Information communication technology and financial inclusion of innovative entrepreneurs

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Abstract

Financial inclusion (FI) constitutes an absolute priority for poverty alleviation and information communication technology (ICT) is an essential component of any FI strategy that aims to enable access to a wide range of financial products and services. This study explores entrepreneurs' assessments of the role of ICT on their FI and its effect in Africa. Using data on 1436 entrepreneurs from the World Bank Enterprise Survey database and applying an inverse probability of treatment weighting (IPTW) based on propensity scores, the results of our study show that ICT increases entrepreneurs' FI. In particular, we find that average FI of entrepreneurs using ICT in their business is approximately 12% higher than their counterparts who do not use ICT. Further, separate treatments of email, website, and mobile phone, show that business website ownership has the highest impact on FI, followed by mobile phone and email. The results are robust through a series of robustness checks including the bivariate probit model, propensity score matching model, and alternative proxies for FI. Our findings confirm the significant role technological deepening plays in advancing FI in Africa and its potential for a wider applicability to other developing economies.

Keywords: *Financial inclusion, Information communication technologies, Entrepreneurs, Developing countries; Propensity score analysis; Inverse probability of treatment weighting*

JEL Classification: *G32; G28; G21; O17.*

1. Introduction

This paper studies the effect of Information Communication Technology (ICT)[1] services on the financial inclusion (FI)[2] for a sample of African entrepreneurs[3]. The technological world is rapidly transforming around digitization, networking, and automation, generating anticipation for a modern industrial revolution (Culot, Orzes, Sartor, & Nassimbeni, 2020). The development of ICT has triggered what is now referred to as the fourth industrial revolution (i.e., Industry 4.0). The fourth industrial revolution is expanding on the third, the digital revolution that has been happening since the middle of the 20th century. It is described by a combination of technologies obscuring the lines between the physical, digital, and biological spheres (Schwab, 2016). Unlike the prior industrial revolution, smart automation of a cyber-physical system is enabled with de-centralised control and advanced connectivity (Peraković, Periša, & Zorić, 2020). The fourth industrial revolution poses enormous changes in all aspects, particularly in the financial systems (Valencia, Lamouri, Pellerin, Dubois, & Moeuf, 2019). FI has become a central component of development policy around the globe which highlights the crucial role of inclusive financial systems in reducing extreme poverty and fostering sustainable growth and development in the country (Ouma, Odongo, & Were, 2017). For manufacturing companies, Industry 4.0 poses many challenges from a technological, management and organizational point of view. With the implementation of this digital technology and process transformation, significant changes in the industries are anticipated. Thus, new skills are required from employees for future production processes (Horváth & Szabó, 2019). Innovative entrepreneurs contribute a disproportionately larger share of job creation, uplifting communities and making positive social changes in developing economies (Acs, Desai, & Hessels, 2008; Fan & Zhang, 2017; Van Stel, Carree, & Thurik, 2005). The availability of external finance is more beneficial to the development of entrepreneurs, who usually face cash constraints (Ayyagari, Demirgüç-Kunt, & Maksimovic, 2011; Brown, Martinsson, & Petersen, 2012; Gorodnichenko & Schnitzer, 2013). Therefore, financial

[1] ICT refers to technologies that allow access to information through telecommunications. These include the internet, mobile phones, wireless networks, and diverse communication devices.

[2] "The core essence of financial inclusion lies in its non-discriminatory principle that everyone, everywhere, should have access to essential financial services that are affordable and that meet their needs" (Pistelli, 2017) This is a direct quote so the reference should include the page number.

[3] The definition of innovative entrepreneurship arises from the intersection of three areas, namely, innovative businesses, young and high-growth businesses, and small and medium enterprises (SMEs) (The Innovation Policy Platform, https://www.innovationpolicyplatform.org/content/innovative-entrepreneurship).

services at affordable costs to the marginalised segment of society (including entrepreneurs), is currently considered to be one of the major enablers of economic growth (Demirgüç-Kunt & Klapper, 2013).

The existing literature considers that limited access to finance is due to information asymmetry (Asongu, Nwachukwu, & Tchamyou, 2016; Triki & Gajigo, 2012). ICT, through a proliferation of information sharing, reduces information asymmetry between market participants (Aminuzzaman, Baldersheim, & Jamil, 2003; Andonova, 2006; Muto & Yamano, 2009). The emergence of mobile money services in developing countries has major implications for the FI of non-banked people (Della Peruta, 2018). The increasing popularity of ICT and mobile money in African economies (Asongu et al., 2016) encourages the investigation of what ICT and these schemes can bring to FI and economic growth through innovative entrepreneurs. Recent literature examining the African region reports a positive impact from ICT penetration and development (Asongu, 2018; Asongu & Le Roux, 2017; Tob-Ogu, Kumar, & Cullen, 2018). The promising potential of ICT usage can be leveraged by policy-makers to address policy challenges to innovative entrepreneur development. Entrepreneurs must be adept at harnessing the potential of technology including integrating technical innovation with business developments, and understanding new consumer needs, emerging challenges, and future opportunities (Yunis, Tarhini, & Kassar, 2018). In addition to this, the importance of improving the wellbeing of people in Africa through successful businesses is essential as a contribution to the United Nations Sustainable Development Goals[4]. We echo prior research regarding the need to assist in and promote the continuous development of entrepreneurship in Africa as a remedy to overcome setbacks in economic growth, social inequality, and poverty alleviation.

This paper has three contributions. First, to the best of our knowledge, it is one of the first papers to examine how technological change posed by Industry 4.0 has an impact on the FI of the entrepreneurs in developing countries. Prior studies have primarily focused on either ICT and FI (see Tchamyou, Erreygers & Cassimon, 2019; Della, 2018) or entrepreneurship and FI (see Hazarika, Bezbaruah, & Goswamia, 2016; Fan & Zhang, 2017). Although ICT is becoming an increasingly important mechanism of FI, to date, minimal research attention has been paid to its capacity to shape the FI of entrepreneurs. One exception is Yunis et al. (2018),

[4] The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations General Assembly in 2015 for the year 2030. The SDGs are part of Resolution 70/1 of the United Nations General Assembly, the 2030 Agenda. https://sustainabledevelopment.un.org/post2015/transformingourworld

who look at ICT and the FI for entrepreneurs in a Lebanese market. Our large sample from several African countries extends the insights offered Yunis et al. (2018).

The second contribution of our study relates to our methodology, which advances previous FI and ICT studies in three important respects. We employ an inverse probability of treatment weighting (IPTW) using the propensity score method. Missing data, a problem recognised in the World Bank dataset, which is often seen as a source of endogeneity problems, is largely accounted for through the IPTW method (Austin, 2011). When IPTW is used with the propensity score method, this ensures that on average, both treated and control groups do not differ systematically in terms of measured and unmeasured baseline characteristics. IPTW involves a control group shrunk to the same size as the treatment group which reduces the side-effect of discarding large amounts of data.

Our third contribution relates to the provision of a fuller, richer portrayal of FI in Africa through a careful investigation of relationships, and through using sound empirical analysis to promote policy formulation, better social outputs, and outcomes benefitting thousands of people desperate to escape the poverty traps of ineffective policy and exploitation. Where there are links between employment and economic growth from supporting entrepreneurial firms, we find that ICT, entrepreneurs and FI are strongly linked. Capability building for strong evidence-based policy, while not a panacea for poverty, contributes positively to improved wellbeing, including positive spillovers into education. Greater accessibility to formal financial services at an affordable cost is an issue that affects all members of an economy, but is particularly pertinent to low-income and vulnerable groups (Sarma & Pais, 2011) as well as entrepreneurs.

Our results indicates that the majority of entrepreneurs use cell phones in their business (71%). Website ownership (37%) is the least common ICT mode while emails (53%) are widely used for communication with clients and suppliers. Although the majority of entrepreneurs have an account with a formal bank (86%), only 28% have overdraft facilities and 33% have line of credit facilities. Our IPTW results suggest that FI is positive and robustly significant among firms that engage in ICT. The FI of entreprenuers who engage with ICT is 12% greater than those who do not use ICT services. The approximate percentage by which a firm's FI increases through the use of individual technologies are listed in parentheses: emails (9%); websites (12%); cell phones (11%); and mobile money (8%).

The rest of the paper is organised as follows. Section 2 reviews the literature and develops the hypotheses. Section 3 presents the data and methodology. Section 4 discusses the empirical findings before Section 5 offers a conclusion.

2. Literature review and hypotheses development

Entrepreneurship involves risk with start-up costs, small businesses opaqueness, and lack of finance, all of which translate into greater risks than those assumed by large mature businesses. Both ICT and FI are important components of this context. Risk management theory, regarding financial intermediation, considers how technological deepening can improve the issue of information asymmetry and transaction costs in the lending-borrowing relationship (Allen, Santomero, & Finance, 1997). Financial sector reforms and technological advancement contribute to the elimination of transaction costs and information asymmetry problems (Scholtens & Van Wensveen, 2003). Mature economies typically embed technology and deregulatory policies addressing structural constraints. Information and communication technologies (ICT), which hinge on strong telecommunications infrastructure, can contribute to economic growth by improving productivity, reducing transaction costs, promoting innovation and development, and also by developing the financial sector (Chatterjee, 2020). The introduction of new technologies has been driven by a phenomenon known as Industry 4.0. Within the concept of Industry 4.0, innovation and technological growth play a crucial role within the organization as the design, procedures, operations and services related to products and production systems must adapt to new technologies. Industry 4.0 also has major implications for management and future employment in signalling the need for new and innovative business models to be developed (Ślusarczyk, 2018).

The creation of new business ventures and digital start-ups are the result of digital technologies, which incorporate novel technology as a vital component of their business models and operations. In this way, digital technologies are enablers of the entrepreneurial activity (von Briel et al., 2018) and they manifest in several forms, such as digital products or services (Lyytinen et al., 2016), digital platforms (Tiwana et al., 2010), digital artefacts (Ekbia, 2009), and Internet-enabled service innovations (Kuester et al., 2018). Freixas and Rochet (2008) argue that technology can reduce transaction costs and even the ex-ante form of informational asymmetry (adverse selection). Additionally, ICT reduces information opacity (Scholtens & Van Wensveen, 2003), a characteristic of most small and medium enterprise

(SME) operations that typically makes them appear less attractive than large firms and more susceptible to the risk of financial exclusion (Dong & Men, 2014; Stiglitz & Weiss, 1981). Technology adoption costs need to be lower than the gains in terms of risk and/or return. Possible cross-dependencies where a firm's application of ICT, such as website and e-mail usage assures external credit suppliers of the veracity of information, is core to the issue.

Two hypotheses, founded on prior research, address the potential link between both ICT usage (e.g., website ownership, email and cell phone use in business) and mobile money with the risk disposition of firms facing financial exclusion. ICT and mobile money provide credit suppliers with a means of gathering critical information on potential borrowers. This is less applicable to low income, emerging and mature countries, given the different levels of market surveillance, corruption, financial literacy, and social mores at hand. Based on these arguments we propose the following hypothesis:

H1: Innovative entrepreneurs' FI level significantly increases with ICT usage.

Prior research appears to suggest that ICT promotes more FI with more entrepreneurship. This is because access to external finance has a significant impact on firm innovation (Hajivassiliou & Savignac, 2008). While small firms with less internal funds may seek external funds, this is not necessarily straightforward (Beck & Demirguc-Kunt, 2006; Schneider & Veugelers, 2010) as an investment in innovation is highly sensitive to financial constraints compared to other investments (Mancusi & Vezzulli, 2010). ICT is increasingly seen as a gap-bridging mechanism for financial service providers, allowing previously unbanked individuals to be served (Diniz, Birochi, & Pozzebon, 2012). As such, ICT facilitates greater FI, and is the key driver of communications and network technology in the financial services sector (Lapukeni, 2015). It is perceived as a means that facilitates access to credit. It leads to more efficient credit allocations and credit transfers in a manner that promotes FI (Kpodar & Andrianaivo, 2011). Mushtaq and Bruneau (2019) find that ICT diffusion positively impacts FI inclusion and negatively influences poverty and inequality. This provides the basis for our second hypothesis.

H2: The FI of innovative entrepreneurs significantly increases with the usage of mobile money.

Mobile money stimulates economic development and has a potential to foster FI of those classified as banked and unbanked alike in Africa (Donovan, 2015). However, the merits of mobile money have been debated by researchers. There is clear evidence supporting the perspective that mobile banking reduces transaction costs, improves liquidity, avoids travelling costs, and saves time for more productive activities (Jack & Suri, 2014). Mas (2009) contends that improving levels of FI contribute to the availability of funds for innovative entrepreneurs and, certainly, the reduction in costs achieved by banks through technological innovation may be directed as surplus to small business innovative ventures. Barnett et al. (2019) provide evidence that ICT utilization such as cell phone ownership and Internet usage positively influences entrepreneurship and argue that these impacts are very strong in the economic sense. In the same vein, Gosavi (2018) provides evidence that mobile money usage helps firms in reducing financial access constraints. Bongomin et al. (2018) report a positive and significant moderating effect of social networks in the relationship between the usage of mobile money and FI. Overall, mobile money improves the access of SMEs to banking services, decreasing the need for bank branches and enabling SMEs to transact remotely. Certainly, branchless banking has gained popularity among developing countries in Africa. However, the idea that mobile banking arrangements induce investments is a matter of concern for financial institutes and banks in Africa where bureaucracy and centralisation are widespread (Jack & Suri, 2014). The role of mobile money as a source of FI for innovative start-ups needs ongoing examination.

3. Methodology and data

3.1. Data and sampling procedure

This study uses cross-sectional data from the World Bank Enterprise Survey (WBES)[5] database for African economies. Although the WBES database includes data from 130 countries, only five African economies provide mobile money information. Our sample covers 1436 innovative entrepreneurs from Ghana, Kenya, Tanzania, Uganda, and Zambia. The WBES database is a credible source of detailed firm-level data, including factors that affect enterprise growth, development and sustainability. Comparable information on the qualities of firms across sectors, size, and participation in the formal financial system and across other demographic attributes such as age, and gender of owners and managers, are used in this study. The WBES database offers a comprehensive dataset on firms' access to finance and other

[5] *World Bank.* Enterprise Surveys (http://www.enterprisesurveys.org),

infrastructural amenities that affect their growth. Most of the data are dichotomous in the form of 'yes' or 'no' type responses to questions and these point toward the use of a binary regression model. The collection process is representative, allowing random sampling of firms in the economies concerned.

The WBES database uses a standardised questionnaire for globally gathering enterprise-level microdata on manufacturing, services and sectors. Measurement error is minimised as the survey uses a uniform method of sampling (The World Bank Group, 2014)[6], delivering cross-country data comparability. The targeted respondents in each entity sampled are business owners, top managers, or both.

<< Insert Table 1 about here >>

Table 1 records the cross-tabulation of each country and firm level ICT and FI attributes. With respect to ICT usage, the majority of the sample firms use cell phones in their business. Website ownership is the least common ICT mode and emails are widely used for communication with clients and suppliers. The use of proxies for obstacles to access finance (*Finance*), bank overdraft facilities[7] *(Over*) and access to a line of credit (*Credit*), show that innovative entrepreneurs in Ghana and Kenya experience high levels of FI. Ninety four percent of Ghanaian firms and 90% of Kenyan firms have an account with a formal bank. In Ghana, 17.5% of firms have an overdraft facility and credit line while in Kenya one-third of firms have a credit line and 23% have an overdraft facility.

3.2. Model variables

FI is often defined in terms of accessibility and use of financial services. Consistent with this approach, we define our key dependent variable finance (*Finance*) as the access to a line of credit. When a firm responds to the survey question, indicating it has minor or no obstacle in accessing finance for current operations of the business, it is classified as being financially included. Obviously, this means that we use a self-reporting measure as our key dependent variable for this study, which is an approach that has been used by others. Gorodnichenko and Schnitzer (2013), for example, adopt a self-reporting measure in their examination of the cost

[6] See Footnote '1' above. Just check that this is correct -- I don't know why the footnote should refer to another footnote.

[7] An overdraft facility allows account holders to withdraw cash from their current (cheque/checking) account up to an approved overdraft limit such that the account has a negative balance. This is a short-term credit facility, which is repayable on demand but typically is reviewed annually.

of financing, taking the value of 0 for no costs through to 4 for high costs (i.e. coding firm responses to questions concerning the difficulty of accessing external credit in the following manner: 0= No obstacle, 1= Minor obstacle, 2= Moderate obstacle, 3= Major obstacle, and 4= Very serious obstacle). Of course, data gathered from self-reports -- in our case, self-reported measures of innovations -- are more prone to measurement errors and biases. Prior research also acknowledges the subjectivity of these self-reported measures of FI (see Gorodnichenko & Schnitzer, 2013)[8].

The regressions include firm characteristics, firm ownership, and institutional environment factors as the main covariates. These variables are common in studies that explain firm-level FI. We rely on prior relevant research to assist in guiding our choice of variables. To capture the impact of ICT, we create an *ICT* dummy variable, which takes the value of 1 if a firm has a website or uses e-mail/cell phone for business, and 0 otherwise. We also include *Email*, *Web* and *Cell* as dummy variables in our analysis to check the individual effect of using e-mail, website, and cell phones for business respectively. To capture the impact of mobile money, we include *Mob_money* as a variable, which equals 1 if the firm uses mobile money for their business transactions, and 0 otherwise. Appendix A includes a summary table of FI and the ICT proxies.

Table 2 presents our ICT proxies and covariates derived from the survey. We also report the source of variables.

<<Insert Table 2 about here >>

3.3. Empirical model

Non responsive and missing data problems are common in survey data (Härkänen, Kaikkonen, Virtala, & Koskinen, 2014). This suggests that unobserved determinants of FI may be correlated with ICT behaviour, requiring careful handling on our part.

[8] We confirm the validity of our results using alternative measures of FI in the robustness section.

In recent times, researchers have used the propensity score matching (PSM) technique to control non responsive and missing data problems in observational data (Wellalage & Fernandez, 2019). PSM control self-selection biases and causal interferences by placing them into a non-random assignment. FI may be correlated with both observable and unobservable factors of firms. If the study fails to correct for this bias, the estimates will give naïve and overestimated results of the impact. We use an inverse probability of treatment weighting (IPTW) technique based on propensity scores to determine the relationship between ICT and FI. The IPTW technique has several advantages over other propensity score methods (Austin, 2013) as it minimises the influence of outlying weights (Vaughan et al., 2015), reduces missing data biases (Iachina, 2009; Molenberghs & Kenward, 2007), and addresses unobservable heterogeneity biases[9] (López-Videla & Machuca, 2014).

An outcome variable (Y) proxies for FI, and ICT is the binary treatment variable (Z), with 1 for treated (firms use ICT in their business) and 0 otherwise. X is a row vector of confounders for the probability of treatment (ICT) and outcome (FI) and φ is the propensity score. Assuming a total N subjects in a dataset, n_1 subjects indicate firms use ICT. Therefore, n_0 firms that do not use use ICT in their business equals N- n_1.

The probability of using ICT in business (without considering covariates) is p=n1/N, and the probability of not using ICT is 1–p. The propensity score $\varphi = prob\ (z = 1|\ X_i)$ is the probability of using ICT given the observed covariates X_i.
Logistic regression estimates the unit non-responsiveness probabilities:

$$\varphi_i = \frac{\exp(X_i\beta)}{1 + \exp((X_i\beta)} - - - - - - (1)$$

[9] Simultaneity/reverse causality is another source of endogeneity in the relationship between financial inclusion and ICT. In the section discussing robustness checks, we describe using instrumental variables to control simultaneity/reverse causality.

With the covariates (X_i) in the propensity score model using IPTW as weights,
if z= 1 then,

$$W_i = \frac{1}{\varphi_i} - - - - - - - - - = (2)$$

and if z= 0, then

$$W_i = \frac{1}{1-\varphi_i} - - - - - - (3)$$

where, W_i denotes the IPTW for subject i.

Therefore, we can define an inverse probability of treatment weighting as follows (Rosenbaum, 1987):

$$W_i = \frac{Z_i}{\varphi_i} + \frac{(1-Z_i)}{1-\varphi_i} - - - - - (4)$$

Assuming that Y_i denotes the outcome (FI) on the i^{th} subject, Lunceford and Davidian (2004) estimate average ICT effects (ATE) as

$$ATE = \frac{1}{n}\sum_{i=1}^{n}\frac{Z_i Y_i}{\varphi_i} - \frac{1}{n}\sum_{i=1}^{n}\frac{(1-Z_i)Y_i}{1-\varphi_i} \; - - - - (5)$$

Finally, we conduct a sensitivity test to justify that the estimated average treatment effect is robust.

<<Insert Table 3 about here >>

Table 3 includes descriptive statistics for variables in the study for 1436 innovative entrepreneurs from five African countries. The descriptive statistics show that only 38% of the sample firms indicate they have finance from formal external sources, suggesting that slightly

more than 60% of innovative entrepreneurs are excluded from formal financial services in Africa. Although, above 85% of the firms have formal bank accounts, only 20%t of innovative entrepreneurs have an overdraft facility and 23% an external credit line. These observations are in line with the persistent view of limited access to finance by small firms in Africa and other developing countries. Research by the African Development Bank (AfDB) is consistent with our observation in its report that only 20% of African SMEs have access to credit ("African Guarantee Fund for Small and Medium-sized Enterprises," 2018). Innovative investments may experience limited or no credit access, because of the high uncertainty, risk and intangibility involved (Hall & Lerner, 2010). The ICT variables show that 89% of innovative entrepreneurs use a cell phone in their business; 57% use email in business; approximately 33% have a website; and nearly 30% use mobile money in their business transactions. The majority of the sample firms are from the manufacturing industry (43.5%). Zambia presents the highest percentage of innovative firms (24%), followed by Tanzania (22%), Ghana (21%), Uganda (20%) and Kenya (13%).

4. Main analysis

4.1. Inverse probability of treatment weighting (IPTW) using propensity score

Our IPTW results, using the propensity score analysis, appear in Table 4. The outcome variable is our FI proxy *(Finance).* We use five treatment variables. In Panel A, the treatment variable is *ICT* and the average treatment effect (ATE) is .1198, indicating that the average FI of entrepreneurs using ICT in their business is approximately 12% higher than their counterparts who do not use ICT. The coefficient of potential-outcome means (*POmean*) indicates that the average FI of entrepreneurs who do use ICT in their business is approximately 6%. ICT has recently been documented as enhancing information availability and sharing between market participants in various sectors of developing countries (Asongu et al., 2016). For example, Muto and Yamano (2009) report that ICT services may reduce marketing costs and increase market participation. Aminuzzaman et al. (2003) suggest that ICT services may reduce the information asymmetry problem. Andonova (2006) reports that ICT from the perspectives of cell phone and internet penetration reduces information asymmetry

In Panel B, C, D, and E, the treatment variables are *Email*, *Web, Cell*, and *Mob_money* respectively. The average treatment effect (ATE) indicating that the average FI of entrepreneurs who use email, a website, cell phones, and mobile money in their business is approximately 9%, 12%, 11% and 8% higher than their counterparts repectively. The coefficient of *POmean* indicates that the average FI of entrepreneurs who do not use email, a website, cell phones, and mobile money in their business is only 10% percent, 12%, 7% and 14% respectively.

Separate treatment of *Email*, *Web, Cell* shows that business website ownership has the highest impact on FI, followed by mobile phone and email.. The results of our analysis are aligned with previous studies covering ICT and FI in the African context. For example, Triki and Faye (2013) report that the recent surge in mobile phone penetration in Africa bodes well for continued progress towards greater FI. Lapukeni (2015) also argues that ICT facilitates greater FI in Africa, and reports that it is the key driver of communications and network technology in the financial services sector. The results in Table 4 suggest the acceptance of H_1 and H_2.

<<Insert Table 4 about here >>

4.2. Balance of covariates after matching by a propensity score

We report three methods that assess balance in the observed baseline covariates between treated and control subjects in IPTW.

4.2.1. Over identification tests (Guo & Fraser, 2014)

Over identification tests for covariate balance are reported in Table 4. They indicte that all Prob > Chi^2 values are greater than 0.05. This result suggests that we cannot reject the null hypothesis that the covariates are balanced for all outcomes.

4.2.2. Covariate balance summary

Appendix B reports the covariate balance summary which indicates that the differences in weighted means are negligible, and variance ratios are all near one[10].

[10] In Appendix [should there be a letter here?] we report the covariate balance rebalance summary for significant outcome variables only.

Hence, the balance diagnostics point to the propensity score model as correctly specified.

4.2.3. Overlap and common support assumption

The assumption of common support ensures that there is sufficient overlap in the characteristics of treated and untreated units to find adequate matches. Our matching satisfies the overlap and common support assumptions consistent with the figure illustrating a significant overlap in the distribution.

<<Insert Figure 1 about here >>

5. Robustness check

For a robustness check, we re-estimate the relationship between FI and ICT with three regression models: a bivariate probit model, a propensity score matching model, and a model using alternative proxies for FI.

5.1. Bivariate probit model

Previous studies have assumed that ICT usage is exogenous to FI. However, there may be dual causality between the two. On the one hand, innovative entrepreneurs may need financial services, especially capital, to buy ICT services. On the other hand, innovative entrepreneurs who already use ICT in their business may be in a better position to secure more funds to better run the business (especially formal loans from a bank) since ICT reduces information opaqueness in relation to a transaction and signals successful businesses. Given the dichotomous nature of both FI and ICT variables, we use a bivariate probit model. This approach is particularly helpful where a dichotomous dependent variable is an observable outcome, and the determinants of the possible outcome include a dummy treatment variable. The primary interest is in estimating the treatment effect on the dependent variable. The possibility of a dummy treatment variable being endogenous to a dummy dependent variable cannot be disregarded.

Table 5 presents the regression results with columns 1 and 2, respectively, recording the probit and marginal probit estimates for the single equation probit models where ICT is the

dependent variable. Columns 3 and 4 respectively present the probit and marginal probit results for the single equation probit models with FI as the dependent variable. Columns 5 and 6 present the bivariate probit and marginal effect results respectively where FI is treated as an endogenous explanatory variable. Columns 7 and 8 respectively present the bivariate probit and marginal effect results where ICT functions as an endogenous explanatory variable. Columns 9 and 10 present the univariate probit and marginal effect results respectively using mobile money (*Mob_money*) as a main dependent variable.

<<Insert Table 5 about here >>

The univariate probit estimation suggests that FI does play a key role in an innovative entrepreneur's decision to use ICT services in their business. More specifically, we find that financially included innovative entrepreneurs are 14% (univariate probit-ME) more likely to use ICT services than those who are not financially included (i.e. do not use financial services). Evidence points to ICT usage affecting FI, suggesting that innovative entrepreneurs who use ICT services in their business may, in turn, have greater access to, and usage of, financial services. Table 5 indicates that 7.09% of the innovative entrepreneurs using email in their business are more likely to use financial services. The effects for both models are statistically significant.

A positive and significant ρ indicates that unexplained factors that affect ICT are positively correlated with unexplained factors that affect FI, suggesting possible reverse causality. The Wald test rejects the hypothesis that p=0, pointing to the likelihood that the initial results from the univariate probit models are biased. Both endogenous variables are binary (*ICT* and *Finance*) and a recursive bivariate probit model provides a means to control endogeneity between binary dependent and independent variables (Farace & Mazzotta, 2011; Morris, 2007). Our results from the recursive bivariate probit model are more reliable than the univariate probit results. After accounting for potential endogeneity, we find that 7.05% of innovative entrepreneurs who use ICT services are more likely to experience FI. Although the effect of ICT on FI (Columns 7 and 8) is significant, the effect of FI on ICT usage (Columns 5 and 6) is insignificant, indicating that the direction of causation is likely to be from ICT to FI rather than from FI to ICT.

The magnitude of the effect of ICT on FI is slightly smaller for the recursive model than for the IPTW model. However, the univariate probit and recursive models show a direction similar to our baseline model.

5.2. Propensity score matching models

The propensity score matching method[11] provides an alternative approach for estimating the effect of ICT on FI. The average treatment effect of treated (ATT) results in Table 6 present nearest neighbour matching, kernel matching, radius matching and stratification matching with common support.

In all matching models, the ATT is positive and statistically significant. When different matching models are compared, the magnitude of the ATT ranges from 0.06 with stratified matching to 0.09 with radius matching. These results confirm the ATT follows a similar direction to that of the average treatment effect (ATE) in the population, indicating the estimated average effect of ICT on FI for entrepreneurs is positive.

<<Insert Table 6 about here >>

5.3. Alternative proxies for FI

To limit the possibility of endogeneity arising from measurement errors, several robustness methods are applied. As previously noted, our study uses a subjective measure of FI (*Finance*), which may include measurement errors. Based on the literature, we derive three objective measures as proxies for FI from the survey data.

Allen, Demirguc-Kunt, Klapper, Soleda, and Peria (2016) report that account ownership and usage have key roles in FI. Our first proxy for FI is *Acc_Own*, taking the value of 1 if the innovative SME has a cheque or savings account with the formal financial institution and 0 otherwise. This study also defines overdraft (*Over*) as a proxy for FI. *Over* variable takes the value of 1 if the innovative firm has an overdraft facility and 0 otherwise. Following Demirguc-Kunt, Klapper, and Randall (2013), the credit (*Credit*) variable takes the value of 1 if an

[11] Propensity score matching models provide alternative estimands, such as the population average treatment effect on the treated (ATT).

innovative firm has a line of credit or loan from a financial institution and 0 otherwise. Love and Martínez Pería (2014) use a similar approach to derive their financial constraints variable from the World Bank survey data. We find that the results are qualitatively the same and that the overall interpretation of the results does not change[12].

6. Conclusions

The objective of this study is to understand the relationship between ICT and FI of innovative entrepreneurs in African countries. Our findings confirm the important role that technological deepening plays in advancing FI in Africa and its potential for a wider applicability to other developing economies.

From a policy perspective, the findings are clear in terms of how ICT usage, when embedded in entrepreneurial firms, offers the potential for growth and employment . Within the urban areas, mobile technology offers the greatest advantage once it moves to a full 3G or 4G band supporting smartphone apps. However, with smartphone technology comes the increasing likelihood of scams and other potential pitfalls, particularly in environments where there is a weak rule of law, minimal commercial literacy, and limited protection of property. It is vital that governments in Africa pursuing the goal of FI strategically plan the penetration of technology within their respective countries. The growth of ICT also represents the potential for reducing information asymmetry which, in turn, provides other macroeconomic benefits including boosting economic growth, employment rates, and ensuring the overall stability of the financial sector. Mobile technology, such as smart phones, offer significant payoffs and it is wise to integrate learning from the experiences of other countries about, among other things, the need for data security and education against scams. Such learning needs to be implemented into sound policy at the early stages of policy formulation. That said, there are tensions to navigate through as the increasing desire for immediacy exerts security pressures and leads to unanticipated outcomes.

This study has its drawbacks with regard to the generalizability of the results, although this was deemed necessary due to the nature of the data collected from the African countries. The

[12] For the sake of brevity, the estimation of propensity score results for alternative FI proxies are available from the authors upon request.

extent to which the control variables examined in this study are equally dominant in other nations is a question that requires further investigation. Moreover, building an evidence-based business case that supports public policy and budget funds is a challenging task that requires careful research. Further development of our model in other settings and contexts should be fruitful and multinational comparative studies incorporating other continents beyond Africa should provide evidence of the prospective pace of change possible over the next decade.

References

Acs, Z.J., Desai, S., Hessels, J., 2008. Entrepreneurship, economic development and institutions. Small Bus. Eecon. 31 (3), 219–234. https://doi.org/10.1007/s11187-008-9135-9

Allen, F., Demirguc-Kunt, A., Klapper, L., Soleda, M., Peria, M., 2016. The foundations of financial inclusion: Understanding ownership and use of formal accounts. J. Financ. Intermed. 27, 1–30. https://doi.org/10.1016/j.jfi.2015.12.003

Allen, F., Santomero, A.M., 1997. The theory of financial intermediation. J. Bank. Financ. 21 (11–12), 1461–1485. https://doi.org/10.1016/S0378-4266(97)00032-0

Aminuzzaman, S., Baldersheim, H., Jamil, I., 2003. Talking back! Empowerment and mobile phones in rural Bangladesh: a study of the village phone scheme of Grameen Bank. Contemp. South Asia 12 (3), 327–348. https://doi.org/10.1080/0958493032000175879

Andonova, V., 2006. Mobile phones, the Internet and the institutional environment. Telecommun. Policy 30 (1), 29–45. https://doi.org/10.1016/j.telpol.2005.06.015

Asongu, S.A., 2018. ICT, openness and CO2 emissions in Africa. Environ. Sci. Pollut. R. 25 (10), 9351–9359. https://doi.org/10.1007/s11356-018-1239-4

Asongu, S.A., Nwachukwu, J.C., Tchamyou, V.S., 2016. Information asymmetry and financial development dynamics in Africa. Rev. Develop. Financ. 6 (2), 126–138. https://doi.org/10.1016/j.rdf.2016.09.001

Austin, P.C., 2013. The performance of different propensity score methods for estimating marginal hazard ratios. Stat. Med. 32 (16), 2837–2849. https://doi.org/10.1002/sim.5705

Austin, P. C. 2011. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivariate behavioral research, 46(3), 399-424. doi:https://doi.org/10.1080/00273171.2011.568786

Ayyagari, M., Demirgüç-Kunt, A., Maksimovic, V., 2011. Firm innovation in emerging markets: the role of finance, governance, and competition. J. Financ. Quant. Anal. 46 (6), 1545-1580. https://doi.org/10.1017/S0022109011000378

Barnett, W.A., Hu, M., Wang, X., 2019. Does the utilization of information communication technology promote entrepreneurship: Evidence from rural China. Technol. Forecast. Soc. Change 141, 12–21. https://doi.org/10.1016/j.techfore.2019.01.007

Beck, T., Demirguc-Kunt, A., 2006. Small and medium-size enterprises: Access to finance as a growth constraint. J. Bank. Financ. 30 (11), 2931–2943. https://doi.org/10.1016/j.jbankfin.2006.05.009

Bongomin, G.O.C., Ntayi, J.M., Munene, J.C., Malinga, C.A., 2018. Mobile money and financial inclusion in sub-Saharan Africa: the moderating role of social networks. J. Africa. Bus. 19(3), 361–384. https://doi.org/10.1080/15228916.2017.1416214

Brown, J.R., Martinsson, G., Petersen, B.C., 2012. Do financing constraints matter for R&D?. Eur. Econ. Rev. 56 (8), 1512–1529. https://doi.org/10.1016/j.euroecorev.2012.07.007

Chatterjee, A. (2020). Financial inclusion, information and communication technology diffusion, and economic growth: a panel data analysis. *Information Technology for Development*, *26*(3), 607–635. https://doi.org/10.1080/02681102.2020.1734770

Culot, G., Orzes, G., Sartor, M., & Nassimbeni, G. (2020). The future of manufacturing: A Delphi-based scenario analysis on Industry 4.0. *Technological Forecasting and Social Change*, 157. https://doi.org/10.1016/j.techfore.2020.120092

Della Peruta, M. (2018). Adoption of mobile money and financial inclusion: a macroeconomic approach through cluster analysis. *Economics of Innovation and New Technology*. https://doi.org/10.1080/10438599.2017.1322234

Demirgüç-Kunt, A., Klapper, L., 2013. Measuring financial inclusion: Explaining variation in use of financial services across and within countries. Brookings Pap. Econ. Act. Spring 2013 (1), 279–340.
Demirguc-Kunt, A., Klapper, L., Randall, D., 2013. Islamic finance and financial inclusion: measuring use of and demand for formal financial services among Muslim adults. Middle East Econ. Financ. 10 (2), 177–218. https://doi.org/10.1515/rmeef-2013-0062
Diniz, E., Birochi, R., Pozzebon, M., 2012. Triggers and barriers to financial inclusion: The use of ICT-based branchless banking in an Amazon county. Electron. Commer. R. A. 11 (5), 484–494. https://doi.org/10.1016/j.elerap.2011.07.006
Dong, Y., Men, C., 2014. SME financing in emerging markets: Firm characteristics, banking structure and institutions. Emerg. Mark. Financ. Trade 50 (1), 120–149. https://doi.org/10.2753/REE1540-496X500107
Donovan, K. (ed.) 2015. The International Encyclopedia of Digital Communication and Society. USA: John Wiley & Sons, Inc.
Ekbia, H.R., 2009. Digital artifacts as quasi-objects: Qualification, mediation, and materiality. J. Am. Soc. Inf. Sci. Technol. 60 (12), 2554–2566. https://doi.org/10.1002/asi.21189
Fan, Z., Zhang, R., 2017. Financial inclusion, entry barriers, and entrepreneurship: Evidence from China. Sustain. 9 (2), 203. https://doi.org/10.3390/su9020203
Farace, S., Mazzotta, F., 2011. The causes and the effects of innovation in small and medium firms. ICSB World Conference Proceedings, 2011. International Council for Small Business (ICSB), 1.
Freixas, X., Rochet, J.-C., 2008. Microeconomics of banking, MIT press.
Gorodnichenko, Y., Schnitzer, M., 2013. Financial constraints and innovation: Why poor countries don't catch up. J. Eur. Econ. Assoc. 11 (1), 1115–1152. https://doi.org/10.1111/jeea.12033
Gosavi, A., 2018. Can mobile money help firms mitigate the problem of access to finance in Eastern sub-Saharan Africa?. J. Africa. Bus. 19 (3), 343–360. https://doi.org/10.1080/15228916.2017.1396791
Guo, S., Fraser, M.W., 2014. Propensity score analysis: Statistical methods and applications (Vol. 11). SAGE publications.
Hajivassiliou, V., Savignac, F., 2008. Financing constraints and a firm's decision and ability to innovate: establishing direct and reverse effects. Available: https://ssrn.com/abstract=1680212 or http://dx.doi.org/10.2139/ssrn.1680212.
Hall, B.H., Lerner, J., 2010. The financing of R&D and innovation. Handbook Econ. Innov. 1, 609–639. https://doi.org/10.1016/S0169-7218(10)01014-2
Härkänen, T., Kaikkonen, R., Virtala, E., Koskinen, S., 2014. Inverse probability weighting and doubly robust methods in correcting the effects of non-response in the reimbursed medication and self-reported turnout estimates in the ATH survey. BMC Public Health 14 (1), 1150. https://doi.org/10.1186/1471-2458-14-1150
Hazarika, B., Bezbaruah, P., & Goswamia, K 2016. Adoption of modern weaving technology in the handloom micro-enterprises in Assam: A Double Hurdle approach
Technology Forcasting & Social Changes. 102, 344-356 https://doi.org/10.1016/j.techfore.2015.08.009
Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, 146, 119–132. https://doi.org/10.1016/j.techfore.2019.05.021

Iachina, M., 2009. The evaluation of the performance of IPWGEE, a simulation study. Commun. Stat. Simul. Comput. 38 (6), 1212–1227. https://doi.org/10.1080/03610910902859566
Jack, W., Suri, T., 2014. Risk sharing and transactions costs: Evidence from Kenya's mobile money revolution. Am. Econ. Rev. 104 (1), 183–223. https://doi.org/10.1257/aer.104.1.183
Kpodar, K., Andrianaivo, M., 2011. ICT, financial inclusion, and growth evidence from African countries. IMF Working Paper no. WP/11/73. Washington, D.C.: International Monetary Fund.
Kuester, S., Konya-Baumbach, E., Schuhmacher, M.C., 2018. Get the show on the road: Go-to-market strategies for e-innovations of start-ups. J. Bus. Res. 83, 65–81. https://doi.org/10.1016/j.jbusres.2017.09.037
Lapukeni, A. F. (2015). Financial Inclusion and the Impact of ICT : An Overview. *American Journal of Economics*, *5*(5), 495–500. https://doi.org/10.5923/j.economics.20150505.09
Levine, R., 2005. Finance and growth: theory and evidence. In: AGHION, P. & DURLAUF, S. (eds.). Handbook Econ. Growth. Elsevier B.V. https://doi.org/10.1016/S1574-0684(05)01012-9.
López-Videla, B., Machuca, C.E., 2014. The effects of remittances on poverty at the household level in Bolivia: a propensity score matching approach. https://mpra.ub.uni-muenchen.de/55201/1/MPRA_paper_55201.pdf.
Love, I., Martínez Pería, M.S., 2014. How bank competition affects firms' access to finance. World Bank Econ. Rev. 29 (3), 413–448. https://doi.org/10.1093/wber/lhu003
Lunceford, J.K., Davidian, M., 2004. Stratification and weighting via the propensity score in estimation of causal treatment effects: a comparative study. Stat. Med. 23 (19), 2937–2960. https://doi.org/10.1002/sim.1903
Lyytinen, K., Yoo, Y., Boland Jr, R.J., 2016. Digital product innovation within four classes of innovation networks. Inf. Syst. J. 26 (1), 47–75. https://doi.org/10.1111/isj.12093
Mancusi, M.L., Vezzulli, A., 2010. R&D, innovation and liquidity constraints. CONCORD 2010 Conference, Sevilla, 2010. 3–4.
Molenberghs, G., Kenward, M., 2007. Missing data in clinical studies (Vol. 61). John Wiley & Sons.
Morris, S., 2007. The impact of obesity on employment. Labour Econ. 14 (3), 413–433. https://doi.org/10.1016/j.labeco.2006.02.008
Mushtaq, R., & Bruneau, C. (2019). Microfinance, financial inclusion and ICT: Implications for poverty and inequality. *Technology in Society*. https://doi.org/10.1016/j.techsoc.2019.101154
Muto, M., Yamano, T., 2009. The impact of mobile phone coverage expansion on market participation: Panel data evidence from Uganda. World Dev. 37 (12), 1887–1896. https://doi.org/10.1016/j.worlddev.2009.05.004
Ouma, S. A., Odongo, T. M., & Were, M. (2017). Mobile financial services and financial inclusion: Is it a boon for savings mobilization? *Review of Development Finance*, *7*, 29–35. https://doi.org/10.1016/j.rdf.2017.01.001
Peraković, D., Periša, M., & Zorić, P. (2020). Challenges and issues of ICT in industry 4.0. In *Lecture Notes in Mechanical Engineering* (pp. 259–269). https://doi.org/10.1007/978-3-030-22365-6_26
Pistelli, M., 2017. How UNHCR is working to encourage lasting connections between refugees and the financial sector. Removing Barriers to Expand Access to Finance for Refugee. Microfinance Gateway.
Rosenbaum, P.R., 1987. Model-based direct adjustment. J. Am. Stat. Assoc. 82 (398), 387–394. https://doi.org/10.1080/01621459.1987.10478441

Sarma, M., Pais, J., 2011. Financial inclusion and development. J. Int. Dev. 23 (5), 613–628. https://doi.org/10.1002/jid.1698

Schneider, C., Veugelers, R., 2010. On young highly innovative companies: why they matter and how (not) to policy support them. Ind. Corp. Change 19 (4), 969–1007. https://doi.org/10.1093/icc/dtp052

Scholtens, B., Van Wensveen, D., 2003. The theory of financial intermediation: an essay on what it does (not) explain, SUERF Studies.

Schwab, K. (2016). The Fourth Industrial Revolution: what it means, how to respond. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Ślusarczyk, B. (2018). Industry 4.0 – Are we ready? Polish Journal of Management Studies, 1-7(1), 232–249. https://doi.org/10.17512/pjms.2018.17.1.19

Stiglitz, J.E., Weiss, A., 1981. Credit rationing in markets with imperfect information. Am. Econ. Rev. 71 (3), 393-410. https://www.jstor.org/stable/1802787

Tchamyou, V.,Erreygers, G., Cassimon, D., 2019. Inequality, ICT and financial access inAfrica Technol. Forecast. Soc. Change 139, 169-184. https://doi.org/10.1016/j.techfore.2018.11.004

The World Bank Group., 2014. Enterprise Surveys Indicator Descriptions [Online]. Washington DC: The World Bank Group. Available: http://www.enterprisesurveys.org/methodology [Accessed Accessed in, 2016].

Tiwana, A., Konsynski, B., Bush, A.A., 2010. Research commentary—Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics. Inf. Syst. Res. 21 (4), 675–687. https://doi.org/10.1287/isre.1100.0323

Tob-Ogu, A., Kumar, N., Cullen, J., 2018. ICT adoption in road freight transport in Nigeria–A case study of the petroleum downstream sector. Technol. Forecast. Soc. Change 131, 240–252. https://doi.org/10.1016/j.techfore.2017.09.021

Triki, T., Gajigo, O., 2014. Credit bureaus and registries and access to finance: new evidence from 42 African countries. J. Afr. Dev. 16(2), 73–101.

Valencia, E. T., Lamouri, S., Pellerin, R., Dubois, P., & Moeuf, A. (2019). Production planning in the fourth industrial revolution: A literature review. *IFAC-PapersOnLine*, *52*(13), 2158–2163. https://doi.org/10.1016/j.ifacol.2019.11.525

Van Stel, A., Carree, M., Thurik, R., 2005. The effect of entrepreneurial activity on national economic growth. Small Bus. Econ. 24 (3), 311–321. https://doi.org/10.1007/s11187-005-1996-6

Vaughan, A.S., Kelley, C.F., Luisi, N., Del Rio, C., Sullivan, P.S., Rosenberg, E.S., 2015. An application of propensity score weighting to quantify the causal effect of rectal sexually transmitted infections on incident HIV among men who have sex with men. BMC Med. Res. Methodol. 15 (1), 25. https://doi.org/10.1186/s12874-015-0017-y

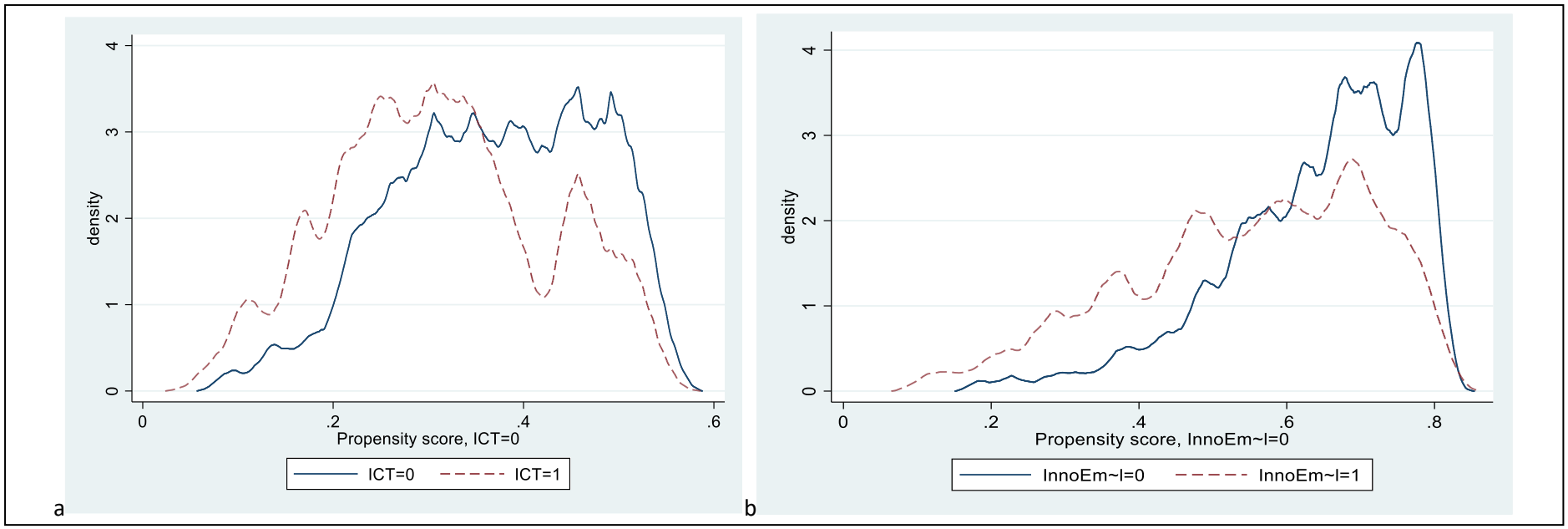
von Briel, F., Davidsson, P., Recker, J., 2018. Digital technologies as external enablers of new venture creation in the IT hardware sector. Entrep. Theory Pract. 42 (1), 47–69. https://doi.org/10.1177/1042258717732779

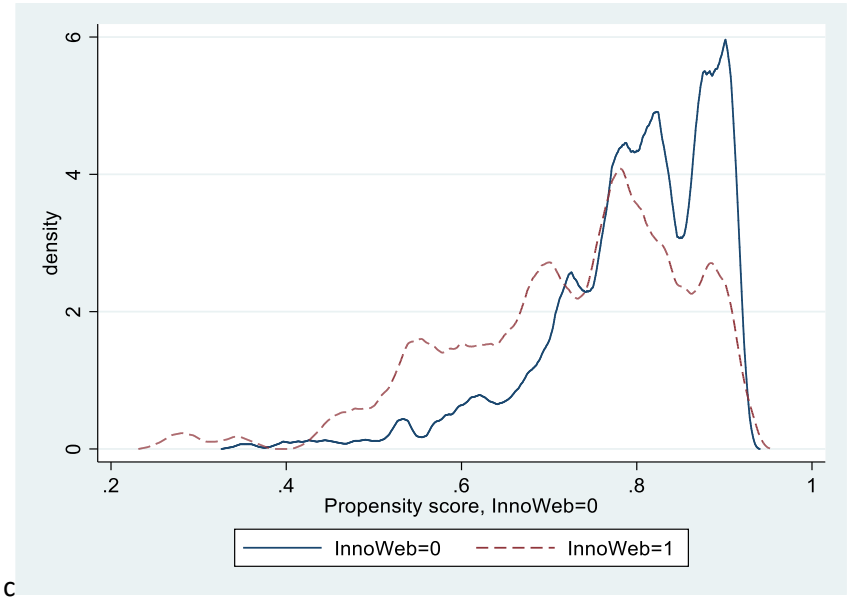
Wellalage, N. H., & Fernandez, V. (2019). Innovation and SME finance: Evidence from developing countries. International Review of Financial Analysis. doi:https://doi.org/10.1016/j.irfa.2019.06.009

Yunis, M., Tarhini, A., & Kassar, A. (2018). The role of ICT and innovation in enhancing organizational performance: The catalysing effect of corporate entrepreneurship. *Journal of Business Research*, *88*, 344–356. https://doi.org/10.1016/j.jbusres.2017.12.030

Fig. 1. Kernel densities of the propensity scores

a) Kernel densities of the propensity scores for the firms using ICT and non-ICT using firms
b) Kernel densities of the propensity scores for the firms using Email and non-Email using firms
c) Kernel densities of the propensity scores for the firms has business website and non-business website firms
d) Kernel densities of the propensity scores for the firms using cell phone for business and noncell phone using firms
e) Kernel densities of the propensity scores for the firms using mobile money and non-mobile money using firms

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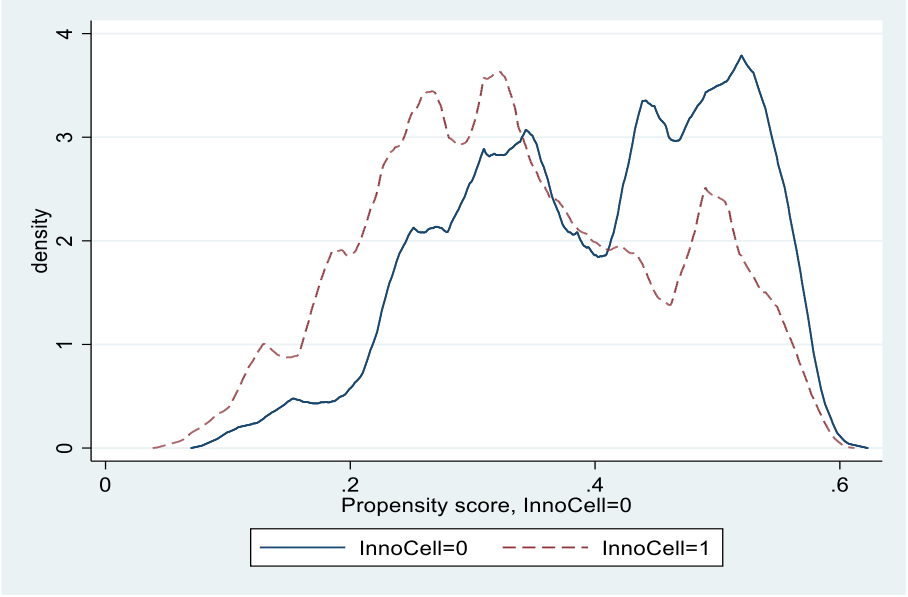
Propensity score, InnoWeb=0
InnoWeb=0
InnoWeb=1

c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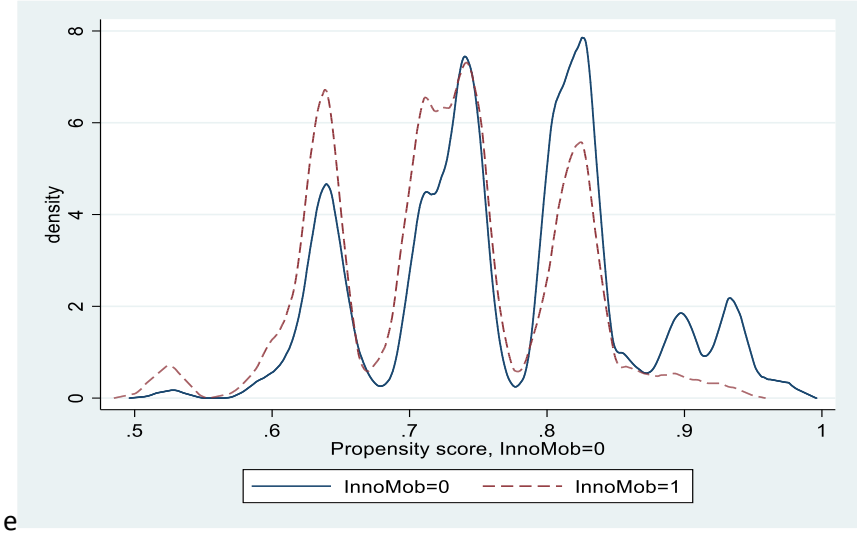
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Propensity score, InnoMob=0
InnoMob=0
InnoMob=1

e

Table 1														
Cross-tabulation of sampled economies and the FI														
Country	Email		Web		Cell		Finance		Acc_Own		Over		Credit	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Ghana (%)	0.4819	0.6284	0.2681	0.3446	0.4819	0.6284	0.1169	0.2174	0.8344	0.9392	0.1088	0.1744	0.1551	0.1763
Kenya (%)	0.4612	0.7945	0.2362	0.5479	0.4612	0.7945	0.1174	0.2857	0.8469	0.9078	0.1071	0.2331	0.1376	0.3145
Tanzania (%)	0.5721	0.2918	0.2998	0.2255	0.8944	0.7565	0.1528	0.0925	0.8912	0.7248	0.1560	0.0655	0.1765	0.1394
Uganda (%)	0.5433	0.3818	0.3065	0.1891	0.8670	0.8556	0.1624	0.0408	0.8619	0.8327	0.1570	0.0476	0.1731	0.1496
Zambia(%)	0.5059	0.5329	0.5059	0.5329	0.5059	0.5329	0.1501	0.1087	0.8471	0.8859	0.8471	0.8859	0.8471	0.8859
Average(%)	0.5129	0.5259	0.3233	0.3680	0.6421	0.7136	0.1399	0.1490	0.8563	0.8581	0.2752	0.2813	0.2979	0.3331

Table 2
Variable description and sources

Variable	Description	Measure	Source
Finance	This variable captures FI. Dummy variable takes value 1 when a firm answer as no or minor obstacle to access finance in the current operations of this establishment.	1=yes; 0=otherwise	(Gorodnichenko and Schnitzer, 2013)
Treatment variables			
ICT	Dummy variable takes value 1 if firm uses email or firm has website or firm uses cell phones for the operations.	1=yes; 0=otherwise	(Andrianaivo & Kpodar, 2011)
Email	Dummy variable takes value 1 if firm uses email to communicate with clients or suppliers	1=yes; 0=otherwise	(Andrianaivo & Kpodar, 2011)
Web	Dummy variable takes value 1 if the firm has its own website	1=yes; 0=otherwise	(Andrianaivo & Kpodar, 2011)
Cell	Dummy variable takes value 1 if firm currently uses cell phones for the operations of the establishment	1=yes; 0=otherwise	(Andrianaivo & Kpodar, 2011)
Mob_money	Dummy variable takes value 1 if the firm uses mobile money for any of its financial transactions.	1=yes; 0=otherwise	(Asongu & Moulin, 2016; Asongu et al., 2016)
Other covariates			
Small	Firm has 5 to 19 employees.	1=yes; 0=otherwise	(Chakravarty and Xiang, 2011)
Medium	Firm has between 20 and 99 employees.	1=yes; 0=otherwise	(Chakravarty and Xiang, 2011)
From_City	Firm from the capital city	1=yes; 0=otherwise	(Kumarasamy and Singh, 2018)
Foreign_Own	Percentage of foreign ownership of the firm	Percentage	(Fungáčová, Kochanova, & Weill, 2015)
Female	Firm has at least one female owner	1=yes; 0=otherwise	(N. Wellalage & Locke, 2016)
TopMgrExp	Total number of working experiences that top manager has in the same sector	Number	(N. H. Wellalage, Locke, & Samujh, 2018) (Nofsinger and Wang (2011)
Bribes	Dummy variable takes value 1 if firm has to pay informal gifts or payments to get things done	1=yes; 0=otherwise	(N. H. Wellalage et al., 2018)
Manufac	Firm from the manufacturing industry	1=yes; 0=otherwise	(Barbosa and Moraes (2004)
Retail	Firm from the retail industry	1=yes; 0=otherwise	
Other_Ind	Firm from other industry	1=yes; 0=otherwise	

Alternative FI proxies			
Acc_Own	Dummy variable takes value 1 if firm has a checking or savings account with formal finance institutions	1=yes; 0=otherwise	(Demirgüç-Kunt & Klapper, 2013)
Over	Dummy variable takes value 1 if the firm has an overdraft facility	1=yes; 0=otherwise	
Credit	Dummy variable takes value 1 if the firm has a line of credit or a loan from a formal financial institution	1=yes; 0=otherwise	(Demirgüç-Kunt & Klapper, 2013)

Table 3
Summary descriptive variables

Variables	Number of observation	Mean	Standard deviation	Minimum	Maximum
Finance	1436	.3788	.4851	0	1
Acc_Own	1317	.8511	.3560	0	1
Over	1436	.1960	.3970	0	1
Credit	1436	.2299	.4208	0	1
ICT variables					
Email	1436	.5669	.4955	0	1
Web	1436	.3287	.4698	0	1
Cell	1436	.8892	.3139	0	1
Mob_money	1436	.3004	.4585	0	1
Firm characteristics					
Small	1332	.6614	.7508	0	1
Medium	1332	.3373	.2244	0	1
From City	1436	.4878	.4999	0	1
Foreign_own %	1436	12.22	30.92	0	100
Female	1436	.3190	.4726	0	1
TopMgrExp	1436	15.11	.4955	0	1
Bribe	1436	.1522	.3593	0	1
Manufac	1332	.4354	.4960	0	1
Retail	1332	.2215	.4153	0	1
Other_Indu	1332	.3431	.4749	0	1
Country factor					
Kenya	1332	.1276	.3338	0	1
Uganda	1332	.1959	.3971	0	1
Tanzania	1332	.2222	.4158	0	1
Ghana	1332	.2139	.4102	0	1
Zambia	1332	.2402	.4274	0	1

Table 4

Treatment effect estimation using inverse-probability weights

Panel A : ICT				Panel B: Email			
FI	Coef.	SE	P>[z]	FI	Coef.	SE	P>[z]
ATE ICT (1 vs 0)	.1198	.0191	0.000	ATE Email (1 vs 0)	.0890	.0222	0.000
POmean ICT 0	.0621	.0135	0.000	POmean Email 0	.1043	.0114	0.000
Obs	1210			Obs	1207		
Over identification test for covariate balance	chi2(9) = 7.3406 Prob > chi2 = .6017 *H₀:Covariates are balanced:*			Over identification test for covariate balance	chi2(9) = 3.4845 Prob > chi2 = .9420 *H₀:Covariates are balanced:*		
Panel C : Web				Panel D: Cell			
FI	Coef.	SE	P>[z]	FI	Coef.	SE	P>[z]
ATE Web (1 vs 0)	.1214	.0313	0.000	ATE Mobile (1 vs 0)	.1051	.0193	0.000
POmean Web 0	.1155	.0104	0.000	POmean Mobile 0	.0736	.0134	0.000
Obs	1208			Obs	1210		
Over identification test for covariate balance	chi2(9) = 4.9981 Prob > chi2 = .8345 *H₀:Covariates are balanced:*			Over identification test for covariate balance	chi2(9) = 9.2207 Prob > chi2 = .4172 *H₀:Covariates are balanced:*		
Panel E : Mob_Money							
FI	Coef.	SE	P>[z]				
ATE Mob_Money (1 vs 0)	.0785	.0274	0.004				
POmean Mob_Money 0	.1346	.0115	0.000				
Obs	1041						
Over identification test for covariate balance	chi2(9) = 13.858 Prob > chi2 = .1275 *H₀:Covariates are balanced:*						

Note: Firm level covariates are included in all models: Firm size (small/ Medium), firm location (from City), Firm ownership characteristics (foreign own%, female_own), manager experience (TopMgrExp), bribes, industry (Manufac, Retail, Other_Indu)

Table 5

Univariate probit and recursive bivariate probit models for FI, ICT and mobile money

	Panel A							
	1	2	3	4	5	6	7	8
Variables	Univariate Probit	Univariate Probit-ME	Univariate Pboit	Univariate Pboit- ME	Bivariate-	Bivariate-ME	Bivariate-	Bivariate-ME
	ICT		FI		ICT		FI	
FI (finance)	.3539*** (.1082)	. 1398*** (.1080)						
ICT (Email)			.3215*** (.0958)	.0709*** (.0211)				
FI'(finance)					1.1984*** (.3675)	.0168 (.0256)		
ICT'(Email)							1.004*** (.8232)	.0705*** (.0159)
Mob_money								
Control variables								
Small	.2406 (.3574)	.0417 (.0573)	.3826 (.4556)	.0761 (.5281)	–.5719** (.3394)	–.1130*** (.0793)	–.4276 (.3579)	–.0949 (.0888)
From City	.0511 (.1248)	.0095 (.0234)	.1623 (.1268)	.0283 (.2132)	.2771** (.1319)	.0463** (.0226)	–.1209 (.1231)	.0020*** (.0005)
Foreign_own %	–.0031 (.0022)	–.0005 (.0004)	.0020 (0023)	.0003 (.0027)	–.0016 (.0021)	–.0002 (.0003)	–.0105*** (.0028)	–.0235 (.0237)
Femaleowner	.0401 (.1278)	.0075 (.0243)	–.1043 (.1277)	–.0188 (.1404)	–.0109 (.1349)	–.0017 (.0219)	.1457 (.12660)	.0294 (.0263)
TopMgrExp	.0069 (.0081)	.0013 (.0015)	.0095 (.0101)	.0016 (.0126)	.0073** (.0082)	.0012** (.0013)	.0123*** (.0079)	.0024** (0015)
Bribes	.1794 (.1589)	.0362 (.0345)	.0676 (.1800)	.0115 (.0928)	.3404** (.1656)	.0650** (.0365)	.3730** (.1550)	.0849** (.0401)
Manufacturing	.15173 (.1364)	.0286 (0259)	–.2423* (.1396)	–.0435 (.3206)	.0875 (.1445)	.0144 (.0240)	.0750 (.1372)	.0147 (.0271)
Retail	.4143 (.3720)	–.0211 (.0301)	.0123 (.1663)	.0022 (0333)	–.0148 (.1775)	–.0024 (.0287)	.0322 (.1668)	.0063 (.0334)
Domestic_credit	.0650*** (.0174)	.0121*** (.0031)	.0022 (.0158)	.0003 (.0040)	.0246 (.0182)	0040 (0029)	.0273** (.0145)	.0053** (.0028)
GINI	–.0005* (.0003)	–.0001* (.0006)	.0005** (.0002)	.0001 (.0007)	.0006 (.0003)	.0001 (.0006)	–.0001 (.0003)	–.0001 (.0006)
Poverty	.0308** (.0128)	.0057** (.0023)	–.0179** (.0095)	–.0031 (.0236)	.0051 (.0146)	.0008 (.0023)	.0010 (.0109)	.0002 (.0021)
Inflation	.3335*** (.0923)	.0623*** (.0166)	–.0356 (.0653)	–.0062 (.0482)	.0163 (.1050)	.0026 (.0171)	.0558 (.0782)	.0109 (.0153)
Summary Stat								
Pseudo–R^2	.2223		.2801					
Rho					.5104*** (.5238)		.8215** (.1943)	
Observations	1207	1207		1207			1208	1208

Note: Two dependent variables (FI and ICT) are dummy variables. Column 2 and 3 report univariate probit and marginal probit regression results, as ICT dependent variable. Column 4 and 5 report univariate probit and marginal effects results, as FI dependent variable. Column 5 and 6 represent the bivariate probit and marginal effect results assuming FI as endogenous explanatory variable. Column 7 and 8 present the bivariate probit and marginal effect results assuming ICT as endogenous explanatory

variable. FI is an endogenous variable in recursive bivariate regression in column 5 and 6 regression results (i.e. ICT= $X_i'\beta_1 + \delta\, FI + e_1$ ---(1) FI= $X_i'\beta_2 + \ e_2 - - - -(2)$. ICT is an endogenous variable in recursive bivariate regression in column 7 and 8 regression results (i.e. $FI = X_i'\beta_1 + \delta\, ICT + e_1$ --- (1) ICT= $X_i'\beta_2 + \ e_2 - - - -(2)$. Following omitted categories are treated as base. Medium (firm size) and, Other_Indu (Industry). These models provide standard errors, which are in parentheses. The Wald test of exogeneity is reported in the last row as a chi-squared statistic with 1 degree of freedom. * Significant at 10% level, **Significant at 5% level, ***Significant at 1% level.

Table 6

The impact on ICT on FI: propensity score matching

	No. treated	No. contr.	ATT[a]	Std.Err.	t
FI					
Nearest neighbour matching	1013	338	0.062	0.026	2.404
Kernel matching	1013	371	0.073	0.018	4.147
Radius matching (radius=0.01)	1001	309	0.085	0.021	4.022
Stratification matching	1013	380	0.059	0.022	2.644

Note a: ATT means average treatment effect on the treated. Firm level covariates are included in all models. The standard error used to compute the t statistics is the standard deviation of the ATT after 100 bootstrap replications.

Appendix A: Summary Table

Variable	Proxy	Description	Source
Financial Inclusion	Finance	This variable captures FI. Dummy variable takes value 1 when a firm answer as no or minor obstacle to access finance in the current operations of this establishment.	The following authors employed all these proxies of financial inclusion in their studies. Gorodnichenko and Schnitzer (2013); Demirgüç-Kunt and Klapper (2013)
	Acc_Own	Dummy variable takes value 1 if firm has a checking or savings account with formal finance institutions	
	Over	Dummy variable takes value 1 if the firm has an overdraft facility	
	Credit	Dummy variable takes value 1 if the firm has a line of credit or a loan from a formal financial institution	
	Index of Financial Inclusion (IFI)	Sarma (2008) has computed the values of IFI using the three basic dimensions of financial inclusion—accessibility, availability and usage of banking services. Accessibility has been measured by the number of bank accounts per 1000 population. Availability has been measured by the number of bank branches and number of ATMs per 100 000 people. The proxy used for the usage dimension is the volume of credit plus deposit relative to the GDP.	The studies of Chatterjee (2020) and Sarma and Pais (2011) used index of financial inclusion (IFI) which is developed by sarma (2008) for measuring financial inclusion.
ICT	Email	Dummy variable takes value 1 if firm uses email to communicate with clients or suppliers	Kpodar and Andrianaivo (2011) and Mushtaq and Bruneau (2019) incorportaes all these proxies of measuring ICT in their respective studies.
	Web	Dummy variable takes value 1 if the firm has its own website	
	Cell	Dummy variable takes value 1 if firm currently uses cell phones for the operations of the establishment	

	Mob_money	Dummy variable takes value 1 if the firm uses mobile money for any of its financial transactions.	Asongu and Moulin (2016) and Asongu et al. (2018) considers mobile money as an indicator of ICT

Appendix B: Covariates balance summary

Covariate balance summary for ICT

	Raw	Weighted
Number obs	1,210.0	1,210.0
Treated obs	808.0	604.9
Control obs	402.0	605.1

	Standardized differences		Variance Ratio	
	Raw	Weighted	Raw	Weighted
manufcatoring~y	.0180	.00065	1.0028	1.0001
retailindustry	–.0265	.0135	.9637	1.0188
firmfrommainb~y	.3401	.0014	1.0873	1.0002
small	–.2232	–.0118	1.3391	1.0145
medium	.2177	.0223	1.3851	1.0319
foreignownper~e	.1474	.0104	1.3969	.9841
femaleowner	.1592	.0203	1.1459	1.0170
topmgrexperie~e	.3096	–.0326	1.6413	.8691

Covariate balance summary for Email

	Raw	Weighted
Number obs	1,207.0	1,207.0
Treated obs	476.0	605.0
Control obs	731.0	602.0

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
manufcatoring~y	.0128	–.0081	1.0035	.9981
retailindustry	–.0939	.0061	.8779	1.0081
firmfrommainb~y	.2247	.0017	1.0191	1.0002
small	–.3825	.0038	1.5364	.9954
medium	.3434	–.0017	1.5660	.9976
foreignownper~e	.3238	–.0039	2.0387	.9406
femaleowner	.1944	.0037	1.1591	1.0029
topmgrexperie~e	.3017	.0023	1.6184	.9404

Covariate balance summary for Web

	Raw	Weighted
Number obs	1,208	1,208.0

Treated obs	265	607.3
Control obs	943	600.7

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
manufcatoring~y	–.0727	.0016	.9843	1.0003
retailindustry	–.05557	.0269	.9268	1.0361
firmfrommainb~y	.3257	–.0184	.9869	.9972
small	–.3814	.0171	1.4363	.9794
medium	.3279	–.0139	1.4566	.9809
foreignownper~e	.2718	.0021	1.7346	.9787
femaleowner	.1706	–.0188	1.1286	.9845
topmgrexperie~e	.2088	–.0172	1.5736	1.0729

Covariate balance summary for Mobile

	Raw	Weighted
Number obs	1,210	1,210.0
Treated obs	774	605.0
Control obs	436	605.0

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
manufcatoring~y	.03302	.0068	1.0065	1.0015
retailindustry	–.03895	–.0013	.9481	.9983
firmfrommainb~y	.3942	.00025	1.1009	1.00003
small	–.1812	–.0218	1.2584	1.0273
medium	.1753	.0317	1.2899	1.0466
foreignownper~e	.1394	.01001	1.3493	.9732
femaleowner	.1584	.0122	1.1435	1.0101
topmgrexperie~e	.2823	–.0345	1.5108	.8261

Covariate balance summary for mobile money

	Raw	Weighted
Number obs	1,203	1,203.0
Treated obs	292	597.3
Control obs	911	605.7

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
manufcatoring~y	–.1356	.0345	.9649	1.0058
retailindustry	.1931	.0198	1.2715	1.0267
firmfrommainb~y	.2791	–.0119	.9992	.9983
small	–.0871	–.0401	1.1057	1.0461
medium	.1513	.0465	1.2125	1.0618
foreignownper~e	–.3106	–.0909	.3543	.7071
femaleowner	.0147	.0099	1.0139	1.0077
topmgrexperie~e	.0338	–.0361	.9888	.9416