RESEARCH ARTICLE

REVISED Gender, digital financial services and vulnerability in the era of pandemics: A cross-sectional analysis [version 2; peer review: 1 approved, 1 not approved]

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Abstract

Background: The COVID-19 pandemic has rapidly spread across the world, infecting millions, and causing economic disruption on an unprecedented scale. While everyone is affected by the COVID-19 pandemic, vulnerable communities are at the greatest risk. This study aims to examine the relationship between digital financial services (DFS), gender, and the vulnerability of informal settlement dwellers to COVID-19.

Methods: We sampled a total of 2,697 households from 101 informal settlements across eleven out of sixteen administrative regions of Ghana. The regions were selected based on the relative severity of the pandemic, and the associated national lockdown regulations.

Results: Adopting the ordinary least square analytical technique, the results reveal three main findings: First, we observe that males in informal settlements are more exposed to infected people or a person who died from COVID-19 than females. However, women are more vulnerable to the pandemic than men as vulnerable populations have a higher susceptibility to pandemics due to less capacity to implement preparedness and response strategies due to disparities in their societal status. Finally, we find that the vulnerability of informal dwellers is moderated using digital financial services.

Conclusions: We conclude that there exist gender disparities regarding COVID-19 exposure and vulnerability. Also, by making use of digital financial services vulnerable groups can reduce their exposure to the COVID-19 pandemic. Our results provide policy implications for authorities designing policies to educate men more on the need to take preventive measures seriously as well as educate vulnerable populations to adopt digital financial services

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Any reports and responses or comments on the article can be found at the end of the article.

Keywords
Digital financial services, Gender, Vulnerability, Pandemics, COVID-19, Ghana

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REVISED **Amendments from Version 1**

We have reflected on the feedback from the reviewers, revised, and re-submitted a significantly improved manuscript. We have taken the reviewers' comments seriously and did our possible best to address them. We have made changes leading to a significantly improved version of the manuscript. We have also copyedited the paper to remove redundancies and repetitions as well as any syntax and grammatical errors. We hope that the changes and additions satisfactorily address the reviewers' concerns.

Any further responses from the reviewers can be found at the end of the article

Introduction

The outbreak of COVID-19 pandemic has spread worldwide, affecting every aspect of life. Millions of people have been affected by COVID-19 and many more have lost their lives. To minimise the impact of COVID-19, governments all over the world instituted measures such as lockdowns, increased handwashing, social distancing, and travel bans. While these measures have helped in containing the spread of COVID-19, they have also led to some unintended consequences (Sumalatha *et al.*, 2021). Indeed, the economy has suffered, jobs have been lost, debts are mounting, people are quarantined in their homes and most vulnerable people are likely to go below the poverty line. While COVID-19 poses a severe threat to all, vulnerable populations are severely affected and face even greater challenges. Indeed, many vulnerable populations are experiencing adverse consequences such as job loss, food insecurity, and the inability to manage existing medical conditions and maintain preventive measures such as social distancing and personal protective gear.

Previous research has found that vulnerable populations are at greater risk during pandemics because they usually cannot implement preparedness and response plans or withstand its consequences due to the disparities in their economic status and other social factors including cultural, settlement, educational and linguistic barriers as well as the inability to access and use health facilities (Debruin *et al.,* 2012 and Hutchins *et al.,* 2009).

The COVID-19 pandemic and the requirement for social distancing have put a spotlight on digital financial services. Digital financial services are broadly defined as financial services offered through digital platforms such as mobile phones, the internet, cards, and point of sale (POS), among others (Alexander, 2017). In the case of this study, digital financial services refer to financial services offered/performed through the mobile phone because this was the most common form of technology available to the respondents of the study. Digital financial services (DFS) not only allow for social distancing but also allow governments to disburse funds to those in need quickly and effectively. More importantly, digital financial services allow many households and firms to rapidly access online payments and financing (Agur *et al.,* 2020). As noted by Arner *et al.* (2020), whereas digital financial services can be harnessed to respond to the COVID-19 pandemic, the pandemic also has the potential to accelerate their development and use. The point is that, for digital financial services, all transactions continue, and more importantly financial support reaches the vulnerable irrespective of COVID-19 restrictions and health guidelines (Auer *et al.*, 2020).

The COVID-19 pandemic also poses questions about its effects on men and women. Indeed, the pandemic has affected women and men differently due to their distinct roles in society and national economies. According to the International Labour Organisation [ILO] (2021), while the COVID-19 pandemic led to unprecedented job losses, women have been disproportionately hit (4.2%) compared to men (3%). Research has also shown differences in COVID-19−related beliefs and behaviours. Thus, in their study, Galasso *et al.* (2020) found that women are more likely to perceive the pandemic as a very serious health problem and to agree and comply with restraining measures. This is partially the reason more men than women are dying of COVID-19 (Grasselli *et al.*, 2020). Aside from the evidence on perceived impacts, very little is known regarding the impact of the pandemic on various indicators of vulnerability.

Despite the plethora of scholarly research on COVID-19, there appears to be a paucity of research examining how digital financial services have been harnessed as a pro-poor tool to minimise the impact of COVID-19 on vulnerability in the context of developing countries. Some studies have concentrated on the utilisation of digital financial services during the COVID-19 pandemic (Auer *et al.*, 2020; Ting *et al.*, 2020), the impact of the COVID-19 pandemic on vulnerable populations such as women (Nyashanu *et al.*, 2020) as well as adoption and implementation of COVID-19 pandemic measures (Prempeh, 2021). This study differs from previous research to the extent that the focus is on the use of digital financial services to support vulnerable populations in a developing country during the COVID-19 pandemic whereas previous studies focused on the impact of COVID-19 on the vulnerable or the use of digital financial services during COVID-19. The issue of how digital financial services can ameliorate the plight of the vulnerable especially women in developing contexts is worth perusing as this has implications for the achievement of the sustainable development goals [SDGs] 3, 10, 11, 15 and 17 (Bhatia and Singh, 2019).

The objective of this paper is to examine the relationship between gender, digital financial services, and vulnerability during COVID-19 in Ghana. This is important to the extent that most of the government policy measures announced in developing countries during the COVID-19 pandemic were in the form of cash assistance (Davidovic *et al.*, 2020). The use of digital means helped in achieving the purpose of government policy by reaching the vulnerable while reducing contact and spread of the virus. This is significant because digital financial services allow for the disbursement of financial support to those in need quickly, effectively, and safely while preventing direct contact among individuals (Auer *et al.*, 2020). Analysing the pandemic from gender and digital financial services perspective is significant as gender is a social category that shapes the pattern of the outbreak itself and people's access to resources (Kim *et al.*, 2020).

The results of the study revealed three main findings: First, we observe that men are more exposed to the COVID-19 pandemic than women living in slum populations. During pandemics, women are usually restricted to traditional roles including caregiving in their homes (Power, 2020). This acts as a movement restriction on the part of women which reduces their exposure to pandemics. Men, often charged with the responsibility of providing for their household are put in a very precarious position to go all out to work to fend for their families, hence increasing their exposure. Secondly, this study finds that women are more vulnerable than men during pandemics which confirms our hypothesis. The vulnerability to health for women during pandemics can be linked to contact between them and others who disregard preventive measures. Thirdly, vulnerable populations can insulate themselves from the harsh effects of pandemics when they make use of digital financial services. The use of digital financial services such as mobile money and M-Pesa helps to reduce disease transmission through human contact. Once the exposure levels of men are reduced, the vulnerability suffered by women is also reduced if not eliminated.

The next section provides a theoretical and empirical review of the literature. This is followed by the methodology employed in the study. The fourth section discusses the results of the study while the last section provides concluding remarks and practical implications of the paper.

Literature review

Theoretical review

Digital financial services are part of the financial inclusion movement that emphasises the provision of, and access to, financial services to all members of the population particularly the poor, vulnerable and several excluded members of the population (Ozili, 2018). Due to the importance of financial inclusion and its great promise, many governments especially in emerging and developing economies have initiated policies and strategies to ensure financial inclusion (Allen *et al.*, 2016). The literature on financial inclusion is replete with many theories – including public good theory, dissatisfaction theory, vulnerable group theory, and systems theory, among others. In this paper, the vulnerable group theory was adopted to anchor this study. This theory suggests that financial inclusion initiatives should target the vulnerable in society as they are mostly at a disadvantage during economic hardships and crises. During pandemics and crises, the vulnerable are the most affected, and as such, it makes a lot of sense to bring these vulnerable people into the formal financial sector (Ozili, 2020). One way to achieve this is through the digital financial system. This includes the use of technology to deliver financial services to members of society including the vulnerable such as poor people, young people, women, and elderly people. The crux of the vulnerable group theory is that financial inclusion efforts through means such as digital financial services should be targeted at vulnerable people in society (Ozili, 2020). During crises such as the COVID-19 pandemic, the use of digital financial services helps to provide support quickly and conveniently to the vulnerable population who need urgent support.

Empirical review

The COVID-19 pandemic started in 2019 in Wuhan China and resulted in immediate, serious human health issues around the world. The pandemic brought dire consequences to lives and livelihoods (Asante *et al.*, 2021). The rapid spread of the pandemic across the world has continued to produce fear, panic and anxiety in people (Ahorsu *et al.*, 2020). More so, the alarming speed of the pandemic has overwhelmed even the most resilient health and social care systems (Guzman and Malik, 2020).

In such a situation, governments need to ensure public safety by prioritising the management of health crises. Also, several economic recovery strategies have been deliberately introduced across countries to support suffering economies affected by COVID-19. Key to these strategies is the need to protect the public health system as well as ameliorate the harmful impact of COVID-19 on the economy (Deloitte, 2020). The key COVID-19 control measures include border closures, lockdowns, social distancing, contact tracing, quarantine, and isolation (Asante *et al.*, 2021).

According to the Lancet (2020), the vulnerable are those that are disproportionally exposed to risk, but vulnerability can change dynamically. In this case, it is added that a person not considered vulnerable at the outset of a pandemic can

become vulnerable depending on the policy response. The Lancet (2020) therefore expanded the definition of vulnerability in the context of COVID-19 beyond individuals with comorbidities and ill health, elderly persons, and homeless people to incorporate people from a range of economic backgrounds who may struggle to cope either physically, and psychologically, or financially as a result of the COVID-19 crisis.

The current COVID-19 crisis has further exacerbated the gender gap in terms of quality of employment particularly for women working in the informal sector and feminised occupations (ILO, 2021). As noted by Sen and Östlin (2008) gender is a crucial social element of health which intersects with several dimensions of society. Gender has implications for how different people cope with vulnerability, and their capacity and responsibilities during unexpected public health emergencies (Kim *et al.*, 2020). Globally, the data has shown that more men are infected by COVID-19 than women (Global Health 50/50, 2020), which indicates that being a man is a risk factor for COVID-19 infection (Chen *et al.*, 2020).

The issue of financial inclusion has received a lot of scholarly and practitioner attention because of its potential to contribute to inclusive economic and financial development as well as improve income equality (Bhatia and Singh, 2019). However, the use of traditional financial products and services for financial inclusion does not seem to reach the vulnerable including women. Indeed, the 2014 Global Findex data shows that 47 per cent of women around the world have a financial account, compared to 53 per cent of men (Demirgüç-Kunt *et al.*, 2015). In the current dispensation, technology can serve as a tool to pursue aggressive financial inclusion. According to Gammage *et al.* (2017), digital finance seems to offer innovative platforms for financial inclusion. This is because digital financial services have the potential to overcome restrictions brought on by geography, reduce the transaction costs of using financial services, and enhance transparency and therefore increase trust in financial systems (Gammage *et al.*, 2017). Digital financial services have the potential to slow the spread of the COVID-19 pandemic as it allows for social distancing, and quick and effective disbursement of financial services online (Agur *et al.*, 2020). Indeed, Auer, Cornelli and Frost (2020) argued that digital financial resources support social distancing measures that were imposed in many countries to minimise the spread of the COVID-19 pandemic. So crucial is the fact that during lockdowns, digital financial services could still be used to deliver financial services to vulnerable, and informal settlement dwellers when other forms become difficult (Auer, Cornelli, and Frost, 2020). Using digital financial technology like mobile money, people without bank accounts, especially women, vulnerable groups and informal sector workers can now have access to financial services which will help improve their economic situation during the pandemic (Agur *et al.*, 2020). During pandemics, speed in the delivery of support is of the essence and digital financial technologies are the game changer when it comes to speed and volumes of financial services (Auer *et al.*, 2020).

Methods

Study design

A cross-sectional survey was conducted among residents of informal settlements in Ghana. Data collection took place from August 2021 to November 2021 across informal settlements in Ghana.

Research setting

Ghana was the area of study. The country has 16 administrative regions with each region containing several districts. There are currently 261 districts. Projections from the Ghana Statistical Service put the current population of Ghana at 30.07 million (Alhassan *et al.*, 2021). This study was conducted in informal settlements in eleven of the sixteen regions in Ghana (Greater Accra, Central, Volta, Ashanti, Western, Northern, Savanna, Northeast, Bono East, Bono, and Ahafo). Peoples Dialogue, a Non-Governmental Organisation that focuses on informal settlements in Ghana provided the list of informal settlements for this study. Peoples Dialogue has enumerated informal settlements in Accra and throughout Ghana (Farouk and Owusu, 2012). As part of the Shack/Slum Dwellers International (SDI) network, Peoples Dialogue has become the most reliable organisation to obtain data on informal settlements in Ghana. Based on the data from Peoples Dialogue, the informal settlements were zoned to thirteen (13).

Participants

Data for this study was collected from 101 informal settlements in 11 of 16 regions in Ghana. Households were eligible if they were within informal settlements. Consistent with the UN-Habitat (2016), informal settlements in this study are defined as residential areas where (a) inhabitants have no security of tenure vis-à-vis the land or dwellings they inhabit, with modalities ranging from squatting to informal rental housing, (b) the neighbourhoods usually lack, or cut off from, basic services and city infrastructure and (c) the housing may not comply with current planning and building regulations and is often found in geographically and environmentally hazardous areas.

Sampling strategy

The study adopted the 2014 Ghana Demographic and Health Survey sampling frame. The frame is a complete list of all the census Enumeration Areas (EAs) created for the 2010 Population and Housing Census (PHC). An EA is a geographic area covering an average of 145 households. A three-stage sampling procedure was adopted. In the first stage, a total of 261 districts were selected from all 16 regions. In the second stage, EAs were selected across all the districts. The total number of EAs across the country is 37,641. We took a cue from the GDHS 2014 and selected a total of 854 EAs by implementing a simple random sampling technique across all 261 districts. After the selection of EAs and before the main survey, a household listing operation was carried out in all the selected EAs. The household listing operation consists of visiting each of the 780 selected EAs and compiling a list of members of the household. In the third and final stage, 8 households were selected from the list of households compiled in the EAs using the systematic sampling procedure to obtain a total of 2,697 households. We administered structured questionnaires to each of the selected households. This sampling strategy ensured that we captured indicators across the national level and as well as districts across the country. A copy of the questionnaire used can be found under *Extended data* (Amidu, 2022).

A total of 2,697 households in informal settlements across Ghana were involved in this study using a three-sampling procedure as described. This sample size is considered adequate and representative of informal settlements in the country.

Data collection

We acquired tablets for the 23 enumerators and engaged the services of a Data Manager to coordinate the transmission of interviewee responses from various sites to a station in Accra, the national capital. The use of tablets to collect the data enhanced the quality of the data collected by prompting and disallowing some responses which were not consistent per checks in the survey instrument. The instant synchronization of the data at the end of the interview helped the survey management team to follow what was happening at all survey sites with ease. However, interviews conducted in areas where internet connection was poor could only be synchronized in the evening when the team returned to the district capitals where they lodged. The data manager run the field check tables to assess the quality of data received through Dropbox daily, whilst the fieldwork was ongoing. Observations from the field check tables were then shared with the enumerators and the team members through a WhatsApp group. Meetings were then held regularly with the field enumerators to ensure that all queries raised were addressed and if clarification was required, the project team responded before the teams proceeded to the next survey areas. These protocols were put in place to ensure data quality.

Survey instruments

There are four main variables under investigation in this study: vulnerable populations, digital financial services, gender, and COVID-19 exposure. These variables are discussed below with their measures.

Sex/Gender: We limit the measurement of sex and gender to binary measurement. Participants could indicate whether they were male or female using a tick box.

COVID-19 exposure: exposure to COVID-19 is defined as the state of being exposed to someone with COVID-19 (Kazak *et al.*, 2021). For the purpose of this study, three questions namely: personal knowledge of COVID-19 infected persons, having heard or associated with a known COVID-19 infected person, and being exposed to a COVID-19-related deceased person were used to measure exposure to COVID. The use of these measures led to the creation of the COVID-19 exposure index, with one being the lowest and three the highest.

Vulnerable population: the vulnerability index questionnaire by Acharya and Porwal (2020) was adopted in this study. This index was built on the social vulnerability index by Flanagan *et al.* (2011) with the addition of the COVID-19 pandemic. The questionnaire consists of five dimensions - (1) socio-economic condition; (2) demographic composition; (3) housing and hygiene condition; (4) availability of healthcare facilities, and (5) COVID-19-related epidemiological factors. First, the *socio-economic vulnerability* of populations was measured with four indicator variables as follows: (1) attaining some level of education with the primary level being the least, (2) employment status of respondents, (3) monthly household income and (4) as a proxy for poverty is the proportion of the population who did not have any household assets. These assets include but are not limited to television, radio, bicycle, phone, and refrigerator. Similarly, the *demographic vulnerability* was measured using the elderly population (this includes persons aged 60 years and above), place of residence (be it urban or rural), and how well homes are suited. Concerning *housing and hygiene conditions*, the paper utilises four variables: number of people per room, availability of toilet facilities within a household, availability of hand hygiene facilities and household access to water. With regards to the availability of healthcare, the study uses four indicators - possessing health insurance, access to healthcare, willingness to visit and access health

facilities, and the number of healthcare facilities in a community. For *epidemiological factors,* the study took into consideration three main indicators as proxies. They include a person's current health condition, a person with any current chronic morbidity, and a person undergoing any long-term medical treatment. A respondent scores 1 when he demonstrates or finds himself in a vulnerable situation and scores 0 when otherwise is observed. A total score of 18 denotes high vulnerability.

Digital financial services: In this paper, digital financial services inclusion was defined as the provision of financial services accessed and delivered through a mobile device. Therefore, mobile money was used as a proxy to measure digital financial inclusion. This study limits digital financial services to mobile money because this was the most common form of technology available to informal settlement dwellers. Indeed, with the advent of COVID-19, the government of Ghana increased the amount that could be transferred while lowering the charges on the mobile financial system. This served as an incentive for a lot of people to use the mobile financial system as a form of digital financial service. We construct an index of 1 to 9, with 9 being a person with more usage of financial technology and inclusion.

We employ several control variables that affect the relationship of interest. These include age, religion, marital status, and region. The main and other control variables are presented in Table 1.

Table 1. Variables and their definitions.

Variable	Definition	Measurement
Gender		
Gender	Gender of respondent	1 = if male; 0 = otherwise
Personal/Household characteristics		
Age	Age range of respondent	Years
Marriage status	Marital Status of respondents	1 = if married; 0 = otherwise
Region	Residence in a particular region	1 = if yes; 0 = otherwise
Religion	Religion of respondent	1 = if Christian; 0 = otherwise
Vulnerability (index score of how vulnerable a respondent is)		
Socioeconomic		
Level of education	Education attainment of the person	1 = if primary or lower, 0 otherwise
Employment status	Employment status of respondent	1 = if unemployment, 0 otherwise
Poor household	Household with assets	1 = if no assets, 0 otherwise
Household income	Monthly household income	1 = if income less than 313, 0 otherwise
Demographic condition		
Elderly population	Person aged 60 and above	1 = if age is less than 60, 0 otherwise
Urbanisation	Place of residence (Urban or Rural)	1 = if urban; 0=otherwise
Poorly suited home	Poorly suited accommodation	1 = if yes; 0=otherwise
Housing and hygiene condition		
People per room/over crowding	Proportion of Number of people in the room	1 = if average more than 3 in the room, 0 otherwise
Household with toilet	Availability of toilet facility	1 = no toilet facility in the house, 0 otherwise
Household with hand hygiene facility	Household without hand hygiene facility	1 = household without hand hygiene facility, 0 otherwise
Household with water	Household with reliable water supply	1 = house without water supply, 0 otherwise

Table 1. *Continued*

Variable	Definition	Measurement
Availability of health care		
Health insurance	Possession of health insurance	1= if no health insurance, 0 otherwise
Access to health care	Availability of health care	1 = if no health care, 0 otherwise
Visit to health facility	Visiting of health care	1 = if no visit has been made, 0 otherwise
The number of health care facility	The number of health care facility in the neighbourhood	1 = if no health care facility, 0 otherwise
Epidemiological factors		
Person current health condition	Person current health condition	1 = if the person is experiencing any illness, 0 otherwise
Person with any chronic morbidity	Person with any chronic morbidity	1 = if the person has any chronic illness, 0 otherwise
Person undergoing long-term medical treatment	Person undergoing long-term medical treatment	1 = if the person undergoing a long-term medical treatment, 0 otherwise
	Vulnerability index	**Total score = 18 being the most vulnerable**
COVID-19 exposure		
COVID-19 contact	Personal COVID-19 exposure	1 = if yes, 0 Otherwise
Exposure to dead	Personal knowledge to COVID-19 exposure to dead	1 = if yes, 0 Otherwise
Contact to a dead	COVID-19 exposure to a dead relative	1 = if yes, 0 Otherwise
	COVID-19 exposure	**Total score = 3 being more exposed**
Digital financial services		
Fintech	Possession mobile phone	1 = if yes, 0 otherwise
Mobile account	Mobile account ownership	1 = if yes, 0 otherwise
Usage		
Saving	Usage of account for savings	1 = if yes; 0 = otherwise
Frequency of Withdraw	Making withdraws	1 = if yes; 0 = otherwise
Usage of Payment	Usage of acct for payments	1 = if yes; 0 = otherwise
Tax payment	Paying taxes	1 = if yes; 0 = otherwise
Receiving payment	Receipt from business/govt	1 = if yes; 0 = otherwise
Lending	Lending	1 = if yes; 0 = otherwise
Borrowing	Borrowing	1 = if yes; 0 = otherwise
Making investment	Making investment	1 = if yes; 0 = otherwise
Paying insurance	Taking out insurance	1 = if yes; 0 = otherwise
	Usage intensive index	**0-9 with highest score of 9 indicating good usage**
	Usage intensive proportion index	**Higher proportion indicating intensity of usage**

Ethical statement

This study was approved by the University of Ghana Ethics Committee for The Humanities (ECH) (approval number: ech 342/21-22). In addition, we indicated the purpose of the study to the respondents and participation in the study was voluntary. Participants were also debriefed, their consent sought and made aware the data was for academic publication purposes.

Analysis and estimation strategy

In this section, firstly, we estimate the effect of gender on COVID-19 exposure, controlling for a wide range of potential drivers of exposure and dummies for individual participant household characteristics. We specify the model below to estimate the impact gender has on COVID-19 exposure.

$$Y^*_{1j} = X'_{1j}\alpha + R'_{1j}\beta + \varepsilon_{1j} \tag{1}$$

In the model above, COVID-19 exposure which is denoted as Y^*_{1j}, is the dependent variable. COVID-19 exposure is measured using three indicator variables namely: personal exposure, exposure to an infected person, and contact with a COVID-19-related deceased person. Each indicator is scored one when a respondent answers in the affirmative with regard to exposure-related questions. The subscript j refers to the individual. X'_j is a vector of individual household-level characteristics such as age, marital status, geographical location, etc. $R'_{1j}\beta$ is the gender. It consists of two mutually exclusive and exhaustive categories that are men and women. It takes the value 1 when the respondent is a man and 0 when the respondent is a woman. ε_j is a normally distributed random error term with zero mean and constant variance.

Next, we explore how gender influences the vulnerability of marginalised populations. In line with the vulnerability literature, we forecast that women are more vulnerable than men during the pandemic outbreaks. This can be attributed to the poor socio-economic status most women have which makes it difficult for them to adopt measures that will help insulate them from the risks of pandemics thus increasing their vulnerability. To help us examine the relationship between gender and vulnerability, we model the equation below:

$$Y^*_{2j} = X'_{2j}\alpha + R'_{2j}\beta + \varepsilon_{1j} \tag{2}$$

Here, Y^*_{2j} is the index score of vulnerability. Vulnerability in this study is constructed as an index comprising five main constructs: socioeconomic, demographic, housing and hygiene conditions, availability of health care and epidemiological factors. A respondent scores 1 when they demonstrate or find themself in a vulnerable situation on a dimension and scores 0 when otherwise is observed. A total score of 18 denotes high vulnerability. The subscript j refers to the individual. X'_j is a vector of individual household-level characteristics such as age, marital status, geographical location, etc. $R'_{2j}\beta$ is the gender. It consists of two mutually exclusive and exhaustive categories, that is men and women. It takes the value 1 when the respondent is a man and 0 when the respondent is a woman. ε_j is a normally distributed random error term with zero mean and constant variance.

Having estimated the relationship between gender and COVID-19 exposure on one hand and vulnerability, on the other hand, the next step is to evaluate the impact of digital financial services on vulnerable populations in the era of COVID-19. The rationale is that even in the face of expected support when the right financial technology is not employed, the support may not achieve the intended outcomes.

$$Y^*_{3j} = X'_{3j}\alpha + P'_{3j}\beta + \varepsilon_{2j} \tag{3}$$

Where, Y^*_{3j}, is the dependent variable, vulnerability. Vulnerability in this study is constructed as an index comprising five main constructs: socioeconomic, demographic, housing and hygiene conditions, availability of health care and epidemiological factors. A respondent scores 1 when they demonstrate or find themself in a vulnerable situation and scores 0 when otherwise is observed. A total score of 18 denotes high vulnerability. The subscript j refers to the individual. X'_j is a vector of individual household-level characteristics such as age, marital status, geographical location etc. $P'_{3j}\beta$ represents digital financial services with an index of 1-9 with 9 being a person with more usage of financial technology and inclusion. ε_j is a normally distributed random error term with zero mean and constant variance.

Furthermore, we estimate the joint effect of gender, vulnerability, and digital financial services on COVID-19 exposure. Here, further analysis is conducted to examine the channel through which gender is exposed to the COVID-19 pandemic. That is, we analyse whether the amelioration of gender to COVID-19 is dependent on vulnerability or the adoption and use of financial technology. We use the model below:

$$Y^*_{4j} = X'_{4j}\alpha + R'_{3j}\beta + Q'_{3j}\beta + P'_{3j}\beta + \left(R'_{3j}\beta * P'_{3j}\beta\right) + \left(Q'_{3j}\beta * R'_{3j}\beta\right) + \varepsilon_{3j} \tag{4}$$

Here again, Y^*_{4j}, the dependent variable is COVID-19 exposure. The subscript *j* refers to the individual. X'_j is a vector of individual household-level characteristics such as age, marital status, geographical location etc. $R'_{3j}\beta$ is the gender. $Q'_{3j}\beta$ is the vulnerability and is constructed as an index comprising five main constructs: socioeconomic, demographic, housing and hygiene conditions, availability of health care and epidemiological factors. A respondent scores 1 when they demonstrate or find themself in a vulnerable situation and scores 0 when otherwise is observed. A total score of 18 denotes

high vulnerability. $P'_{3j}\beta$ represents digital financial services with an index of 1-9 with 9 being a person with more usage of financial services and inclusion. In equation (4) above, $\left(R'_{3j}\beta * P'_{3j}\beta\right)$ represents the interaction between gender and digital financial service, and $\left(Q'_{3j}\beta * R'_{3j}\beta\right)$ represents the interaction between vulnerability and gender. ε_j is a normally distributed random error term with zero mean and constant variance. All variables used in the models, their definitions, and measurements are shown in Table 1.

Results

Descriptive statistics

This section provides the summary and descriptive statistics of our key variables of interest employed in the study. Given the gendered perspective of this study, we first present in Table 2a the data gathered on gender under two broad classifications. We collected data from men and women over the age of 18 who consented to be a part of the study. Men constitute 1,070 (40%) out of the 2,697 individuals sampled; women make up the remaining 1,627 (60%). The raw data can be found under *Underlying data* (Amidu, 2022).

Another characteristic feature of our sampled respondents is their marital status. We classified respondents into various categories as single/never married, cohabiting, married, separated/divorced, and widowed. We find most of them were married. The second-largest cohort in terms of marital status classification is the single/never married. They make up approximately 33% of the study's sample population. Those cohabiting, separated/divorced, and widowed made up approximately 17% of the sample.

Furthermore, respondents were sampled across 11 out of the 16 regions of Ghana. The regional distribution of our sample reveals that persons from the Greater Accra region constituted about 38.75% of the sample thus ranking as the region with the highest representation in this study. The other regions included in this study were fairly represented with their sample size hovering above 1% but not more than 10%. Table 2a acts as a reference for the aforementioned statistics.

Table 2a. Frequency distribution of demographics.

		Freq.	Percent	Cum.
Gender				
	Female	1627	60.33	60.33
	Male	1070	39.67	100
Marital status				
	Single/never married	883	32.74	32.74
	Co-habiting	126	4.67	37.41
	Married	1348	49.98	87.39
	Separated/Divorced	184	6.82	94.22
	Widow	156	5.78	100
Region				
	Western	262	9.71	9.71
	Central	104	3.86	13.57
	Greater Accra	1045	38.75	52.32
	Volta	129	4.78	57.1
	Ashanti	512	18.98	76.2
	Ahafo	62	2.3	78.49
	Bono	227	8.42	86.91
	Bono East	96	3.56	90.47
	Northern	170	6.3	96.77
	Savanna	59	2.19	98.96
	North-East	28	1.04	100

Table 2b. COVID-19 vulnerability by regional slum.

Regions	Socio economic Vulnerability	Demographic vulnerability	Housing & hygiene vulnerability	Health care vulnerability	Epidemio logical vulnerability	Total vulnerability Score
Bono	0.855	0.184	1.101	1.654	0.303	4.096
North East	0.966	0.172	1.966	0.793	0.207	4.103
Ahafo	0.887	0.161	1.226	1.710	0.258	4.242
Savanna	0.879	0.052	1.879	1.500	0.172	4.483
Northern	0.859	0.065	1.853	1.729	0.176	4.682
G. Accra	0.809	0.815	0.978	2.035	0.189	4.826
Ashanti	0.533	1.105	1.346	1.744	0.152	4.881
Volta	0.938	0.422	0.852	1.711	0.961	4.883
Bono East	0.875	0.563	1.333	1.698	0.469	4.938
Central	0.792	0.953	0.943	2.151	0.142	4.981
Western	1.027	1.115	1.290	1.656	0.351	5.439

To explore the gender and vulnerability nexus, we again collected data across the five domain vulnerabilities and computed indices accordingly. The vulnerability scores of the regional slums under consideration are presented in Table 2b and each column denotes a specified vulnerability under the five domains. In the last column of the table, we find total vulnerability which happens to be the composite score of all five domain vulnerabilities per region. We observe from Table 2b that the total vulnerability score ranges between 4 and 6. Amongst the regions, we find the Western region recording the highest total vulnerability with a score of 5.439 whereas the Bono region scored the least with an index of 4.096. Again, the Western region suffers the highest socio-economic and demographic compared to the regional slums sampled by this study. In terms of housing and hygiene, health care and epidemiological vulnerability, we observe slums in the North-East, Central, and Volta regions suffering the most with vulnerability indices of 1.966, 2.151, and 0.961 respectively. On average, the domain vulnerability score for socioeconomic, demographic, housing and hygiene, health care vulnerability and epidemiological vulnerability are 0.856, 0.510, 1.342, 1.371, and 0.310 respectively.

We also collected data on the ownership of mobile accounts and usage of mobile-enabled digital financial services by our respondents as it forms part of our objective to examine the effect digital financial services have on the vulnerability of slum populations. In Table 2c, we present data on the usage of digital financial services as enabled by possessing a mobile account on a mobile device. We arrived at this by soliciting a Yes or No response from respondents. It comes to bear that most respondents (95.81%) possess a mobile device whereas 86.87% of sampled respondents responded in the

Table 2c. Digital financial services.

Digital financial services	Frequency		Percentage	
	No	Yes	No	Yes
Possession of mobile device	113	2584	4.19	95.81
Mobile account ownership	354	2343	13.13	86.87
Savings	842	1855	31.22	68.78
Frequent withdraw	535	2162	19.84	80.16
Payments	2225	472	82.50	17.50
Tax obligation	2693	4	99.85	0.15
Receiving money	2630	67	97.52	2.48
Lending money	2694	3	99.89	0.11
Borrowing	2419	278	89.69	10.31
Investments	2650	47	98.26	1.74
Insurance	2673	24	99.11	0.89

Table 2d. COVID-19 exposure.

COVID-19 exposure index	Freq.	Percent	Cum.
0	501	18.58	18.58
1	1963	72.78	91.36
2	173	6.41	97.78
3	60	2.22	100

The highest score of 3 indicating more exposure.

affirmative that they own an account on their mobile device. On the usage variables, withdrawal and savings were the most patronised mobile-enabled digital financial services. Payment using a mobile account ranked third with 17.50%. The least used service was lending money using mobile money account. The statistics show untapped mobile account usage gaps and reflect some extent the financial behaviour of Ghanaians.

This section of the study closes with data collected on the COVID-19 exposure status of respondents as shown in Table 2d. The exposure of respondents is scored as an index ranging from 0 to 3. We observe that most respondents (constituting 91.36%) score 0 and 1 suggesting no to very low level of exposure. Respondents who scored 2 to 3 make up the remaining 8.64%. We can therefore infer from the exposure distribution of our sampled respondents that living in slums does not necessarily imply high exposure to COVID-19 despite overcrowding and insanitary conditions prevailing in such communities. Furthermore, we reported in Table 2e all the key variables, especially the dependent variables, and then the explanatory variables.

Table 2e. Report on key variables.

Tabulation of Covid-19 exposure			
Sum of exposure or contact with covid patient and dead covid patient	**Freq.**	**Percent**	**Cum.**
0	501	18.58	18.58
1	1963	72.78	91.36
2	173	6.41	97.78
3	60	2.22	100.00
Total	2697	100.00	
Tabulation of socioeconomic_vulnerability score			
Average of socioeconomic vulnerability	**Freq.**	**Percent**	**Cum.**
0	1074	39.82	39.82
.25	1174	43.53	83.35
.5	371	13.76	97.11
.75	77	2.86	99.96
1	1	0.04	100.00
Total	2697	100.00	
Tabulation of demographic vulnerability score			
Average of demographic conditions vulnerability	**Freq.**	**Percent**	**Cum.**
0	945	35.04	35.04
.3333333	1518	56.28	91.32
.6666667	230	8.53	99.85
1	4	0.15	100.00
Total	2697	100.00	

Table 2e. *Continued*

Tabulation of housing and hygiene vulnerability score			
Average of housing and hygiene condition	**Freq.**	**Percent**	**Cum.**
0	843	31.26	31.26
.25	898	33.30	64.55
.5	622	23.06	87.62
.75	283	10.49	98.11
1	51	1.89	100.00
Total	2697	100.00	
Tabulation of epidemiological vulnerability score			
Average of epidemiological factors	**Freq.**	**Percent**	**Cum.**
0	2325	86.21	86.21
.3333333	96	3.56	89.77
.6666667	242	8.97	98.74
1	34	1.26	100.00
Total	2697	100.00	
Tabulation of healthcare vulnerability score			
Average of availability of health care	**Freq.**	**Percent**	**Cum.**
0	41	1.52	1.52
.25	975	36.15	37.67
.5	1065	39.49	77.16
.75	616	22.84	100.00
Total	2697	100.00	
Tabulation of total vulnerability_score			
Average of all the vulnerabilities	**Freq.**	**Percent**	**Cum.**
0	5	0.19	0.19
.0555556	63	2.34	2.52
.1111111	227	8.42	10.94
.1666667	400	14.83	25.77
.2222222	557	20.65	46.42
.2777778	534	19.80	66.22
.3333333	411	15.24	81.46
.3888889	273	10.12	91.58
.4444444	128	4.75	96.33
.5	52	1.93	98.26
.5555556	35	1.30	99.56
.6111111	8	0.30	99.85
.6666667	3	0.11	99.96
.7222222	1	0.04	100.00
Total	2697	100.00	

Table 2e. *Continued*

Tabulation of usage of DFS			
Sum of financial services usage variables	**Freq.**	**Percent**	**Cum.**
0	494	18.32	18.32
1	250	9.27	27.59
2	1334	49.46	77.05
3	504	18.69	95.74
4	96	3.56	99.30
5	17	0.63	99.93
6	1	0.04	99.96
7	1	0.04	100.00
Total	2697	100.00	
Tabulation of gender			
Gender	**Freq.**	**Percent**	**Cum.**
Female	1627	60.33	60.33
Male	1070	39.67	100.00
Total	2697	100.00	
Tabulation of DFS usage			
Average of usage of DFS	**Freq.**	**Percent**	**Cum.**
0	113	4.19	4.19
.1666667	466	17.28	21.47
.3333333	1330	49.31	70.78
.5	549	20.36	91.14
.6666667	193	7.16	98.29
.8333333	36	1.33	99.63
1	10	0.37	100.00
Total	2697	100.00	

1. The influence of gender on COVID-19 exposure

In Table 3, we present the results of the influence of gender on COVID-19 exposure. We arrive at this by regressing gender against COVID-19 exposure whilst controlling for possible drivers of exposure. The results suggest that men are exposed to the COVID-19 pandemic than women. We observe a positive and highly significant relationship between men and COVID-19 exposure. This occurrence can be attributed to ignorance of preventive measures by this gender group. More so, men have a perception of having a stronger immune system that will enable them to fight the virus more than women (Bwire, 2020). Galasso *et al.* (2020) found that women perceive the pandemic as a very serious health problem and therefore agree and comply with restraining measures. Grasselli *et al.* (2020) put forward similar sentiments. They opine that the disregard for restrictive measures is partially the reason more men than women are dying from COVID-19.

Individuals' age serves as a significant determinant in exploring COVID-19 exposure. The outbreak of the COVID-19 pandemic resulted in the death of the elderly population around the world. This is attributed to weak immune systems and various underlying health conditions suffered by this age class. However, in this study, we find a negative and highly significant relationship between age and exposure for persons living in slums. We also find that the marital status and religious affiliation of an individual have no significant bearing when it comes to exposure to pandemics like COVID-19. Although the co-efficient of these variables are positive, they do not show any statistical significance. We can therefore suggest that marital status and religion are not significant determinants of one's exposure status.

Table 3. The influence of gender on COVID-19 exposure.

	(1)	(2)	(3)	(4)
	Covid exposure	**Covid exposure**	**Covid exposure**	**Covid exposure**
Gender	0.0677***	0.0707***	0.0707***	0.0731***
	(0.0229)	(0.0228)	(0.0228)	(0.0228)
Age		-0.00410***	-0.00431***	-0.00438***
		(0.000896)	(0.000922)	(0.000922)
Marital status			0.0196	0.0213
			(0.0228)	(0.0229)
Religion				0.0252
				(0.0260)
Central	-0.533***	-0.570***	-0.569***	-0.571***
	(0.0703)	(0.0700)	(0.0700)	(0.0698)
G. Accra	-0.169***	-0.198***	-0.197***	-0.198***
	(0.0425)	(0.0428)	(0.0428)	(0.0428)
Volta	-0.0907	-0.0990	-0.0972	-0.0990
	(0.0731)	(0.0733)	(0.0733)	(0.0733)
Ashanti	-0.230***	-0.266***	-0.265***	-0.258***
	(0.0431)	(0.0438)	(0.0438)	(0.0444)
Ahafo	0.0488	0.0245	0.0255	0.0279
	(0.0551)	(0.0548)	(0.0548)	(0.0547)
Bono	-0.0901*	-0.116**	-0.114**	-0.107**
	(0.0474)	(0.0477)	(0.0476)	(0.0483)
Bono East	-0.0395	-0.0596	-0.0604	-0.0484
	(0.0522)	(0.0523)	(0.0524)	(0.0538)
Northern	0.0201	-0.00483	-0.00941	0.00963
	(0.0455)	(0.0453)	(0.0460)	(0.0504)
Savanna	0.00275	-0.00513	-0.0106	0.00830
	(0.0553)	(0.0551)	(0.0554)	(0.0586)
North East	0.341**	0.322**	0.319**	0.337**
	(0.152)	(0.152)	(0.152)	(0.153)
Constant	1.034***	1.209***	1.207***	1.188***
	(0.0378)	(0.0531)	(0.0531)	(0.0564)
Observation	2697	2697	2697	2697
R square	0.0514	0.0596	0.0598	0.0601
Adjusted R square	0.0475	0.0553	0.0553	0.0552
P-values	0.000	0.000	0.000	0.000

The table presents the results on the influence of gender on COVID-19 exposure. In this table, gender of respondents is regressed against COVID-19 exposure. *Gender* is measured as a dichotomous variable that takes the value of one if the respondent is a male and zero otherwise. *Marital status* is a dummy variable, taking the value of one if the respondent is a married person and zero otherwise. The *religion* is a dichotomous variable taking the value of one if the respondent is a Christian and zero otherwise The parameters are estimated with the small sample adjusted standard errors in parenthesis. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Regional slums including Central, Greater Accra, Ashanti, Bono, and North-East regions showed statistical significance with exposure with variations in terms of direction and magnitude. The results suggest that among the above-mentioned regions, the North-East region has higher susceptibility to COVID-19 exposure. We find positive and highly significant association between the region and exposure.

2. The influence of gender on vulnerability

In this section, we explore the influence of gender on vulnerability. The results of this are displayed in Table 4. The results suggest that men are less vulnerable compared to women. This observation is true and falls in tandem with the vulnerability literature. Women around the world suffer an array of vulnerabilities not limited to social, economic and health vulnerabilities. From Table 4, we observe a negative and highly significant relationship between men and four domain vulnerability measures together with their composite. Although men may suffer epidemiological vulnerability more than women, the magnitude of the other four vulnerabilities far outweighs the effect of their epidemiological vulnerabilities thus explaining the negative total vulnerability observed. The epidemiological vulnerability men may suffer can be associated with the neglect of preventive measures.

Table 4. The influence of gender on the vulnerability of slum populations.

	(1) Socio economic Vulnerability	(2) Demographic vulnerability	(3) Housing & hygiene vulnerability	(4) Health care vulnerability	(5) Epidemio logical vulnerability	(6) Total vulnerability score
Gender	-0.0676***	-0.00611	-0.0642***	-0.0352***	0.0958***	-0.0149***
	(0.00726)	(0.00628)	(0.00985)	(0.00780)	(0.00732)	(0.00406)
Age	0.00363***	0.00379***	-0.000117	0.00592***	-0.00147***	0.00207***
	(0.000313)	(0.000308)	(0.000404)	(0.000430)	(0.000290)	(0.000174)
Married	-0.0541***	-0.0380***	0.00733	-0.0384***	-0.0345***	-0.0308***
	(0.00754)	(0.00694)	(0.0105)	(0.00883)	(0.00750)	(0.00430)
Religion	-0.0300***	-0.0114	-0.0288**	-0.00650	0.0183**	-0.0120**
	(0.00868)	(0.00779)	(0.0118)	(0.00932)	(0.00862)	(0.00486)
Central	-0.0247	-0.0237	-0.0790***	-0.0174	0.0947***	-0.00885
	(0.0240)	(0.0167)	(0.0300)	(0.0230)	(0.0222)	(0.0120)
G. Accra	-0.0292**	-0.0779***	-0.0713***	-0.0141	0.0703***	-0.0221**
	(0.0137)	(0.0121)	(0.0195)	(0.0155)	(0.0130)	(0.00860)
Volta	-0.0134	-0.227***	-0.101***	0.214***	-0.00298	-0.0283**
	(0.0223)	(0.0186)	(0.0274)	(0.0327)	(0.0205)	(0.0137)
Ashanti	-0.102***	0.0215*	0.0113	-0.0188	0.000170	-0.0197**
	(0.0142)	(0.0128)	(0.0210)	(0.0167)	(0.0140)	(0.00910)
Ahafo	-0.0129	-0.300***	-0.00911	0.00373	-0.0123	-0.0571***
	(0.0213)	(0.0193)	(0.0367)	(0.0285)	(0.0245)	(0.0136)
Bono	-0.0301*	-0.294***	-0.0500**	0.0167	-0.0171	-0.0679***
	(0.0173)	(0.0137)	(0.0244)	(0.0207)	(0.0165)	(0.0104)
Bono East	-0.0290	-0.171***	0.00255	0.0677**	0.00221	-0.0226*
	(0.0190)	(0.0249)	(0.0317)	(0.0320)	(0.0223)	(0.0134)
Northern	-0.0207	-0.329***	0.130***	-0.0143	0.00919	-0.0310***
	(0.0190)	(0.0132)	(0.0287)	(0.0221)	(0.0185)	(0.0119)
Savanna	-0.0272	-0.345***	0.134***	-0.0375	-0.0363	-0.0481***
	(0.0231)	(0.0144)	(0.0378)	(0.0275)	(0.0242)	(0.0139)
North East	0.00270	-0.301***	0.164***	-0.0131	-0.232***	-0.0669***
	(0.0340)	(0.0222)	(0.0452)	(0.0444)	(0.0282)	(0.0176)
Constant	0.176***	0.242***	0.365***	-0.0998***	0.455***	0.245***
	(0.0194)	(0.0169)	(0.0262)	(0.0214)	(0.0178)	(0.0113)

Table 4. *Continued*

	(1) Socio economic Vulnerability	(2) Demographic vulnerability	(3) Housing & hygiene vulnerability	(4) Health care vulnerability	(5) Epidemio logical vulnerability	(6) Total vulnerability score
Observation	2697	2697	2697	2697	2697	2697
R square	0.115	0.387	0.0851	0.180	0.144	0.0901
Adjusted R square	0.110	0.384	0.0803	0.175	0.140	0.0854
P-values	0.000	0.000	0.000	0.000	0.000	0.000

The table presents the results on the influence of gender on vulnerability of slum populations. In this table, gender of respondents is regressed against the individual indicators of *vulnerability* (which has five domains: (1) socioeconomic condition; (2) demographic composition; (3) housing and hygiene condition; (4) availability of health-care facilities, and (5) COVID-19-related epidemiological factors and their total. *Gender* is measured as a dichotomous variable that takes the value of one if the respondent is a male and zero otherwise. *Marital status* is a dummy variable, taking the value of one if the respondent is a married person and zero otherwise. The *religion* is a dichotomous variable taking the value of one if the respondent is a Christian and zero otherwise The parameters are estimated with the small sample adjusted standard errors in parenthesis. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Also, we find the following controlling variables to be significant determinants of vulnerability: age, marital status, and one's region of residence. For age, we observe a positive and highly significant total vulnerability relationship. This suggests that an individual's age can increase their overall vulnerability whereas marriage status goes a long way to reducing vulnerability. We find the coefficient of the total vulnerability of the married to be negative. Marriage provides some form of synergy which makes it possible for couples to reduce their vulnerability. The total vulnerability across the sampled regions appears to be negative and highly significant despite some of its domain vulnerabilities being positive.

3. The influence of digital financial service usage on the vulnerability of slum populations

Table 5 shows how the usage of digital financial services influences vulnerable populations in the era of COVID-19. In this section we regress the digital financial services usage index against individual domain vulnerabilities (socioeconomic, demographic, housing and hygiene conditions, availability of healthcare and epidemiological factors) and their composite. In this instance, we control for the age, marital status, region of residence and religion of respondents. We observe from the table in reference, a negative and highly significant relationship between the usage of digital financial services during the COVID-19 pandemic and vulnerability (domain and composite). This suggests that the usage of

Table 5. The effect of digital financial services on vulnerability.

	(1) Socio economic Vulnerability	(2) Demographic vulnerability	(3) Housing & hygiene vulnerability	(4) Health care vulnerability	(5) Epidemio logical vulnerability	(6) Total vulnerability Score
DFS Usage index	-0.0438***	-0.0131***	-0.0341***	-0.00782**	-0.00951***	-0.0229***
	(0.00317)	(0.00285)	(0.00447)	(0.00354)	(0.00337)	(0.00174)
Age	0.00321***	0.00368***	-0.000462	0.00581***	-0.00141***	0.00188***
	(0.000305)	(0.000304)	(0.000397)	(0.000427)	(0.000299)	(0.000165)
Marital status	-0.0478***	-0.0362***	0.0124	-0.0370***	-0.0341***	-0.0276***
	(0.00743)	(0.00689)	(0.0104)	(0.00881)	(0.00780)	(0.00417)
Religion	-0.0177**	-0.00953	-0.0178	-0.00128	0.00650	-0.00824*
	(0.00853)	(0.00765)	(0.0116)	(0.00926)	(0.00895)	(0.00468)
Central	-0.0279	-0.0229	-0.0829***	-0.0209	0.108***	-0.00794
	(0.0228)	(0.0164)	(0.0301)	(0.0231)	(0.0222)	(0.0114)
G. Accra	-0.0338**	-0.0777***	-0.0762***	-0.0175	0.0815***	-0.0222***
	(0.0132)	(0.0118)	(0.0190)	(0.0155)	(0.0129)	(0.00813)
Volta	-0.0145	-0.225***	-0.103***	0.212***	0.00776	-0.0268**
	(0.0215)	(0.0185)	(0.0267)	(0.0327)	(0.0204)	(0.0131)

Table 5. *Continued*

	(1) Socio economic Vulnerability	(2) Demographic vulnerability	(3) Housing & hygiene vulnerability	(4) Health care vulnerability	(5) Epidemio logical vulnerability	(6) Total vulnerability Score
Ashanti	-0.104***	0.0221*	0.00954	-0.0206	0.00765	-0.0189**
	(0.0138)	(0.0126)	(0.0205)	(0.0167)	(0.0142)	(0.00865)
Ahafo	0.00436	-0.293***	0.00260	0.00335	0.00801	-0.0450***
	(0.0202)	(0.0193)	(0.0371)	(0.0286)	(0.0266)	(0.0134)
Bono	-0.0157	-0.289***	-0.0394	0.0180	-0.00768	-0.0592***
	(0.0170)	(0.0135)	(0.0240)	(0.0208)	(0.0169)	(0.0100)
Bono East	-0.0271	-0.170***	0.00356	0.0670**	0.00743	-0.0207
	(0.0191)	(0.0246)	(0.0317)	(0.0323)	(0.0232)	(0.0131)
Northern	-0.0294	-0.330***	0.121***	-0.0187	0.0208	-0.0330***
	(0.0185)	(0.0130)	(0.0283)	(0.0221)	(0.0187)	(0.0115)
Savanna	-0.0337	-0.346***	0.128***	-0.0407	-0.0278	-0.0496***
	(0.0240)	(0.0144)	(0.0378)	(0.0275)	(0.0245)	(0.0137)
North East	-0.00423	-0.300***	0.156***	-0.0189	-0.212***	-0.0665***
	(0.0332)	(0.0220)	(0.0450)	(0.0444)	(0.0312)	(0.0167)
Constant	0.235***	0.264***	0.407***	-0.0973***	0.506***	0.283***
	(0.0194)	(0.0172)	(0.0269)	(0.0218)	(0.0187)	(0.0111)
Observation	2697	2697	2697	2697	2697	2697
R square	0.146	0.392	0.0908	0.175	0.0920	0.139
Adjusted R square	0.141	0.388	0.0861	0.171	0.0873	0.134
P-values	0.000	0.000	0.000	0.000	0.000	0.000

The table presents the results on the influence of digital financial services on vulnerable populations. In this table, the usage of digital financial services among respondents is regressed against the individual indicators of *vulnerability* (which has five domains: (1) socioeconomic condition; (2) demographic composition; (3) housing and hygiene condition; (4) availability of health-care facilities, and (5) COVID-19-related epidemiological factors) and their total. *Age* is a continuous variable. *Marital status* is a dummy variable, taking the value of one if the respondent is a married person and zero otherwise. The *religion* is a dichotomous variable taking the value of one if the respondent is a Christian and zero otherwise The parameters are estimated with the small sample adjusted standard errors in parenthesis. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level respectively.

digital financial services reduces vulnerability thus confirming the importance of using digital financial services during and even beyond pandemics. Digital financial services reduce human contact hence reducing the risk of transmission of contagious diseases like COVID-19. The specific vulnerabilities are socio-economic, housing and hygiene, and health care. In terms of marital status, a negative and highly significant relationship is observed for all vulnerability measures except for housing and hygiene. This may be a result of the married sharing limited space with their spouse and children thus increasing their vulnerability along with that domain. Although age appears to be positive and highly significant, in terms of epidemiological vulnerability it shows a negative effect. This suggests that the age of a respondent can reduce this epidemiological vulnerability.

On the regional influence, we observe a negative and highly significant relationship for the total vulnerability of sampled regions given the usage of digital financial services. A closer look at results on the Greater Accra Region suggests the high potency of digital financial services to reduce vulnerability in its slums given its status as the epicentre of the COVID-19 outbreak in the country. This can be attributed to the greater concentration of digital infrastructure in the region which promotes the usage of digital financial services. We observe that, given the usage of digital financial services, both domain vulnerabilities and their total are negative and highly significant except for epidemiological vulnerability which shows a positive and highly significant association. Generally, all the regions show at least a negative significant relationship with a domain vulnerability. The results also suggest that regional differences and dynamics should be factored in when policies are being formulated towards improving the living conditions of persons living in slums and considered vulnerable. This is against the backdrop of COVID-19 disproportionately affecting regions. For religion, we observe that, among the five domain vulnerabilities, only socio-economic vulnerability shows some statistical significance.

4. The sensitivity of gender, vulnerability, and digital financial services to COVID-19 exposure

Finally, the study explores the sensitivities of gender, vulnerability, and usage of digital financial services of respondents on their exposure to the COVID-19 pandemic. We observe from Table 6 that COVID-19 exposure is highly sensitive to the interaction among gender, vulnerability, and usage of financial services. The results show a negative and highly significant relation. The results suggest that given the seemingly high exposure of men to the pandemic, men can take advantage of the opportunities offered by the usage of digital financial services to reduce their exposure to the COVID-19 pandemic.

Table 6. The sensitivity of gender, vulnerability and digital financial services to COVID-19 exposure.

	(1)	(2)	(3)
	covid_exposure	covid_exposure	covid_exposure
Gender	0.115***		
	(0.0375)		
Total vulnerability score	-0.712***	-0.859***	
	(0.116)	(0.108)	
DFS index	0.0376***		0.0469***
	(0.0128)		(0.0102)
Gender* DFS index		0.0214**	
		(0.00906)	
Gender* Vulnerability			-0.0284
			(0.0764)
Gender* vulnerability * DFS	-0.132**		
	(0.0634)		
Age	-0.00259***	-0.00251***	-0.00390***
	(0.000938)	(0.000945)	(0.000924)
Married	-0.00333	-0.00714	0.0144
	(0.0227)	(0.0226)	(0.0229)
Religion	0.0109	0.0130	0.0109
	(0.0256)	(0.0257)	(0.0258)
Central	-0.583***	-0.574***	-0.566***
	(0.0699)	(0.0700)	(0.0706)
G. Accra	-0.215***	-0.213***	-0.192***
	(0.0431)	(0.0432)	(0.0425)
Volta	-0.126*	-0.120*	-0.0972
	(0.0722)	(0.0723)	(0.0723)
Ashanti	-0.276***	-0.271***	-0.256***
	(0.0447)	(0.0448)	(0.0442)
Ahafo	-0.0319	-0.0220	0.0102
	(0.0561)	(0.0564)	(0.0551)
Bono	-0.170***	-0.168***	-0.123**
	(0.0504)	(0.0505)	(0.0480)
Bono East	-0.0694	-0.0670	-0.0503
	(0.0551)	(0.0555)	(0.0535)

Table 6. *Continued*

	(1)	(2)	(3)
	covid_exposure	covid_exposure	covid_exposure
Northern	-0.0160	-0.0110	0.0198
	(0.0512)	(0.0511)	(0.0497)
Savanna	-0.0341	-0.0271	0.0153
	(0.0605)	(0.0604)	(0.0590)
North East	0.281*	0.284*	0.346**
	(0.150)	(0.151)	(0.154)
Constant	1.297***	1.401***	1.127***
	(0.0729)	(0.0661)	(0.0584)
Observation	2697	2697	2697
R square	0.0872	0.0834	0.0640
Adjusted R square	0.0814	0.0783	0.0588
P-values	0.000	0.000	0.000

The table presents the results on the sensitivity of COVID-19 exposure to gender, digital financial services and vulnerability of slum populations. In this table, the usage of digital financial services among respondents is interacted with gender and their total vulnerability score. *Age* is a continuous variable. *Marital status* is a dummy variable, taking the value of one if the respondent is a married person and zero otherwise. The *religion* is a dichotomous variable taking the value of one if the respondent is a Christian and zero otherwise The parameters are estimated with the small sample adjusted standard errors in parenthesis. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level respectively.

Robustness tests

To test the robustness of the benchmark results, some variations are made to the estimation of the earlier equations. Here, we analyze the relationship of interest between digital financial services and vulnerability using two-stage least squares (2SLS) regression. Even though the use of 2SLS regression does not necessarily need an explicit specification of the baseline equation, DFS is treated as endogenous. The use of the instrumental variable (IV) technique helps to explicitly specify the instruments. We employ distance to financial institutions as an appropriate instrument. Our instrument correlates with DFS and does not influence vulnerability, our exogenous variable. The result is presented in Table 7. It can be observed that distance to which a person must travel to visit a financial institution affects the person's ability to access financial services. The coefficient is positive and significant. Thus, our instrument is valid.

Table 7. The Relationship between distance to bank and DFS.

	(1)
	DFS index
Distance to bank	0.3199634***
	(0.0474803)
Age	-0.0077487
	(0.0017464)
M.status	0.1246424***
	(0.0441673)
Religion	0.0538351
	(0.534332)
Central	0.1778984
	(0.118062)
G. Accra	0.1139278
	(0.081073)

Table 7. *Continued*

	(1)
	DFS index
Volta	0.1548692
	(0.1139419)
Ashanti	0.1345043
	(0.0888453)
Ahafo	0.7042044***
	(0.1631463)
Bono	0.4714424***
	(0.1229532)
Bono East	0.1573396
	(0.1519058)
Northern	0.0392889
	(0.1128127)
Savanna	0.0060776
	(.1320018)
North East	0.1874734
	(0.153877)
Constant	1.786159***
	(0.1097292)
Observation	2,697
R square	0.0378
Adjusted R square	0.0328
P-value	0.0000

Note: *, ** and *** indicates statistical significance at the 10%, 5% and 1% level respectively.

On the relationship between DFS and vulnerability, the results are similar to those reported in Table 5. The direction of the sign and the significance of the coefficient remains the same. We find from Table 7.1 that the usage of digital financial services reduces specifically socioeconomic vulnerability, housing and hygiene vulnerability, epidemiological vulnerability as well as healthcare vulnerability. The relationship between digital financial usage and two of the domain vulnerability measures (socioeconomic and housing and hygiene) is highly significant. The overall effect of the usage of digital financial services on vulnerability is also negative and highly significant. The coefficient and direction of the total vulnerability score point to this. Similar to the results presented in Table 5, we finds age and marital status to significantly influence the relationship between the usage of digital financial services and vulnerability. However, the same cannot be said for religion. We observe that religion as a control variable does not have any significant influence on the relationship of interest. On the regional influence, we find at least one domain vulnerability being reduced by the usage of digital financial services significantly. We, therefore, conclude that access to digital financial services is critical to reducing vulnerability hence the need to bridge access gaps in slum communities.

Conclusion and policy implications

In this study, we examined the usage of digital financial services, vulnerability, and exposure of slum populations during the COVID-19 pandemic. We employed data from 101 informal settlements across 11 out of the 16 administrative regions of Ghana. By exploring these variables from a gendered perspective, our study makes the following contribution to the literature: firstly, men are more exposed to the COVID-19 pandemic. Secondly, similarly to other findings, this study finds that women are more vulnerable than men even during pandemics. Thirdly, by making use of digital financial services vulnerable groups can reduce their exposure to the pandemic.

We, therefore, conclude that there exist gender disparities regarding COVID-19 exposure and vulnerability. Also, there is a ripple effect of men's exposure to COVID-19 on the vulnerability of women at large. Given that men are more exposed to the pandemic than women, there is a need to educate men more on the need to take preventive measures seriously since their negligence would affect women negatively thus increasing their vulnerability. Given that women perform more

Table 7.1. The impact of digital financial services on vulnerability: IV Estimation.

	(1) Socio Vuln score	(2) Demographic vulnerability score	(3) Housing hygiene vulnerability score	(4) Epidemiological vulnerability score	(5) Health care vulnerability score	(6) Total vulnerability score
DFS index	-0.205***	0.00988	-0.216***	-0.0391	-0.0335	-0.106***
	(0.0348)	(0.0222)	(0.0439)	(0.0298)	(0.0273)	(0.0188)
Age	0.00201***	0.00385***	-0.00182***	0.00558***	-0.00159***	0.00126***
	(0.000494)	(0.000347)	(0.000602)	(0.000475)	(0.000363)	(0.000257)
M.status	-0.0266**	-0.0392***	0.0362**	-0.0329***	-0.0309***	-0.0167***
	(0.0113)	(0.00738)	(0.0143)	(0.00951)	(0.00857)	(0.00605)
Religion	-0.00516	-0.0113	-0.00368	0.00115	0.00836	-0.00180
	(0.0127)	(0.00802)	(0.0157)	(0.00982)	(0.00928)	(0.00670)
Central	-0.00826	-0.0257	-0.0609*	-0.0171	0.111***	0.00213
	(0.0280)	(0.0171)	(0.0367)	(0.0237)	(0.0223)	(0.0141)
G. Accra	-0.0232	-0.0792***	-0.0643***	-0.0154	0.0831***	-0.0168*
	(0.0176)	(0.0123)	(0.0226)	(0.0156)	(0.0130)	(0.00972)
Volta	0.00631	-0.228***	-0.0800**	0.216***	0.0108	-0.0161
	(0.0273)	(0.0189)	(0.0323)	(0.0327)	(0.0208)	(0.0151)
Ashanti	-0.0904***	0.0203	0.0242	-0.0181	0.00959	-0.0122
	(0.0196)	(0.0131)	(0.0246)	(0.0171)	(0.0144)	(0.0108)
Ahafo	0.105***	-0.308***	0.116**	0.0229	0.0230	0.00684
	(0.0394)	(0.0235)	(0.0533)	(0.0348)	(0.0317)	(0.0228)
Bono	0.0517*	-0.299***	0.0363	0.0310	0.00232	-0.0246
	(0.0301)	(0.0164)	(0.0371)	(0.0242)	(0.0205)	(0.0161)
Bono East	-0.00907	-0.173***	0.0238	0.0705**	0.0101	-0.0115
	(0.0314)	(0.0253)	(0.0423)	(0.0326)	(0.0238)	(0.0180)
Northern	-0.0311	-0.330***	0.120***	-0.0190	0.0206	-0.0339**
	(0.0249)	(0.0134)	(0.0342)	(0.0227)	(0.0187)	(0.0144)
Savanna	-0.0350	-0.346***	0.127***	-0.0410	-0.0280	-0.0503***
	(0.0330)	(0.0146)	(0.0422)	(0.0283)	(0.0244)	(0.0172)
North East	0.0195	-0.303***	0.183***	-0.0143	-0.209***	-0.0543***
	(0.0390)	(0.0223)	(0.0518)	(0.0437)	(0.0324)	(0.0198)
Constant	0.538***	0.221***	0.748***	-0.0386	0.551***	0.438***
	(0.0709)	(0.0453)	(0.0878)	(0.0601)	(0.0543)	(0.0379)
Observation	2697	2697	2697	2697	2697	2697
R square	.	0.377	.	0.152	0.0748	.
Adjusted R square	.	0.373	.	0.148	0.0700	.
Chi square	187.191	3386.804	183.020	286.699	290.314	180.280
P-value	0.000	0.000	0.000	0.000	0.000	0.000

Note: *, ** and *** indicates statistical significance at the 10%, 5% and 1% level respectively.

traditional homemaking roles during pandemics (Power, 2020), support should be given to women to ensure they do not lose their source of livelihood to be able to adequately provide for their needs and that of their families. Again, the labour department of organisations should not be quick in making women redundant during pandemics but should rather find innovative means by which women can contribute towards growth.

Like several other studies, this paper has some limitations. First, the cross-sectional nature of the data means that we cannot assume causality in the findings, rather they should be interpreted as associations. Again, the data was limited to Ghana and residents of informal settlements. However, these limitations do not affect the validity of the findings which can be used in similar contexts, especially for vulnerable populations across the world.

Data availability

Underlying data

OSF: Gender, digital financial services and vulnerability in the era of pandemics. https://doi.org/10.17605/OSF.IO/US6AV (Amidu, 2022).

This project contains the following underlying data:

- Gender DFS and Vulnerability CLEAN.xlsx [This file contains data collected from informal settlement dwellers in Ghana]

Extended data

OSF: Gender, digital financial services and vulnerability in the era of pandemics. https://doi.org/10.17605/OSF.IO/US6AV (Amidu, 2022).

This project contains the following extended data:

- Questionnaire.pdf

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Version 2

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✓ **Daniel Sakyi**
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The authors have addressed all the comments raised and I have no further suggestion regarding the manuscript.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

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REVIEW REPORT ON GENDER, DIGITAL FINANCIAL SERVICES AND VULNERABILITY IN THE ERA OF PANDEMICS: A CROSS-SECTIONAL ANALYSIS

GENERAL COMMENT

The paper investigate the relationship between digital financial services (DFS), gender, and the vulnerability of informal settlement dwellers and COVID-19. The paper makes use of 2697 households from 101 informal settlement from 11 out the 16 regions of Ghana. The paper looks at an interesting topic and it is timely considering the enormity of the impact as a results of the pandemic - COVID 19. The comment on the paper are presented based on the various sections.

ABSTRACT

The abstract is generally good and reflects the tittle of the paper. However, the abstract needs improvement. For instance, the authors mention that they used the multiple regression analytical technique for the analysis, but the authors have to mention the exact estimation technique for the analysis. Multiple regression is not an estimation technique. Also, the authors should be specific on the policy implication in the abstract instead of just saying that they results provide policy implications for authorities ……. in Africa.

INTRODUCTION

The introduction section is good and reflects the topic very well. The link between the pandemic and the key variables – gender, digital financial services and vulnerability have been highlighted. The motivation of the paper is generally good as the authors have highlighted the need for this present paper.

However, the authors should address the following:

1. The authors should read through the whole paper and correct any error. For instance, the use of “reason why” is tautology. The authors have to use one of them and not both.

2. The authors mention in paragraph 5 that this present study is essential as it has implications for the achievement of several SDGs. It will be ideal for the authors to mention the specific SDGs referring to.

3. In the paragraph 6, the authors use the “digital financial inclusion” which is different from the term used earlier which is the “digital financial services”. The authors should note that the two are not the same therefore this must be reconciled. Financial services and financial inclusion are different concepts.

4. The authors should delete the findings added to the introduction section. This is because same results is presented in the results section and are highlighted in the conclusion as well as in the abstract, and so it will be more of repetition.

LITERATURE REVIEW

The authors have provided some theoretical foundation for the paper and seem satisfactory.

Some empirical review has also been provided. However, the authors should try and read through and correct some errors in the text. For example, the authors write “….data has showed that ….” Instead of “…data has shown that …..”.

METHODS

The authors have provided information regarding the methods adopted in this paper. The sampling technique has also been explained. How the data was collected has been highlighted as well. However, the authors should address the following concerns.

1. It will be ideal for the authors to explain or define what the informal settlement is. This is because the authors have stated that the data was collected from 2697 households from informal settlements in Ghana. The authors further stated that an individual becomes eligible if he or she is within informal settlement. So the question is, what constitute the informal settlements?

2. The authors have to really explain the key variable – Covid-19 exposure very well. The authors mentioned that they asked three questions in connection with this variable – having knowledge of Covid-19 infected person, having heard or associated with Covid-19 infected person and finally being exposed to Covid-19 related deceased person. The first question is what were the responses to these questions? Again, after obtaining these responses how was the index created and the range of the index – 1 (lowest) to 3 (highest) for instance. This has to be explained in detail because it is a key variable in the study and hence its reliability/appropriateness is very key. If this is not done, the analysis will not be well appreciated.

3. The authors also have to explain the digital financial service variable very well. What question was asked? What was the response? And how was the index created? The authors mentioned that they created an index of 1 to 9 with 9 being a person with more usage of financial technology and inclusion. The question is why 1 to 9 and not any other number like 1 to 10 or 1 to 15 etc.? How did the authors determine "more usage of financial technology?" This is because the authors rightly mentioned that they limited the DFS to the use of only mobile phone. So how then does the "more usage of technology" become the measure? This is not clear at all and needs to be elaborated. The same issue applies to the vulnerability variable. How did the authors come up with the score of 0 to 18 for the vulnerability variable? This is because the authors mentioned that they built the index based on five dimensions, so what went into the analysis and this index of 0 to 18 was arrived at. These have to be made clear in the study. In fact, the authors have to spend some time explaining properly how the key variables were obtained. Without this exercise, one will not be able to appreciate the results as well as the discussion.

4. The authors have to in fact explain very well to the readers the model specified in Equations 1, 2 and 3. Based on the measures of the various dependent variables mentioned the authors should tell readers the exact models that have been specified. The dependent variable for equations 2 and 3 is vulnerability population, which is a score – 0-18. So what model and estimation technique was employed to achieve this objective? Again, the dependent variable for equation 1 is Covid-19 exposure, which is also an index or score – 1 to 3. So what model and estimation technique was employed for this also?

   These are very crucial issues that need to be addressed to validate the results of the study.

5. The authors should also justify some of the measurement of some variables. For instance, in Ghana, there are many religions so why did the authors decide to use binary dummy – 1 for

Christian and 0 for otherwise? This needs to be justified, else the other religions in Ghana must be considered in the study. Same for marital status, education level (1 for primary and 0 for otherwise – but there are other educational levels, why are they not considered?), household income (what influenced the threshold of 313 for this variable? This must be explained) etc. Again, the variables definitions mentioned in Table 1 is fine but the most important thing is that how they were used to create the indexes and scores should be the focused as I have mentioned earlier. This is because most of these variables are used in creating the index and they are not used individually in the regression analysis.

6. The authors mentioned that the Covid-19 exposure has a score of 1 to 3 (see under the survey instrument, the third paragraph on covid-19 exposure), but when one observe Table 2d, the Covid-19 exposure variable has a "0" in there, making it 0-3. The authors need to reconcile this accordingly.

7. The authors should read through and correct all errors. For example, "with regards" instead of "with regard".

RESULTS

In fact, given the issues raised concerning the model specified and estimation technique, the authors have to reconsider the regression analysis all over again.

First, the authors should have a table that reports all the key variables, especially the dependent variables, and then the explanatory variables. This will help the authors to explain the exact nature of the dependent variables and hence the estimation technique to be employed. Because this is not done it is clear that the right estimation has not been done and hence the results are not appropriate.

For instance, let's consider the first analysis where the authors said they want to look at the effect of gender on Covid-19 exposure. The Covid-19 exposure variable per the authors' definition under section 3 is a score – 1 to 3 / 0 to 3 (as mentioned earlier). Neither the questions that were used to measure the exposure nor the score itself is an ordered or multiple response and hence the question is what estimation was done? But the authors use expressions like "more likely" in explaining the results. See below:

"In Table 3, we present the results of the influence of gender on COVID-19 exposure. We arrive at this by regressing gender against COVID-19 exposure whilst controlling for possible drivers of exposure. The results suggest that ***men are more likely to be exposed to the COVID-19 pandemic than women.*** *We observe a positive and a highly significant relationship between men and COVID-19 exposure. This occurrence can be attributed to ignorance of preventive measures by this gender group. More so, men have a perception of having a stronger immune system that will enable them to fight the virus more than women (Bwire, 2020). Galasso et al. (2020) found that women are more likely to perceive the pandemic as a very serious health problem and therefore are more likely to agree and comply with restraining measures. Grasselli et al. (2020) put forward similar sentiments. They opine that the disregard for restrictive measures is partially the reason why more men than women are dying from COVID-19."*

It is clear from the above that the right estimation technique is not used and hence the need to revise the analyses throughout the paper.

The same applies to the second objective where the authors look at the effect of gender on vulnerability. The authors use expressions like “less likely” but one does not know the estimation technique used. See below:

*"In this section, we explore the influence of gender on vulnerability. The results of this are displayed in Table 4. The results suggest **that men are less likely to be vulnerable compared to women**. This observation is true and falls in tandem with the vulnerability literature. Women around the world suffer an array of vulnerabilities not limited to social, economic and health vulnerabilities. From Table 3, we observe a negative and a highly significant relationship between men and four Domain vulnerability measures together with their composite. Although men may suffer epidemiological vulnerability more than women, the magnitude of the other four vulnerabilities far outweighs the effect of their epidemiological vulnerabilities thus explaining the negative total vulnerability observed. The epidemiological vulnerability men may suffer can be associated with the neglect of preventive measures."*

The authors should note the expressions like “more likely / less likely” are used in probability models such binary probit/logit, ordered probit/logit, multinomial probit/logit etc. But in this present study, and as I have mentioned earlier one does not know the estimation techniques used. Again, the estimation techniques I have mentioned above are dependent on the nature of the dependent variable in question. Per the definition and measurement of the dependent variables in this study – the Covid -19 exposure and vulnerability –, these techniques (binary probit/logit, ordered probit/logit, multinomial probit/logit) are not even applicable. Therefore, the authors should spend some time and go through the literature and get the appropriate estimation technique the analyses.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 06 Jan 2023

Mohammed Amidu, University of Ghana, Legon, Ghana

Dear reviewer, we have reflected on the feedback, revised, and re-submitted a significantly improved manuscript. We have taken the reviewers' comments seriously and did our possible best to address them. We have made changes leading to a significantly improved version of the manuscript. We have also copyedited the paper to remove redundancies and repetitions as well as any syntax and grammatical errors. We hope that the changes and additions satisfactorily address the reviewers' concerns. We will now turn to the reviewers' comments with an attached document.

In the remainder of this document, we have copied the referee's comments in bold and italics, and then described the manner in which we have addressed the comments

ABSTRACT

The abstract is generally good and reflects the title of the paper. However, the abstract needs improvement. For instance, the authors mention that they used the multiple regression analytical technique for the analysis, but the authors have to mention the exact estimation technique for the analysis. Multiple regression is not an estimation technique. Also, the authors should be specific on the policy implication in the abstract instead of just saying that the results provide policy implications for authorities ……. in Africa.

The grammatical errors in the abstract have been addressed including a clear policy implication of the paper.

The analytical technique for the analysis has been clearly stated as the ordinary least square (OLS) analytical technique. We employed 2sls Instrumental Variable technique for the robustness test.

INTRODUCTION

However, the authors should address the following:

1. The authors should read through the whole paper and correct any errors. For instance, the use of "reason why" is a tautology. The authors have to use one of them and not both.

The grammatical errors have been addressed in this manuscript with the support of a professional editor

These corrections have been made

2. The authors mention in paragraph 5 that this present study is essential as it has implications for the achievement of several SDGs. It will be ideal for the authors to mention the specific SDGs referring to.

This has been corrected and specific SDGs have been mentioned – SDGs 3, 10, 11, 15 and 17

3. In the paragraph 6, the authors use the "digital financial inclusion" which is different from the term used earlier which is the "digital financial services". The authors should note that the two are not the same therefore this must be reconciled. Financial services and financial inclusion are different concepts.

This has been duly corrected to digital financial services

4. The authors should delete the findings added to the introduction section. This is because same results is presented in the results section and are highlighted in the conclusion as well as in the abstract, and so it will be more of repetition.

Even though this sounds repetitive, we prefer to keep the summary of the findings in the introduction for three main reasons. First, most journals require that a summary of the findings is mentioned in the introduction. Second, some readers may only read the introduction, and this will help them get to know the findings of the paper. Third, this is a general practice

LITERATURE REVIEW

The authors have provided some theoretical foundation for the paper and seem satisfactory. Some empirical review has also been provided. However, the authors should try and read through and correct some errors in the text. For example, the authors write "….data has showed that …." Instead of "…data has shown that …"

The grammatical errors have been addressed in this manuscript with the support of a professional editor.

METHODS

However, the authors should address the following concerns:

1. It will be ideal for the authors to explain or define what the informal settlement is. This is because the authors have stated that the data was collected from 2697 households from informal settlements in Ghana. The authors further stated that an individual becomes eligible if he or she is within informal settlement. So the question is, what constitute the informal settlements?

Informal settlements have been clearly defined in this paper. Consistent with the UN-Habitat (2016), informal settlements in this study are defined as residential areas where (a) inhabitants have no security of tenure vis-`a-vis the land or dwellings they inhabit, with modalities ranging from squatting to informal rental housing, (b) the neighbourhoods

usually lack, or cut off from, basic services and city infrastructure and (c) the housing may not comply with current planning and building regulations and is often found in geographically and environmentally hazardous areas.

2. The authors have to really explain the key variable – Covid-19 exposure very well. The authors mentioned that they asked three questions in connection with this variable – having knowledge of Covid-19 infected person, having heard or associated with Covid-19 infected person and finally being exposed to Covid-19 related deceased person. The first question is what were the responses to these questions? Again, after obtaining these responses how was the index created and the range of the index – 1 (lowest) to 3 (highest) for instance. This has to be explained in detail because it is a key variable in the study and hence its reliability/appropriateness is very key. If this is not done, the analysis will not be well appreciated.

Respondents were asked to indicate a YES/NO response to the questions posed. Thus, all respondents who answered yes to any one of the three questions scored 1. A respondent scores two when answers in the affirmative to two of any of the three questions and three when he /she indicates yes to all three covid exposure questions.

3. The authors also have to explain the digital financial service variable very well. What question was asked? What was the response? And how was the index created? The authors mentioned that they created an index of 1 to 9 with 9 being a person with more usage of financial technology and inclusion.

The question is why 1 to 9 and not any other number like 1 to 10 or 1 to 15 etc.? How did the authors determine "more usage of financial technology?"

This is because the authors rightly mentioned that they limited the DFS to the use of only mobile phone. So how then does the "more usage of technology" become the measure? This is not clear at all and needs to be elaborated.

The same issue applies to the vulnerability variable. How did the authors come up with the score of 0 to 18 for the vulnerability variable? This is because the authors mentioned that they built the index based on five dimensions, so what went into the analysis and this index of 0 to 18 was arrived at. These have to be made clear in the study. In fact, the authors have to spend some time explaining properly how the key variables were obtained. Without this exercise, one will not be able to appreciate the results as well as the discussion.

Digital financial service as used in this study captures the ownership and usage of mobile-enabled digital financial services including the ownership of a mobile account and having accessed financial services such as savings, withdrawal, tax payment etc on the mobile device. The financial services index of 0-9 is a factor of respondents' responses of either Yes or No. So, the index increases with increased usage of any of the 9 financial services variables.

Again, for each vulnerability variable respondents' responses were coded as 1 (which

indicated vulnerability or 0 when otherwise observed. For Demographic vulnerability, 3 questions were asked. Housing and hygiene, 4. For healthcare vulnerability, we posed 4 questions. Also, for Epidemiological factors, we had respondents answer 3 questions. For socio-economic vulnerability respondents had 4 questions to respond to. The sum of the scores for all five domain vulnerabilities gives a score of 18.

4. The authors have to in fact explain very well to the readers the model specified in Equations 1, 2 and 3.

Based on the measures of the various dependent variables mentioned the authors should tell readers the exact models that have been specified.

The dependent variable for equations 2 and 3 is vulnerability population, which is a score – 0-18. So what model and estimation technique was employed to achieve this objective?

Again, the dependent variable for equation 1 is Covid-19 exposure, which is also an index or score – 1 to 3.

So what model and estimation technique was employed for this also? These are very crucial issues that need to be addressed to validate the results of the study.

The models used in the write-up have been defined to measure four main relationships. Hence in equation 1, the model is specified to explore the relationship between gender and COVID-19 exposure. In equation 2, we explore the influence of gender on the vulnerability of the sampled populations. In equation 3, we establish the relationship between digital financial services on COVID-19 exposure and vulnerability.

For each domain vulnerability, the study found the averages of the score and based on the averages developed an index between 0 and 1. The OLS estimation technique was employed for all specified models.

5. The authors should also justify some of the measurement of some variables. For instance, in Ghana, there are many religions so why did the authors decide to use binary dummy – 1 for Christian and 0 for otherwise? This needs to be justified, else the other religions in Ghana must be considered in the study. Same for marital status, education level (1 for primary and 0 for otherwise – but there are other educational levels, why are they not considered?), household income (what influenced the threshold of 313 for this variable? This must be explained) etc. Again, the variables definitions mentioned in Table 1 is fine but the most important thing is that how they were used to create the indexes and scores should be the focused as I have mentioned earlier. This is because most of these variables are used in creating the index and they are not used individually in the regression analysis.

Data was collected for other religions in Ghana as well. However, the others make up the minority as there are more Christians in Ghana than otherwise. We used married or otherwise as the classification as divorced, single, widowed etc suggests not staying in with a spousal equivalent. Moreso, we expect that spouses may be the source of the spread of

the virus to their counterparts hence recording higher exposure levels.

6. The authors mentioned that the Covid-19 exposure has a score of 1 to 3 (see under the survey instrument, the third paragraph on covid-19 exposure), but when one observe Table 2d, the Covid-19 exposure variable has a "0" in there, making it 0-3. The authors need to reconcile this accordingly.

The index score of 1 to 3 captures respondents who answered in the affirmative that they have been exposed to COVID. Persons who responded that they have by no means been exposed were scored zero. The three questions asked were:

1. if the respondent knows a dead COVID patient
2. if the respondent has heard or has been associated with a COVID-infected person.
3. if the respondent personally knows a person infected with COVID-19.

Thus, the index is such that a respondent score one if he answers in the affirmative to any of the above questions. As the positive responses increase the index also increases.

RESULTS

In fact, given the issues raised concerning the model specified and estimation technique, the authors have to reconsider the regression analysis all over again.

1. First, the authors should have a table that reports all the key variables, especially the dependent variables, and then the explanatory variables. This will help the authors to explain the exact nature of the dependent variables and hence the estimation technique to be employed. Because this is not done it is clear that the right estimation has not been done and hence the results are not appropriate.

For instance, let's consider the first analysis where the authors said they want to look at the effect of gender on Covid-19 exposure. The Covid-19 exposure variable per the authors' definition under section 3 is a score – 1 to 3 / 0 to 3 (as mentioned earlier). Neither the questions that were used to measure the exposure nor the score itself is an ordered or multiple response and hence the question is what estimation was done? But the authors use expressions like "more likely" in explaining the results. See below:

"In Table 3, we present the results of the influence of gender on COVID-19 exposure. We arrive at this by regressing gender against COVID-19 exposure whilst controlling for possible drivers of exposure. The results suggest that men are more likely to be exposed to the COVID-19 pandemic than women. We observe a positive and a highly significant relationship between men and COVID-19 exposure. This occurrence can be attributed to ignorance of preventive measures by this gender group. More so, men have a perception of having a stronger immune system that will enable them to fight the virus more than women (Bwire, 2020). Galasso et al. (2020) found that women are more likely to perceive the pandemic as a very serious health problem and therefore are more likely to agree and comply with restraining measures. Grasselli et al. (2020) put forward similar sentiments. They opine that the disregard for restrictive measures is partially the reason why more men than women are dying from COVID-19."

It is clear from the above that the right estimation technique is not used and hence the need to revise the analyses throughout the paper.

We have provided a table that reports on the key variables now.

We believe that the right estimator, i.e OLS was used and is appropriate for cross sectional data. The robustness test using the Instrumental variable provided the same result. It should also be noted that the data is cross-sectional and there is a limit to the type of estimators to be used

The same applies to the second objective where the authors look at the effect of gender on vulnerability. The authors use expressions like "less likely" but one does not know the estimation technique used. See below:

"In this section, we explore the influence of gender on vulnerability. The results of this are displayed in Table 4. The results suggest that men are less likely to be vulnerable compared to women. This observation is true and falls in tandem with the vulnerability literature. Women around the world suffer an array of vulnerabilities not limited to social, economic and health vulnerabilities. From Table 3, we observe a negative and a highly significant relationship between men and four Domain vulnerability measures together with their composite. Although men may suffer epidemiological vulnerability more than women, the magnitude of the other four vulnerabilities far outweighs the effect of their epidemiological vulnerabilities thus explaining the negative total vulnerability observed. The epidemiological vulnerability men may suffer can be associated with the neglect of preventive measures."

The OLS estimation technique was used for the purpose of exploring the relationship between gender and vulnerability. This is appropriate valid estimator for the use of cross-sectional data

The authors should note the expressions like "more likely / less likely" are used in probability models such binary probit/logit, ordered probit/logit, multinomial probit/logit etc. But in this present study, and as I have mentioned earlier one does not know the estimation techniques used. Again, the estimation techniques I have mentioned above are dependent on the nature of the dependent variable in question. Per the definition and measurement of the dependent variables in this study – the Covid -19 exposure and vulnerability –, these techniques (binary probit/logit, ordered probit/logit, multinomial probit/logit) are not even applicable. Therefore, the authors should spend some time and go through the literature and get the appropriate estimation technique the analyses.

The expressions mentioned were used to avoid over-generalisation and apply some nuances to the results. They have been corrected in the manuscript

Yes, as the Reviewer suggested, we could not have used (binary probit/logit, ordered probit/logit, or multinomial probit/logit) as the dependent variables are not binary.

For the robustness test, we employed Instrumental Variable.

Competing Interests: There is no competing interest

Reviewer Report 05 December 2022

https://doi.org/10.5256/f1000research.122927.r155855

Matthew Ocran
Department of Economics, University of the Western Cape, Bellville, South Africa

The study is timely and well-motivated. But the authors have to pay attention to a few issues.

1. There are grammatical errors that need correction. They can do this with the services of a good copy editor.

2. The measure of COVID-19 exposure is problematic. The authors cite the work of Kazak et al 2021. However, the measure of exposure defined in the present study is inconsistent with that given by Kazak et al 2021 (pp.506). The cited study used 5 exposure items related to COVID-19. The present study does not account for most of the exposure items in Kazak's work and does not provide reasons for the adopted measurement approach. The least they can do is provide a disclaimer or caution in interpreting the results.

3. The authors have to provide information on the estimator used in the empirical analysis.

   The regression estimates do not provide any robustness checks. I suspect that they might have used OLS estimators. If they did, then they have to indicate how they have dealt with the challenges associated with the estimator. Indeed, the practice is that whatever econometric tool or estimator one uses, one has to provide statistics to indicate the robustness of the estimations. This is missing.

   The instrumental variable (IV) approach is often used to estimate causal relationships in studies such as the present one. The authors may want to consider IV as an estimator for the regression analysis.

4. In sum, the econometric approach is neither transparent nor persuasive.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Econometrics, development finance, and development economics.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 06 Jan 2023

Mohammed Amidu, University of Ghana, Legon, Ghana

Dear reviewer, we have reflected on the feedback, revised, and re-submitted a significantly improved manuscript. We have taken the reviewers' comments seriously and did our possible best to address them. We have made changes leading to a significantly improved version of the manuscript. We have also copyedited the paper to remove redundancies and repetitions as well as any syntax and grammatical errors. We hope that the changes and additions satisfactorily address the reviewers' concerns. We will now turn to the reviewers' comments with an attached document.

In the remainder of this document, we have copied the referee's comments in bold and italics, and then described the manner in which we have addressed the comments

There are grammatical errors that need correction. They can do this with the services of a good copy editor.

The grammatical errors have been addressed in this manuscript with the support of a professional editor

The measure of COVID-19 exposure is problematic. The authors cite the work of Kazak et al 2021. However, the measure of exposure defined in the present study is inconsistent with that given by Kazak et al 2021 (pp.506). The cited study used 5 exposure items related to COVID-19. The present study does not account for most of the exposure items in Kazak's work and does not provide reasons for the adopted measurement approach. The least they

can do is provide a disclaimer or caution in interpreting the results.

The study cited Kazak et al. 2021 for its definition of COVID-19 exposure. However, the measurement of the variable was conceptualised by the authors given the setting in which the study is being carried out. Data was collected at the time that there was high stigmatization of persons who had been exposed to the virus. Hence questions were carved such that respondents will be willing to provide such information since the questions did not relate to them personally.

The authors have to provide information on the estimator used in the empirical analysis:

The regression estimates do not provide any robustness checks. I suspect that they might have used OLS estimators. If they did, then they have to indicate how they have dealt with the challenges associated with the estimator. Indeed, the practice is that whatever econometric tool or estimator one uses, one has to provide statistics to indicate the robustness of the estimations. This is missing.

The instrumental variable (IV) approach is often used to estimate causal relationships in studies such as the present one. The authors may want to consider IV as an estimator for the regression analysis.

The estimator used in the analysis is the Ordinary Least Square (OLS) estimator. We performed multicollinearity tests and run the regressions by specifying the robust standard errors to take care of the issues of heteroskedasticity. We also used the link test to check that the model is correctly specified.

Robustness checks statistics have now been added. The use of the instrumental variables (IV) technique helps to explicitly specify the instruments.

In sum, the econometric approach is neither transparent nor persuasive.

We believed that the econometric approach is transparent as we have provided enough data to support the replication of the study's results

Competing Interests: There is no competing interest