease in the coefficient, mobile phones have a reduced marginal effect on writing scores in seventeen months compared to five months. However, despite the reduction in the coefficient, the effects of mobile phones still had a positive effect on writing scores. Students who were a part of the ABC programme had approximately 0.155 higher marks on their tests than students who were part of the regular teaching programme. Therefore, although mobile phones have a greater effect in five months compared to seventeen months, it is proven that mobile phones still have a positive effect on writing scores.

Furthermore, the ABC coefficient's statistical significance for writing scores reduces from 1% in five months to 10% in seventeen months. The reduction in significance level increases the likeliness of accepting the null hypothesis that mobile phones do not affect education. Therefore, although mobile phones have a positive effect on education in seventeen months, there is also a higher probability that this is due to chance.

5.2.3: Comparison

These results are an essential finding in understanding how mobile phones affect education over some time. Furthermore, the results show that mobile phones have a more substantial marginal effect on maths scores. These results imply that mobile phones are more effective on educational outcomes, more specifically maths scores, in the long run. Therefore, mobile phones would be more beneficial to improving educational outcomes in Africa over a long period.

On the contrary, the results for writing scores contradict the previous results. Instead, the results suggest that mobile phones are more effective on writing scores in the short run because the marginal effects of mobile phones on writing scores reduce between five and seventeen months. These results imply that perhaps there is an optimal point between five and seventeen months where mobile phones are most optimal (i.e., they provide the most benefit on scores). Therefore, mobile phones would give a short boost to educational scores, specifically writing scores.

Overall, educational outcomes' actual short-term and long-term effects are still unclear due to the contradictions between the maths and writing scores. However, these results show that mobile phones cause a positive benefit on scores, perhaps due to the reasons suggested in Chapter 1.2.2.

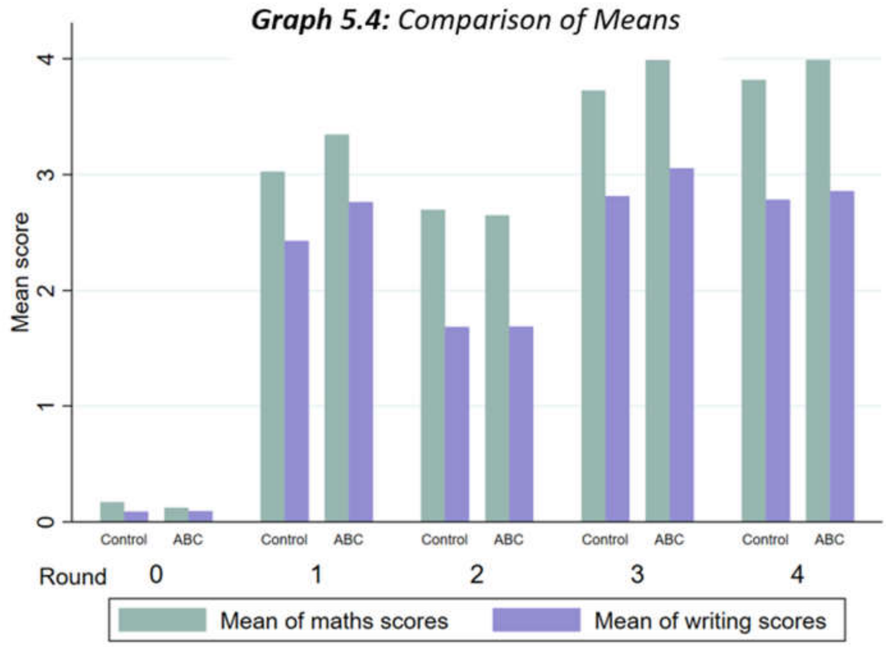
5.2.4: Clustered results

Figure 5a in Appendix B estimates the same model as above but with clustered standard errors. Similarly, in Chapter 5.1.2, the coefficients have remained the same. However, the standard errors have increased, and the statistical significance has changed.

5.3: Comparison of Means

Graph 5.4 shows the magnitude of the average scores for maths and writing in each round. Round 0 represents the average baseline scores for each cohort. Round 1, round 2, round 3, and round 4 represent five months, twelve months, seventeen months, and twenty-four months retrospectively.

Graph 5.4 highlights that the greatest difference in writing scores was in round 1, five months after the programme had started. These results support the previous findings in Chapter 5.2.2 that mobile phones have a more significant impact on writing scores in the short-run compared to the long-run. However, the most remarkable difference in maths scores was in rounds one and three. According to these results, mobile phones have a positive marginal effect on math scores, in the long run, also supporting the findings from Chapter 5.2.1.



An important finding from this graph is the significant increase in the average baseline scores and the average five months test scores. Students' scores increased dramatically regardless of the teaching programme. Students went from being illiterate and not being able to understand numbers to understanding some form of numbers and words. Therefore, it shows the importance of teaching African students these skills, as, within five months, skills for students had improved significantly.

5.4: Comparison with Aker, Ksoll, and Lybbert's (2012) Paper

Despite using the same data from Aker, Ksoll, and Lybbert's (2012) paper, this analysis in this paper followed different methods. In Aker, Ksoll and Lybbert's paper, they conducted a difference-in-difference model to test the effects of mobile phones on learning. However, since there were no individual codes, conducting a difference-in-difference study was not possible. Furthermore, these researchers focused more on the z scores of maths and writing rather than the raw scores. Another key difference is that these results only focused on the 2009 cohort, whereas Aker, Ksoll and Lybbert's paper used both cohorts.

This paper and Aker, Ksoll and Lybbert's paper reported similar results despite the differences in methods. Firstly, both results found a positive correlation between mobile phones and test scores. Moreover, both results conclude that mobile phones had a more significant effect on maths scores than writing.

However, the main difference between the results is the statistical significance of the coefficients. For example, in this paper, ABC became statistically insignificant with clustered standard errors. On the contrary, Aker, Ksoll, and Lybbert found the coefficients for ABC statistically significant at the 5% significance level. The causation of the difference may be due to one of the following reasons. Firstly, the cluster size was too large for the data, causing the rejection region to be too large. Alternatively, it could be due to the difference in control variables, precisely the difference in the dependant variable scores.

Chapter 6: Limitations, Future Research and Conclusion

6.1: Limitations

There are some limitations in the analysis presented in this paper, as in all research. Firstly, the issue with the clustered and non-clustered results in Chapter 5.1.2. When clustering the standard errors by the villages, many coefficients become statistically insignificant, therefore accepting the null hypothesis. Clustered standard errors are correct in this model as it eliminates homogeneity and ensures that the standard errors are concise. The causation of the insignificance issue may be due to the high cluster sample (57 clusters). Thus, more data is needed to ensure accurate results.

Secondly, Graph 5.4 significantly reduces scores for both programmes on round two and round four. In this study, students had no classes for the second half of the year (July to December). Hence, the lack of classes could explain the significant reduction in the results. Therefore, comparing the short- and long-term impacts may be unreliable, and it may not demonstrate the impacts in the long term very well. Furthermore, the long-term impact only measured the seventeen-month period, which could still be considered a short-term policy. Thus, results may vary over a more extended period.

Thirdly, it is difficult to determine what factors caused the increase in test scores for those who had access to mobile phones. The results speculate factors that influenced the additional test scores, such as allowing students to recognise numbers/letters more frequently, incentivising students to learn, and engaging them in learning. However, it is difficult to tell what specific factors affected the results as they only show a correlation. Furthermore, although there was an increase in the results for the students on the ABC programme, other confounding variables may have played a part in increasing these results. For example, the quality of teaching may have changed depending on the programme the students were on. Therefore, it is difficult to make a definitive statement about whether mobile phones affect educational outcomes.

6.2: Future Research

The analysis in this paper studies the effect of mobile phones on education in Niger. As explained in Chapter 3.1, Niger lacks education despite its high public funding. Hence, studying the benefits of mobile phones on education was beneficial as significant impacts on educational outcomes would be shown. These results could be generalised to other countries in Africa with similar education levels. Future research should examine the impact of mobile phones on more developed African countries with higher educational standards. Additional research would then consider whether mobile phones significantly impact high-quality education or low-quality education in Africa.

A deep understanding of mobile phone use in education over many years will be necessary to determine the true long-term effects of mobile phones. Analysis in this paper determines how mobile phones affect education in a year. However, the effects of mobile phones may have a more significant effect or minor effect in five years, or ten years, for example.

In addition, further research should be conducted to determine what factors contribute to the increase in scores. In this paper, many factors were discussed, such as communication benefits, free access to sources, and motivation. However, it is impossible to draw any conclusions from the results in this paper about what benefit is more significant. Perhaps other alternative methods that focus on these factors could be applied to education if these results were found.

6.3: Conclusion

Low-quality education in Africa is due to many barriers to education, such as the extortionate costs, low-quality textbooks and teachers, and limited school infrastructure. In addition, studies have shown that low-quality education costs the economy in the form of human capital. All of these factors point to the necessity of improving education in Africa. Furthermore, mobile phones' relatively low cost and ease of implementation could be a fundamental tool for education reform in Africa.

In general, the findings of this paper add to the existing literature about mobile phones' role in assisting education in Africa. Using pooled OLS methods, the results show that mobile phones positively affect educational outcomes by approximately between 0.09 and 0.2 marks. These results imply the importance of applying mobile phones to aid education in Africa. Furthermore, the results conclude that mobile phones have a more significant effect on maths scores than writing scores. Additionally, the marginal effects of mobile phones on writing scores tend to reduce over a more extended period, whereas for maths scores, the marginal effects increase.

On the contrary, results differed due to clustered standard errors. Using clustered standard errors, the coefficient for ABC is statistically insignificant, resulting in accepting the null hypothesis that mobile phones do not influence educational outcomes. However, the difference in the results may be due to a high cluster sample. Therefore, more data is required to use this cluster sample.

On the other hand, it is vital to consider confounding variables in the analysis for all results. An extra variable may have affected mobile phones and test results. For example, the teaching quality in the ABC programme may have been of a higher quality than the non-ABC programme. A difference in teaching quality may have increased scores for students who had access to mobile phones. Therefore, other factors may have affected scores beyond the influence of mobile phones.

Although the results show that mobile phones should be implemented into Africa's education system, more research needs to be conducted to answer critical questions. For example, are the results from this paper consistent with results over a longer period, such as five years. Additionally, future research needs to conclude what factors linked to mobile phones benefit education the most.

Chapter 7: Bibliography and Appendices

7.1: Bibliography

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7.2: Appendices

Appendix A

The following figures are discussed in Chapter 4.1.

Figure 4.1a: *Testing for Correlation*

	Class Writing Scores	Class Maths Scores
Writing Scores	0.177	
Maths Scores		0.219

Figure 4.1b: *Descriptive Statistics*

Variable	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Math scores	12,015	2.61	2.20	0	7
Writing scores	11,978	1.93	2.32	0	7
ABC programme	15,289	0.50	0.5	0	1
Young	13,819	0.67	0.47	0	1
Female	15,289	0.50	0.50	0	1
Age	14,522	36	12.38	9	79
Age squared	14,522	1449.14	977.23	81	6241
Dosso	15,289	0.54	0.50	0	1
Round	15,289	3	1.41	1	5
Percentage of classes attended	6,975	0.66	0.39	0	1
Average baseline maths scores for each class	15,289	0.15	0.23	0	1.04
Average baseline writing scores for each class	15,289	0.09	0.16	0	0.73

Appendix B

The following figure shows the clustered standard errors for the short and long term impact of mobile phones on education (discussed in Chapter 5.2.4).

***Figure 5a:** Clustered Short and Long-Term Impacts of Mobile Phones on Education*

Variables	Maths 5 months (1)	Maths 17 months (2)	Writing 5 months (3)	Writing 17 months (4)
ABC	0.276	0.395	0.210	0.155
	(0.244)	(0.247)	(0.241)	(0.244)
Baseline class scores	0.836 *	1.62 ***	1.56 **	1.91 **
	(0.442)	(0.484)	(0.771)	(0.724)
Female	-0.511 ***	-0.610 ***	-1.00 ***	-1.68 ***
	(0.132)	(0.128)	(0.149)	(0.188)
Dosso	0.142 *	0.152	-0.843 ***	0.101
	(0.142)	(0.225)	(0.247)	(0.245)
Age	0.00770	-0.00948	-0.00137	-0.0144
	(0.0188)	(0.0192)	(0.0259)	(0.0234)
Age squared	-0.000373	-0.000257	-0.000331 *	-0.000392
	(0.000239)	(0.000228)	(0.000320)	(0.000294)
Percentage of classes attended	1.19 ***	-0.0968	1.14 ***	0.0689
	(0.296)	(0.124)	(0.322)	(0.148)
Number of observations	2314	2322	2312	2319

Notes: This table is estimating the model:

$$Score_t = \beta_0 + \delta_0 ABC_t + \delta_1 female_t + \delta_2 dosso_t + \beta_1 age_t + \beta_2 age_t^2 + \beta_3 baseline_t + \beta_4 attendance_t + u_t;\ \text{where t} = 5 \text{ months or } 17 \text{ months}$$

Column 1 presents the regression results for maths results in 5 months whereas column 2 presents maths results in 17 months. Column 3 presents the writing results in 5 months and column 4 presents the writing results in 17 months. Robust standard errors are shown in parentheses.

*** = 1% significance level where the P value <0.01
** = 5% significance level where the P value <0.05
* = 10% significance level where the P value <0.1