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ARTICLE



The effect of internet services on child education outcomes: evidence from *poa! Internet* in Kenya

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ABSTRACT

In 2016–2018 *poa! Internet*, a private internet service provider, distributed free internet services across schools in Nairobi, Kenya. Using inverse probability weighting (IPW) method, the study finds that the intervention significantly increases students' internet use and training, receipt of information on educational content, and participation in information and communication technologies (ICTs) education programmes. However, the study does not find evidence that internet services increase school attendance. The results suggest that facilitating access to internet services in schools can significantly increase child computer and internet skills and training in developing countries, even if those investments have limited gains on school attendance.

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1. Introduction

Available estimates from various ICT surveys indicate that globally, about 3.9 billion people lack access to the internet. In developed countries, internet penetration rate is over 80%, while this figure is only 40% in developing countries. However, in Africa only 15.4% of households have access to internet, making the region the least connected region in the world. Besides, there are gender and age differences in internet access with males and youth having more access than females and aged persons, respectively (ITU 2017).

Kenya, with a population of over 48.5 million people (based on 2016 estimates), is widely reported as one of the ICT savvy countries in Africa – for example, in 2017, estimates show that about 85% of the population are within third generation (3 G) coverage whilst only 17.8% of individuals and 33.7% of households have access to internet (ITU 2018a, 2018b). In addition, estimates show that Kenya's telecommunication revenues increased from USD 1.32 billion in 2014 to USD 1.65 billion in 2016 (ITU 2018a). Internet services in Kenya similar to other African countries suffer from two main challenges: (1) non-affordability due to the high cost and (2) non-reliability due to limited use of third or fourth generation (3 G or 4 G) networks (for detailed analysis on ICT including internet services refer to a report by Intelcon Research and Consultancy Limited (2016)). For instance, the cost of 500 megabytes (MB) per month of mobile internet connectivity was estimated to constitute about one-third (i.e., 30%) of the median income of working individuals in Kenya in 2017 (ITU 2018a). Furthermore, a study by Kenya National Bureau of Statistics and Communications Authority of Kenya (2016) on enterprises' ICT use in Kenya showed that about 91% of the sampled education

enterprises have internet in their premises whilst 36.4% reported having IT policy which was slightly lower than the national average of 37% for the sampled enterprises.

Interestingly, despite the government launching a broadband strategy from 2013 to 2017 (United Nations Economic Commission for Africa 2017), access to broadband remains low in Kenya. For instance, fixed-broadband subscription per 100 inhabitants was only 0.6 whilst active mobile-broadband subscription per 100 inhabitants was 35.7 (ITU 2018b). About 40.5% of enterprises used mobile broadband whilst the majority (81.3%) relied on fixed broadband for their internet services (Kenya National Bureau of Statistics and Communications Authority of Kenya 2016). Thus, there is the need to accelerate current efforts to achieve the sustainable development goals of ICT access and quality education, particularly on the target of 'universal and affordable internet access' by 2030. This will require, among others, facilitating access to internet services in schools, since internet services are claimed to be important tools for improvement in child education outcomes (World Economic Forum, 2016; Whitaker 2017; United Nations 2019; Tondeur et al. 2015; The Kenyan Ministry of Education 2012; Castellacci and Tveito 2018). The aim of this article is to examine the effects on child education outcomes of *poa!* Internet services, a novel private business model of free distribution of internet services to selected schools in Nairobi, Kenya, through the installation of wireless fidelity (Wi-Fi) routers and free education content.

Several governmental and non-governmental organisations in many developing countries have initiated interventions such as investment in ICTs including internet services, due to its importance in providing students and teachers appropriate teaching and learning materials (information) in addition to its potential contribution to improving child education outcomes. Kenya's Ministry of Education and other stakeholders have long recognised the important role of ICT in improving education outcomes with initiatives such as One Laptop per Child programme and Digital Literacy Programme (Tondeur et al. 2015; Ministry of Education/Republic of Kenya 2012; Kozma and Vota 2014; ITU 2018c). This has contributed to researchers in various fields, including economics and ICT, increasingly interested in understanding the effects of teaching and learning conditions (particularly the use of the internet) during school hours on child education outcomes. Unfortunately, little rigorous evidence exists on the impacts of internet on child education outcomes for Sub-Saharan Africa. However, the findings from most of the studies from Europe, South America and Central America on the impacts of ICTs including internet on child education outcomes are mixed and are also affected by the technologies involved. In Malamud et al. (2019)'s randomised evaluation in Peru, internet access increase computer and internet skills but had no statistically significant effect on academic performance. Similarly, Cristia, Czerwonko, and Garofalo (2010) found that increasing access to computer does not improve school participation and enrolment in Peru. In another study, Malamud and Pop-Eleches (2011) found that access to home computers has mixed impacts in Romania with increase computer and cognitive skills, lower grades and no statistically significant effect on non-cognitive outcomes. Meza-Cordero (2017) evaluated '*The One Laptop per Child (OLPC) initiative*' in Costa Rica and found that the programme increased computer and internet use for academic purposes. On the contrary, the results also showed decrease in time students spent doing homework and playing outside, and no evidence on improvement in school performance. Bet, Cristia, and Ibararán (2014) also found that increase in access to computer improves digital skills but had no impact on test scores in Peru. However, Kho, Lakdawala, and Nakasone (2018) found that internet access increase standardised mathematics test scores at the school level in Peru. Their results also indicated a time lag for the investment in internet access to generate the moderate results on education outcomes.

Using a randomised evaluation, Banerjee et al. (2007) found that 'computer-assisted learning programs focusing on mathematics increased mathematics test scores in India.' Attewell and Battle (1999) found that students using computers at home are associated with higher test scores in mathematics and literacy. However, other studies have found no positive impacts of investment in educational technology on test scores. According to Angrist and Lavy (2002), there is limited evidence (based on short-term effects) that higher investment in education technology (including

internet access) in the US in the 1990s led to improvements in the academic performance of students. Their study also found that while the introduction of computers in schools in Israel increased the use of computer-aided instruction (CAI) by teachers, this did not translate to better education outcomes (i.e., higher test scores). A survey of the literature by Castellacci and Tveito (2018) shows that the internet has generated new opportunities and positive benefits, as well as new risks and negative impacts including other indirect effects on well-being. On the positive side, this includes more efficient use of time, increased access to information on labour market participation, consumption of new products, and better knowledge on health and education. Other researchers, such as Işık and Alkaya (2017) and Choi, Park, and Cha (2017), report on the impact of internet use on mental health and psychosocial problems. On the other hand, Leung (2010) demonstrated that internet connectivity is positively related to information literacy.

Internet access and use must be complemented with the provision of supporting devices (e.g. smartphones, computers, and tablets) and educational content. In other words, internet provision is not a stand-alone intervention; rather it is part of a larger investment in education technology. Therefore, evaluating the effects of internet use on education outcomes is usually addressed as part of a larger framework of assessing the effects of an investment in education technology, including educational content, requisite devices, and internet availability. Lu, Tsai, and Wu (2015), found that the use of ICT-supported courses and multimedia classrooms in primary and middle schools in rural China depends on the availability of an adequate ICT infrastructure.

poa! Internet is a community and in-home wireless (Wi-Fi) internet service provider in Nairobi, Kenya. *poa! Internet* launched its operations in Kibera and its environs in May 2016. As part of its business model, *poa! Internet* provides free connectivity for institutions such as cafes, youth groups, and religious organisations, in return, these institutions hosting a Wi-Fi router. In particular, it has provided free internet services for educational institutions, making it a relevant case study on understanding the link between ICTs (particularly internet adoption and usage) and education. *poa! Internet* intervention also contributes to achieving the Kenyan government's education and ICT objectives, as well as those of the sustainable development goals (SDGs) by improving ICT access in educational institutions. The study finds that internet services increase students' internet skills and training, access to information on educational content, and general ICT skills; however, there is no improvement in school attendance. The study also finds gender-differentiated impacts with substantial benefits for males in most of the outcomes. This result partly confirms biases in resource allocation towards this group previously found in the literature.

The study makes four main contributions to the literature on the effects of internet services. First, Kenya is an interesting case study given its reputation as an ICT hub in sub-Saharan Africa. Second, the study focuses on a unique business model by a private internet service provider of providing free internet services to schools. The schools then serve as hosts of the company's routers for the company to target sales to homes (a potential win-win scenario) in a low-income setting, on which there has been no impact evaluation assessment. Interestingly, similar programmes have been launched in Kenya, such as Kenya Education Network (KENET). To the best of my knowledge no impact evaluation analysis has been conducted on the effects of these programmes on child education outcomes. Third, the study attempts to estimate the effects of the intervention using a quasi-experimental design to address selection bias. Relatively few papers have examined the effects of internet use on child education outcomes in Africa; those that have mainly use descriptive statistics and multiple regression without considering issues related potential selection bias (see, for example, Tondeur et al. 2015). Lastly, the study analyzes the potential pathways connecting internet services to education outcomes (i.e., school attendance) by using both immediate and intermediate indicators. This connection is needed to show how internet services could lead to improved child education outcomes. However, a limitation of the study is the inability to use test scores or observed computer and internet skills, which will represent objective measures rather than the subjective measures based on self-reports. This is an avenue for future research.

The remainder of the paper is as follows: [Section 2](#) presents the background on *poa! Internet*, including its mode of operation. [Section 3](#) describes the materials and methods including estimation strategy and data, while [Section 4](#) presents the results. [Section 5](#) concludes the study.

2. Background on *poa! Internet* in Kenya

poa! Internet – a private investee company received funding from Novastar Ventures as part of Impact Financing Envelope of the European Investment Bank (EIB) – provides low cost and unlimited internet services to individuals, households, and small businesses in relatively poor communities in Kenya. In May 2016, *poa! Internet* started its community-based Wi-Fi services in Kibera, Nairobi – a large informal settlement (slum). *poa! Internet* installs Wi-Fi routers (access points) which make internet accessible for Wi-Fi enabled devices for a particular locality up to a radius of about 250 metres. The cost of their internet services provided is estimated to be lower than alternative internet service providers in Kenya. Therefore, *poa! Internet* addresses existing challenges faced by internet users in Nairobi, Kenya, such as reliance on high-cost and limited mobile internet data services provided by telecommunication companies. *poa! Internet* aims that by providing affordable, reliable, unlimited internet services and free content, customers will be able to access information in order to improve their wellbeing.

In 2016, *poa! Internet* began providing free and unlimited internet access to several schools in Kibera. The schools serve as ‘social hosts’ for *poa! Internet*’s routers: a *poa! Internet* router is placed on the roof of the schools and is then used to provide wireless internet services to paying customers in the surrounding communities/localities. The selected schools were provided with free online content during the initial stages of the installation of the routers. *poa! Internet* planned expansion to other parts of the country and was considering providing similar internet services to other educational institutions in Kiambu County.

As of May 2018, 23 educational institutions received free and unlimited internet access through the installed Wi-Fi routers. However, this study uses data from seven public and private schools in Nairobi County that have been working with *poa! Internet* since the inception of the intervention in May–June 2016. In addition, 13 private and public non-intervention schools in Kiambu and Nairobi Counties – potential beneficiaries of the intervention in the future – were selected to serve as the comparison group. This study examines whether providing free and unlimited internet access to schools in Nairobi has changed the use of related ICT services, leading to higher ICT use and improved education outcomes among students.

3. Materials and methods

3.1 Estimation strategy

The study employs a quasi-experimental cluster design, where students in selected intervention schools (the ‘treatment’ group) and non-intervention schools (the ‘comparison’ group) within intervention Counties were interviewed. The study is, in essence, a quasi-experimental study since the treatment (or intervention) was not randomly assigned to the participating schools in Kenya (refer to White and Raitzer 2017 for details on impact evaluation). Specifically, the study is based on cross-sectional (i.e. non-experimental) data, where outcome measures of school children in intervention schools (i.e., those with *poa! Internet*) are compared to their counterparts in non-intervention schools (comparison schools). By providing schools with free and unlimited internet, intervention schools will be able to readily access information for academic activities during school hours (refer to Online Appendix Table A1 for details of the *poa! Internet* intervention in schools in Kenya). As a result, school children in the intervention schools will have more opportunities for using the internet for educational purposes during school hours.

Specifically, the provision of internet services by *poa! Internet* is expected to increase internet use in the selected schools (as compared to schools that do not have *poa! Internet*), and the study uses this exogenous variation in levels of internet access to identify its effects on students. The main question is whether students with free and unlimited internet provision have improved education outcomes, including internet skills and knowledge (such as navigation skills, and exposure to online teaching and learning content). The basic empirical specification for estimating the effects of internet services on education outcomes is as follows:

$$E_{ij} = \beta_0 + \beta_1 P_j + \beta_2 X_i^C + \beta_3 X_i^{HH} + \beta_4 X_j^S + \varepsilon_{ij}$$

where E_{ij} denotes education outcomes of child i in school j , and P_j is a dummy variable that denotes *poa! Internet* in school j . X_i^C are student-specific indicators (age, gender, academic performance, etc.), X_i^{HH} are household-level characteristics (location of household, access to ICT, etc.), X_j^S are school-specific characteristics (age and gender of school respondent, etc.) and ε_{ij} is the error term. Robust standard errors are reported. The parameter of interest is β_1 : the effect of *poa! Internet* at the school level on child education outcomes. To address the problem of selection bias, the results are estimated using inverse probability weighting (IPW), which is used to estimate treatment effects from observational data (see Cattaneo 2010; Boleman 2020). As a robustness check for the validity of the estimates, the study also uses propensity score matching (PSM).

3.2 Sampling design

The study uses multistage sampling techniques. The list of 20 educational institutions forming the initial sample frame was provided by *poa! Internet*. The list included both intervention and non-intervention schools. The non-intervention schools as earlier indicated in section 2 are those that *poa! Internet* planned to provide internet services to in the future (i.e. those in the pipeline for the intervention). Therefore, the selected schools for the study could be assumed to have met the selection criteria by *poa! Internet*. In addition, these schools were selected because they had already established a collaboration with *poa! Internet*, which made it easier to organise the structured interviews. The selected educational institutions included both primary and secondary schools. A total of 18 primary and secondary schools were selected for the data collection. For specific case studies, two educational institutions – one special-needs school (i.e. a primary school for students with a disability) and one vocational centre– were selected; making a total of 20 schools selected for the study. In the selected primary schools, students from standard six to eight were targeted for interviews, while in the secondary schools the study targeted all the students in form one to four. In the primary schools, it was decided that students below standard six were too young to take part in the survey.

In each school a near equal sample of boys and girls were randomly selected for the structured interviews through a simple ballot. Students were asked to pick pieces of paper with *yes* or *no* responses written on them. Students who picked *no* did not partake in the structured interviews and vice versa. The same sampling strategy was employed for the special-needs school and the vocational centre. Finally, in each school, 20 students at the various grades were selected for the structured interviews—making a total of 400 students for the data collection.

3.3 Data

The study collected data from students and schools at three geographical locations in Kenya (Kibera, Kiambu, and Kawangware) on school attendance, access to ICTs including internet services, among others. The data allow comparison of outcomes across students who are potentially exposed to different internet services while in school.

3.3.1 Administrative data

Administrative data were collected from *poa! Internet* on the installation of internet services in the schools. The data included a list of schools and their characteristics, which served as the sample frame for the study.

3.3.2. School data

School-based surveys were conducted in May–June 2018. Data were collected by field enumerators using pretested survey instruments. Information on access to and use of internet services, as well as other school characteristics, were collected. In each selected school, interviews were conducted with the vice-principal and/or ICT manager. During a field visit to the study area in February and March 2018, it was noted that the vice-principals are primarily in-charge of dealing with institutions or stakeholders providing educational support to the schools. The ICT managers are responsible for computer laboratories and internet services at the schools. The study relies on self-reported measures of internet-related activities at the school level.

Data collection was undertaken in 20 educational institutions in Nairobi and Kiambu Counties. During the school survey, 19 schools were successfully enumerated, with one school refusing to be interviewed. The school authorities claimed to be too busy with other activities, and the interview could not be rescheduled. This missing data issue is addressed during the treatment effect analysis by imputing the data (replacing with the means) from the remaining 19 schools that completed the interviews (refer to [Section 4](#)). Seven of the educational institutions had *poa! Internet* (intervention schools), while the remaining 13 were non-intervention (comparison) schools. In terms of the type of school, 12 were private schools, and eight were public schools (refer to Online Appendix Table A2 for details on sample frames and observational counts for the school and student surveys).

3.3.3 Demographic data

Similar to the school data, information on student education outcomes and household characteristics was collected using structured interviews in May–June 2018. The structured interviews were conducted in both Swahili and English, depending on the language the student was most comfortable with. The responses were recorded in English on the paper questionnaires administered to the respondents. While school authorities were given advanced notice and permission was sought for the data collection exercise, the survey instruments were not shared with them beforehand to maintain the validity or authenticity of the survey responses (i.e. so as not to pre-empt the responses).

In each school, a random sample of 20 students – with a similar proportion of males and females – was selected through a simple balloting exercise. The sampling also took into consideration student's grades. During the student survey, 404 students were enumerated, which was slightly above the target of 400. Of these, 183 were boys, and 221 were girls.

In addition to data on internet knowledge and skills at school, information on access to ICT services at home was collected in order to accurately attribute the effects of *poa! Internet*. Additional information on socioeconomic characteristics was also collected, which was used as covariates during the treatment effect estimations. The study used internationally standardised questions on internet activities, including those from ITU questionnaires and other published studies (for example, van Deursen, Helsper, and Eynon 2015; van Deursen et al. 2014). The survey instruments also included a series of actual and hypothetical questions on the dissemination and types of educational content. For estimation purposes, demographic information is matched with each child's school-level data. Therefore, the final datasets combine both school and student data for the treatment effect estimations.

4. Empirical results

4.1 *poa! Internet* operations in Kenya

4.1.1 Enrolment in the *poa! Internet* initiative

The targeted schools for the *poa! Internet* intervention were those in poor communities with limited access to and use of the internet during school hours. As earlier indicated in [Section 2](#), targeted schools were selected by *poa! Internet* as part of their new business model: providing free and unlimited internet access to schools, which, in turn, serves as hosts for their Wi-Fi routers. Therefore, the selection process which was at the discretion of *poa! Internet* takes into consideration the following factors: proximity to intervention's location; interactions with school heads; willingness to host Wi-Fi routers; and limited access to internet for educational purposes. A qualitative analysis based on key informant interviews during a field trip to Nairobi in February and March 2018 presents evidence of the selection process. A key informant at Kibera Girls Soccer Academy noted:

The school got *poa! Internet* through an interaction between the school owner (Mr. Abdul Kassim) and *poa! Internet*'s staff (Mr. Dirk-Jan Koeman). *poa! Internet* wanted a location for their Wi-Fi routers. Through this contact, *poa! Internet* started installing its routers for the school and other customers. *poa! Internet* started by giving the school 20 gigabytes (GB) data for a month. Currently, there is unlimited data bundle.

The selection process was partly confirmed by owner of a business centre in Kibera. The owner noted:

The center is a computer shop rendering services to the public including photocopy, internet browsing, among others. The center has eight computers connected to internet. Currently, there are about 15 students (mainly youth from Kibera) being trained at the center. The center has been using *poa! Internet* since May 2016. The center was approached by *poa! Internet* to serve as one of its social hosts.

4.1.2 Benefits of *poa! Internet* intervention

Qualitative analysis of the benefits of *poa! Internet* in the selected educational institutions is also presented under this section. An in-depth interview with the *Vice-Principal, Olympic High School, Nairobi* is presented as follows:

The school, before receiving *poa! Internet*, used to rely on a modem from other internet service providers. *poa! Internet* is used to undertake research in all subjects and also project work. *poa! Internet* also provided free consultancy services on how to install anti-virus and updating software for the computer labs. Currently, 18 out of the 26 computers are fully operational. Students use internet in order to get high scores/marks during examinations both at school and national levels.

Another in-depth interview with a Key Informant, Kibera Girls Soccer Academy, Nairobi is as follows:

Currently, *poa! Internet* provides unlimited data bundle. Moving to unlimited data has led to behavioral change, particularly on how the internet is used for teaching and learning. The school uses the internet for several teaching and learning activities. For instance, it is a hosting center for an online course undertaken in Kenya. The internet is used for graphic design. In the evening, the internet is used to access revision questions for KCC [national exams]. The internet is used to stream online videos on how to learn photography. There are plans to use the internet to access the online syllabus developed by a local company.

4.2 Knowledge and usage of *poa! Internet*

[Table 1](#), Panel A, presents results on the level of awareness of *poa! Internet* among students in the educational institutions. Students in non-intervention schools were included due to their potential use of *poa! Internet* services through other sources including cafés, their homes, among others. This was relevant in understanding the general operations of *poa! Internet* outside of intervention schools. The majority of the students (55.2%) had heard of *poa! Internet*. The result is higher for students in the intervention schools (72.9%) than students in the non-intervention schools (45.4%).

Table 1. Knowledge and usage of *poa! Internet*.

Items	Full sample		Intervention schools		Non-intervention schools	
Panel A: Knowledge of <i>poa! Internet</i>						
Response	Frequency	Percent	Frequency	Percent	Frequency	Percent
Yes	223	55.20	105	72.92	118	45.38
No	181	44.80	39	27.08	142	54.62
Total	404	100.00	144	100.00	260	100.00
Panel B: Sources of Knowledge of <i>poa! Internet</i>						
Family or friends	64	28.70	30	28.57	34	28.81
Neighbour	32	14.35	19	18.10	13	11.02
Brochure or print advert	64	28.70	32	30.48	32	27.12
TV or radio	56	25.11	29	27.62	27	22.88
School teacher	26	11.66	21	20.00	5	4.24
<i>poa!</i> staff/agent	23	10.31	12	11.43	11	9.32
Other	50	22.42	23	21.90	27	22.88
Panel C: Knowledge of <i>poa! Internet</i> in schools						
Yes	54	24.22	43	40.95	11	9.32
No	169	75.78	62	59.05	107	90.68
Total	223	100.00	105	100.00	118	100.00
Panel D: Had used <i>poa! Internet</i>						
Yes	58	26.01	43	40.95	15	12.71
No	165	73.99	62	59.05	103	87.29
Total	223	100.00	105	100.00	118	100.00

Per cent of cases are reported for sources of knowledge of *poa! Internet* as this indicator has multiple responses.

This is not surprising as students in intervention schools are likely to have noticed signals of *poa! Internet* on their computers and other ICT devices.

Table 1, Panel B, presents the sources of knowledge of *poa! Internet* among the students. Family and friends, and brochures or printed adverts are the main sources of knowledge (both at 28.7%), followed by TV or radio (25.1%), and others including road shows (22.4%). The least common source of information was through *poa! Internet* staff (10.3%). The results are quite similar across students in both intervention and non-intervention schools. For instance, brochures or printed adverts are the main sources of information on *poa! Internet* for students in both intervention and non-intervention schools. Informal sources, such as family and friends, are also important in the dissemination of information about *poa! Internet* in both intervention and non-intervention schools.

Table 1, Panel C, shows that about 24.2% of the 223 students who have heard of *poa! Internet* were aware of its presence in their schools. In the intervention schools, about 41% of students reported that they were aware that *poa! Internet* had been installed in their schools, while 9.3% of the students in non-intervention schools indicated likewise. Those in the non-intervention schools may have observed signals of *poa! Internet* on their ICT devices as a result of the signal from nearby sources, including private users or from other schools. For instance, Olympic Primary School, Kibera, a comparison school could pick up the signal from the nearby Olympic High School, Kibera (intervention school), leading students to think that their school was connected to *poa! Internet*. The limited awareness of students in intervention schools could be due to the lack of outreach or dissemination of information about the presence of *poa! Internet* in their schools. This requires further action by *poa! Internet* and school authorities, to inform students of the source of internet services in their schools.

According to Table 1, Panel D, 223 students (26%) who have heard of *poa! Internet* had used the service. In the intervention schools, about 41 percent of the students had used *poa! Internet*, while in the non-intervention schools, only 12.7 percent had used it. The reported usage among students in comparison schools shows the possibility of contamination of the treatment assignment, and therefore the estimated treatment effects are in the lower bound.

4.3 Descriptive statistics

The summary results are presented separately for students in the treatment and comparison schools (Table 2). The average number of family members is five. Over two-third of the students reside in Nairobi County. Academic performance is moderately high, with about 55% of the students reporting their school performance to be either excellent or above average. Most of the students (54%) live with both their father and mother in the same house. The majority (55%) of the students are female. Average daily school expenses are about 26 Kenyan Shillings (KSH). The survey also shows that, on average, it takes the students about 20 minutes to travel from their homes to the schools (results on average outcomes are available upon request).

In general, the students in the treatment and comparison groups differ for most of the covariates (Table 2). About 35.6% of the students are in the treatment schools, while the majority are in the comparison schools. As expected, the students in the treatment schools performed better for most of the indicators on access to information, ICT and internet skills and training than their counterparts in the non-intervention schools. On the contrary, as can be seen in Table 2, students in the comparison schools were better off in terms of household access to ICT and self-reported academic performance. However, the differences in the socio-economic indicators between students in the treatment and comparison groups have the potential to bias the estimated treatment effects, therefore justifying the choice of IPW and PSM methods. The study includes several controls to limit this potential source of bias.

4.4. Quasi-experimental results

The study uses the IPW method to estimate the effects of *poa! Internet* on child education outcomes, controlling for student and school characteristics. Average treatment effects (ATE), which is the mean differences of the outcome measures between the treatment students and that of the comparison students are estimated. We rely on the Stata's *tebalance summarise* and *tebalance override* post-estimation commands to report the diagnostic statistics to verify the covariate balance for the estimates. The results (available upon request) show that we cannot reject the null hypothesis that the IPW model balanced the 14 covariates included in the regression specifications (see also StataCorp 2015; Boleman 2020 for additional information on diagnostics statistics for IPW). For ease of reference, the results have been structured into four categories: internet use and training; school attendance; access to information for educational purposes; and general ICT-related skills and knowledge.

4.4.1. Effects on internet use and training

Table 3, Panel A, Column 1, shows that *poa! Internet* improves internet use among students in the intervention schools by 29 percentage points. In Panel A, Column 1, the number of students receiving internet training during school hours is 41.1 percentage points higher for those in intervention schools. Similarly, students in the intervention schools are 13.2 percentage points more likely to have social media account than their counterparts in the non-intervention schools. However, it is important to acknowledge the potential adverse effect of owning social media account at a tender age due to privacy issues, cyberbullying, among others. This requires regulation by internet providers in addition to supervision by guardians or adults. The results are consistent with previous studies (Malamud et al. 2019; Cristia, Czerwonko, and Garofalo 2010; Malamud and Pop-Eleches 2011; Meza-Cordero 2017; Bet, Cristia, and Ibarrarán 2014) showing that increase in access to ICT increases digital skills.

The study finds gender differentiated effects on internet use and training. For instance, in Table 3, Panel A, Columns 2 and 3, male and female students in the intervention schools have higher internet use compared to their male and female counterparts in the non-intervention schools, respectively. Male students in the intervention schools are 36 percentage points more likely to report on internet use compared to their male counterparts in non-intervention schools. Similarly, male students in

Table 2. Summary statistics.

Variable	Treatment students	Comparison students	Treatment – Comparison		Observations
	Mean (SD)	Mean (SD)	(SE)	(SE)	
<i>Household access to ICT</i>					
Household has a radio	0.708 (0.456)	0.796 (0.404)	-0.088 (0.044)**		404
Household has a television	0.757 (0.430)	0.888 (0.315)	-0.132 (0.037)***		404
Household has a mobile telephone	0.951 (0.216)	0.985 (0.123)	-0.033 (0.017)**		404
Household has a computer	0.201 (0.402)	0.373 (0.485)	-0.172 (0.047)***		404
Household has internet	0.549 (0.499)	0.600 (0.491)	-0.051 (0.051)		404
<i>Student characteristics</i>					
Student is a male	0.375 (0.486)	0.496 (0.501)	-0.121 (0.051)**		404
Age of student	16.563 (3.802)	11.891 (2.011)	4.671(0.290)***		402
Student self-reported academic performance is excellent or above average	0.444 (0.499)	0.608 (0.489)	-0.163 (0.051)***		404
Average daily school expenses (Kenya Shillings)	44.206 (51.424)	15.366 (17.426)	28.840 (3.542)***		395
Minutes taken from home to school	24.014 (15.559)	18.542 (11.824)	5.472 (1.384)***		402
Student resides in Nairobi County	1.000 (0.000)	0.535 (0.500)	0.465 (0.042)***		403
Number of years in the school	2.923 (2.729)	3.622 (2.477)	-0.699 (0.268)***		397
Student stays with both mother and father in the same house	0.448 (0.499)	0.589 (0.493)	-0.142 (0.052)***		401
Number of household members	5.222 (2.967)	4.829 (1.729)	0.393 (0.234)*		402
<i>Internet skills</i>					
Internet use in the past three months	0.688 (0.465)	0.442 (0.498)	0.245 (0.051)***		404
Number of internet activities in the last three months	3.455 (2.067)	2.191 (1.290)	1.263 (0.232)***		214
Internet knowledge is high (if percentile 50–100 of internet activities in the last three months)	0.879 (0.328)	0.670 (0.472)	0.209 (0.056)***		214
Student uses internet daily	0.242 (0.431)	0.130 (0.338)	0.112 (0.053)**		214
Student has received training on internet use during school hours	0.361 (0.482)	0.131 (0.338)	0.230 (0.041)***		404
Student has a social media account	0.451 (0.499)	0.127 (0.334)	0.324 (0.042)***		404
Number of years of internet use	2.589 (1.840)	1.997 (1.403)	0.592 (0.223)		213
<i>School attendance</i>					
Student has been absent from school during the past academic term	0.368 (0.484)	0.354 (0.479)	0.014 (0.050)		404
Student has been absent from school during the current academic term	0.285 (0.453)	0.242 (0.429)	0.042 (0.045)		404
<i>Access to information</i>					
Student has used internet for educational purposes	0.909 (0.289)	0.800 (0.402)	0.109 (0.049)**		214
Number of educational purposes student has used internet for	1.411 (0.701)	1.315 (0.645)	0.096 (0.100)		182
Internet use for educational purposes is high (1 if percentile 50–100 of number of educational purposes)	0.300 (0.461)	0.239 (0.429)	0.061 (0.066)		182
Student has received online educational content	0.403 (0.492)	0.185 (0.389)	0.218 (0.045)***		404
Student would like to receive online educational content	0.972 (0.165)	0.954 (0.210)	0.018 (0.020)		404
<i>General ICT-related skills and knowledge</i>					
Student has used computer in the last three months	0.694 (0.462)	0.462 (0.499)	0.233 (0.051)***		404
Number of computer-related activities in the past three months	2.390 (1.853)	1.358 (0.951)	1.032 (0.194)		220
Computer knowledge is high (if 50–100 percentile of computer-related activities)	0.550 (0.500)	0.225 (0.419)	0.325 (0.062)***		220
Student has participated in ICT education programme	0.688 (0.465)	0.477 (0.500)	0.211 (0.051)***		404
Student is either very satisfied or satisfied with current ICT use in school	0.538 (0.500)	0.436 (0.497)	0.103 (0.052)**		400

SD represents a standard deviation. SE indicates standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The data is unweighted. Summary statistics of each variable will be affected by missing data.

intervention schools are 39.9 percentage points more likely to report internet training during school hours than their male counterparts in non-intervention schools. A similar result is obtained when a comparison is made between female students in intervention schools to their female counterparts in non-intervention schools. Lastly, male students in the intervention schools are 30.3 percentage points more likely to own social media accounts than their counterparts in the non-intervention schools. No similar positive effect is found when a comparison is made between female students in the intervention to their counterparts in non-intervention schools.

4.4.2. Effects on school attendance

As can be seen in Table 3, the study found no statistically significant additional effect of uptake and use of *poa! Internet* on school attendance (Table 3, Panel B, Columns 1). In Table 3, Panel B, Columns 2 and 3, the study finds no gendered treatment effect on school attendance. On the broader study on ICT and education outcomes, the findings on school attendance are contrary to those of Banerjee et al. (2007) and Kho, Lakdawala, and Nakasone (2018) who found that investment in ICT infrastructure increases education outcomes; but are in line with previous studies (Angrist and Lavy 2002; Malamud et al. 2019; Cristia, Czerwonko, and Garofalo 2010; Malamud and Pop-Eleches 2011; Meza-Cordero 2017; Bet, Cristia, and Ibararán 2014) that found that investment in ICT infrastructure has limited impacts on education outcomes.

4.4.3. Effects on access to information for educational purposes

The study estimates the effects of *poa! Internet* on access to information for educational purposes and the results are shown in Table 3, Panel C. The study found that *poa! Internet* increases students' use of educational content during school hours. The results show that treatment students are 14.3 percentage points more likely than their counterparts in non-intervention schools to respond in the affirmative of receiving educational content. In addition, students in treatment schools aspire to receive more educational content as part of internet use during school hours (result not significant at the traditional confidence interval but closer to 10%).

In addition, in Table 3, Panel C, Column 2, male students in intervention schools are 30.8 percentage points more likely to report receiving educational content. Similarly, male students are more likely to report of aspiring to receive educational content than their male counterparts in non-intervention schools.

4.4.4. Effects on general ICT-related skills and knowledge

The study explored the effects of *poa! Internet* on general ICT skills and knowledge, and the results are presented in Table 3, Panel D. The study finds that students in the intervention schools are 25.2 percentage points more likely to report participating in an ICT education programmes. Lastly, uptake and use of *poa! Internet* does improve satisfaction among students on the current use of ICT in schools (Panel D, Column 1). These results are in tandem with previous studies (Schofield and Davidson 2003; Malamud et al. 2019) that internet use generates both direct and indirect effects in the United States (US) and Peru. For instance, Schofield and Davidson (2003)'s study found that internet use in schools increased student autonomy and relationship with their teachers.

Finally, in Table 3, Panel D, Columns 2 and 3, the study finds gendered treatment effects, with male students in the intervention schools are more likely to report participating in ICT education programmes, computer use and satisfaction with current use of ICT in schools than their male counterparts in non-intervention schools (Panel D, Columns 2 and 3). Besides, female students in intervention schools are more likely to report that they have participated in ICT education programmes than their female counterparts in non-intervention schools.

Table 3. Effects on child education outcomes.

Dependent variable:	Full sample (1)	Males (2)	Females (3)
<i>Panel A: Internet Use and Training</i>			
Internet use	0.290*** (0.068)	0.360*** (0.082)	0.429** (0.182)
Internet training	0.411*** (0.090)	0.399*** (0.094)	0.693*** (0.236)
Student has social media account	0.132** (0.064)	0.303*** (0.096)	0.016 (0.101)
<i>Panel B: School Attendance</i>			
Student absent from school during the past academic term	-0.090 (0.067)	-0.082 (0.097)	-0.169 (0.134)
Student absent from school during the current academic term	0.118 (0.115)	-0.003 (0.078)	0.429 (0.319)
<i>Panel C: Access to Information for Educational Purposes</i>			
Student has received educational content	0.143* (0.079)	0.308*** (0.105)	0.057 (0.129)
Student would like to receive educational content	0.022+ (0.015)	0.058* (0.031)	0.008 (0.017)
<i>Panel D: General ICT-related Skills and Knowledge</i>			
Student has used computer in the last three months	0.057 (0.096)	0.221** (0.087)	-0.088 (0.234)
Student has participated in ICT education programme	0.252*** (0.070)	0.216*** (0.072)	0.380** (0.174)
Student is either very satisfied or satisfied with current ICT use in school	0.201** (0.083)	0.229** (0.096)	0.250 (0.224)
Observations	369	138	195

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, + < 0.15 . Robust standard errors reported in parenthesis. Number of observations differs due to correction for the violation of overlap assumption for each model using Stata's *osample* command. Student controls include: student is a male, student's age, student's self-reported academic performance is excellent or above average, minutes student take from home to reach school, student stays with both mother and father in the same dwelling, number of years the student has spent in the school, county of residence is Nairobi County, household size, household has a television, household has a mobile telephone, and household has an internet at home. School controls include: school has a library, type of educational institution is a primary school, and age of respondent for school survey. Missing data for one of the schools are replaced with averages for the remaining 19 educational institutions.

4.5. Robustness check

Sensitivity analyses apply the PSM with nearest neighbour of four (NN = 4) to check the stability of the estimated results for the IPW method. The study uses a probit regression for the treatment assignment equation and reports independent and identically distributed Abadie-Imbens standard errors. The same controls as in the IPW method were included in the PSM method. As expected 'the matched sample results indicate that matching on the estimated propensity score balanced the 14 covariates' based on Stata's *tebalance summarise* command (see StataCorp 2015). As can be seen in Online Appendix Table A3, the regression results from the IPW method do not qualitatively differ from the estimates from the PSM method.

5. Conclusion

The use of internet services in educational institutions has become more important due to the novel coronavirus (COVID-19) pandemic in the late 2019 leading to the global close down of educational institutions. The COVID-19 pandemic has shown the need for the transformation of digital space of educational institutions, particularly the use of e-learning options in Kenya and other developing countries. The study presents evidence on the potential effects of investing in school internet services in poor communities in a developing country setting. This study reports results on the

effect of uptake and use of *poa! Internet* on child education outcomes in Nairobi and Kiambu Counties, Kenya. The study employed inverse probability weighting (IPW) method complemented with propensity score matching (PSM) to address potential selection bias due to the non-random assignment of schools to the internet services. The estimation strategies compared the outcome measures of students in intervention schools with their counterparts in non-intervention schools. However, using observational data in the absence of pre-intervention data limits the ability of the study to make causal inferences about the impacts of the internet services. Despite these limitations, the results provide useful lessons for researchers and policymakers for the investment in ICT in educational institutions in developing countries.

The main conclusion derived from the results is that the uptake and use of *poa! Internet* has had mixed effects. While the study finds positive effects on students in intervention schools on primary outcomes such as internet skills and training, there are limited effects on intermediate outcomes (for instance, access to information), and no effects on final outcomes (e.g., school attendance). In addition, the study finds some effects on general ICT skills and knowledge. The study also finds gender-differentiated effects on some of the outcome measures, with male students experiencing large improvements. In some of the outcome measures, the effects are negligible. This is not surprising as the treatment effect estimations rely on cross-sectional data (i.e., observational data).

On the whole, *poa! Internet* has some positive effects on short-term and intermediate outcomes such as internet skills and access to information, which makes a good case for expansion to other educational institutions. Besides, other internet service providers can adapt their business model, to provide free and unlimited internet access to educational institutions in poor communities in Kenya and other developing countries. However, there are underlying challenges with the ICT infrastructure in schools that hinder the optimal benefits of the internet services. Areas that require urgent attention include the need to supply appropriate hardware (for example, computers, tablets, smart phones) to access the internet and also the provision of the requisite training on internet use for educational purposes. The latter is particularly important because internet use could generate other negative externalities, and students have to be taught how to make the best use of it for their educational needs. The results suggest that policies and projects aimed at promoting use of internet services in schools can contribute to improvement in some aspects of child education outcomes, including computer and internet skills and training in developing countries.

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