Impact of mobile phones on HIV public stigma: a cross-sectional and pseudo-panel analysis from Ghana

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ABSTRACT

Objective HIV-related stigma still remains a major barrier to testing and a significant burden for people living with HIV (PLWH) in sub-Saharan Africa. This paper investigates how mobile phone ownership can influence HIV-related stigma.

Design This is an observational study using both cross-sectional and pseudo-panel data. Analysis is conducted at both community and individual levels.

Setting The analysis is run for the country of Ghana using data from 2008 and 2014.

Participants Individual-level and household-level data were obtained from Ghana’s Demographic and Health Survey.

Primary and secondary outcome measures The analysis measures the impact of mobile phone ownership on prejudice against people with HIV. Secondary outcomes are knowledge of HIV, which is included as a mediating element.

Results Community-level analysis finds that a 10% increase in the share of mobile phone owners reduces the prevalence of discriminatory attitudes towards PLWH/AIDS by up to 3%. Results are consistent at the individual level. Additionally, mobile phone-enabled HIV knowledge is found to be about 26% of the effect of mobile phones on public stigma.

Conclusions These findings shed light on the role played by access to mobile technology on HIV-related stigma and discrimination and can support the development of future awareness-raising and health communication campaigns in Ghana and other West African countries.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study represents the first observational study on mobile phones and HIV stigma in Ghana.
⇒ The use of pseudo-panel analysis and instrumental variable methods allows estimation of causal effects.
⇒ While the results are consistent and robust, the availability of longitudinal data would have benefited the analysis.
⇒ Future studies could complement these findings with qualitative evidence.

INTRODUCTION

Rates of HIV-related deaths and infections have been steadily declining in sub-Saharan African countries in the past decades. International and national campaigns ensured that more people than ever are aware of their HIV status and can access the necessary services.1 However, HIV-related prejudice and stigma remain a major barrier to testing and a significant burden for people living with HIV (PLWH).2-4 Different means of communication, including the almost ubiquitous mobile phone, have been used to raise awareness and reduce discrimination.3 Mobile phones greatly facilitate social contact and have been found to be powerful awareness-raising and health communication tools, which makes them cost-efficient devices to spread knowledge on HIV/AIDS.5-8

Mobile phone penetration in Sub-Saharan Africa has grown exponentially, in some instances even outpacing high-income countries. South Africa, Kenya and Nigeria have become regional hubs, attracting foreign and national investments to expand mobile phone networks. However, mobile phone expansion was not limited to these large hubs, and smaller countries, like Botswana or Mali, were able to match the development of more populated or richer countries (The World Bank Group data on mobile cellular subscriptions per 100 people, accessible via https://data.worldbank.org/indicator/IT.SETS.P2?locations=GH&display=graph-%3E). However, none of these expansions has matched that of Ghana’s mobile network in the recent past. Ghana’s past decade has been characterised by an impressive increase in the number of mobile phone subscriptions. Since 2013, there are more mobile subscriptions in the country than there are people. This has been facilitated by an open and competitive market for mobile providers (there are currently six companies providing mobile services in Ghana, a number that locates the country in the top quartile of sub-Saharan African countries (data from OpenCellid: https://www.opencellid.org/#zoom=16&lat=...
networks of economic development by creating knowledge-sharing networks among those who have access to them. Recent research has been investigating the role of mobile phones in public health and found them to be powerful awareness-raising tools and facilitators of individuals’ communication with health workers and other patients. To harness mobile technology potential in this area, Ghana’s administration is working to expand mobile phone functions to the health sector. It started the Mobile Technology for Community Health programme in 2009, which uses mobile phone technology to improve health outcomes for mothers and their newborns in rural areas and, more recently, it has allowed subscription to the national health insurance system through mobile phones (see Ghana National Health Insurance Scheme at http://www.nhis.gov.gh/). The aim of this study is to identify the effect of mobile phone ownership on prejudice against PLWH and HIV disclosure concerns in Ghana. Using nationally representative repeated cross-sectional data, the paper establishes a link between access to broader mobile phones and lower HIV-related public stigma at both community and individual levels. Our main analysis, conducted at community level, is strengthened by the use of instrumental variable (IV) analysis and a pseudo-panel design. We also contribute to the identification of effect mechanisms by identifying in HIV knowledge a relevant mediating factor of the effect of mobile phones on HIV stigma. This paper is one of the first studies on the role of mobile phones on HIV stigma in sub-Saharan Africa and the first to be conducted for Ghana. Its findings add to recent literature on the positive effects of mobile phone ownership on reproductive health status in low-income countries.

THEORETICAL AND EMPIRICAL LITERATURE

Compared with the rest of sub-Saharan Africa, Western African countries show lower HIV prevalence levels. In Ghana, approximately 340,000 people live with HIV, with a prevalence rate among adults of 1.7% (UNAIDS data for Ghana, 2019; accessible via https://www.unaids.org/en/regionscountries/countries/ghana). The country is working fast to reach the 90-90-90 UNAIDS targets (ie, 90% of HIV-positive people know their status; 90% of those diagnosed are on treatment; and 90% of those on treatment are virally suppressed). The Ghana AIDS Commission is currently updating its social and behavioural change communication materials to put greater emphasis on the reduction of stigma and discrimination. New activities include, among others, information-based approaches to stigma reduction through community events, media campaigns on TV and radio or educational forums (although no reference is made to the use of new media), and empowerment activities to increase the active participation of PLWH in society. (A full description of the new strategy to fight HIV-related discrimination is reported in the Ghana’s National HIV and AIDS Anti-Stigma and Discrimination Strategy 2016–2020, available at https://ghanaisds.gov.gh/mcadmin/Uploads/NationalHIV&AIDSAnti-Stigma&DiscriminationStrategy2016-2020.pdf.) The emphasis on stigma reduction by the Ghana’s AIDS Commission is driven by the fact that prejudice and discrimination levels among health workers, HIV patients and the general public remain worrying in the country. James et al, for example, report that approximately one-fourth of interviewed health workers knew of tests being conducted without consent of PLWH, and one-fifth admitted trying to avoid contact with PLWH. Perceived and experienced stigma has an impact on individuals on both the intrapersonal and interpersonal levels. Fear of prejudice can limit opportunities for social connection and access to healthcare, while status disclosure concerns can exacerbate social isolation.

Awareness, education and positive social interaction can mitigate discriminatory behaviour. The idea that social contacts might reduce stigma is not new. Several studies have theorised and empirically demonstrated the role of positive social contact in reducing mental health-related stigma and also in the context of mass social contact events or campaigns. The direct (or indirect) social contact with stigmatised groups induces empathy between the non-affected and affected individuals. Evidence from a study comparing 26 sub-Saharan African countries found that knowing a person living with HIV is consistently associated with lower levels of stigma. However, positive outcomes are dependent on the quality of the social interaction. When people suffering from a condition, such as a mental illness or HIV/AIDS, experience discrimination during social interactions, they might opt for concealing their status and avoiding discussing the topic for fear of stigma, thereby reducing the chance for future positive social contact. Knowledge and education, in this sense, play a role in reducing the potential for discriminatory opinions and practices caused by misconception. Increased knowledge of HIV and HIV treatments has recently been associated with a reduction in HIV-related social stigma, even among experts working in the healthcare sector. The propensity to discriminate against PLWH is higher in areas with lower exposure to HIV, limited knowledge of antiretroviral therapies and weaker HIV/AIDS communication. As HIV-related knowledge reduces misconceptions related to the transmissibility of the virus, a reduction in stigma might be associated with a reduction
in fear of contagion. Similarly, knowledge acquisition through media entertainment has been found to be relevant in shaping attitudes towards sensible topics like domestic violence or HIV. Edutainment could achieve large individual effects in shaping attitudes towards HIV even without challenging collective social norms.

Although the evidence presented shows the benefits of social and personal contact and knowledge of HIV for reducing stigma, uncertainty remains on which tools could be used to combine both elements to build high-quality stigma reduction programmes. Evidence has shown that mobile phones can increase social capital by both bonding individuals within a social network and bridging individuals between otherwise disconnected parts of the network. Closed bonding structures, in which individuals strengthen ties with other members of their network, increase economic prosperity, sustain trust and nurture the development of a common social identity. On the other hand, open bridging structures enable individuals to leverage the diversity of their contacts and expose them to new ideas, knowledge and information. While some evidence shows that mobile-enabled bonding structures between PLWH might reduce self-stigma levels thanks to peer support, bridging structures are the ones that are most effective in building valuable forms of social capital (eg, civic and democratic values) and reduce public stigma and discrimination. In the case of mobile phones, they have been proven to be valuable tools for refugees and internally displaced people to bridge cultural gaps with hosting communities and increase social inclusion. In a similar way, bridging structures between otherwise distant groups facilitate access to new knowledge and ideas, something that mobile phones have already been proven to do through increased access to resources and mHealth services.

The hypothesis tested in this study is that access to mobile phones is directly connected to lower prevalence of HIV prejudice and public stigma. This is because mobile phones’ ability to create open bridging structures can affect HIV-related public stigma in two ways. On one side, direct and indirect positive social contacts with a member of a stigmatised group (or people with direct knowledge of these members) results in decreased fear, misunderstanding and prejudice; this hypothesis has been defined as the ‘contact hypothesis’. On the other side, mobile-enabled knowledge acquisition reduces misconceptions on HIV contagion pathways and fear of HIV, facilitating a decrease in discriminatory attitudes. In the following section, we present the data and analytical approach adopted to test this hypothesis.

METHODS

Data

The analytical structure of this study entails both a community-level and an individual-level analysis. Individual-level data are drawn from two consecutive rounds of the Ghana Demographic and Health Survey (GDHS). The data provide details on demographics, HIV-related knowledge and stigma, and mobile phone ownership in 2008 and 2014. These rounds represent the two most recent standard GDHS surveys and the only ones with information on mobile phone ownership. Unfortunately, due to survey design, it is impossible to distinguish between smartphone and non-smartphone ownership. The pooled sample includes over 22 000 individuals aged 15–69. (GDHS individual surveys include only males aged 15–69 and females aged 15–49 in their samples. Household member surveys include also individuals of different age groups, although questionnaires are not as detailed and no information about HIV stigma is asked in these surveys.) To conduct community-level analysis, individual-level information on mobile phones ownership and HIV-related stigma are collapsed at the community level. (Observations with missing values have not been included in the calculation of the averages.) Communities are identified as the survey clusters used during DHS sample selection process. Individuals in these clusters are usually selected from the same villages and can, therefore, be considered part of the same community. A total of 838 clusters are included in the pooled sample. In addition to information on mobile phone ownership and HIV stigma prevalence, area-level confounders have been added to the analysis proxying for religion and ethnicity, both elements which have been found to be associated with HIV stigma, and community’s economic development, urbanisation (As literacy levels may differ between more and less urbanised areas, which could in turn affect the ability to use mobile phones, we perform additional community-level analysis, splitting the sample between areas with an urbanisation rate below and above the median level. Results, presented in online supplemental appendix B, table B3, remain largely unchanged when compared with our main estimation, although IV regression results lose statistical significance), HIV prevalence, and proximity to national borders and water sources. Table 1 reports descriptive statistics at cluster level. A full description of data sources for community-level variables is presented in online supplemental appendix A, table A1.

HIV stigma takes different forms which can be broadly categorised into two groups: public stigma and self-stigma. Public stigma entails societal negative beliefs, emotions and behaviours towards PLWH. Self-stigma, on the other hand, happens when stigmatised individuals internalise public stigma and accept its validity. To build the main outcome variable, we follow van der Kooij et al’s choices for the relevant DHS questions, which refer mostly to public stigma. Included questions are ‘would you buy fresh vegetables from shopkeeper who has the AIDS virus?’, ‘would you say that a teacher with the AIDS virus is sick should not be allowed to continue teaching?’ and ‘are you willing to care for a family member with the AIDS virus in the respondent’s home?’ to measure prejudice against PLWH, and ‘if a member of your family got infected with the AIDS virus, would you...
want it to remain a secret or not?’ to measure disclosure concerns. The final outcome variable is a variable indicating the share of individuals per community for which any or all answers show stigmatisation against PLWH. To test the sensitivity of the obtained results, prejudice against PLWH and disclosure concerns prevalence are also analysed separately (see the Results section).

**Empirical strategy**

**Main analysis**

Since GDHS interviews are conducted with different samples in each survey, the study adopts two different methodologies to analyse the data and provide robust estimates. First, a pooled ordinary least squares (OLS) model is estimated to investigate the correlation between mobile phone ownership and HIV-related stigma. The model includes year and region fixed effects to account for non-observable spatial and time characteristics existing between regions in each survey and between surveys. The regression model can be written as follows:

\[
\text{Stigma}_{cr} = \beta_0 + \beta_1 \text{Phone}_{cr} + \beta_2 Z_{cr} + u_{cr}.
\]

(1)

**Phone}_{cr}, our main explanatory variable, indicates the share of mobile phone ownership in community \( c \) in region \( r \) in year \( t \). \text{Stigma}_{cr} represents the share of individuals discriminating against PLWH. \( Z_{cr} \) is a vector of community-level confounders. A full list of variables is presented in table 1. \( \beta_1 \) and \( \beta_2 \) are (vectors of) coefficients to be estimated and \( u_{cr} \) is the error term. Errors are clustered at the community level. All estimations use population weights.

A concern arising from our initial specification deals with the potential endogeneity of mobile phone ownership within the country. In fact, urban or more high-income areas, or areas located closer to a road or to a national border, have a higher chance of being in the proximity of a cell phone tower, which usually indicates a better network quality might be correlated to a higher share of mobile phone ownership. To deal with our concerns for endogeneity, we select distance from the nearest cell tower as a proxy for network coverage and as our IV to mobile phone ownership. We measure linear distance of each community to the nearest cell tower reported in the OpenCellid database. OpenCellid is the largest, daily updated, publicly available database of cell towers. Database entries for the African continent have been added to the OpenCellid dataset, under the assumption that towers have been built before their date of construction. For this reason, we calculate distance from the nearest cell tower including all cell towers in Ghana regardless of the date in which they have been added to the OpenCellid dataset, under the assumption that towers have been built before their date of entry in the dataset. This is, obviously, a very strong assumption, and therefore, we strengthen our instrument by adding a time-variant component. We interact our distance measure with a country-level measure of mobile phone penetration for each year included in the pooled sample (ie, 2008 and 2014), represented by the number of mobile phone subscriptions per 100 people. In this way, we add yearly variability to our instrument. The final two-stage least square model is the following:

\[
\text{Phone}_{cr} = \rho_0 + \rho_1 \text{Distance}_{cr} \text{*Subscription}_t + \rho_2 Z_{cr} + \epsilon_{cr},
\]

(2)

\[
\text{Stigma}_{cr} = \beta_0 + \beta_1 \text{Phone}_{cr} + \beta_2 Z_{cr} + u_{cr},
\]

(3)

where \( \text{Phone}_{cr} \) represents our instrumented phone ownership variable. We perform underidentification tests and report Kleibergen-Paap rk Wald F statistic to

| Variable | Average | SD  | Minimum | Maximum |
|----------|---------|-----|---------|---------|
| Mobile phone ownership | 73.6 | 27.4 | 0 | 100 |
| Any discrimination against PLWH | 83.4 | 11 | 38.4 | 100 |
| Prejudice against PLWH | 72.4 | 15.5 | 18.9 | 100 |
| Disclosure concerns | 50.1 | 18.1 | 4.3 | 100 |
| Catholic (%) | 15 | 17.3 | 0 | 100 |
| Belongs to the dominant ethnic group (Akan, %) | 44.9 | 39 | 0 | 100 |
| Gross cell production (US$)* | 1205.2 | 114.4 | 983.9 | 1562.7 |
| Global Human Footprint† | 44.3 | 20.1 | 16 | 100 |
| HIV prevalence‡ | 1.9 | 0.53 | 0.6 | 3.8 |
| Distance to closest national border (km) | 53.6 | 53.3 | 0.1 | 184.9 |
| Distance to closest water source (km) | 65 | 71.1 | 0 | 271.9 |

Reported figures are representative of the pooled sample (not weighted). Ghana Demographic and Health Survey from 2008 and 2014. *Derived from the Geographically based Economic Data.†Retrieved from Global Human Footprint dataset.‡Retrieved from Africa HIV Prevalence Geospatial Estimates. PLWH, people living with HIV.
show the robustness of our model. However, to further strengthen our findings, we build a different IV by calculating distance from cell towers built on or before 2008 for communities surveyed in 2008, and from cell towers built on or before 2014 for communities surveyed in 2014. In this way, we are sure not to include any cell tower that was built after survey years, although we most probably exclude several others that were simply not yet added in OpenCellid database by that time. Finally, a second alternative IV is calculated, interacting distance from nearest cell tower with total lightning flash rates obtained from NASA’s Global Hydrology Resource Centre (resource available at https://ghrc.nasa.gov/lightning/). This represents a similarly solid identification strategy, as connectivity is weaker in areas where lightning strikes are more frequently due to the damage they cause to antennas, reducing the utility of mobile phone ownership. (As a last test, we include all our different IVs in the 2SLS for our main analysis and present results in online supplemental appendix B, table B4. Results remain significant and similar in magnitude, although the inclusion of three instruments leads to a failure of the overidentification test, most probably due to the complementarity of distance from cell tower and lightning strike rate as proxies for connectivity quality.)

Pseudo-panel analysis

Although our IV strategy provides a reliable point estimate of the impact of mobile phone ownership on prevalence of HIV public stigma, we try to improve our analysis by taking into account the intertemporal nature of our data. As it has been mentioned, DHS rounds are cross-sectional and do not allow for panel analysis. However, location coordinates of each cluster can be used to generate an artificial panel based on clusters’ proximity. To do so, we follow Martorano et al. The strategy consists in matching clusters from different survey rounds (ie, 2008 and 2014) that share latitude and longitude coordinates up to the first decimal unit (or an area of approximately 50 km in radius). A total of 616 artificial areas were obtained through this method. Of these areas, 103 were covered in both 2008 and 2014 DHS rounds and could be matched between the two, leaving us with a total sample of 206 artificial areas. The analytical strategy of our pseudo-panel analysis follows equations (1), (2), and (3) replacing year fixed-effects with area-year fixed effects. As newly defined areas might stretch over more than one region, regional fixed effects are not considered in this analysis. Population weights are still included.

Individual-level analysis

To support the main findings and conduct additional robustness checks, individual-level analysis was conducted. This analysis is operationalised through a binary outcome model estimated to investigate the correlation between mobile phone ownership and HIV-related public stigma first, and TV and radio ownership and HIV-related public stigma later. Media exposure through television and radio appears to have an ambiguous role on HIV stigma. While HIV communication campaigns foster accepting attitudes towards PLWH, mainstream media have a diminished or even non-significant impact. Ownership of radio and television are therefore used as alternative explanatory variable at the individual level to test their role on stigma in the sample. The probit regression model can be written as follows:

$$\text{Stigma}_{i,t} = \beta_0 + \beta_1 \text{Phone}_{i,t} + \beta_2 X_{i,t} + u_{i,t},$$

where $\text{Stigma}_{i,t}$ is the binary outcome variable indicating whether the individual discriminates against PLWH. $\text{Phone}_{i,t}$ is our main explanatory variable, indicating whether individual $i$ in region $r$ in year $t$ owns a mobile phone. $X_{i,t}$ is a vector of individual-level and household-level confounders. A full list of confounders is presented in online supplemental appendix A, table A2. Errors are clustered at community level to account for the correlation existing between levels of stigma of individuals living in the same community. All estimations use population weights.

To dissect further the effect of access to mobile phone on HIV public stigma at individual level, the Oaxaca-Blinder (OB) method is used to decompose differences in levels of stigma between individuals with and without phone access.

Other studies have used this approach to uncover whether positive effects of mobile phone ownership were driven by underlying household or individual characteristics or were connected to ownership alone. This question is quite relevant considering that previous evidence indicates that socioeconomic status and not mobile phone ownership predicts better reproductive health. The selected OB decomposition method is a twofold decomposition following the equation:

$$\Delta \text{Stigma} = \left\{ \begin{array}{ll} (Z_A - Z_B) & b_B^+ \\ Z_B (b_A - b_B) + Z_A (b_B - b_A) & \end{array} \right.,$$

where $A$ represents the group of mobile phone owners and $B$ represents that of non-owners; $\Delta \text{Stigma}$ is the differential in stigma between the two groups; and $Z$ represents the list of confounders. $b_A$ and $b_B$ are regression estimates of $\beta_2$ from equation (4) separately for group $A$ and group $B$. Two components are obtained from the OB decomposition: the first component amounts to the part of the differential that is due to group differences in the confounders (the explained component). This is calculated in the upper part of the equation. The second component measures differences unexplained by differences in confounders (the unexplained component). This is calculated in the bottom part of the equation. The unexplained component presents an estimation of the portion of the differential related to the ownership of a mobile phone, although some literature has pointed out that it might also be affected by unobserved characteristics of individuals.

Mediation analysis

Finally, a mediation model is applied to unveil the mechanisms connecting the explanatory variable to the outcome of interest. As evidence has pointed at the positive effects
of knowledge sharing in reducing HIV-related stigma, prejudice and discrimination,\textsuperscript{22,66} we test the role of HIV-related knowledge both at community- and at individual-level. Average mediation effects are estimated through a parametric model fitting first an OLS regression for the analysis of the mediator, followed by a second OLS regression for the analysis of the outcome variable including the mediator as a covariate.\textsuperscript{67} The resulting equation for the mediation analysis is the following:

\begin{equation}
\text{Know}_{\text{ort}} = \gamma_0 + \gamma_1 \text{Phone}_{\text{ort}} + \gamma_2 \text{Zort} + u_i
\end{equation}

\begin{equation}
\text{Stigma}_{\text{ort}} = \theta_0 + \theta_1 \text{Phone}_{\text{ort}} + \theta_2 \text{Know}_{\text{ort}} + \theta_3 \text{Zort} + \varepsilon_i
\end{equation}

Equation (6) applies to both community-level and individual-level analyses, or for observations \( o \) in region \( r \) at time \( t \). The indirect (mediated) effect of mobile phone ownership through HIV knowledge is provided by \( \gamma_1 \theta_2 \).

**Patient and public involvement**

There is neither patient nor public involvement in this study.

**RESULTS**

In this section, findings from our main analysis are presented. Table 2 shows the results for equations (1) and (3). A negative correlation between mobile phone ownership and HIV public stigma is identified (Column 1) and the correlation remains significant after population weights (Column 2) and community-level confounders (Column 3) are included in the analysis. According to our estimation, a 10% increase in share of individuals owning a mobile phone would lead to a 1.2% reduction in share of individuals presenting any form of HIV public stigma within a community. Table 2, Column four reports finding of the IV analysis adopted to address endogeneity. In this model (our preferred one), we estimate that the causal effect of mobile phone ownership on HIV stigma is higher than what was estimated by our OLS models, in the sense that a 10% increase in ownership reduces HIV stigma by about 3%. Our 2SLS model’s first stage indicates a significant relationship between the instrument and mobile phone ownership (see online supplemental appendix B, table B1), while a significant Anderson-Rubin Wald test suggests it is a strong instrument. Underidentification test and Kleibergen-Paap rk Wald F statistic reported in Table 2 paint a similar picture.

In support of our main findings, we present in Table 2, Columns 5 and 6 results from the pseudo-panel analysis. The number of areas included in the analysis drops significantly. However, even with a reduced sample size, both the OLS and IV models show a significant positive relationship between mobile phone ownership and HIV public stigma, confirming our initial findings. According to our IV strategy estimation, a 10% increase in ownership reduces HIV public stigma prevalence by 1.2%. These findings, together with those of our main model, support our hypothesis that increased mobile phone ownership is directly connected to lower levels of HIV public stigma.
Robustness checks

In this section a series of robustness checks are run to test whether our findings remain consistent to different model specifications. First, we replace our IV with two alternative ones: the first, in which a refined distance from cell tower measure has been calculated including only towers present in the OpenCellid database before DHS surveys were conducted; the second, in which this refined distance from cell towers is interacted with total lightning flash rates, which affect connectivity quality. Results are presented in table 3, columns 1 and 2. As it can be noticed, findings are consistent with our main specification. If anything, these robustness tests show that our initial findings might underestimate the impact of mobile phone ownership on HIV public stigma.

The subsequent robustness check is run to separately analyse the components of our outcome of interest. As explained, the main outcome variable is built out of four survey questions, three of which identify prejudice towards PLWH, while the last one proxies for disclosure concerns that individuals’ might have for fear of stigma (against their relatives and themselves). These two components are different in nature although they share a common denominator. It is therefore relevant to understand whether mobile ownership affects them differently. Results are presented in table 3. Mobile phone ownership is only marginally and non-significantly affecting disclosure concerns, while its effect on prejudice against PLWH is significant and larger in magnitude than the main specification, with a 5.4% lower probability of showing prejudice against PLWH for every 10% increase in mobile phone ownership. This finding might be motivated by the fact that, while mobile phones can do little to shape intrahousehold dynamics related to disclosure concerns, they act as sources of HIV-related information and reduce discriminatory attitudes.

Individual-level analysis

Although strong, our main model still presents the limitation of not being able to compare the effects of mobile phone ownership between owners and non-owners. Through the individual-level analysis presented in this section, we aim to overcome this limitation and further strengthen findings. Results are presented in table 4.

First, we test whether the relationship between mobile phone ownership and HIV public stigma is still relevant at the individual level (column 1). Second, we investigate if the reduction in probability of showing any type of HIV public stigma is also achieved with different communication technologies such as radio and television (columns 2 and 3). Individual-level analysis confirms the findings of our community-level model. More importantly, it shows that television ownership is not significantly correlated with stigma against PLWH. Radio ownership, on the other hand, appears to increase the probability of discriminating against PLWH. Although counterintuitive, a potential explanation of this finding is that mainstream radio programmes might reinforce individuals’ prejudice against HIV. The role played by radio in fostering discrimination and violence in specific contexts, like that of Rwanda, is well documented as well as its use to, at times, incite hatred in countries all over the world.

As shown in online supplemental appendix A, table A2, mobile owners and non-owners have rather different socio-economic characteristics. The OB decomposition, the results of which are presented in this section, is intended to disentangle the effects related to the baseline characteristics from effects related to mobile phone ownership. The extent to which access to mobile phone contributes to the gap in HIV public stigma between phone owners and non-owners is included in the unexplained component. In the analysis, the explained component represents 69% of total gap, while the unexplained component represents 31% of it. Both components are statistically significant.
The OB analysis, therefore, confirms that the effect of mobile phone ownership on the probability of stigmatising against PLWH is non-negligible even after baseline characteristics have been accounted for. Complete results for the OB decomposition are provided in online supplemental appendix B and table B2.

Knowledge of HIV: a mediating factor
Mobile phones enable near-instant communication through voice and text. Mobile phone-enabled communication might facilitate social contact, which has shown to greatly reduce stigma and increase treatment adherence. However, mobile phones also facilitate individuals’ access to information from sources that would otherwise be unreachable or costly. The knowledge acquired through mobile phones, as well as the consequent reduction in misconceptions, might represent a mediating factor enabling individuals to better understand HIV, its risks and its spreading mechanism, and ultimately reducing stigma.

The aim of the mediation analysis, performed in this section following equation (6), is to identify whether the effect of mobile phones on stigma against PLWH can be differentiated into a direct effect (related to increased communication) and an indirect effect (through better HIV-related knowledge), and to estimate the size of any existing indirect effect. Our HIV-related knowledge variable is presented as a dummy in which value one is assigned to individuals with no misconceptions about HIV. Individuals are categorised as not having misconceptions if they know that healthy-looking people can be HIV-positive, and if they don’t believe that HIV can be contracted through food consumption, mosquito bites or witchcraft.

Table 5 reports results for both community-level and individual-level analyses. Findings show a negative indirect effect between HIV knowledge and public stigma, indicating that individuals with no misconceptions are less prone to stigmatise against PLWH. To quantify the size of the indirect effect, its share over the total effect is calculated. Results suggest that the indirect effect of mobile phone ownership through HIV-related knowledge accounts for approximately 26% of the total effect in both community-level and individual-level analyses.

**DISCUSSION**
This study analysed the connection between ownership of mobile phones and HIV-related public stigma...
in Ghana. The aim was to understand whether access to mobile technology can help reduce individuals’ prejudice against PLWH and their fear of disclosure in case of infection. Ghana represents an ideal case study as it has seen a stark increase in access to mobile technology in the past two decades, and it has shown a will (and need) to enhance HIV-related messaging on stigma and discrimination. Based on empirical analysis, the study identifies a positive impact of mobile phone ownership on HIV public stigma prevalence. The identified impact is robust to multiple specifications, while estimates are consistent at both community level and individual level. These findings support the hypothesis that mobile phone ability to create open bridging structures promotes the type of positive social interactions and knowledge acquisition that have been proven to reduce different forms of stigma. Although we conduct community-level analysis in our main estimation, we are wary of ascertaining the identified impact to a change in social norms regarding HIV in communities with higher rates of mobile phone ownership, as our outcomes measure individual attitudes more than social ones. Nonetheless, evidence has shown that HIV-related informational programmes can have large individual effects even in the absence of collective effects, modifying attitudes and ultimately shaping behaviours in exposed communities. The lack of coordination on social norms might be related to the fact that private decisions, as the ones related to HIV, are not always taken according to customs. Following this line of reasoning, the more private the topic, the more difficult it would be to affect people’s behaviour towards it through communication and knowledge sharing. It is not surprising, therefore, to find that when considering only HIV status disclosure concerns as our outcome of interest, we find no significant impact of mobile phone ownership. Disclosing someone’s HIV status is a very sensible matter, even more so when the PLWH is a family member. Disclosure is often associated with shame and fear of ostracism from the community, and fear of stigma against the PLWH. Studies show that increased knowledge of HIV or more frequent social contact (both elements influenced by access to mobile phones) is rarely mentioned as relevant factors motivating disclosure of one’s own HIV status. On the other hand, public stigma and prejudice are positively influenced by peer support and social contact, which mobile phone access facilitates through the creation links between groups otherwise not connected.

In our individual-level analysis, we find that socioeconomicharacteristics alone do not explain differences in public stigma between mobile phone owners and non-owners. This finding challenges previous evidence that attributed mobile phone effects to differences in economic status between phone owners and non-owners. The paper further investigates the role of HIV-related knowledge as a mediating factor in the effect of mobile phones on stigma. Mobile technology is a powerful tool to spread information and increase social cohesion in the Global South. Mobile phones facilitate knowledge diffusion, which in turn reduces information asymmetries, also with regard to reproductive health awareness. Previous studies proved that increased knowledge about HIV is a contributing factor in reducing HIV-related stigma. Findings from our study are in line with this literature, showing that HIV knowledge represents a significant mediating factor of the effect of mobile phone ownership on stigmatisation of HIV, accounting for approximately 25% of the total effect at both community and individual levels.

**Strengths and weaknesses**

To the best knowledge of the authors, this paper represents the first example of an observational study on the effects of mobile phones on HIV stigma in West Africa. Our findings follow those of a growing literature on the positive effects of mobile technology on development, literacy and health. However, our study is not exempt from methodological limitations. While the use of a pseudo-panel approach increases the credibility of our results, the unavailability of longitudinal data with the necessary indicators has prevented the authors from performing even stronger analysis. In the analysis of the effects of mobile phones on health, the use of qualitative evidence has been proven to be very valuable (see Hampshire et al). As this type of data is missing from our study, our analysis sacrifices depth in exchange for statistical strength. Future research should employ both techniques to identify better the channels through which mobile phone ownership influences stigma and prejudice to provide an even clearer analysis of this topic.

**Policy relevance**

Nevertheless, the results presented in this study can provide suggestions for the design of HIV-related health communication campaigns in Ghana. Although the country has been expanding the use of mobile phones in healthcare, Ghana’s most recent National HIV and AIDS Anti-Stigma and Discrimination Strategy 2016–2020 did not explicitly include mobile phones in its awareness raising plan. However, as this study suggests, phone-based informational campaigns and mass communication strategies and the inclusion of helplines, which have proven successful in other settings, might represent valid additions to the next 4-year strategy to reduce discrimination against PLWH. A similar suggestion is valid for other West African countries where HIV prevalence remains lower as compared with the rest of SSA, but where prejudice and misconceptions about HIV remain.

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Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication

Not applicable.

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Data may be obtained from a third party and are not publicly available.

Supplemental material

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