NEW APPROACHES TO INCLUSIVE FINANCING

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Introduction

In recent years, financial inclusion or inclusive finance has been positioned as being one of the primary concerns for many countries. The value of inclusive finance lies in its capacity to deliver affordable and sustainable financial services to all individuals and businesses, especially the unbanked and underbanked groups of people (World Bank, 2014, GPFI, 2017). Because of the failures of the traditional banking system to finance remote or rural areas, the financially excluded communities are forced to borrow from the informal sector, such as pawnbrokers, informal financial or savings groups, private moneylenders which are uncertain, unreliable, and expensive. Thus, there is a need for more adequate approaches to inclusive financing, which is the main focus of this dissertation.

Financial inclusion is commonly defined as equal opportunities for all groups of people in accessing useful finance services at an affordable and sustainable cost. Starting with loan provision, the services offered for inclusive financing are extended to savings, payments, insurance, money transfers. Several benefits and opportunities for the poor can be brought into their practical reach thanks to an inclusive financial system. For example, higher financial accessibility provides the low-income individuals and small enterprises with a chance to pursue their education or develop their business, which in turn, promotes poverty alleviation (Beck et al., 2007, Ozili, 2018). Furthermore, several well-established research studies have illustrated the overall contribution of financial inclusion towards the eciency and sustainability of the nancial system and economic growth (Cull et al., 2012, Kim et al., 2018a, Le et al., 2019). As the world moves towards sustainable development, more people are recognizing the importance of, and increasing need for, an inclusive financial system which encompasses economic, social, and environmental objectives. Even though financial inclusion is not stated as a concrete goal under the Sustainable Development Goals (SDGs) by United Nations (2015), greater access to financial services is considered as one of the most crucial enablers

for several of its development goals (Mader, 2018, Ma'ruf and Aryani, 2019). [1]

Microfinance, whose primary goal is to deliver financial services to the poor and unbanked, proves to play an important role in lifting up the progress of financial inclusion. Established in the 1990s with the foundation of Grameen Bank in Bangladesh, the classical microfinance with crucial initiatives to financial services, such as group lending with joint liability, progressive lending, a regular small amount of repayment schedule and the focus on women, has demonstrated its key role in serving the low-income segments of society (Morduch, 1999, Khandker, 2005). The microfinance industry differs from the other part of the financial system in the way that its specificity is to focus more on social responsibility, thus appears to remain prior on the list of strategies to financial inclusion (Soederberg, 2013). The promise of microfinance in providing greater financial accessibility to the economically disadvantaged communities is illustrated in a wide range of well-established literature (Morduch, 1999, Brown et al., 2016, Mushtaq and Bruneau, 2019). According to Cull and Morduch (2017), the global outreach of microfinance programs increased approximately 16 times in the time between 1997 and 2013, from 13 million borrowers to 211 million borrowers.

However, financial inclusion remains a major bottlenecks since approximately one-fifth of people around the world are reported to be financially excluded (Demirgüç-Kunt et al., 2018). Notably, the majority of the unbanked population are living in developing countries. Furthermore, the proportion of the poor and women are overrepresented in this disadvantaged communities. This issue could possibly be explained by the traditional banking system's dependence upon face-to-face contact and manual paperwork, which hinders the delivery of financial services to remote and rural areas. Although classical microfinance is marked by its unique approaches to poverty reduction and outreach as mentioned above, microfinance sector has encountered several issues. Recent studies have highlighted increasing and intense concerns about the effectiveness of microfinance institutions (MFIs). These microfinance providers are frequently criticized for two reasons: the high interest rate charged towards the poor (Brigit and Xavier, 2004, Roberts, 2013) and their tendency towards commercialization (Cull et al., 2011, Hermes et al., 2011). MFIs could justify this approach by stating that serving small loans to disadvantaged groups tends to increase overheads and operating costs; therefore, MFIs are required to increase their focus on financial sustainability to survive, so they can continue to fight poverty in the long-term. The phenomenon in which MFIs are distracted from their social mission and seek profit by providing financial services to financially stable customers is defined as so-called mission drift (Cull et al., 2007, Kar, 2013, Mersland and Strøm, 2010). Thus, new thinking towards the provision of financial services can be considered necessary.

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[1]Financial inclusion is implicitly mentioned in SDG 1: No poverty; SDG 2: Zero hunger; SDG 3: Good health and well-being; SDG 5: Gender equality; SDG 7: Affordable and clean energy; and SDG 8: Decent work and economic growth.

Furthermore, the implementation of inclusive financing for sustainable development represents an overwhelming challenge without access to modern energy, which is stated in SDG 7. [2] The general practices to achieve this target consist of three commonalities: increasing access to electricity, the improvement of energy efficiency, and increasing level of renewable energy (United Nations, 2015). Energy poverty has proven to be a major issue; however, financial inclusion could provide a solution to this problem (Koomson and Danquah, 2021). Moreover, to mitigate the increasingly negative impacts of climate change and environmental issues, more consideration should be given to alternative sources of nance for renewable energy and energy eciency projects. Financial institutions, particularly MFIs, have reasonable motives to concern themselves with green energy projects. Firstly, energy poverty and the traditional sources of energy, such as coal, fuels, are criticized for having detrimental impacts upon human welfare and the environment (Edenhofer et al., 2013, Sambodo and Novandra, 2019, Omri and Belaïd, 2021). However, poor and unbanked communities, especially those living in rural and remote areas, would struggle to gain access to green energy due to the high up-front costs (Bhattacharyya, 2006, Barua, 2001, Scheutzlich et al., 2002). Thus, MFIs which are driven by social values, should be knowledgeable about affordable and sustainable sources of energy finance. Secondly, energy lending can be a potential and differentiated strategy which helps fulfill the MFI's social mission and increases its competitiveness. In addition, as SDGs emphasize the harmonization of the economic, social, and environmental dimensions (United Nations, 2015, Eisenmenger et al., 2020), inclusive financial system should ideally take into account awareness of sustainable and environmentally-friendly energy strategies.

In general, there is a need to call for the adoption of more comprehensive methods to deliver financial services that help address these aforementioned issues. These delivery mechanisms should not only be efficient but also appropriate to avoid undesired negative impacts and defaults (World Bank, 2014). Therefore, this dissertation aims to shed some light on modern approaches that can reshape the way we achieve financial inclusion under a sustainable transformation model. More specifically, digital and green energy finance within the scope of microfinance and financial access for the poor will be examined in this dissertation.

Digital finance

Digital finance represents the integration of digital technology in a wide range of financial products, applications, and business operations which are delivered by financial service providers or Financial Technology (FinTech) companies. The encouragement of digital technology adoption in the financial sector is shown in a

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[2]SDG 7 refers to the assurance that households and individuals have affordable and sustainable access to modern energy.

vast number of studies. Digital innovations are perceived as being a basic construct in modern finance (World Bank, 2017). According to Rizzo (2014), greater financial inclusion is achievable thanks to the more convenient and affordable financial services delivered via new technologies. Stimulating financial inclusion progress through digital finance appears to be an innovative approach. The rationale for this approach can be explained by the significant and distinctive advantages to be gained from providing relief for the poor and unbanked, especially those living in remote and rural areas. As confirmed by Wyman (2017), those advantages include a faster process and lower cost in delivering services, increases in physical access of customers, enriching the payments ecosystem, greater access to credit thanks to better data on credit score and transactions, and the mobilization of savings. The period between 2011 to 2017 saw an 18% increase from 51% in the number of financial account owners globally, with this figure partially accounted for by the development of digital payment access (Demirgüç-Kunt et al., 2018).

The academic literature on various aspects of digital innovation in financial inclusion has been extensively examined in various aspects. One of the mainstream analyses is the proliferation of mobile financial services (MFS), which refers to the delivery of financial services based on mobile phones. This consists of various types of services and can be categorized into three groups, namely mobile banking services (e.g. deposit, repayment of loans, account balance management), money transfers, and mobile payment (e.g. payment of a utility bill) (Yousif et al., 2013). A range of academic literature analyzes the perception and usage patterns of customers towards mobile-enabled financial services (Mattila, 1970, Morawczynski and Pickens, 2009, Stuart and Cohen, 2011, Yen and Wu, 2016). The common findings reveal that sending money and receiving remittances are the prevailing services used by the poor. Meanwhile, the individual's perception of risk, ease of use, and usefulness play a key role in the adoption of MFS. Additionally, scholars provide an extensive number of studies on the linkage between MFS and financial inclusion. A study by Kim et al. (2018b) provides a comprehensive review. While the positive relationship between these two agenda has been identified in most of the theoretical and empirical literature (Mushtaq and Bruneau, 2019, Anand and Chhikara, 2013, Wyman, 2017), additional digital consumer protection is illustrated to have a significant influence (Bongomin and Ntayi, 2020).

The situation of micronance service providers in relation to the provision of MFS has also been the focus of another strand of literature. Several ndings obtained show that the growth of nancial suppliers intending to oer MFS is associated with the context of less developed countries (Minto-Coy and McNaughton, 2016, Lashitew et al., 2019). Meanwhile, Donovan (2012) provides some insights into the challenges faced by financial institutions and technology providers such as regulation, legal status and the interoperability of systems. These findings are subsequently supported by Maurer (2012), Asfaw (2015), and Evans and Pirchio (2014). However, most of the existing literature on the supply side is dominated by

qualitative analyses, consisting of mostly case studies (Kim et al., 2018b). Thus, the discussion on the adoption of MFS by financial service providers calls for more empirical analyses, especially in the case of MFIs since microfinance has been proven to meet the financial needs of the poor and unbanked effectively (Morduch, 1999).

Recently, an increasing number of empirical and theoretical studies have cast a spotlight on peer-to-peer microfinancing which features several successful online platforms, for example, Kiva, Zidisha, and Rangde. A range of analyses have been the focus of many scholars which encompass, for example, concerns about repayment behavior (Dorfleitner and Oswald, 2016, Berns et al., 2021), and the investigation of funding success (Yum et al., 2012, Ly and Mason, 2012, Anglin et al., 2020). Other studies suggest text content analysis as a signal about the investment decisions of investors (Mittelman and Rojas-Méndez, 2013, Dorfleitner et al., 2019b).

Meanwhile, the existing body of knowledge on assessing digital finance impacts indicates the predominance of qualitative studies. Several studies on the relationship between women's empowerment and greater access to digital finance have been added to the discourse and drawn supportive conclusions (Morawczynski, 2009, Hendriks, 2019, Adegbite and Machethe, 2020, Buvinić and Furst-Nichols, 2016). Contrary to this, Ibtasam et al. (2018) reports possible threats and risks associated with digitalization, such as harassment and frauds. Furthermore, the women are constrained in their ability to reap the full benefits of digital financial services due to the gender gap in technology access (Wyman, 2017). Subsequently, the trade-off between the benefits and costs of digital finance deployment for women is also discussed in a study by Kofman and Payne (2020). The author argues that the undesired effects are insignificant and could be mitigated by appropriate actions from stakeholders. In addition, the existing body of literature has reported upon investigations into the effectiveness of digital nance in reducing poverty, and has observed mixed results. The majority of findings indicate that digital finance is needed to reduce issues of poverty issue (Lyons et al., 2020b). Other studies suggest that digital finance is responsible for the increasing accessibility of other nancial services (Gosavi, 2018, Ouma et al., 2017, Lyons et al., 2020a).

As discussed above, the positive spillovers from digital finance are desirable for attaining social objectives, such as poverty reduction and women's empowerment. However, the question persists as to whether digital finance only lives up to social values. It is claimed that digital finance is likely to exacerbate the existing inequality in the provision of financial services if providers of digital finance are profit-oriented (Ozili, 2020). On the one hand, poor customers are unable to deal with the high costs of using digital transactions, and hence, refrain from the adopt of digital financial service. On the other hand, financial institutions may set a minimum threshold for digital deposit accounts or transactions, which limits the involvement of the poor. In addition, financial technology firms are empirically

illustrated to pose detrimental effects on bank performance (Phan et al., 2020). As a consequence, financial institutions are likely to refuse or curtail the integration of financial technology.

Green energy finance

The promotion of safe and reliable sources of energy is necessary for a path of sustainable growth and brings several benefits, such as poverty alleviation, women's empowerment, and the increase in education level (Thiam, 2011). Access to finance has significant impacts on the likelihood of green energy adoption (Le et al., 2020), yet poor and unbanked communities are likely to be excluded by the traditional financial system. Therefore, microfinancing presents a great opportunity for these disadvantaged groups of people. While the inclusion of green energy consideration in different types of finance is not new and extensively investigated in a large number of existing literature (Elie et al., 2020), little is known in the case of microfinancing. However, there have been important academic works that explore the environmental performance of MFIs, of which green energy microcredit has been presented as being one of the key dimensions. An explanatory analysis by Allet (2014) identifies that the institution's social orientation and the perception of an MFI's leader towards environmental protection are predictors of the level that financial and non-financial services promote green practices. Later in the analysis, Allet and Hudon (2015), and Forcella and Hudon (2016) shed a light on the impact of the MFI's size, age, and legal status in their empirical studies. However, whether or not the obtained results are also consistent in the cases related to energy lending requires further investigations.

A growing strand of literature has investigated the potential of green energy-related projects and products which are financed by MFIs. Khan et al. (2019) study the determining factors of customers' preferences towards payment methods for their microfinanced solar home systems and provide findings based mainly on the socio-demographic profile factors, such as education level and place of residence, and energy system capacity. Meanwhile, the interest rate charged on the microfinanced renewable energy systems is found to influence the borrowers' choice of microcredit (Yamegueu et al., 2019).

Moreover, by comparing the adoption behavior of households and micro-enterprises, Kurata et al. (2018) implicitly provide valuable suggestions on how MFIs should finance green energy-related projects with respect to type of borrowers. Further investigation in this field of study has been devoted to the potential business model that can assert the success of the green energy access projects (Rao et al., 2009, Carrillo, 2015, Groh and Taylor, 2015, Forcella et al., 2017). Given that energy-related technologies are fairly sophisticated, the study's main suggestion emphasizes the adoption of a two-hand model focused on the collaboration between MFIs

and energy service providers. More importantly, the problem of profitability is expected to be solved through this business model.

Additionally, concerns about the link between microfinance and the improvement of green energy access has also been discussed in previous academic papers. A range of research indicates that microfinance is essential in promoting the use of green energy, especially in rural areas (Kabir et al., 2010, Sovacool, 2013, Sriwannawita and Laestadiusb, 2015, Boutabba et al., 2020). Moreover, a wide range of literature has documented socio-economic welfare issues, such as poverty alleviation and women's empowerment as further positive impacts of microfinanced green energy projects (Srinivasan, 2007, Allderdice and Rogers, 2000). It is worthy noting that the research methods proposed in the existing literature on green energy microfinancing have concentrated on qualitative analyses, mostly via single case studies. In other words, there appears to be a gap of knowledge on empirical studies in this field of research.

On a whole, the existing body of literature appears to lack a clear roadmap. This dissertation consists of four academic papers which cover the aspects of digitalization and green consideration with regard to microfinance as a foundation for financial inclusion. The contributions of this doctoral thesis are two-fold. Firstly, the empirical analyses provide an overview of the explanatory factors of new financing approaches that help achieve financial inclusion. Secondly, the findings from the research papers can help to spur the development of digital and green energy finance.

The remainder of this chapter proceeds with an overview of four research projects which form the core of this dissertation. For each paper, the research objective, the data source, the employed methodology, the findings and the implications, if applicable, are briefly summarized. Details on these research articles are subsequently presented in the next chapters. More specifically, the first paper, 'Microfinance institutions and the provision of mobile financial services: First empirical evidence', will be introduced in Chapter 2, while Chapter 3 continues with the second article 'Microfinance and green energy lending: First worldwide evidence'. Chapter 4 presents the study 'Why microfinance institutions go digital: An empirical analysis'. The subsequent research 'Mobile money for women's economic empowerment: The mediating role of financial management practices' is set forth in Chapter 5 before the conclusion at Chapter 6.

Microfinance institutions and the provision of mobile financial services: First empirical evidence

The adoption of mobile technology in delivering financial services is becoming prevalent in the microfinance sector; therefore, there is a need for a better understanding of this trend. In this paper, we examine the characteristics of microfinance institutions offering mobile financial services (MFS). The data sample employed in this research comes from several sources. Information on the MFI's mobile financial services adoption was self-collected from their homepage, which is subsequently joined with MFI-specific information from the MIX Market database and macroeconomic data from World Development Indicators to form a unique sample of 999 MFIs worldwide.

By using probit regressions on the probability of offering MFIs, institutions opting for MFS does not appear to be synonymous with mission drift. More specifically, the models yield regression coefficients in favor of MFS adoption, taking into consideration proxies for the MFI's depth of outreach, such as percentage of female borrowers and average outstanding loan balance. Meanwhile, the MFI's cost structure reveals itself to have a significant relationship with the likelihood of providing MFS. Institutions intending to provide MFS exhibit a higher percentage of financial expense which is a sign of commercial orientation. Moreover, the MFI's maturity is discovered to be a critical predictor of the application of mobile technology in microfinance services, with more mature MFIs exhibiting more involvement. Finally, the findings indicate that microfinance banks and large MFIs are more likely to introduce financial services integrating mobile technology.

Our study provides first-hand quantitative evidence on the global integration of mobile technology in microfinance financial services, which is valuable for several stakeholders and MFI itself. Knowledge about the determinants of MFS adoption paints a clearer picture for strategies to facilitate the digitalization process in the microfinance industry.

Microfinance and green energy lending: First worldwide evidence

In recent years, the microfinance sector has shown growing engagement with green finance, especially green microcredit which is the main service of microfinance operation. To the best of the authors' knowledge, this is the first empirical study about the MFI's provision of global green energy lending. More specific, this article

investigates the driving factors that lead to MFIs' decision to provide green energy loans, with a particular emphasis on supply side. To source empirical evidence, an institutional-level data set of 105 MFIs is derived from a global survey, which is subsequently joined with the macroeconomic-level data from World Bank database to yield the final data sample.

We apply several ordered probit analyses and Heckman correction models with maximum likelihood approach on our estimations. The findings in this research article illustrate the critical determinants of the MFI's maturity measured by age and debt to equity ratio. Our results regarding borrower retention rate as a proxy for business sustainability reveal significant positive coefficients, suggesting the linkage between good business management and the intention of going green by MFIs. Moreover, MFIs located in countries with better economic development appear to care more about environmental issues, and thus tend to offer a larger number of green energy loans in comparison with their peers in less developed countries. Although we observe weak evidence on the linkages between the percentage of female managers and the level of engagement in green energy finance, detrimental effects to the participation of female managers should not be triggered. In addition, to explain the possible impacts of striving for sustainable development goals (SDGs) in the home country of the institutions, regressions with additional SDGs scores are performed for the robustness analysis. The implementation of SDGs appears to have a positive influence on the provision of green energy loans.

This chapter provides a better understanding of the growing literature on the environmental performance of MFIs and implies several insights to stakeholders involved in renewable energy and energy efficiency finance in the microfinance industry. The findings illustrated in this paper may provide valuable suggested strategies to smooth out and accelerate the path towards green finance.

Why microfinance institutions go digital: An empirical analysis

There is no denying that the penetration of digital technology into the microfinance sector is attracting increasing concerns from scholars. The main purpose of this research is to identify the motives of the MFI's digital solutions adoption. Understanding the underlying reasons for integrating digital solutions can help stimulate the digitalization process in the microfinance sector. The research is conducted based on both primary and secondary data. The first set of data is derived from a worldwide survey by YAPU Solutions. In the meanwhile, the second one which comprises institutional characteristics and macroeconomic level data comes from the World Bank data platform.

Probit regression models with Eicker–Huber–White standard errors are initially employed for the main analysis with digital solutions being the dependent variable. Alternative measures of digital solutions are introduced to test for the robustness of our results. The Heckman selection model is factored in order to control for the potential selection bias. Furthermore, robustness checks with modified specifications are also considered. The results first reveal supportive evidence for the linkage between social performance and the MFI's adoption of digital solutions. More specifically, the percentage of female borrowers —a proxy for the social orientation of MFIs—is positively related to the likelihood of adopting IT solutions. Secondly, we detect a positive relationship between the MFI's profitability and the decision towards using IT solutions, suggesting that MFIs with better financial performance tend to engage more in digital applications. This, however, should be considered as being a sufficient driver rather than a sign of mission drift. Finally, MFIs located in a more developed economy are more likely to adopt digital solutions.

In a nutshell, the results from our paper shed some light on the extent to which MFIs' digital solution uses have become mainstream globally, which has not been empirically addressed in the existing body of literature. The current paper suggests a future direction for the involvement of practitioners and the field's research agenda.

Mobile money for women's economic empowerment: The mediating role of financial management practices

The objective of this study is to examine the impacts of mobile money (MM) adoption on women's economic empowerment, with an additional focus on the mediating effect of financial management practices. For this purpose, a sample of 30,549 women in several South Asian and Sub-Sahara African developing countries is derived from the 2017 Financial Inclusion Insights survey. Based on this data sample, we conduct several econometric analyses to compare the effects on women's economic empowerment across different measures of mobile money adoption. In addition to the whole sample, we run regressions on the rural and urban sub-samples to investigate whether the effects vary for women across different geographical areas. Furthermore, estimations with an appropriate instrument are utilized to control for the potential problem of endogeneity.

The findings our study reveal the significant and positive association between womens economic empowerment and access to MM services. This suggests that the use of MM accelerates the economic empowerment of women. Furthermore,

the results show that financial management practices significantly and positively mediate this relationship, which leads to a critical policy implication. To effectively foster the economic empowerment of women through the use of MM, the key question here is about how to train and equip women with appropriate financial management skills. We also identify that the effects are more profound in the cases of women living in rural areas than their urban counterparts. This finding may inform a better approach in delivering mobile money services to economically empower rural female customers.

To the best of the writers' knowledge, this is the first study to documents the quantitative evidence on the mediating role of financial management practices on the linkage between MM adoption and women's economic empowerment. Based on our findings, mobile money-related stakeholders and scholars could take a deeper step into the practice agenda in order to accelerate women's economic empowerment through financial management training programs.

Chapter 2

Microfinance institutions and the provision of mobile financial services

This chapter is based on a joint work with Gregor Dorfleitner and Michaela Röhe. The paper has been published as: Gregor Dorfleitner, Quynh Anh Nguyen and Michaela Röhe (2019), Microfinance institutions and the provision of mobile financial services: First empirical evidence, *Finance Research Letters* 31, 357-362.

Abstract: This study empirically investigates the factors driving the provision of mobile financial services (MFS) by microfinance institutions (MFIs). Using a worldwide data set on 999 MFIs and employing a probit regression, we find a positive relationship between the financial expenses of an institution and MFS adoption. Our results also show that the share of deposits is positively related to the probability of offering MFS. Moreover, larger institutions and MFIs of the bank type are more likely to adopt mobile technology in providing financial services. Furthermore, the depth of outreach is weakly positively related to the provision of MFS, suggesting that the social mission of MFIs is not impaired by the provision of MFS.

2.1 Introduction

In recent years, the global financial services industry has experienced a steady increase of digitization. This development com- prises the entire spectrum of financial services and, in particular, includes mobile financial services (MFS). Also, the microfinance sector, which aims at providing financial services to otherwise unbanked individuals in developing countries, is exposed to the trend of digitization, and especially to the provision of MFS (Yousif et al., 2013). MFS is broadly defined as the usage of mobile devices with the aim of accessing or utilizing a wide range of transactions, banking activities and information. According to Yousif et al. (2013), MFS encompass various types of services and can be categorized into three groups, namely mobile banking services (e.g. withdrawals, deposits, repayment of loans), money transfers and mobile payment (e.g. payment of invoices). The adoption of mobile technology enables MFIs to efficiently provide financial services to their clients, in particular to those who live in remote areas, and thereby to achieve their bottom line of poverty alleviation. Even though there is some literature on mobile technology adoption in microfinance (Metre, 2011, Ogweno et al., 2014, Sanz et al., 2012) as well as on the general determinants of user adoption of MFS (Ouma et al., 2017, Mwafise and Stapleton, 2012, Dass and Pal, 2011), little is known about the characteristics of those MFIs that offer MFS to their clients.

This study is the first to explore the drivers of offering MFS in the microfinance sector. More specifically, we explore the linkage between the application of mobile technology by an MFI and its outreach, expenses, funding structure, and specific characteristics. Our study is based on a worldwide sample consisting of 999 MFIs.

Mobile technology has been generally considered as one of the most important measures used to improve access to financial products for the unbanked population and to foster an MFIs operational efficiency (Kauffman and Riggins, 2012, Ogweno et al., 2014). Although there are no global empirical studies on MFS in the microfinance sector, a body of literature on factors influencing the use of internet banking for several developing countries (Hanafizadeh et al., 2014, Toufaily et al., 2009, Raza et al., 2017, Malhotra and Singh, 2007) already exists. Summarized, these studies show that rather large —in terms of loan portfolio or deposits —and more mature banks wishing to lower their costs tend to offer internet banking. To which extent these findings can be transferred to the use of MFS in the microfinance sector is unclear because (1) MFIs are different to banks regarding their social and environmental objectives, (2) MFIs target the otherwise unbanked, (3) the financial structure and products of MFIs are, to some extent, different to those of conventional financial institutions and (4) there are some notable differences between internet banking and mobile banking.

It is well-known that MFIs are generally committed to a double bottom-line ap-

proach comprising financial and social goals (D'Espallier et al., 2013). This implies that they have to focus on their income-costs structure on the one hand, but strive to provide outreach (in terms of poverty alleviation and the like) on the other. Therefore, a trade-off between both goals can be observed for some MFIs. If, in such a situation, an MFI then over-emphasizes the financial goals and tends to disregard the social goals, we also speak of mission drift (Ghosh and Van Tassel, 2011, Kar, 2013). However, it is also conceivable that MFIs are well-managed and generally efficient and do not, as a consequence, suffer too greatly from the trade-off as they are able to achieve both goals. For instance, Wijesiri et al. (2017) provide evidence that larger MFIs tend to be more efficient with respect to both goals. The provision of MFS is generally related to the level of efficiency of an MFI. Thus our investigation not only sheds some light on how the global trend regarding MFS materializes in the microfinance industry but also on whether or not a new and more efficient technology fosters mission drift or can, on the contrary, even help to increase the depth of outreach.

Note that our empirical investigation, which utilizes probit regression techniques, is not intended to be a study of causality but instead one to produce first evidence on the question of how those MFIs providing MFS can be characterized. Next, we present our data and methodology and thereafter the results.

2.2 Data and methodology

2.2.1 Data sources

Our data set comprises a unique combination of information from three different sources. Data on MFI-level were obtained in April 2016 from MIX Market, an online-platform, which is a standardized and widely accepted source of institutional, financial and social characteristics of MFIs. In 2014, there were 1028 MFIs that reported their annual information to MIX Market. Although MIX Market has continuously improved the data by employing a qualified control system, data from MIX Market are self-reported by MFIs. Therefore, 29 MFIs are excluded due to unrealistic and contradictory values, e.g. percentage of female borrowers greater than one, return on assets less than 1.5, average loan balance per borrower greater than 15,000, gross loan portfolio smaller than zero and portfolio at risk or nominal yield on gross loan portfolio greater than one. The initial sample consists of 999 MFIs with realistic and consistent data. To determine whether or not MFIs utilize mobile technology, we carefully evaluated information on the MFIs homepages in November 2017. The MFIs website addresses were obtained from MIX Market in November 2012; when no in- formation on an institutions homepage was available, we employed Google to search for the MFIs website. Note that we

were only able to explore the availability of MFS as of November 2017 without knowing the starting time of the MFS provision. In addition, we are only able to assess the availability of MFS for institutions with accessible homepages at that time. Furthermore, macroeconomic data were derived from the World Bank data platform (World Development Indicators). The final sample contains 999 MFIs. A number of 701 of these have an accessible website, 177 of which offer MFS.

2.2.2 Definition of variables

Our main dependent variable is Offering MFS, which takes a value of 1 if an MFI offers MFS and 0 otherwise. In the context of this study, we follow Mobile Financial Services Working Group (2013)[p. 1], which defines mobile financial services as the use of a mobile phone to access financial services and execute financial transactions. This includes both transactional and non-transactional services, such as viewing financial information on a users mobile phone. Table 2.1 provides a detailed overview of variables used in this study.

Our variables of interest are categorized into four groups, namely outreach, expenses, funding structure, and further MFI-specific variables. Outreach is typically measured by the share of female borrowers an MFI has and by the average loan size of its microloan portfolio, with the logic being that the lower this quantity the higher the outreach (Hermes et al., 2011, Quayes, 2012, Ahmed et al., 2016). The MFIs expenses are considered as being important variables determining the provision of MFS. Therefore, we take into account the financial expense and operating expense ratio. The proportional operating costs are typically considerably lower if an MFI provides MFS (Kumar et al., 2010, Vizcarra and Ramji, 2015). However, this does not necessarily apply to the fixed operating costs. Generally, one can assume that MFIs that strive for efficiency also tend to be more likely to offer MFS. Regarding the financial expenses there is no clear expectation on the direction of the correlation. The variables deposits to assets ratio and capital to assets ratio are included to account for the funding structure of the MFI. The extent to which an MFIs has deposits can be interpreted as a proxy for maturity, as only regulated MFIs are allowed to take deposits, and as an MFI typically starts as a non-regulated organisation and later transforms into an bank or a non-bank financial institution (NBFI). Additionally, the ratio of deposits can serve as a measure for the level of trust by the clients. As further MFI-specific variables, we include the size and the legal status of the institution. As implementing MFS comes with a certain amount of fixed costs, we conjecture that—analogously to the case of the adoption of internet banking by banks (Mullan et al., 2017)—the size (measured by the natural logarithm of the gross loan portfolio), which can be seen as a further measure for the maturity of an MFI, is expected to be positively related to the MFS provision. The type of MFI can also play a role for the provision of MFS.

An MFI can be a bank, a rural bank, an NBFI, a cooperative, a credit union or an NGO. As the type of organisation becomes less formal according to this order, one can also suspect that this variable has an influence on the provision of MFS. To account for macroeconomic factors, the GDP per capita of the country in which the MFI is located and the geographical region of the MFI are employed.

2.3   Results

2.3.1   Descriptive analysis

Table 2.2 reports the frequency of categorical variables by values of Offering MFS. Due to missing values, the number of observations for these variables varies. In our sample, approximately 25% of the MFIs offer MFS. The statistics also reveal that NBFIs and NGOs appear to be overrepresented compared with other types of MFI in the total sample (36.38% and 34.09%), while the MFS offering sub-sample is dominated by NBFIs and banks (42.37% and 32.20%). Furthermore, the distribution across different regions indicates the dominance of Latin America and the Caribbean in both the total and the MFS offering sub-sample (38.09% and 32.77%, respectively). In contrast, Middle East and North Africa is the region with the lowest number of MFIs.

Table 2.3 shows descriptive statistics for metric explanatory variables by Offering MFS. At a glance, our data are normally dis- tributed and maintain comparable values to previous worldwide studies on MFIs (see e.g. Dorfleitner et al., 2017b, Tadele et al., 2018). The mean values of the deposits to assets ratio and size are higher in institutions offering MFS while neither expense indicator appears to vary between groups. The lower share of female borrowers and the higher values for average loan size in the offering sub-sample suggest that MFIs that provide MFS could exhibit lower levels of outreach. Next, we perform several regressions to further evaluate the relationship between these variables and *Offering MFS*.

2.3.2   Regression analysis

2.3.2.1   Determinant of offering MFS

We estimate various probit models with Eicker–Huber–White heteroskedastic-consistent standard errors.

Columns (1)–(5) of Table 2.4 show the coefficients of probit regressions with robust standard errors. While model specification (1) includes outreach measures, model

(2) only considers expense ratios. The impact of the funding structure and MFI-specific variables is separately investigated in models (3) and (4), respectively. Model (5) observes the entire set of stated predictors. Macroeconomic control variables are included in all regressions. Models (1) and (5) indicate ambiguous results for the two outreach measures. When we consider the average outstanding balance relative to GNI, the coefficient of this variable turns out to be negative and significant at the 10% level, but only in the full model. For the coefficient of the percentage of female borrowers, a negative sign is observed in both models, which is, however, insignificant in the full model. Therefore, the full model provides no evidence in favor of mission drift, but rather indicates that lower average loan sizes are associated with a higher probability of offering MFS.

Considering the first expense ratio, the coefficients show a significantly positive sign in models (2) and (5), suggesting that MFIs with higher financial expense ratios are more likely to provide MFS. An explanation for this result could be that the financial expense ratio can be seen as a measure for the commercialization of the MFI, as institutions with higher levels of commercialization are less dependent on subsidized finance, leading to higher financial expense ratios. In contrast, a lower operating expense ratio is associated with higher mobile technology adoption. In order to reach more clients—particular those who live in the remote areas—and efficiently deliver financial services, utilizing mobile technology can be considered to be the most cost-effective channel. However, we do not claim that there is a causal relationship of operating expenses to the provision of MFS, as one can also argue—in the sense of reverse causality—that the use of MFS potentially results in higher cost efficiency, since mobile technology is more productive than traditional services. However, the most plausible explanation is that MFIs, which generally tend to be efficient, are also more likely to offer MFS, which in turn helps to maintain or even increase efficiency. As expected, the coefficients of the deposits to assets ratio are positive and highly significant in models (3) and (5). However, the outcomes for the capital to assets ratio are ambiguous. While we observe a highly significant and negative coefficient in model (3), this effect becomes insignificant in combination with other explanatory variables (model 5). Models (4) and (5) show that with increasing size of the MFIs the probability of offering MFS also increases.

Regarding the type of MFI, it is also worth noting that institutions that are organized as credit union/cooperative, NFBI, and NGO are less likely to adopt MFS compared to MFIs registered as bank, while rural banks or other types display insignificant results. One possible interpretation for this result could be that MFIs of the type bank encounter fewer problems of limited resources available to invest in mobile banking. Furthermore, these MFIs may be able to exploit their own massive existing infrastructure as well as distribution network.

2.3.2.2   Heckman Two-Step Estimator

It is possible that our results are impacted by a potential sample selection bias due to those MFIs whose website was neither available nor accessible as of November 2017. To check for unobservable effects on the error term, we additionally employ a Heckman selection model with dependent binary variables in both of the two stages. While keeping the regression on the offering of MFS in line with model (5), we process an explicit website accessibility model in the first stage (selection equation).

Web accessibility is a binary dependent variable indicating whether or not an MFI has an accessible website. Determinants of website accessibility include the variables type, GDP per capita, and region. As additional explanatory variables, we employ Internet and Domestic credit, which are obtained from the World Development Indicator database. As illustrated by Kyobe (2011), the adoption of information and communication technology is strongly related to the availability of and ability to use these technologies. We argue that the internet penetration is considered to be one of the primary requirements for web accessibility. We assume a relationship between the percentage of domestic credit to GDP, as a measure of the development of the financial sector, and the website accessibility of an MFI. As shown in column (6), the results of the Heckman selection model are consistent with the main findings from our full model. Only the coefficients of the average loan size and the operating expense to assets ratio turn out to be insignificant. Furthermore, we find a strong association between website accessibility and internet penetration in the country while domestic credit appears to be unrelated.

2.4   Conclusion

This article analyzes factors driving the provision of MFS by MFIs. Our results indicate a significant relationship between variables for financial expenses and size with MFS. Furthermore, institutions with a higher share of deposits appear to be more likely to offer MFS. We also find that MFIs registered as banks are more likely to provide MFS. These results suggest some important implications and practical strategies which MFIs and stakeholders should take into account. Regarding social objectives, we find no evidence for mission drift in the context of offering MFS.

Table 2.1: Definiton of variables

Variable	Description
Offering	Dummy variable that indicates whether or not the MFI provides MFS in 2017. It takes the value of 1 if MFI offers MFS and 0 otherwise. Source: self-constructed
Average outstanding balance/GNI	Average gross loan portfolio per loan outstanding divided by gross national income per capita. Source: Mix Market
Percent of female loan borrowers	Share of borrowers that are female. Source: Mix Market
Financial expense to assets	Financial expense divided by total assets. Source: Mix Market
Operating expense to assets	Operating expense divided by total assets. Source: Mix Market
Deposit to assets	Total deposits amount divided by total assets. Source: Mix Market
Capital to assets ratio	Total equity divided by total assets. Source: Mix Market
Log(GLP)	Natural logarithm of gross loan portfolio. Source: Derived from Mix Market
Type	Current legal status of MFI. The forms of organization are: Bank, Credit Union/Cooperative, Non-bank financial institutions (NBFI), non-government organization (NGO), Rural bank and Other. Categorical variable. Source: Mix Market
Region	The geographical area of institution. The regions consist of Africa, East Asia and the Pacific, Eastern Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia. Categorical variable Source: Mix Market

Table 2.2: Frequency for categorical variables by Offer mobile financial services

| | **Offering MFS** | | | | | |
| | **No** | | **Yes** | | **Total** | |
	Obs	%	Obs	%	Obs	%
Type						
Bank	29	5.53	57	32.20	86	12.27
Credit Union/Cooperative	65	12.40	18	10.17	83	11.84
NBFI	180	34.35	75	42.37	255	36.38
NGO	224	42.75	15	8.47	239	34.09
Rural Bank & Other	17	3.24	9	5.08	26	3.71
No information	9	1.72	3	1.69	12	1.71
Region						
Africa	70	13.36	37	20.90	107	15.26
East Asia and the Pacific	59	11.26	20	11.30	79	11.27
Eastern Europe and Central Asia	52	9.92	35	19.77	87	12.41
Latin America and the Caribbean	209	39.89	58	32.77	267	38.09
Middle East and North Africa	24	4.58	1	0.56	25	3.57
South Asia	110	20.99	26	14.69	136	19.40
Financial Intermediation						
High FI	187	35.69	111	62.71	298	42.51
Low FI	52	9.92	14	7.91	66	9.42
Non FI	251	47.90	43	24.29	294	41.94
No information	34	6.49	9	5.08	43	6.13
Age						
Mature	416	79.39	141	79.66	557	79.46
New	22	4.20	6	3.39	28	3.99
Young	73	13.93	25	14.12	98	13.98
No information	13	2.48	5	2.82	18	2.57
N	524		177		701	

Table 2.3: Descriptive statistics for metric variables before mean imputation

	No		**Yes**		**Total**	
	Mean	SD	Mean	SD	Mean	SD
Average outstanding balance/GNI	0.480	1.182	0.901	1.310	0.583	1.227
Percent of female loan borrowers	0.696	0.270	0.586	0.256	0.669	0.270
Financial expense to assets	0.055	0.034	0.060	0.040	0.056	0.035
Operating expense to assets	0.193	0.142	0.146	0.102	0.181	0.134
Deposit to assets	0.215	0.323	0.395	0.307	0.261	0.328
Capital to assets ratio	0.315	0.248	0.214	0.210	0.289	0.243
log(GLP)	16.144	1.777	17.704	2.342	16.538	2.049
GDP per capita	4089.331	3462.815	3677.216	3087.803	3985.565	3374.915
Internet	31.870	17.738	32.287	18.662	31.975	17.963
Domestic credit	55.500	27.364	47.660	26.298	53.546	27.294
Observations	701					

Table 2.4: Factors affecting MFI's decision to offer MFS

Dependent variable: Offering MFS	Probit models with robust standard error					Heckman Estimates	
	(1)	(2)	(3)	(4)	(5)	(6)	
	Offer	Offer	Offer	Offer	Offer	Offer	Web access
Average outstanding balance/GNI	0.066				−0.082*	−0.066	
	(0.058)				(0.044)	(0.047)	
Percent of female loan borrowers	−0.821***				−0.226	−0.216	
	(0.281)				(0.331)	(0.292)	
Financial expense to assets		4.578***			4.232**	3.647**	
		(1.766)			(1.963)	(1.852)	
Operating expense to assets		−2.648***			−1.157*	−0.922	
		(0.635)			(0.609)	(0.565)	
Deposit to assets			0.862***		0.444**	0.403**	
			(0.201)		(0.208)	(0.182)	
Capital to assets ratio			−0.862***		−0.180	−0.122	
			(0.281)		(0.317)	(0.248)	
log(GLP)				0.178***	0.147***	0.125***	
				(0.043)	(0.045)	(0.034)	
Type							
Credit Union/Cooperative				−0.905***	−1.072***	−0.644**	−1.190***
				(0.230)	(0.236)	(0.277)	(0.208)
NBFI				−0.742***	−0.715***	−0.493**	−0.685***
				(0.182)	(0.182)	(0.196)	(0.197)
NGO				−1.506***	−1.419***	−1.125***	−0.694***
				(0.229)	(0.234)	(0.256)	(0.204)
Rural Bank and Other				−0.499	−0.483	−0.359	−0.620**
				(0.330)	(0.331)	(0.307)	(0.310)
No information				−0.463	−0.421	0.281	−1.654***
				(0.497)	(0.485)	(0.445)	(0.275)
Macroeconomic variables							
GDP per capita	−0.000	−0.000	−0.000	−0.000*	−0.000	−0.000	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Region							
East Asia and the Pacific	−0.034	−0.332	−0.169	−0.073	−0.112	−0.178	−0.053
	(0.209)	(0.209)	(0.207)	(0.237)	(0.243)	(0.217)	(0.178)
Eastern Europe and Central Asia	0.178	−0.009	0.582***	0.156	0.046	−0.153	0.161
	(0.216)	(0.218)	(0.223)	(0.233)	(0.257)	(0.242)	(0.211)
Latin America and the Caribbean	−0.200	−0.395**	−0.085	−0.261	−0.350*	−0.642***	0.851***
	(0.186)	(0.191)	(0.195)	(0.202)	(0.210)	(0.217)	(0.166)
Middle East and North Africa	−1.290***	−1.419***	−0.825*	−1.207**	−1.185**	−1.351***	0.448
	(0.491)	(0.482)	(0.485)	(0.473)	(0.495)	(0.477)	(0.325)
South Asia	−0.187	−0.891***	−0.306	−0.436**	−0.652***	−0.857***	0.773***
	(0.192)	(0.193)	(0.191)	(0.204)	(0.233)	(0.223)	(0.184)
Internet							0.021***
							(0.005)
Domestic credit							0.002
							(0.002)
Constant	0.051	0.021	−0.517***	−2.483***	−1.812**	−1.254*	0.685***
	(0.245)	(0.205)	(0.184)	(0.771)	(0.882)	(0.689)	(0.200)
Observations	701	701	701	701	701	999	
Pseudo R^2	0.054	0.076	0.098	0.222	0.241		

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Chapter 3

Microfinance and green energy lending: First worldwide evidence

Abstract: The increasing requirement for action on climate change in developing countries has led to the inclusion of environmental aspects in microfinance objectives, in addition to social and financial performance, and hence to the appearance of green microfinance. To date, financing for modern energy service has proven to be an attractive option to offset adverse climate change related effects for the poor. This article sheds some light on factors predicting clean energy finance involvement of MFIs. By using a worldwide survey among microfinance institutions on rural lending and IT solutions implemented by YAPU Solutions, this study investigates how institutional characteristics and economic growth relate to green energy micro-credit. The findings provide evidence of a significantly positive relationship between the maturity and business sustainability of an MFI and the likelihood of offering green energy loans. Moreover, MFIs managed by female managers and located in wealthy countries are less willing to commence the finance of green energy.

Keywords: Microfinance institutions, green energy financing, clean energy, Sustainable Development Goals

JEL Classification: G21, Q01, Q42

3.1   Introduction

Over the past decades, the enhancement of negative environmental issues such as global warming, increasing air pollution, and rising sea levels, have presented notable global threats to economic growth and sustainable development. This universal problem is also reflected in the UN Sustainable Development Goals (SDGs) and the COP21 Paris agreement for climate change (United Nations, 2015, UN-FCCC, 2015), whereby here, exceptional emphasis on environmental performance in addition to social and economic objectives should be taken into account (UN-FCCC, 2015). Consequently, the importance of a triple bottom line in the financial sector is also highlighted due to its notable importance and its broad impact to various elements of development (Taghizadeh-Hesary and Yoshino, 2019, Sachs et al., 2019). In this context, the microfinance industry plays a pivotal role for the following reasons. Microfinance clients, especially those who live in rural areas, are indeed some of the most vulnerable people despite their modest impact on the environment (Dowla, 2018, Harrold et al., 2009). The reason for this could be their great reliance on natural resources and their high level of exposure to environmental threats. Moreover, negative impacts on the operation of microfinance institutions (MFIs) are directly or indirectly linked to the consequences of climate change. While MFIs feasibly encounter physical harm and operational interruption due to disasters, environmental-related losses faced by their clients possibly trigger the increase of debt defaults, which in turn adversely impact MFIs performance and sustainability (Pantoja, 2002).

These issues urge MFIs to reaffirm their objectives and to take proper actions in adapting to the consequences of climate change and environmental degradation (Allet, 2014, Rippey, 2012). This development is accompanied by the emergence of green microfinance as a response toward increasing environmental awareness of businesses and organizations in order to maintain sustainable economic growth. Green microfinance encourages microfinance service providers and clients to engage in more environmentally-friendly practices, such as green businesses, renewable energy projects, green loans, climate smart agriculture, and the assessment of environmental risks (Huybrechs et al., 2015). Through the increased support of their clients in combating environmental related losses, MFIs could benefit from a higher repayment probability and thus a reduction of the credit risk of the socio-environmental vulnerable beneficiaries (Abdur Rouf, 2012, Moser et al., 2016).

When discussing the need for environmental management, one subject to be considered is the energy sector. According to IEA (2019), two-thirds of greenhouse gas emissions, which are considered to be the main culprit of global warming, are generated by power systems. Moreover, energy poverty is responsible for further problems such as lowering one's livelihood, since most of the daily activities (lighting, appliances, cooking, and transportation) require the frequent use of en-

ergy. Therefore, energy is considered to be essential in achieving a sustainable social and economic development and in protecting the environment (Goldemberg et al., 2000). In other words, there is a need for promoting the transition to environmentally-friendly energy, i.e. green energy, which comprises both the deployment of renewable sources and energy efficiency measures. The increase of renewable energy and energy efficiency (RE & EE) contributes to achieving many targets of the SDGs such as combating climate change, eliminating poverty and hunger, promoting sustainable economic growth, and improving public health and well-being (Inglesi-Lotz, 2016, Haseeb et al., 2019, Del Rio and Burguillo, 2009, Bhattacharya et al., 2017, Colombo et al., 2013). However, modern energy generation is often more expensive than the traditional biomass-related approach and thus imposes a relatively high cost burden on the poor. Thus, the allocation of sufficient finance of low carbon energy plays an important role in breaking the poverty cycle and in sustaining human development (Brunnschweiler, 2010, Lewis, 2010, Baker, 2015, Rao et al., 2009). The story is not only about the use of renewable energy, but also about the mobilization of finance to further develop the use of sustainable renewable energy. This is particularly a problem for the clients of MFIs, who are often financially excluded by traditional finance systems.

In this context, microfinancing mechanisms for clean energy are particularly important for closure of the finance gap, which consequently boosts the deployment of RE & EE (Surendra et al., 2014, Allderdice et al., 2007). MFIs are perceived to be in an advantageous position in their ability to adapt green energy lending due to the following reasons. First, one of the prominent features of microfinance is the tight relationship between MFIs and their clients (Stiglitz, 1990). The nature of this relationship allows MFIs to better understand the energy needs of their beneficiaries and to develop suitable products and services and thus to foster the adaptation of clean energy at a local level (Nepal and Amatya, 2006, World Bank, 2012). Second, microfinance beneficiaries are more vulnerable from climate change and power crises than other parts of the population. By providing sustainable financial and non-financial support to them, individuals and small businesses are able to invest in green energy technologies, which in turn boosts their awareness of environmental issues and sustainable development (Rao et al., 2009, Walekhwa et al., 2009). Furthermore, the role of MFIs is also important since providing this kind of business to financially-excluded population is commercially inadvisable, henceforth drawing less motivation from traditional banking systems or private investors (UNEP FI, 2012, Allderdice et al., 2007).

Surprisingly, microcredit for green energy purposes remains limited and appears to lack motivational factors by many institutions despite its promising benefits. The question of what drives the inadequate interest of MFIs in green energy finance requires closer examination. One possible explanation could be that while there is a growing body of literature on general green microfinance (Allet and Hudon, 2015, Forcella and Hudon, 2016) and sustainable energy finance in general (Mazzucato

and Semieniuk, 2018, Yildiz, 2014), the integration of microfinance and RE & EE appears to only have been modestly studied. The lack of information paints an ambiguous picture of sustainable energy lending. A broader knowledge-base needs to be developed to better understand what factors affect the small-scale lending for green energy purposes, as well as to facilitate the MFIs' response to this new field of business investment.

This study is one of the first to determine several factors that influence the involvement of MFIs in sustainable energy finance. To analyze this matter, we employ a unique dataset, which is composed of a rural lending and IT solutions survey implemented by YAPU solutions and the MIX Market database, comprising a cross-sectional sample of 969 MFIs in 2015. With this dataset, we examine a set of variables with regard to the question of whether they are related to an MFIs provision of green energy lending. These variables are constituted by MFI-specific variables such as the maturity of an MFI or business sustainability as well as country-specific variables.

The key findings of our article confirm the explanatory power of the maturity and customer retention of sustainable energy loans. Specifically, more mature MFIs, as measured by age and the debt-to-equity ratio, tend to engage more frequently in green energy lending practices. We identify a positive significant impact of the active borrower retention rate on the provision of green energy loans. Moreover, our results show evidence of the fact that MFIs with a high percentage of female managers are less likely to grant loans to sustainable energy projects. Furthermore, MFIs located in poorer countries show more willingness to foster green energy. Remarkably, the depth of outreach and financial performance of an MFI are not significantly correlated to an MFI's capacity to engage in green energy issues, suggesting that this relatively new field of business may not require a better financial performance or a strong focus on social objectives.

The remainder of our article is structured as follows. While section 2 describes related literature and deduces the hypotheses, the data collection and the methodology are presented in Section 3. The discussion of descriptive statistics and several empirical results are displayed in Section 4, followed by recommendations and a brief conclusion in the final section.

3.2 Related work and hypotheses

3.2.1 Sustainable development goals and green energy finance

In September 2015, the SDGs, which comprise 17 targets including combating poverty, climate change, improving living standards, achieving gender equality, and the empowerment of women were first adopted by the United Nations General Assembly as the most important plan to create a better society. Importantly, 'sustainable energy' is not only one of the critical goals (namely SDG 7), but can also be regarded as a key factor for the success of other sustainable development goals (Allen et al., 2016, Nerini et al., 2018). Therefore, increasing the use of RE & EE products contributes to the achievement of the SDGs, which then drive additional demand for financing energy production. Given the importance of green renewable energy finance in obtaining the SDGs, an interesting question concerns how to facilitate the engagement of institutions in this field of business. The existing body of literature on sustainable energy investments, both in theoretical and in empirical regards, has hitherto focused on the role of governmental support, private investors, capital markets, and traditional banks as opposed to the microfinance sector. In this literature, many factors are evidenced to be determinants of low carbon energy finance. Mazzucato and Semieniuk (2018) conduct an exploratory study on the directionality of renewable energy project investments among the financing parties (private and public banks, utility companies) and determine that the risk level is the key factor leading to financial decision making. The influence of appropriate governmental policies is examined in the study by Cárdenas Rodríguez et al. (2014), which confirms the positive impact on the financing of private sector. Besides, other factors such as the financial actors' preferences, apt policy instruments, the borrowers' RE awareness, technology-related management abilities, and the availability of capital resources have also been investigated (Masini and Menichetti, 2012, Martinot, 2001, Narbel, 2013).

Regarding the microfinance sector, although some analyses of various dimensions of green management and its impact factors exist (Allet and Hudon, 2015, Forcella and Hudon, 2016, Forcella and Huybrechs, 2016, Forcella et al., 2015), only very little is known about analysis of clean and sustainable energy finance. Nonetheless, several studies focus on the status quo and finance mechanisms of RE and EE. Allderdice et al. (2007), in their study (for Latin America and the Caribbean), report that energy related loans play a minor role for MFIs and that these are frequently embedded in other financial products such as enterprise loans, housing improvement loans, etc. The authors also highlight the cooperation between energy providers and MFIs, the role of government support, and donor programs in favor of MFIs in order to boost the expansion of energy conversion. Moreover,

Allderdice et al. (2007) consider a strategic approach and proper awareness of MFIs and clients to be helpful in constructing an energy loan portfolio. Forcella et al. (2017), in their survey-based research conducted in the same region, investigate the lending activities of MFIs related to green projects. Approximately 20 percent of respondents of their survey confirm having had RE and/or EE loans in their portfolio, albeit with a high rate of green practice involvement.

So far, these findings have not provided clear evidence of the question concerning whether and when an MFI engages in green energy lending. In the next part, we develop our hypotheses by further discussing existing work related to our factors of interest. Subsequently, the four hypotheses are investigated in the empirical analysis to explore whether these hypotheses can be supported by real-world evidence.

3.2.2 Maturity of institutions

Among the wide range of determinants of an MFI's environmental performance, the age of the institution as a measure for maturity is mentioned as having been the key factor in several previous studies. According to Allet and Hudon (2015), there exists a particularly positive and significant relationship between an MFI's age and the provision of green microcredit prevails. This finding is derived from an investigation of a sample of 160 global MFIs. Following Allet and Hudon (2015), Forcella and Hudon (2016) provide the same evidence, yet with a smaller sample of 59 MFIs operating in Europe. These results suggest that the maturity of an MFI may influence the likelihood of providing RE & EE finance.

As a further proxy for maturity, Mersland and Urgeghe (2013) and Dorfleitner et al. (2017b) employ the capital structure of an MFI with an interpretation based on the business life cycle theory. In more specific terms, these authors argue that MFIs initially operate as non-regulated institutions with their sources of funding originating from retained earnings or external donations such as the granting of subsidies. As the MFIs mature and transform into a more regulated form, they are able to gain access to commercial debt, which, in turn, enables them to reach more clients as well as to seize the advantage of economies of scale (Kyereboah-Coleman, 2007). Renewable energy projects are associated with various types of risk, such as political, market, technical risk, and a low rate of return (Liu and Zeng, 2017, Lee and Zhong, 2015). Young institutions are considered to be less risk-inclined than their older counterparts, which can make them less motivated to manage a green energy loan portfolio. Because of economies of scale, which have a tendency to be available for mature MFIs, they are better equipped to deal with these risks.

Summarizing the arguments of the mentioned literature, we expect that the stage of the life cycle of an MFI has a crucial impact on engaging in small scale RE &

EE lending, representing a dimension of green performance. In other words, we expect more mature MFIs (in terms of age and debt to equity) to engage more frequently in green energy lending. Hence, our hypothesis is stated as follows.

Hypothesis 1 (H1) *The maturity of an MFI is positively related to the likelihood of green energy lending.*

3.2.3   Female leadership

Along with maturity, another important factor which is frequently documented in the literature with respect to environmental governance of an organization is the gender diversity of leadership (Ben-Amar et al., 2017, Liao et al., 2015, Cucari et al., 2018, Birindelli et al., 2018). Building on theoretical foundations, namely the critical mass theory and the stakeholder theory, researchers provide mixed evidence on the direction of the relationship. While a positive link can be found in the studies of Ben-Amar et al. (2017) and Liao et al. (2015), different results are evidenced by Cucari et al. (2018) and Birindelli et al. (2018). According to Strøm et al. (2014), female leadership is positively associated with having more females clients. However, focusing on a female clientele possibly places a burden on an MFI, which then worsens its performance (D'Espallier et al., 2013). The interpretation is that women are associated with smaller loans, which are costly to monitor and to process, suggesting a negative impact on financial performance. Consequently, MFIs may lack appropriate funding sources for other initiatives such as green energy lending.

Furthermore, women are commonly found to be more risk-averse than men in making decisions (Charness and Gneezy, 2012, Byrnes et al., 1999). As shown by Ertac and Gurdal (2012) in their experimental study, women not only show a more risk-averse behavior when making decisions on their own, but also tend to be less prone to risky options for their groups compared to men. Similarly, Bogan et al. (2013) demonstrate that the share of males in the management is positively associated with a higher likelihood of engaging in risky investments. Taking into account the fact that finance for energy projects is related with high levels of risk, this evidence suggests a lower willingness to involve in energy lending if the share of female managers is high.

Summarizing, the discussed literature suggests that female-managed MFIs are less likely to focus on the mission of supplying loans for green energy purposes. We, therefore, formulate the following hypothesis.

Hypothesis 2 (H2) *The variable female leadership is negatively related to an MFI's involvement in green energy lending.*

3.2.4 Customer retention

The term customer retention generally refers to the situation in which customers return to organizations in order to demand further products and services. Therefore, maintaining a high rate of customer retention is essential for institutions in the attainment of smooth operations and financial sustainability (Reichheld and Kenny, 1990). In their research, the authors point out that the positive relationship between retention rate and a bank's margins and growth is not only true in the case of deposit services, but also in other financial services. Later on, research by Reichheld (1993) also confirms the influence of a high level of customer loyalty on the improved economic performance of firms. Zahorik and Rust (1993) additionally suggest that retained market share increases economic benefits far more than market share growth gained from new customers. In general, it is widely agreed that increasing retention rate, i.e the reduction of the customer defection rate, is an important factor that strengthens an organization's performance. The explanation is that acquiring new clients costs more than retaining the existing ones (Buchanan and Gillies, 1990, Reichheld, 2001). Furthermore, the retention rate is particularly important since it reflects how good an institution's service quality is, i.e whether customers are supported well. Reichheld (1993) emphasizes the importance of delivering superior values to the customer as one of the key strategies responsible for the retention of customer's loyalty. Analogously, Oyeniyi and Abiodun (2010) also remark the interdependent link between these two factors. Applying to the microfinance context, where the ultimate goal is customer' welfare, a high rate of customer retention implies better social performance. We argue that higher retention rates signal more efficient performance due to reduced transaction costs, and may also result in an improvement of the capacity for new lending products such as green energy. Indeed, the influence of sufficient human and capital resources on the new product development performance has been investigated in several studies (Vermeulen et al., 2005, Chang, 2016). Following these considerations, we conjecture the positive effect of the customer retention rate on green energy lending. Accordingly, we formulate the third hypothesis.

Hypothesis 3 (H3) *The rate of customer retention is positively correlated with MFI's involvement in green energy lending.*

3.2.5 The economic status of the destination country

Besides the possible influences on MFI level, reflected by the Hypotheses 1 to 3, the tendency to offer green energy lending may also be a matter of regional differences, and thus of the country in which an MFI is located. There are several reasons why green energy microfinance could vary across countries with different economic welfare status. One could think that in advanced economies with high

levels of urbanization, there is a high level of electricity penetration, which can lead to low demand of RE as another source of electricity generation. Consequently, less MFIs in such countries will veer toward support of renewable energy solutions. As opposed to this, the need for renewable energy remains high in less urbanized countries due to the great reliance in these areas on traditional biomass such as wood used for lighting, cooking, and heating. According to Allderdice et al. (2007), the bottleneck of insufficient green energy solutions in rural areas in Latin America can be explained by the extreme concentration of MFIs in urban areas, leaving the rural poor population behind. While the traditional energy sources boost man-made global warming, they also remain in short supply. According to Aguirre and Ibikunle (2014), commitments to renewable energy tend to be reduced in nations with a paucity of potential resources, particularly in the case of biomass and solar energy. Thus there is a high need for green energy in less developed countries. Given the benefits of green energy, the aim of tackling the lack of sustainable energy could prove to be a portfolio optimization strategy of MFIs with particularly high social benefits. The association of social preferences and microfinance lending decisions has been discussed in previous research (D'Espallier et al., 2013, Allet, 2014) in which focusing on specific types of lending (woman lending and environmental lending) becomes a method of reaffirming MFIs' social objectives.

Furthermore, when studying the cases of Asian countries, which are characterized by a bank-dominated financial market, Peimani (2018) identified the unwillingness of the banking sector to fund clean energy projects. The authors conclude that the lack of appropriate financial support is the main challenge to the expansion of green energy in these countries. The reason for this situation is that RE & EE projects are considered to be high risk and yield a low return rate, triggering the reluctance of banks to engage in green energy lending. It is, therefore, reasonable to assume that in more developed countries with superior financial systems, the mobilization of funding is more efficient, possibly leading to a low requirement for support from MFIs. As opposed to this, due to the lack of access to bank finance and the inefficient capital markets, microcredit mechanisms can be considered a potential solution in tackling financial barriers to green energy in developing nations. In other words, MFIs could play the pivotal role of a complementary actor in closing green energy finance gap. This argument is consistent with previous findings of Vanroose and D'Espallier (2013) in the sense that MFIs fulfill the needs that the traditional financial system fails to support. Therefore, the last hypothesis makes a statement on the provision of green energy loans in less developed countries. In our study, we measure the development status by the GDP per capita to capture the pure economic development, but also by an index measuring the development according to the SDGs.

Hypothesis 4 (H4) *MFIs operating in less developed countries are more likely to engage in providing green energy loans.*

3.3 Data and Methodology

3.3.1 Data

Our unique dataset comes from several sources. The first part of the data comes from a survey designed and implemented by the company *YAPU Solutions* (https://www.yapu.solutions). The data have been provided in an anonymized way for academic research purpose only. YAPU obtained these data by individually sending an online survey to MFIs worldwide during the time frame from November 2017 to March 2018. In order to enhance the response rate and assure the quality of responses, the survey was written in three languages, namely English, Spanish and French, being the world's most prevalent ones. The questionnaire generally concentrates on climate smart finance, agriculture and rural lending, as well as the deployment of IT solutions to facilitate green businesses. Participants were also asked to provide some institution-specific information, e.g. number of employees and number of offices. The questionnaire also included questions on the financing of renewable energy and energy efficiency technologies, which is the main focus in this study. After three reminders, the number of responses amounted to 179. However, we were able to use 90 questionnaires for the purpose of our analysis due to the incompleteness and inconsistency of some of the responses.

The second dataset was derived from the MIX Market database, which today is a part of the World Bank data platform. MIX Market is the largest transparent and public data source for the financial and social performance of MFIs worldwide, as well as for general profile information such as year of establishment, legal status, etc. One limitation is that all the financial information is self-declared by the institutions, which mostly lack reasonable auditing. Therefore this source of information could contain some unrealistic data. The MIX Market set of MFIs was also used as an address list for sending out the questionnaire to a worldwide sample of MFIs.

Aligning with Dorfleitner et al. (2017b), we eliminated institutions with the following criteria: percentage of female managers or borrowers is larger than one, return on asset is larger than one or smaller than -1.5, gross loan portfolio to total assets larger than one, and average loan balance per borrower is larger than $ 15,000. Following Allet and Hudon (2015), to mitigate the potential of reverse causality, especially regarding the effect of energy microlending on variables related to the social and financial performance of MFIs, we use lagged MFI-specific variables. For the year 2015, 969 MFIs reported realistic and consistent data to MIX Market. In addition to this, other macroeconomic indicators are also included in order to examine the power of effects of economic status and environmental policy. These data were obtained from World Development Indicators and Sustainable Development Solutions Network (SDSN). The final sample contains 969 MFIs, of which

90 have responded to YAPU Solutions survey questions relating to the provision of credit products dedicated to RE/EE.

Table 3.1 presents detailed definitions of the employed variables of our study. Our dependent variable is *Energyloan*, which refers to the involvement of MFIs in small-scale credit provision for green energy purposes. It is an ordinal variable that takes the value of 1 if MFIs do not declare any activities for energy services. If institutions do not offer explicit green energy loans, but some of their loans are also used for projects dedicated to RE or EE, the dependent variable takes the value of 2. Finally, it equals 3 if the MFI states that it is doing this type of business or plans to do so within the following year. In this paper, renewable energy refers to all sources of energy generated from natural processes (solar, wind, biomass, geothermal, hydropower and ocean resources, solid biomass, biogas, and liquid biofuels) that are continually replenished (Mandil, 2005). According to IEA (International Energy Agency), the capability of managing energy consumption in an efficient way is subsumed as being energy efficiency. In a technical sense this means either reducing the use of energy for the same type of service or producing more services with the same amount of energy.

The hypothesis-related predictor variables we use in our set-up are *Age* and debt-to-asset ratio of the MFI, the percentage of female managers, the retention rate, and the gross domestic product per capita (GDPpc) of the country in which the MFI operates. The evolution of stage of life and funding structure are commonly used in the existing literature as an indicator of an MFI's maturity (Dorfleitner et al., 2017b, Allet and Hudon, 2015, Mersland and Urgeghe, 2013). Therefore, we employ the age of the MFI (number of year functioning as an MFI) and debt to equity to proxy for the maturity of MFIs. To capture the effect of female leadership, we include a variable for the percentage of female managers. The variable *Retention* is included to account for the ability of maintaining existing customers of MFIs. The number of active borrower retention provides a positive implication for the financial sustainability of institutions. Finally, to assess the effect of the pure economic development status, the logarithm of gross domestic product per capita is taken into account. Additionally, the SDGs score of a country is employed as an alternative measure to represent the effect of the level of development.

Furthermore, we use *ITintensity*, *OSS*, log(*GLP*), *Rural*, and *Region* as MFI-specific control variables. More specifically, we employ a dummy variable indicating whether or not more than one IT solution is used by the MFI. We define IT solution deployment as being the use of one of the distinct IT products: specialized desktop software, software/app for tablets or smartphones in the field, tablets in the field, and smartphones in the field. Furthermore, operational self-sufficiency serves as a proxy for financial performance of the MFI based on the logic that the higher this quantity is the better the business management of the institution. The *log(GLP)* variable, measuring the size of the organization, is employed to control for the effect of economies of scale. Following Mersland and Urgeghe (2013) and

Allet and Hudon (2015), the focus on rural areas can be seen as a proxy for business orientation. Therefore, we construct the variable to represent the fraction of the loan portfolio in rural areas. We expect that MFIs with a greater concentration in rural areas will be more highly motivated in addressing energy needs than the remainders.

Additionally, a set of dummy variables is included to manage the effect of geographical locations. Specifically, there are five different regions, including Africa and the Middle East and North Africa (MENA), East Asia and the Pacific (EAP), Eastern Europe and Central Asia (EECA), Latin America and the Caribbean (LAC) and South Asia.

3.3.2   Methodology

To investigate which factors are related to an MFI's decision to offer green energy lending, we conduct various analyses with ordered probit models with Eicker-Huber-White heteroskedastic-consistent standard error by applying the following regression equation:

$$y_i^* = \alpha + \beta_1 x_i + \beta_2 c_i + \epsilon_i$$

where y_i^* represents the outcome variable which comprises the provision of green energy lending of an MFI i. While x_i stands for a vector of hypothesis-related variables of an MFI i, a vector of control variables is denoted by c_i.

Three different levels are assigned for MFIs' involvement in green energy lending and the scores refer to the order within this involvement (see Table 3.1). In the model, it is assumed that y_i^* is an unobserved variable and only involvement level can be observed. Thus, the first step is to map the categories of the involvement levels y_i into a partition of the latent variable y_i^* as follow:

$$y_i = \begin{cases} 1, & \text{if } y_i^* \leq \mu_1 \\ 2, & \text{if } \mu_1 < y_i^* \leq \mu_2 \\ 3, & \text{if } y_i^* > \mu_2 \end{cases}$$

where μ_r (r=1,2) represents the partitions of the range of y_i^* linked with each value of level of involvement.

For the reason that MFIs are not obligated to declare every piece of information to Mix Market, our dataset encompasses a number of missing values. In order to mitigate this problem, we substitute missing observations with their arithmetic mean of the variable. More specifically, we employ the mean imputation technique to overcome the problem. One of the limitations of YAPU Solutions survey

is the self-reporting of the respondents, which feasibly triggers the potential of bias. The survey could have the potential to attract more MFIs with an interest in energy loan provision, which then leads to higher response rate of them. Even though we obtain 33.67% of respondents (33 out of 90 MFIs — see Table 3.3) who stated that they did not provide green energy loans, we still address potential selection bias. In particular, we employ the Heckman endogeneity ordered probit model and follow a two-step procedure. In the first step, the selection equation, we assess the likelihood of MFIs responding to YAPU Solutions survey. We are then able to use the obtained result in the second step, the ordered probit model, to estimate the actual regression of interest. In the selection regression, *Answer* is a binary dependent variable indicating whether or not an MFI replied to our survey. Determinants of response decision include the variables of *Age, log(GLP), log(GDPpc)*. *CPIA* and *Type* are employed as additional predictor variables. According to Helgeson et al. (2002), the respondent's perspective towards research plays an important role in determining the probability of response. Based on this finding, we argue that green energy interest groups are more likely to react to our questionnaires. As demonstrated by Allet and Hudon (2015), there is an interdependent relationship between an MFI's legal status and environmental performance. Therefore, we assume that there are certain types of MFI that are more likely to be in favor of green energy credit, and are more willing to participate in the survey. Additionally, several scholars emphasize the influence of appropriate policy design on inducing renewable energy (Rodríguez et al., 2015, Mazzucato and Semieniuk, 2018). Specifically, well-designed policies play an important role in attracting financial actors. Subsequently, we assume a link between the effectiveness of policies, measured by CPIA policy and institutions for environmental sustainability rating, and the likelihood of an MFI's response to the survey.

3.4 Results

3.4.1 Descriptive analysis

Table 3.2 and Table 3.3 present the frequency distribution of the categorical variables with respect to the response status and the green energy loan status of the MFIs. In the data sample, 34.57% MFIs are from LAC, thus dominating other regions regarding the number of these MFIs. This, however, corresponds to the study by Allet and Hudon (2015). The same holds true (32.22% of MFIs) for the sub-sample of those 90 MFIs for which we can verify whether they offer energy loans. Additionally, MFIs of the type NBFI account for a large proportion of the total sample with a share of 37.56%, while in the sub-sample of 90 MFIS the type NGO prevails. Remarkably, the percentage of unrated MFIs that did not answer the survey is higher than that of the rated MFIs (18.32% versus 7.78%), confirm-

ing, to some extent, the quality of the survey is confirmed. Table 3.3 shows that many MFIs are unwilling to deploy more IT solutions as only 27.78% MFIs in the sub-sample use more than one software application. When taking a closer look at each category of engagement in green energy lending, we observe a dominance of MFIs using less than two IT solutions. Moreover, MFIs located in LAC appear to outweigh their peers from other regions regarding the provision of green energy loans as 35.36% MFIs offer these products or plan to do so within the next year.

The descriptive statistics of the metric variables can be found in both Table 3.4 and Table 3.5. The results reveal that the average proportion of female managers is 37% and 32% in the total and in the respondent sub-sample respectively, which are comparably low figures, suggesting that female-managed institutions are less likely to favor clean energy technologies. The OSS of both response and non-response groups are higher than 1, indicating that, on average, MFIs generate sufficient income to cover their operating costs. The statistics also indicate that the average loan size adjusted to GNI per capita is 0.45 among the respondents, which is lower than that of non-respondents (0.59). This variable is often used as a proxy for the outreach efficiency in the microfinance institutions based on the logic that the lower the quantity, the better the outreach. Therefore, this observation could signal that the respondents tend to those MFIs that place more emphasis on social objectives. However, the difference is not significant.

3.4.2 Regression analysis

This section provides the empirical results obtained for the straightforward ordered-probit model and the Heckman selection regression (see Table 3.6). We first run ordered-probit regressions to test the impact of maturity, measured by age and debt-to-equity ratio (model specification (1)). The model specification (2) focuses on the effect of performance variables while our baseline model with a full set of included variables is represented in the model specification (3). The models (5) and (6) exhibit the estimation results for the Heckman two-stage model.[1]

The Wald test of independence displays an insignificant result, and thus there is no clear sign of a sample selection bias. Regarding our first hypothesis on the maturity of an MFI, we find substantiation in the results of model specification (1) and (3), in which the variable age has a 1% significant positive coefficient. A similar observation can be made with respect to debt to equity. We also observe a positive sign of the proxies for maturity in the Heckman model, but here, age is significant at a lower level, namely 5%. Summarizing, the hypothesis on the impact of maturity is strongly supported with respect to both proxy variables

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[1]Note that while the Heckman model is presented in two stages, we implement the ordered-probit Heckman model with a maximum likelihood approach, in which both stages are estimated simultaneously.

age and debt-to-equity ratio. In addition, the results from model specification (2) and (3) reveal that the variable of female managers is negatively related to green energy loans even in the case of the Heckman selection model. This result suggests that female managers have a lower chance to engage in the topic of green energy. Therefore, we are also able to find supporting evidence for our second hypothesis. However, note that this variable could also be a proxy for a specific type of MFI being rather dedicated to classical micro-lending instead of green energy lending.

Regarding hypothesis 3, we find that the retention rate has a significantly positive coefficient in all three regressions, which generally supports our third hypothesis. One possible explanation for this finding could be that the establishment of green energy finance requires more upfront costs and thus more stability in operations to reduce the risks associated with the provision of such a new service. Finally, our regression results show significant evidence related to the economic status of the respective country. The positive coefficient of the variable GDPpc is in line with the argument that in less developed regions, the role of MFIs in green energy lending is more important. Furthermore, we employ the SDGs score, which measures the yearly SDGs performance of a country, as an alternative proxy for development status. Replacing *log(GDPpc)* by this additional measure to run the full ordered probit and Heckman model yields regression results (model specification (4) and (6), respectively), which are consistent to our above main findings. To be more specific, we observe the same signs of the coefficients and similar significance levels as in the case of *log(GDPpc)*. A low SDGs country score represents a lack of engagement in sustainable activities, such as the use of RE and EE. Our finding indicates that the MFIs in a country with a low SDGs index may also be affected by that tendency. Ostensibly, the forth hypothesis can also be supported with corresponding evidence.

In addition to our main findings, we detect a significant correlation between green energy lending and several other variables. The regression results reveal that MFIs in Latin America and the Caribbean are more likely to offer green energy lending products. This finding was subsequently explained by the high potential of renewable energy sources in these regions. A similar, but weaker effect can be observed in the case of EECA. This is, to some extent, in line with the findings of Forcella and Hudon (2016), which shows that MFIs from Eastern Europe are in superior position to those in Western European regarding environmental management.

To confirm the reliability of our findings, we also conduct robustness checks for the employed empirical method. First, there are 15 MFIs that answered the questionnaire but refrained from answering the question upon green energy lending. For these MFIs, we further explore their involvement in energy lending by researching their websites and other officially public documents. This leads to a larger sample of 105 MFIs, but with a little less accuracy. Table 3.7 and Table 3.8 show summary statistics for categorical and metric variables, respectively. Overall, we observe relatively similar descriptive statistics to those of based samples (90 MFIs).

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Second, we implement the Heckman model with full information maximum likelihood (FIML) to address the missing data issue in an alternative way and obtain unbiased parameter estimations with a more correct standard error. However, due to the limited number of observations without missing values, the problem of convergence occurs when the model is estimated. To deal with this issue, we exclude the variable with the most missing values in the selection model, namely *CPIA*.

The results of the re-estimated models provided in Table 3.9 show the consistency with previous findings. The model specification (1) to (4) replicate the estimations presented in Table 3.6, yet with an extended sample of 105 MFIs. Meanwhile, the results of the Heckman model with FIML are given in the model specification (5). At first glance, the signs remain largely unchanged compared with Table 3.6, but the significance levels are overall lower in these cases. Even the control variables show the same results. Therefore, the extended response sample and estimation with FIML can be considered to yield robust results.

3.5 Conclusion

MFIs are notably important as they are instrumental in attaining human sustainable development. The triple bottom line in microfinance specifically emphasizes that not only the social mission, i.e. the focus on low-income beneficiaries, especially women, but also financial objectives must be pursued in an environmentally friendly manner. Regarding the environmental perspective, green energy is one of today's most prevalent issues due to its high demand and a lack of sustainable finance possibilities. This paper investigates the conditions under which MFIs are likely to engage in green energy lending and to what extent they engage. The employed data cover the years 2015 and 2017 for explanatory and predicted variables, correspondingly. Statistics on MFI level and macroeconomic level are provided by World Bank data platform.

This study provides results derived from several ordered-probit and Heckman selection model regressions. The first main result is a positive relationship between green energy finance and maturity. The more mature the MFIs, the deeper their engagement in green energy lending is. Considering green energy lending as a remarkable feature of environmental concerns, this finding reinforces the previous statements from Allet and Hudon (2015), and Forcella and Hudon (2016), in the sense that an MFI's maturity is associated with improved environmental performance. The second key conclusion provides a suggestion on the relationship between the share of female managers and green energy lending. Contrary to previous literature dealing with the link between the management gender diversity and an institution's response to environmental issues (Ben-Amar et al., 2017, Liao et al., 2015), our results show that a higher share of female managers tends to be

associated with weaker support for green energy lending projects. However, this finding should not be over-interpreted as the share of female managers may be a proxy for some structural features of the respective MFI. Third, the ability to retain existing customers is another pivotal characteristic that is likely to have a positive influence on the provision of green energy loans. Finally, credit products for green energy appear to be more attractive to MFIs in less developed countries. Taking into account the fact that poor countries suffer energy crises and have a higher number of microfinance clients, it can be postulated that the effectiveness of green energy lending could be more powerful in developing countries than in developed ones.

The policy implications of our results are straight-forward, as they show the characteristics of MFIs which offer green energy lending. If these types of financial services are to be expanded on a global scale, we show which MFIs can be allured more easily toward offering these services. This also helps to identify challenges and obstacles in spreading finance and thus the use of green energy.

One limitation of this study lies in the employed data. Almost all of the key input data are collected from the MIX Market database, which contains self-reported data, and may thus encounter the problem of being biased. With dependent and independent variables collected in one specific year, the analysis could be refined if the covered period of time is longer and a panel data set is utilized. Therefore, a more advanced study could focus on capturing institution- specific and time-dependent effects. Additionally, it may be useful to further research the question of how strong these RE & EE energy microfinance services affect sustainable development activities in different demographic groups, e.g. rural versus urban low-income population or female versus male. Due to the distinct characteristics of each group, the effects are also expected to vary. Everything considered, this paper takes a decisive step forward in academic discussion on the question of how to foster appropriate finance sources of green energy for the poor.

Acknowledgments

3.A   Appendix: Rural lending and IT solutions survey

Here we display those original questions and answer options of the employed questionnaire that are related to the variables *Energyloan* and *ITintensity*.

Energyloan

"Does the institution offer specific loan products dedicated to renewable energy (e.g. solar panels, biodigesters, etc.) and/or energy efficiency (e.g. efficient cookstoves, etc.)?

- Yes

- No, my institution does not offer credit products specifically dedicated to renewable energy or energy efficiency, but with its loan products it also finance investments in renewable energy or energy efficiency

- No, but my institution plans to introduce credit products specifically dedicated to renewable energy or energy efficiency within next year

- No"

ITintensity

"By digital solutions we mean any software support that contributes to digitalise the processes and/or activities of your financial institution: collection of client's information, credit assessment, credit management, monitoring, reporting, etc. Examples are dedicated software solutions for desktop computers, Apps for tablets or smartphones, etc.
. . .
Does your institution use any digital support solutions for data collection, analysis, reporting on lending activities? (multiple answers are possible)

- No

- Yes, desktop: excel

- Yes, specialized desktop software (not excel)

- Yes, software/App. for tablets or smartphone in the field

- Yes, tablets in the field

- Yes, smart phones in the field

- Other (please specify)"

Table 3.1: Definition of variables

Variable	Description
Energyloan	Indicator for whether MFIs have specific loan products dedicated to RE/EE. It equals 1 if MFIs do not have, 2 if MFIs do not have but with their loans, they also invest in RE/EE, and 3 if they have or will launch within next year (RE/EE).[1]
Answer	Dummy variable refers to response status of MFIs. It takes the value of 1 if MFIs replied to the survey. Otherwise, it equals 0.
ITintensity	Dummy variable indicates whether MFI uses more than one IT solution (exclude excel). If yes, it takes the value of 1 and 0, otherwise. IT solutions are: Specialized desktop software; Software/App for tablets or smartphones in the field; Tablets in the field, Smartphones in the field by MFIs.[1]
Age	Indicator for number of year institution has functioned as an MFI, as of 2017.
log(GLP)	Logarithm of gross loan portfolio.
ALSGNI	Indicator for average loan size, obtained by dividing average loan balance per borrower by gross national income per capita (GNI).
DTE	Indicator for debt to equity ratio.
Retention	Indicator for retention rate, obtained by dividing number of active borrowers at the end of the reporting period by the sum of active borrowers at the beginning of the reporting period and new borrowers during the reporting period.
FEMMAN	Indicator for the percentage of female managers.
OSS	Indicator for operational self-sufficiency, obtained by dividing financial revenue by operation cost, including financial and operating expense, and impairment losses on loans.
Rural	Indicator for the percentage of number of rural loan portfolio.
Diamonds	Rating score of MFIs defined by MIX. It is categorized into 3 groups, namely Unrated (not ranked yet), Low (MFIs are ranked 1-3 diamonds), and High (ranked 4-5 diamonds). The based category is Unrated.
CPIA	Policy and institutions for environmental sustainability rating (1=low to 6=high). It ranks how environmental policies foster the protection and sustainable use of natural resources and the management of pollution.
log(GDPpc)	Logarithm of gross domestic products per capita of the country, in which the MFI is located.
SDGs score	Indicator for the level of sustainable development of a country.
Region	Categorical variable for the geographical location of the MFI. The regions are Africa and the Middle East and North Africa (MENA), East Asia and the Pacific (EAP), Eastern Europe and Central Asia (EECA), Latin America and the Caribbean (LAC), and South Asia. The reference category is Africa and MENA.
Type	Categorical variable for the legal status of MFIs. There are MFIs of type Bank and Others, Credit Union/Cooperative, Non-bank financial institutions (NBFI), and Non-government organization (NGO). The reference category is Bank and Others.

Note: Sources of data
Variables "Energyloan" and "ITintensity" are derived from the survey on Rural Lending and IT Solutions.
Variable "Rural" is computed based on the MIX Market database.
Data for GDPpc and CPIA are collected from the World Development Indicators.
Data for SDGs scores are collected from SDG Index and Dashboards prepared by Sustainable Development Solutions Network (SDSN) and the Bertelsmann Stiftung.
Data for all other variables are collected from the MIX Market database.
[1] : Detailed questions and answer options constructed to these variables can be founded in Appendix A

Table 3.2: Frequency table by response status

| | Reply to survey | | | | | |
| | No | | Yes | | Total | |
	Obs	%	Obs	%	Obs	%
Region						
Africa and MENA	202	22.98	19	21.11	221	22.81
EAP	114	12.97	13	14.44	127	13.11
EECA	118	13.42	11	12.22	129	13.31
LAC	306	34.81	29	32.22	335	34.57
South Asia	139	15.81	18	20.00	157	16.20
Type						
Bank and others	180	20.48	9	10.00	189	19.50
Credit Union/Cooperative	121	13.77	6	6.67	127	13.11
NBFI	333	37.88	31	34.44	364	37.56
NGO	245	27.87	44	48.89	289	29.82
Diamonds						
Unrated	161	18.32	7	7.78	168	17.34
Low	307	34.93	31	34.44	338	34.88
High	411	46.76	52	57.78	463	47.78
N	879		90		969	

Table 3.3: Frequency table by energy lending

	(1)		(2)		(3)		Total	
	Obs	%	Obs	%	Obs	%	Obs	%
IT intensity								
No	23	69.70	8	66.67	34	75.56	65	72.22
Yes	10	30.30	4	33.33	11	24.44	25	27.78
Region								
Africa and MENA	8	24.24	2	16.67	9	20.00	19	21.11
EAP	5	15.15	3	25.00	5	11.11	13	14.44
EECA	5	15.15	0	0.00	6	13.33	11	12.22
LAC	9	27.27	4	33.33	16	35.56	29	32.22
South Asia	6	18.18	3	25.00	9	20.00	18	20.00
Type								
Bank and others	2	6.06	3	25.00	4	8.89	9	10.00
Credit Union/Cooperative	4	12.12	0	0.00	2	4.44	6	6.67
NBFI	12	36.36	2	16.67	17	37.78	31	34.44
NGO	15	45.45	7	58.33	22	48.89	44	48.89
N	33		12		45		90	

(1): MFIs offer no specific loan products dedicated to RE/EE.
(2): MFIs offer no specific loan products dedicated to RE/EE, but with its loan products, it also finance investments in RE/EE.
(3): MFIs offer specific loan products dedicated to RE/EE or plan to introduce them within the next year.

Table 3.4: Descriptive statistics of metric variables by response status

	No		Yes		Total	
	Mean	SD	Mean	SD	Mean	SD
Age	19.41	10.35	21.02	9.69	19.56	10.30
DTE	3.51	8.68	4.44	4.26	3.60	8.37
FEMMAN	0.38	0.25	0.32	0.22	0.37	0.25
log(GDPpc)	7.84	0.95	7.65	0.88	7.83	0.94
SDGs score	61.74	7.38	60.32	7.57	61.61	7.41
log(GLP)	16.07	2.24	16.18	1.99	16.08	2.22
OSS	1.13	0.29	1.13	0.26	1.13	0.28
ALSGNI	0.59	1.18	0.45	0.55	0.58	1.13
Retention	0.83	0.21	0.79	0.14	0.82	0.21
CPIA	3.29	0.32	3.24	0.35	3.28	0.32
Observations	879		90		969	

Table 3.5: Descriptive statistics of metric variables by the provision of energy loan

	(1)		(2)		(3)		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	17.94	9.34	22.75	9.19	22.82	9.70	21.02	9.69
DTE	3.66	2.63	4.31	3.88	5.04	5.21	4.44	4.26
FEMMAN	0.38	0.18	0.41	0.34	0.26	0.19	0.32	0.22
log(GDPpc)	7.80	0.88	7.88	0.63	7.47	0.91	7.65	0.88
SDGs score	60.72	7.74	61.61	6.26	59.67	7.86	60.32	7.57
log(GLP)	15.82	2.02	17.51	2.88	16.09	1.55	16.18	1.99
OSS	1.13	0.28	1.30	0.38	1.08	0.19	1.13	0.26
ALSGNI	0.37	0.50	0.55	0.86	0.48	0.48	0.45	0.55
Retention	0.77	0.17	0.85	0.18	0.80	0.11	0.79	0.14
Rural	0.58	0.31	0.55	0.28	0.55	0.25	0.56	0.27
CPIA	3.23	0.36	3.20	0.47	3.26	0.32	3.24	0.35
Observations	33		12		45		90	

(1): MFIs offer no specific loan products dedicated to RE/EE.
(2): MFIs offer no specific loan products dedicated to RE/EE, but with its loan products, it also finance investments in RE/EE.
(3): MFIs offer specific loan products dedicated to RE/EE or plan to introduce them within the next year.

Table 3.6: Estimation results

	Odered probit model				Heckman model			
	(1)	(2)	(3)	(4)	(5)		(6)	
					Energy loan	Answer	Energy loan	Answer
Age	0.060***		0.058***	0.067***	0.057**	0.008	0.068***	0.007
	(0.016)		(0.018)	(0.020)	(0.023)	(0.006)	(0.021)	(0.006)
Debt to equity	0.092***		0.120***	0.126***	0.120***		0.124**	
	(0.032)		(0.043)	(0.042)	(0.041)		(0.052)	
Female managers		−1.614**	−1.992***	−2.181***	−1.982***		−2.169***	
		(0.684)	(0.634)	(0.648)	(0.593)		(0.815)	
ALSGNI		−0.184	−0.078	0.186	−0.079		0.183	
		(0.218)	(0.247)	(0.217)	(0.255)		(0.206)	
Retention rate		1.799**	1.932**	1.706**	1.920**		1.710*	
		(0.871)	(0.822)	(0.818)	(0.812)		(0.948)	
OSS		−0.413	−0.098	−0.398	−0.095		−0.394	
		(0.555)	(0.665)	(0.531)	(0.645)		(0.593)	
log(GLP)	0.019	0.073	−0.014	−0.030	−0.013	0.003	−0.032	0.002
	(0.060)	(0.071)	(0.076)	(0.080)	(0.080)	(0.030)	(0.095)	(0.031)
IT intensity	−0.546	−0.221	−0.458	−0.463	−0.465		−0.445	
	(0.355)	(0.346)	(0.362)	(0.352)	(0.378)		(0.402)	
Rural	−0.346	−0.307	−0.566	−0.514	−0.559		−0.522	
	(0.546)	(0.597)	(0.590)	(0.574)	(0.596)		(0.584)	
log(GDPpc)	−0.921***	−0.656***	−0.901***		−0.891***	−0.162**		
	(0.233)	(0.252)	(0.273)		(0.278)	(0.067)		
SDGs score				−0.095***			−0.096***	−0.016*
				(0.032)			(0.032)	(0.008)
Region								
EAP	0.486	0.325	0.605	0.975*	0.593		0.992*	
	(0.450)	(0.487)	(0.486)	(0.536)	(0.480)		(0.542)	
EECA	1.059*	0.947*	1.470**	2.025***	1.462**		2.022**	
	(0.549)	(0.542)	(0.610)	(0.755)	(0.590)		(0.789)	
LAC	1.199**	1.373***	1.489**	1.419**	1.485**		1.415***	
	(0.499)	(0.507)	(0.580)	(0.552)	(0.602)		(0.520)	
South Asia	0.144	0.240	0.068	0.332	0.055		0.354	
	(0.428)	(0.412)	(0.445)	(0.439)	(0.442)		(0.467)	
CPIA						−0.136		−0.134
						(0.184)		(0.222)
MFI type								
Credit Union/Cooperative						−0.037		−0.036
						(0.288)		(0.287)
NBFI						0.281		0.278
						(0.193)		(0.189)
NGO						0.561***		0.546***
						(0.199)		(0.192)
Diamonds								
Low						0.291		0.285
						(0.222)		(0.225)
High						0.414**		0.406*
						(0.209)		(0.208)
Observations	90	90	90	90	90	969	90	969
Pseudo R^2	0.156	0.110	0.204	0.181				

Model specifications (1)-(4) are ordered probit model with *Energyloan* as dependent variable. Model (5) and (6) present the results of Heckman estimations with *Answer* and *Energyloan* being dependent variables in the first and second stage of Heckman model, respectively. Variables are defined in Table 3.1.
Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3.7: Frequency table by energy lending - extended sample

	(1)		(2)		(3)		Total	
	Obs	%	Obs	%	Obs	%	Obs	%
ITintensity								
No	28	63.64	8	66.67	37	75.51	73	69.52
Yes	16	36.36	4	33.33	12	24.49	32	30.48
Region								
Africa and MENA	11	25.00	2	16.67	10	20.41	23	21.90
EAP	7	15.91	3	25.00	5	10.20	15	14.29
EECA	5	11.36	0	0.00	8	16.33	13	12.38
LAC	14	31.82	4	33.33	16	32.65	34	32.38
South Asia	7	15.91	3	25.00	10	20.41	20	19.05
Type								
Bank and others	3	6.82	3	25.00	4	8.16	10	9.52
Credit Union/Cooperative	7	15.91	0	0.00	3	6.12	10	9.52
NBFI	13	29.55	2	16.67	20	40.82	35	33.33
NGO	21	47.73	7	58.33	22	44.90	50	47.62
N	44		12		49		105	

(1): MFIs offer no specific loan products dedicated to RE/EE.
(2): MFIs offer no specific loan products dedicated to RE/EE, but with its loan products, it also finance investments in RE/EE.
(3): MFIs offer specific loan products dedicated to RE/EE or plan to introduce them within the next year.

Table 3.8: Descriptive statistics of metric variables by the provision of energy loan - extended sample

	(1)		(2)		(3)		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	17.95	8.54	22.75	9.19	22.39	9.55	20.57	9.28
DTE	3.60	2.77	4.31	3.88	5.00	5.08	4.34	4.14
FEMMAN	0.38	0.17	0.41	0.34	0.26	0.19	0.33	0.21
log(GDPpc)	7.86	0.91	7.88	0.63	7.45	0.89	7.67	0.89
log(GLP)	15.91	2.04	17.51	2.88	16.16	1.59	16.21	2.00
OSS	1.16	0.29	1.30	0.38	1.09	0.22	1.15	0.27
ALSGNI	0.36	0.47	0.55	0.86	0.48	0.47	0.44	0.53
Retention	0.78	0.15	0.85	0.18	0.79	0.10	0.79	0.13
Rural	0.61	0.29	0.55	0.28	0.56	0.24	0.58	0.26
CPIA	3.28	0.35	3.20	0.47	3.25	0.33	3.26	0.35
Observations	44		12		49		105	

(1): MFIs offer no specific loan products dedicated to RE/EE.
(2): MFIs offer no specific loan products dedicated to RE/EE, but with its loan products, it also finance investments in RE/EE.
(3): MFIs offer specific loan products dedicated to RE/EE or plan to introduce within next year.

Table 3.9: Robustness checks

| | Odered probit model | | | Heckman model | | | |
| | (1) | (2) | (3) | (4) | | (5) | |
				Energy loan	Answer	Energy loan	Answer
Age	0.063***		0.062***	0.063***	0.003	0.045***	0.007
	(0.016)		(0.017)	(0.022)	(0.006)	(0.012)	(0.006)
DTE	0.099***		0.130***	0.125*		0.057**	
	(0.031)		(0.043)	(0.069)		(0.026)	
FEMMAN		−1.708**	−2.180***	−2.151**		−1.504***	
		(0.749)	(0.680)	(1.005)		(0.531)	
ALSGNI		−0.201	−0.073	−0.076		0.101	
		(0.212)	(0.270)	(0.310)		(0.183)	
Retention		1.822**	2.089**	2.079		1.054*	
		(0.877)	(0.841)	(1.492)		(0.559)	
OSS		−0.511	−0.174	−0.184		−0.474	
		(0.510)	(0.629)	(1.016)		(0.375)	
log(GLP)	0.041	0.098	0.003	0.001	0.018	−0.054	0.026
	(0.060)	(0.072)	(0.078)	(0.095)	(0.029)	(0.059)	(0.035)
ITintensity	−0.631*	−0.385	−0.542*	−0.514		−0.075	
	(0.323)	(0.320)	(0.327)	(0.421)		(0.274)	
Rural	−0.761	−0.700	−0.979*	−0.960		−0.482	
	(0.519)	(0.555)	(0.554)	(0.640)		(0.465)	
log(GDPpc)	−1.029***	−0.767***	−1.006***	−1.008***	−0.140**	−0.494***	−0.152**
	(0.226)	(0.241)	(0.266)	(0.382)	(0.064)	(0.180)	(0.076)
Region							
EAP	0.554	0.412	0.657	0.674		0.553	
	(0.439)	(0.462)	(0.468)	(0.689)		(0.362)	
EECA	1.567***	1.378***	1.973***	1.937**		0.894**	
	(0.543)	(0.522)	(0.589)	(0.976)		(0.421)	
LAC	1.260**	1.405***	1.541***	1.521**		0.796*	
	(0.492)	(0.482)	(0.564)	(0.647)		(0.445)	
South Asia	0.368	0.434	0.233	0.256		0.279	
	(0.406)	(0.388)	(0.423)	(0.491)		(0.333)	
CPIA					−0.056		
					(0.177)		
MFI types							
Credit Union/Cooperative					0.184		0.133
					(0.257)		(0.287)
NBFI					0.279		0.336
					(0.183)		(0.218)
NGO					0.617***		0.623***
					(0.188)		(0.218)
Diamonds							
Low					0.310		0.029
					(0.204)		(0.236)
High					0.402**		0.271
					(0.196)		(0.221)
Observations	105	105	105	105	984	68	868
Pseudo R^2	0.193	0.141	0.244				

Model specifications (1)-(3) are ordered probit model with *Energyloan* as dependent variable. Model (4) and (5) present the results of Heckman estimations with extended response sample and FIML, correspondingly. *Answer* and *Energyloan* are dependent variables in the first and second stage of Heckman model, respectively. Variables are defined in Table 3.1.
Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Chapter 4

Why microfinance institutions go digital: An empirical analysis

This chapter is based on a joint work with Gregor Dorfleitner and Davide Forcella. The paper has been submitted to the *Journal of Applied Accounting Research* and is currently under first revision.

Abstract: While the role of digital solutions to foster financial inclusion and the development of the microfinance sector are widely acknowledged, questions concerning the variation in the ability and willingness of microfinance institutions' (MFIs) adoption of these tools remain unanswered. This paper studies the determinant of the use of digital support solutions in the microfinance sector by using a global sample of MFIs derived from a survey by YAPU Solutions on rural lending and IT solutions. We discover the evidence that suggests the adoption of these tools is consistent with the social performance of MFIs. Furthermore, the results of the study indicate that the profitability of the institutions is associated with a larger application of digital support solutions. Macroeconomic factors, the development of the country in which the institution is located, also impact MFIs' decisions regarding integrating digital solutions into their services and internal operational processes.

4.1 Introduction

In 2015, the United Nations General Assembly emphasized the importance of sustainable development through the introduction of a plan of action, named "Transforming our World: The 2030 Agenda for Sustainable Development". The Agenda comprises 17 Sustainable Development Goals (SDGs) aimed at paving the way for the improvement of people's lives in United Nations member countries. Although the term financial inclusion is not explicitly cited in the statement of United Nation's 17 SDGs, it has been considered to play a pivotal role in attaining several targets through this, for example combating poverty, improving living standards, and promoting economic growth (Ma'ruf and Aryani, 2019, Fu et al., 2017). In other words, SDGs may only be achieved through some support of an inclusive financial system. Therefore, financial inclusion has been placed in a priority position in the development agenda of many countries (World Bank, 2018, Arun and Kamath, 2015). Although the financial inclusion concept is expressed differently in words (World Bank, 2018, UNCDF, 2017, UNSGSA, 2018), it generally refers to the affordable and sustainable accessibility and use of appropriate financial services for all sections of the population. Its ultimate goal is to create better opportunities and environment for finance.

However, low-income individuals may find it hard to overcome several barriers in order to access to formal financial systems due to their lack of collateral or low level of credit-worthiness. As noted by Demirgüç-Kunt et al. (2018), the financing gap remains severe with approximately 1.7 billion adults in possession of neither a financial institution nor mobile money account, which the poor mainly comprises. The difference in terms of account ownership by gender remains significant, with formal accounts of men accounting for 9% more than those of women in developing countries. Additionally, data from their study shows that 47% of survey participants borrowed money in 2017 but only 11% of these borrowed from financial institutions. Moreover, credit supply to small and micro - enterprises met less than half of the potential needs in the developing countries, compared with the financial demand of 8.9 trillion US Dollars (Bruhn et al., 2017). Thus, there is a great potential for the microfinance sector to support the goal of financial inclusion. Several theoretical and empirical studies demonstrate the linkage between microfinance and financial inclusion (Mushtaq and Bruneau, 2019, Mader, 2018, Brown et al., 2016).

Digital finance, which is defined as being the application of digital tools/solutions for finance, not only promotes better customer services but also encourages the effective operational management of MFIs. Only few decades ago, access to digital financial services, mobile banking or electronic payments appeared to be impossible. Ritchie (2017) summarizes data on the global trend toward adopting the technology until 2017. The study shows impressive shreds of evidence on the ex-

plosion of mobile phone and mobile money account adoption. While digital technology used to be viewed as a comparatively expensive approach toward finance as a whole, expecting the financially excluded population to adopt digital tools and services appeared to some extent to be unrealistic and unfeasible, mainly with respect to financial affordability. Yet with the rapid revolution of digital technology and modern smart devices, digital finance has emerged as a new way of delivering financial services and products efficiently and effectively. The recent years have seen a dramatic change in not only policymakers' and financial institutions' attention, but also in customers' perception towards digital finance (Pazarbasioglu et al., 2020). For example, M-PESA is one of the most famous and successful experiences of integrating new fintech apps to payment and lending services, which highlights the effort of delivering financial services to the formally unbanked population (Van Hove and Dubus, 2019). Furthermore, the role of digital solutions in financial inclusion is seen indirectly through the positive impacts on institutions' operational management. By incorporating digital tools into the business process, financial service providers can better manage risk and cost-related problems as well as thoroughly analyze customer data and information (Wyman, 2017, Pytkowska and Korynski, 2017).

Considered in its entirety, moving toward digital tools, when implemented effectively and sustainably within the framework of appropriate regulation, appears to be one of the important drivers for promoting not only faster progress but also an efficient method toward attaining financial inclusion (Yeow et al., 2017, Ghani et al., 2018, Vong and Song, 2015). Thus, exploring the determinations of digital supporting solutions adoption is needed in order to promote their diffusion. However, in contrast to the demand side, research on supply-side drivers, i.e. from financial service providers side, seem to be lagged behind. Additionally, while there is a vast amount of literature which focus on digital transformation in the banking system (Mbama and Ezepue, 2018, Shaikh et al., 2017, Jünger and Mietzner, 2020), little is known about the underlying reasons that motivate MFIs toward their position within the application of digital tools.

This paper is one of the first empirical ones to shed light on the digital solutions adoption of MFIs. The discussion in the current study contributes to the exploration of several factors that determine the application of digital solutions by MFIs. Using a data set from a worldwide MFIs survey on IT solutions and Rural lending, which was conducted by YAPU Solutions, we test whether MFIs' digital software adoption is influenced by MFI-specific characteristics and macroeconomic factors. To be more specific, we examine whether there is a relationship between the social mission of an MFI and its decision to adopt digital tools. Furthermore, we investigate whether or not the profitability of MFIs, measured by return on equity, is related to an MFI's digital solutions application. Finally, we explore to which extent the economic development of the country in which an MFI is located is related to the adoption of digital solutions of MFIs. The key findings of our

article show that the use of digital solutions is related to economic development, an MFI's profitability, and social performance.

The remainder of this paper is structured as follows: Section 2 highlights the importance of digital solutions to microfinance in deepening financial inclusion, identifies related and recent literature on the application of digital, and builds on the hypotheses. Section 3 presents the data source and methodology used to investigate the proposed statements. The empirical examinations and results are then explored in section 4. Finally, section 5 briefly summarizes the findings and discusses some potential future work.

4.2 Theoretical background and hypotheses

4.2.1 Literature review on microfinance digital adoption and social performance

Historically, bringing microfinance services to the vulnerable groups in the population is evidently a costly business process (D'Espallier et al., 2013, Cull et al., 2018). Over the past decades, MFIs have been struggling with finding and applying alternative business models to reduce costs, accelerating greater outreach to remote areas, and quickly and efficiently meeting customer financial requirements (Labie et al., 2011). In response to these challenges, especially during the explosive digital era, digital applications and other smart devices such as smartphones or tablets have been increasingly deployed by MFIs to digitize core business operations, such as loan disbursement. Information and communication technology (ICT) is illustrated as being one of the key pillars in the microfinance innovation process toward becoming more mature and surviving in an increasingly competitive environment (Kauffman and Riggins, 2012). The authors argue that ICT is not only an important tool for the business operation of MFIs, but also a motivation that forces a more competitive environment in the microfinance industry. Moreover, Vong and Song (2015) illustrate that mobile service solutions do have positive impacts on lowering transaction and administration costs of MFIs, which subsequently helps to reduce the lending rate. From this perspective, both MFIs and their borrowers benefit from the application of mobile technology. Pytkowska and Korynski (2017), in their survey-based research, point out that even if MFIs are not fully digitized, digital solutions have shown themselves to be helpful in some aspects of their business processes. Otherwise, they would lose their competitiveness to other digital credit providers, for example mobile banking providers and lending platforms.

Yet, in the vast majority of MFIs, the existence of digital solutions varies consid-

erably. There are several conceivable reasons why institutions are still reluctant to implement digital solutions. Although digital solutions bring several benefits to institutions, it cannot be denied that the high cost of running a digital system feasibly puts a burden on the MFIs' budget. For instance, in a survey on digitizing transformation of MFIs in Europe, the lack of financing sources is reported to be the dominant obstacle to the introduction of digital solutions, with 53% of the respondents citing this problem (Pytkowska and Korynski, 2017). Moreover, the lack of effective infrastructure to support the digital transformation process in some countries is perceived as being amongst of the most frequently mentioned challenges. Parada and Bull (2018) report that underdeveloped infrastructure for digitalization is one of the key barriers in the hindrance of the rise of digital finance in Africa. The operational cost of MFIs is demonstrated as being one of the driving factors for the involvement in new financial technology services, i.e., mobile financial services (Dorfleitner et al., 2019a).

In summary, it can be postulated that the adoption of digital solutions appears to be unsuitable for some organizations and requires careful consideration. Since the first and foremost objective of microfinance is poverty alleviation and a promotion of social responsibility, it is crucial that MFIs assess the digital transformation process in association with their social promise. Therefore, one must also consider the social performance of MFIs.

The percentage of female borrowers has been utilized as a proxy for the social performance of MFIs in several previous articles (Dorfleitner et al., 2017b, D'Espallier et al., 2013, Hermes et al., 2011). According to Morduch (1999) and D'Espallier et al. (2013), female borrowers have traditionally been perceived to constitute a large percentage of clients for the majority of MFIs. The MFIs' focus on this population group is even more strong in regions with low levels of social trust since they are viewed as being more trustworthy (Aggarwal et al., 2015). Thus, MFIs lend more to female customers in order to apply digital solutions.

Another frequently employed measure for the social performance of MFIs in the existing literature is the average loan balance which is interpreted as following: the lower this value, the poorer the customers are. Additionally, it has been shown that women clients are associated with small loans, which require more effort and cost from MFIs in terms of management (Hermes et al., 2011, D'Espallier et al., 2013). To better manage the operational business and related risks, digital solutions pose a potential solution.

4.2.2 Hypotheses development

It is well known that the yield from gross loan portfolios is the main source of revenue for the business sustainability of MFIs. To cover the cost of delivering

financial services to the poor, who often take out loans of small sums, MFIs are forced to charge a high interest rate (Dorfleitner et al., 2013, D'Espallier et al., 2017b, Meyer, 2019). However, it could be the case that MFIs prioritize their social mission and thus do not raise interest rates as this could negatively impact their customers. Thus, to maintain a cost-effective operation, digital solutions can be integrated into an MFI's business model. In light of the relationship between social performance and the expenses, D'Espallier et al. (2013) claim that the small loans which are frequently associated with lending to women result in higher relative costs. In other words, the focus on social performance through the provision of small loans is considered to be costly. Regarding the factors that drive MFIs' social performance, Amersdorffer et al. (2015) remark on the importance of financial self-sufficiency. The authors provide evidence in the case of Bulgarian agricultural credit cooperative and show that only financially well-managed MFIs manifest a better social output. This view is also examined by Beisland et al. (2020) but in a larger sample of 204 MFIs from 58 countries. The study finds that the strong balance between the social and financial performance of MFIs yields a higher social rating. Thus, one can assume that the more efficiently MFIs are managed, the better their social performance. Furthermore, the existing body of literature also highlights the positive relationship between the application of digital solutions and the managerial capability of financial institutions (Moro Visconti and Quirici, 2014, Mora and Prior, 2018). In addition, Dorfleitner et al. (2019a) provide proof that social performance (measured by average loan size) is positively associated with the provision of mobile financial services. This suggests that digitization and social missions can harmonize. Therefore, integrating digital solutions into the business model proves to be a promising solution to solve the cost related problems, which subsequently enables a higher level of profitability as well as lower interest rates.

Furthermore, Mersland and Strøm (2012) illustrate that while struggling with the management of high costs and low returns in delivering services to the poor, social performance of MFIs remains unchanged. Based on this finding, one can be expected that MFIs that are proficient at operational management will exhibit a better social performance and an adoption of digital solutions. In sum, we formulate the following hypothesis:

Hypothesis 1 (H1) *The social performance of an MFI is positively related to the likelihood of digital solutions adoption.*

It should be remarked upon that the process of integrating digital finance solutions is considered to require a lot of effort in planning, adapting the current systems, and in finding funding sources, or specialized experts to operate the new technology. As discussed above, well-managed MFIs as well as those which are cost-efficient ones could have a better social performance, yet positive changes in profitability and financial sustainability could result from improved governance and financial management (Mersland and Strøm, 2009, Ayayi and Sene, 2010, Iqbal et al., 2019). Therefore, if the digital solutions are introduced as a means of good

management and cost-efficiency, there also can be a positive correlation between the use of digital solutions and profitability. Thus, we expect MFIs with sustainable returns to have a tendency to introduce new digital solutions. We predict that:

Hypothesis 2 (H2) *The profitability of an MFI is positively related to the likelihood of the adoption of digital solutions.*

Even though digital solutions can positively impact financial value chain activities (Pytkowska and Korynski, 2017), the integration of these tools requires the presence of sufficient and stable infrastructure. Parada and Bull (2018) also argue that the insufficiency and instability of infrastructures is one of the main reasons that hinders the ability to adopt digital tools. As highlighted by Kumar et al. (2010), many MFIs realize the importance of digitalization and show their willingness to introduce new technology, i.e. mobile-banking, but one of the largest obstacles is the availability of the related infrastructure. Later on, Ketterer (2017) also argues that insufficient infrastructure can lead to the unwillingness in implementing digital finance due to the lack of connectivity. This, however, appears to be notably prevalent in less developed countries (Hinson et al., 2019). Furthermore, institutions in more developed regions tend to exhibit greater awareness of the competitiveness of digitization (Pytkowska and Korynski, 2017). Therefore, we propose the following hypothesis:

Hypothesis 3 (H3) *The economic development of a country is positively related to the likelihood of the adoption of digital solutions by MFIs.*

4.3   Data and methodology

4.3.1   Description of data and variables

In late 2017, an online survey which was conducted by YAPU Solutions, a social fintech company, aimed at supporting financial institutions through software services, was sent to microfinance institutions in various regions globally. The questionnaire was dedicated to the use of IT solutions and rural lending by MFIs and prepared using the Monkey survey platform. The email with the link to the online survey was then distributed to MFIs initially in November 2017, and was then followed by three reminder emails. By March 2018, the survey had finally been completed. The questionnaire was written in the three most frequently spoken languages, namely English, Spanish, and French, to acquire more interest and more response from the surveyed institutions. Several topics of interest were included in the survey, such as the use of digital solutions, the perception toward rural and agriculture finance, renewable energy and energy efficiency lending. Questions re-

lated to the adoption of digital solutions were presented at the top of the survey. After careful consideration, the number of consistent and reliable responses to the survey is 150 MFIs. However, due to the availability of the institutions' specific information obtainable from MIX Market database, we are only able to utilize 105 questionnaires.

Mix Market database has been used as an important public source of data regarding the profile information and financial performance of MFIs for many studies in the microfinance field due to its transparency and availability of a large amount of data (Dorfleitner et al., 2017b, D'Espallier et al., 2013, Allet and Hudon, 2015, e.g.). This institutional database can be used to track several finance and accounting related activities since it encompasses data on assets, liabilities, revenues, costs, income, employees, end customers and types of financial products. In 2015, there were over 1000 MFIs that reported their annual financial performance data to MIX Market. From these, we selected only those MFIs with realistic and consistent data, the reason being that MFIs voluntarily publicize their financial performance data and profile information to MIX Market. These reports often lack official authorized audits, which in turn feasibly causes several unrealistic and contradictory values to be viewed with caution.

To tackle these problems, we follow the approach used by Dorfleitner et al. (2017b). To be more specific, we exclude MFIs with the following criteria: percentage of female borrowers greater than 100%; return on assets ratio less than -1.5; average loan balance per borrower greater than 15,000 US Dollars; gross loan portfolio small than zero, and portfolio at risk or nominal yield on gross loan portfolio greater than one. Note that our empirical estimation, with *Digital* as a binary dependent variable, is not intended for the study of the causality between the application of digital solutions and an MFI's performance, but rather to identifying characteristics of MFIs' integration of digital solutions. Therefore, following (Dorfleitner et al., 2019a), lagged values for MFI-specific variables are employed. We then merge our two adjusted data sets with macroeconomic data from World Development Indicators and the G20 Financial Inclusion Indicators database, which are both sourced from the World Bank data platform. The resulting sample contains 984 the reported information of the MFIs to MIX Market in 2015, 105 of which responded to the survey.

Detailed descriptions of the variables used in the study are presented in Table 4.1. Our dependent variable is the use of digital solutions *Digital*. We define *Digital* as being the use of any digital software that contributes to the support of various aspects of an MFI's operation, such as data collection and/or analysis, risk assessment, loan disbursement and/or monitoring. Dedicated software solutions used by MFIs could be, inter alia, specialized desktop software or software/Apps for tablets or smartphones. In the context of this study, spreadsheet software is not treated as a digital tool in helping to define the concept of modern movement towards digitalization. Our dependent variable of interest is a binary variable that

takes the value of 1 if MFIs do apply digital solutions to their operational business activities and otherwise 0.

The MFI-specific explanatory variables indicate factors linked to the social performance and the profitability of the MFIs. In the existing body of literature on the social performance of MFIs, the poverty of the customers is measured through average loan balance because the smaller the average loan amount lending to customers, the poorer they are. Moreover, women are frequently treated as being more financially vulnerable than men. Therefore, a high ratio of female borrowers implies a deep outreach of an MFI, i.e., better social performance. Thus, the percentage of female borrowers and average loan balance per borrower divided by GNI per capita (ALBGNI) are employed to measure MFI social performance (see, for example, Dorfleitner et al. (2017a), D'Espallier et al. (2013)). MFI profitability, which is represented by the return-on-equity ratio, measures the ability to generate the profits of MFIs in comparison with shareholder equity, with the intuition being the higher the better. *ROE* has been a traditional proxy for profitability in previous studies (Abrar et al., 2016, D'Espallier et al., 2017a). The GDP per capita is employed to represent the impact of macroeconomic factors.

We use MFI donations, write-off ratio (*WOR*), and percentage of rural loans (*Rural*) as MFI-specific control variables. The *Donations* dummy takes the value of 1 if the MFIs receive donations in the reference year and 0 otherwise. *WOR* measure the proportion of loans which have been written off, which is divided by the average gross loan portfolio. Finally, the variable *Rural* is included to reflect the expectation that the greater the concentration on rural lending, the more interest in digital tools. The legal status of MFIs can also influence the decision to adopt digital solutions. Therefore, a set of dummy variables is included to manage the effect of the type of the MFIs. In particular, there are four different groups of legal status of MFIs, including Credit Union/Copperative; Non-bank financial institutions (NBFI); Non-government organizations (NGO), and the reference category Bank and others.

As additional explanatory variables, we further include two macroeconomic variables, namely the domestic credit distributed by the financial sector as a percentage of GDP (*DOMCRE*) and dispute resolution index, reflecting the existence of dispute resolution mechanisms in the country (*Dispute*) in the selection equation (see detailed definition in Table 4.1). According to Doumbia (2016), the economic growth of a country is consistent with the development of the financial sector measured by the domestic credit by financial sector as a percentage of GDP. In addition, Kriese et al. (2019) show the positive influence of dispute resolution mechanisms on the level of economic development. Thus, it can be argued that the level of domestic credit by financial sector and dispute resolution mechanisms are indicators of the economic growth of a country. Moreover, we expect MFIs with a higher level of transparency to be more likely to disclose their viewpoint to our survey. Therefore, the variable *Diamonds*, which represent the MIX Market

rating score on MFIs' reports, is employed with three three categories (Unrated, Low, and High)

4.3.2 Methodology

As previously stated, our dependent variable, *Digital* is a binary variable that takes two values, namely 0 and 1. Therefore, we run several probit regressions with Eicker - Huber - White heteroskedastic - consistent standard errors in order to estimate the effects of the social performance, the profitability of the institution, and the level of the economic development of the country. The following regression model is estimated:

$$y_i^* = \alpha + \beta_1 x_i + \beta_2 c_i + \epsilon$$

$$y_i = \begin{cases} 1, & \text{if } y_i^* > 0 \\ 0, & \text{if } y_i^* \leq 0 \end{cases}$$

where y_i^* is the latent continuous variable reflecting the use of digital solutions by MFIs i. Meanwhile, y_i is an observed dummy variable referring to the adoption of digital solutions. It takes the value of 1 if an MFI employs digital tools and 0 otherwise. While β_1 refers to the coefficient of the hypothesis-related variables, the vector of variables, x_i, consists of four independent variables (see Table 4.1). A vector of control variables is denoted by c_i with β_2 representing the coefficient for this vector, while ϵ is the error term for the model. One of the limitations of our data set is the the self-declaration of the MFIs to MIX Market, which can lead to the problem of missing values for several variables. For the reason that the number of MFIs who responded to the survey is already very limited, mean imputation is employed as a technique to overcome the problem of missing values, i.e, the mean of observed values of one variable is used to replace all the missing values of said variable.

The problem of bias due to sample selection may exist because of the inability to obtain a perfect representative random sample, especially when selected observations are impacted by the outcome of the interest, which then triggers a bias of the estimated coefficients in the regressions (Heckman et al., 1998). In our case, those MFIs which are already using digital tools or planning to introduce digitization show more interest in responding to our survey. Moreover, respondents may intend to self-select their preferred options due to the voluntary disclosure to the survey. Thus, inconsistent estimations could arise. To address this issue, one of the most common approaches used in research is the Heckman selection model (Tucker, 2010, Wu and Shen, 2013, Lee et al., 2015). We run a Heckman two-part model with a separate probit estimation for sample inclusion and maximum likelihood.

Table 4.1: Definition of variables

Variable	Description
Digital	Dummy variable indicates whether MFI uses IT solutions or not (exempt excel). If yes, it takes the value of 1 and otherwise 0. IT solutions are: Specialized desktop software; Software/App for tablets or smartphones in the field; Tablets in the field, Smartphones in the field by MFIs.
Apps	Dummy variable indicates whether MFI uses the following digital solutions or not: Software/App for tablets or smartphones in the field; Tablets in the field, Smartphones in the field by MFIs. If yes, it takes the value of 1 and otherwise 0.
Software	Dummy variable indicates whether MFI uses Software/App for tablets or smartphones in the field or not. If yes, it takes the value of 1 and otherwise 0.
Answer	Dummy variable refers to response status of MFIs. It takes the value of 1 if MFIs replied to the survey. Otherwise, it equals 0.
Age	Indicator for number of years institution has functioned as an MFI, as of 2017.
Assets (ln)	Logarithm of total assets.
DTE	Indicator for debt to equity ratio.
Yield (r)	Indicator for yield of gross portfolio (real).
ROE	Indicator for return on equity.
OEA	Indicator for operating expense to total assets.
ALBGNI	Indicator for average loan balance, obtained by dividing average loan balance per borrower by gross national income per capita (GNI).
Female	Indicator for the percentage of female borrowers.
GDPpc (ln)	Logarithm of gross domestic products per capita of the country in which the MFI is located.
WOR	Indicator for write-off ratio.
PAR30	Indicator for portfolio at risk over 30 days, calculated by dividing sum of outstanding balance, portfolio overdue 30 days and renegotiated portfolio to gross loan portfolio.
Rural	Indicator for the proportion of number of rural loans.
Donations	Dummy variable that indicates whether or not the MFI received donations in the year observed. It takes the value of 1 if the MFI obtained donations and otherwise 0.
DOMCRE	Indicator for domestic credit by financial sector as percentage of GDP of the country where MFI is located.
Dispute	Indicator for the dispute resolution index reflecting the existence of formal internal and external dispute resolution mechanisms. (1) Internal mechanism indicator: law or regulation setting standards for complaints resolution and handling by financial institutions. (2) External mechanism indicator: System in place that allows a customer to seek affordable and efficient recourse with a third party.
Diamonds	Rating score of MFIs defined by MIX. It is categorized into 3 groups, namely Unrated (not ranked yet), Low (MFIs are ranked 1-3 diamonds), and High (ranked 4-5 diamonds). The reference category is Unrated.
Region	Categorical variable for the geographical location of the MFI. The regions are Africa and the Middle East and North Africa (MENA), East Asia and the Pacific (EAP), Eastern Europe and Central Asia (EECA), Latin America and the Caribbean (LAC), and South Asia. The reference category is Africa and MENA.
Type	Categorical variable for the legal status of MFIs. There are MFIs of the type Bank and Others, Credit Union/Cooperative, Non-bank financial institutions (NBFI), and Non-government organization (NGO). The reference category is Bank and Others.

Note: Sources of data
Variables "Digital" is derived from the survey on Rural Lending and IT Solutions.
Data for GDPpc and the variable "DOMCRE" are collected from the World Development Indicators.
Data for the variable "Dispute" is collected from G20 Financial Inclusion Indicators.
Data for all other variables are collected from the MIX Market database.

The estimation of a probit model for selection is initially included to investigate the probability of MFIs responding to the survey. In this first step, *Answer* is our dependent dummy variable, indicating whether or not MFIs have responded to the Yapu solutions survey. Determinants employed in this paper include an MFI's age, the logarithm of total assets, the average loan balance to borrower divided by GNI per capita, legal status as well as the domestic credit and dispute resolution index of the reference country (see Table 4.1 for more details). After controlling for the correction of selection bias, we are then able to proceed with the estimation of determinants of the adoption of digital solutions by MFIs. Under the condition that *Answer* takes the value of 1, we assess the likelihood of the integration of digital solutions based on the set of explanatory variables described in Table 4.1. A p-value smaller than 0.05 of the Wald test of independent equations indicates that the model is appropriate and there is the presence of selection bias.

4.3.3   Descriptive statistics

Table 4.2 and Table 4.3 display the sample characteristics by the response status and the use of digital solutions correspondingly. At first glance, one can see that our sample reflects the diverse microfinance sector. In the data sample, a predominance of MFIs from Latin America and the Caribbean can be found, accounting for a total of 34.55%. Moreover, MFIs of type NGO tend to be active in answering the questionnaire with the proportion of the response rate being higher than that of the rejection rate (47.62% compared with 27.87%). As expected, the higher the trustworthiness ranking of an MFI, the more likely they are to participate in the survey. To be more specific, the proportion of unrated MFIs in the responded group is less than half that of those who are in the abstained group (7.62% in comparison to 18.32%). Meanwhile, the statistics are more positive in the case of MFIs who have high rating scores. The percentage of this type of MFIs is approximately 10% greater in the responded group than the non-responded one (56.19% compared with 46.76%).

Regarding the characteristics of MFIs who are using and not using digital solutions, institutions located in LAC and South Asia tend to favor the integration of digital solutions more than other regions. In terms of legal status, MFIs of the type NGO exhibit more interest in digital solutions than the other types with 51.09% of observations using these tools being NGOs. Among the MFIs adopting digital solutions, institutions ranked high by MIX Market show an over-representation, accounting for 57.61% of the observations.

Table 4.4 compares the descriptive statistics between respondents and non-respondents. The results reveal that MFIs who responded to the survey appear to be more mature in terms of age than their counterparts. No significant difference regarding total assets can be ascertained between the two groups of MFIs. The same

holds true for the dispute resolution index. Regarding the domestic credit variable, the statistics indicate that MFIs located in countries with more developed financial markets appear to be more interested in the survey than their counterparts. However, the difference in the mean value is not notable.

Table 4.5 illustrates descriptive statistics for the explanatory variables related to our estimations for MFIs with and without digital solutions. In line with our assumption, MFIs which use digital solutions have a higher percentage of female borrowers and lower average real yield on gross loan portfolios (0.7% compared to 0.54% and 0.25% compared to 0.29%, respectively). Furthermore, institutions with the use of digital tools exhibit, on average, a higher return on equity compared with those without digital solutions. These results allow us to make initial predictions for the significant impacts of the social performance and the profitability of MFIs in the regression analysis.

Table 4.6 depicts the correlation coefficients between independent variables. At first glance, we observe various significant correlations between explanatory variables in the table. According to this, no multicollinearity problems should arise from the observed correlations, which are below 0.34 with respect to absolute values. The only exception is the correlation between the variable *OEA* and *Yield(r)*, which is, however, not used simultaneously in our regressions.

Table 4.2: Frequency table by response status

	No		Yes		Total	
	Obs	%	Obs	%	Obs	%
Region						
Africa and MENA	202	22.98	23	21.90	225	22.87
EAP	114	12.97	15	14.29	129	13.11
EECA	118	13.42	13	12.38	131	13.31
LAC	306	34.81	34	32.38	340	34.55
South Asia	139	15.81	20	19.05	159	16.16
Type						
Bank and others	180	20.48	10	9.52	190	19.31
Credit Union/Cooperative	121	13.77	10	9.52	131	13.31
NBFI	333	37.88	35	33.33	368	37.40
NGO	245	27.87	50	47.62	295	29.98
Diamonds						
Unrated	161	18.32	8	7.62	169	17.17
Low	307	34.93	38	36.19	345	35.06
High	411	46.76	59	56.19	470	47.76
N	879		105		984	

4.4 Empirical results

Determinants of the digital solution adoption of MFIs

Table 4.3: Frequency table by the use of digital solutions

	No		Yes		Total	
	Obs	%	Obs	%	Obs	%
Region						
Africa and MENA	4	30.77	19	20.65	23	21.90
EAP	2	15.38	13	14.13	15	14.29
EECA	3	23.08	10	10.87	13	12.38
LAC	3	23.08	31	33.70	34	32.38
South Asia	1	7.69	19	20.65	20	19.05
Type						
Bank and others	3	23.08	7	7.61	10	9.52
Credit Union/Cooperative	2	15.38	8	8.70	10	9.52
NBFI	5	38.46	30	32.61	35	33.33
NGO	3	23.08	47	51.09	50	47.62
Donations						
No	7	53.85	59	64.13	66	62.86
Yes	6	46.15	33	35.87	39	37.14
Diamonds						
Unrated	1	7.69	7	7.61	8	7.62
Low	6	46.15	32	34.78	38	36.19
High	6	46.15	53	57.61	59	56.19
N	13		92		105	

Table 4.4: Descriptive statistics of metric variables by response status

	No		Yes		Total	
	Mean	SD	Mean	SD	Mean	SD
Age	19.41	10.35	20.57	9.28	19.53	10.25
Assets (ln)	16.41	2.15	16.50	1.89	16.42	2.12
DTE	3.51	8.68	4.34	4.14	3.60	8.32
GLP (ln)	16.07	2.24	16.21	2.00	16.08	2.21
Female	0.65	0.23	0.68	0.23	0.65	0.23
ALBGNI	0.59	1.18	0.44	0.53	0.58	1.12
Yield (r)	0.27	0.17	0.26	0.14	0.26	0.17
ROE	0.06	0.31	0.07	0.27	0.06	0.30
OEA	0.18	0.13	0.18	0.11	0.18	0.13
PAR30	0.07	0.10	0.07	0.13	0.07	0.11
GDPpc (ln)	7.84	0.95	7.67	0.89	7.83	0.94
DOMCRE	50.86	27.70	51.12	26.54	50.89	27.57
WOR	0.02	0.04	0.02	0.02	0.02	0.04
Rural	0.52	0.27	0.58	0.26	0.52	0.27
Dispute	0.77	0.34	0.72	0.35	0.76	0.35
Observations	879		105		984	

This section discusses the results obtained from estimating the above equation using a probit model with robust standard errors. In Table 4.7, while model specification (1), (2), and (3) focus on different characteristics of MFIs separately, the model specification (4) displays the full model with all the explanatory variables. The model specification (5) presents the regression results for the Heckman model. All regressions are investigated with the inclusion of the entire control variables mentioned above.

The coefficients of the debt to equity ratio show a significantly negative sign in the model specification (1) and (4), indicating that MFIs which depend less on external sources of funding tend to utilize digital solutions. The models also reveal that with the increasing size of the MFIs, which is measured by total assets, the probability of employing digital solutions also increases as the coefficients reveal themselves to be significant and positive at the 5% level in two models. This finding is consistent with the previous literature on the impact of economies of scale on the introduction of financial technology support solutions (Pytkowska and Korynski, 2017). A lack of funding resources is one of the barriers that prevents the application of software solutions. For the coefficient of the age of MFIs, a positive but insignificant sign can be observed in both models, which implies that there is no clear effect on the adoption of digital solutions.

Table 4.5: Descriptive statistics of metric variables by the the use of digital solutions

	No		Yes		Total	
	Mean	SD	Mean	SD	Mean	SD
Age	16.92	7.42	21.09	9.44	20.57	9.28
Assets (ln)	15.79	1.96	16.60	1.87	16.50	1.89
DTE	6.01	5.47	4.10	3.90	4.34	4.14
GLP (ln)	15.51	1.94	16.31	2.00	16.21	2.00
Female	0.54	0.18	0.70	0.23	0.68	0.23
ALBGNI	0.73	0.63	0.40	0.50	0.44	0.53
Yield (r)	0.29	0.14	0.25	0.14	0.26	0.14
ROE	-0.08	0.42	0.09	0.24	0.07	0.27
OEA	0.21	0.15	0.18	0.10	0.18	0.11
PAR30	0.12	0.15	0.06	0.12	0.07	0.13
GDPpc (ln)	7.19	0.75	7.74	0.89	7.67	0.89
DOMCRE	30.18	19.35	54.08	26.16	51.12	26.54
Dispute	0.49	0.36	0.75	0.34	0.72	0.35
WOR	0.02	0.03	0.02	0.02	0.02	0.02
Rural	0.59	0.16	0.58	0.28	0.58	0.26
Observations	13		92		105	

Table 4.6: Correlation - imputed data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Age	1.00													
2.Assets (ln)	0.30***	1.00												
3.DTE	0.11***	0.16***	1.00											
4.Female	−0.01	−0.09***	0.00	1.00										
5.ALBGNI	−0.04	0.15***	0.05	−0.28***	1.00									
6.Yield (r)	−0.21***	−0.19***	−0.06*	0.12***	−0.15***	1.00								
7.ROE	0.07**	0.13***	−0.02	0.11***	0.01	−0.01	1.00							
8.OEA	−0.25***	−0.31***	−0.12***	0.14***	−0.16***	0.77***	−0.22***	1.00						
9.GDPpc (ln)	0.17***	0.09***	0.04	−0.07**	−0.25***	0.25***	0.02	0.16***	1.00					
10.DOMCRE	0.05	0.01	0.03	0.27***	−0.13***	−0.23***	0.10***	−0.17***	0.18***	1.00				
11.Dispute	0.17***	0.10***	0.07**	0.05*	−0.19***	0.09***	0.01	0.08**	0.34***	−0.06**	1.00			
12.PAR30	0.01	−0.08**	−0.06**	−0.26***	0.01	−0.02	−0.12***	0.09***	0.02	−0.13***	0.00	1.00		
13.WOR	−0.07**	−0.01	−0.02	−0.03	−0.04	0.32***	−0.13***	0.29***	0.13***	−0.07*	0.06*	0.11***	1.00	
14.Rural	−0.01	−0.05	0.02	0.17***	−0.11***	−0.16***	0.06*	−0.14***	−0.16***	0.14***	−0.14***	−0.07**	−0.09***	1.00

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The regression results in columns (2) and (4) show that our hypothesis related to the correlation between the social performance of MFIs and the adoption of digital solutions (H1) is supported. First, the significance and positive sign of the coefficients suggest that MFIs that focus on lending to women tend to integrate digital solutions into their business. One possible interpretation for the significant relationship between the percentage of female borrowers and the likelihood of adopting digital solutions may be attributed to the explicit social orientation of the microfinance sector. Although microfinance is considered as an effective tool in poverty alleviation (Quinones and Remenyi, 2014), the impact on women empowerment or higher income still remains unclear (Brau and Woller, 2004, Banerjee et al., 2015). Therefore, a new approach to microfinance business model which can create more benefits for female customers is necessary. Under these circumstances, digital technology can serve as an effective solution that will bring women empowerment. Although the effects of the average loan balance prove to be insignificant, the negative sign of coefficients provides no evidence of the mission drift of MFIs related to the application of digital solutions. Therefore, it is quite clear that those MFIs which strive for better outreach exhibit a higher level of motivation with respect to moving toward the application of IT solutions.

Furthermore, we detect significant evidence of the impact of the yield on gross loan portfolios on an MFI's digital solution adoption. The coefficients remain negative and are significant in both specifications, suggesting that the utilization of digital solutions does not necessarily need to be related to a heavier burden on customers through increasing financial revenues, i.e, a higher interest rate. Despite high upfront costs of implementing digital solutions, we suppose that MFIs are able to handle this problem with the outside source of finance rather than raising interest rate which would, in turn, harm their social goals. According to (Hudon and Traca, 2011), subsidies prove to be an effective outside source of finance that positively influence the efficiency of MFIs. Furthermore, it is empirically evidenced that high interest rates are associated with unsubsidized MFIs in African and Asian (D'Espallier et al., 2013). Hence, we argue that the relationship between low portfolio yield and the adoption of digital software may be linked to the existence of subsidies. Altogether, we can support the argument that MFIs with better social performance tend to utilize digital solutions.

Regarding H2, we only find weak evidence in favor of this hypothesis. The indicated results in regressions (2) and (4) reveal the significant effects of returns at the 10% level. The positive relationship between the variable (ROE) and the MFI's intention of adopting digital solutions implies that MFIs with digital solutions can exhibit higher returns. These outcomes are consistent with our hypothesis H2, which leads us to the conclusion that more profitable MFIs are more likely to adopt digital tools. Next, we discuss the findings concerning the effect of economic development (H3). We find supporting evidence for H3. As illustrated in the model specification (3) and (4), the coefficients of the variable *GDPpc (ln)* possess the

expected positive sign, which validates the assumption that economic development influences the adoption of digital solutions. This provides a sound reason in favor of the argument that a higher level of development provides positive role models to the integration of digital solutions.

Heckman two-stage estimations

As discussed above, our regressions may suffer from the problem of selection bias, which can trigger inconsistent results. This is due to the nature of the survey since MFIs are not obligated to respond to the survey. Those MFIs that are unobservable in our analysis have a negative effect on the error term. Therefore, a Heckman selection model with *Answer* as the binary dependent variable in the selection stage is further employed to overcome this problem. In addition to the explanatory variables included in the main model, namely *Age*, *Assets*, *ALBGNI*, and type of MFIs, we further include two macroeconomic variables, which control for the country-level effects, i.e., *DOMCRE* and *Dispute* (see Table 4.1).

As shown in column (5), the results confirm our hypotheses related findings with the level of significance largely remaining unchanged. We observe a slight change to 10% in the significance of the coefficient for the variable of the percentage of female borrowers. However, the sign of the correlation remains positive. Furthermore, we find our prediction on the difference in the response rate among types of MFIs to be true. To be more specific, we depict a strong and positive association between MFIs of the type NGO and the likelihood of participating in the survey. Moreover, there is no relationship between the percentage of domestic credit to GDP and the possibility of a response.

Robustness checks

To test for the strength and validity of our results, we further conduct several robustness tests by modifying the specification of the regressions (see Table 4.8) and by employing different measures for digital solutions (see Table 4.13). First, the results illustrated in Table 4.8 show slight differences. To be more specific, we examine the robustness of the models in the absence of the variable *Female* (model specification (2) and (5)). In comparison with our baseline models (model specification (1) and (4)), it is interesting to observe the negative and significant relationship between *ALBGNI* and the introduction of digital solutions, which means the lower the average loan balance the higher the probability of introducing digital solutions. Since both of these variables are good proxies for an MFI's social performance, this observation again supports the hypothesis H1. Furthermore, the robustness tests display a significant and negative relation between portfolio yields and an MFI's adoption of digital supporting solutions, confirming the argument that MFIs can utilize digital solutions while keeping low interest rates.

Table 4.7: Estimation results

	Probit model				Heckman model	
	(1)	(2)	(3)	(4)	(5)	
					Digital	Answer
Age	0.014			0.000	−0.001	0.002
	(0.022)			(0.025)	(0.003)	(0.006)
Assets (ln)	0.236**			0.342**	0.028	0.025
	(0.099)			(0.139)	(0.017)	(0.030)
DTE	−0.065*			−0.120***	−0.019**	
	(0.036)			(0.034)	(0.008)	
ALBGNI		−0.378		−0.391	−0.064	−0.102
		(0.240)		(0.308)	(0.058)	(0.080)
Female		1.624**		2.654***	0.295*	
		(0.739)		(0.939)	(0.155)	
Yield (r)		−3.246**		−4.908***	−0.659***	
		(1.325)		(1.454)	(0.238)	
ROE		2.045*		1.726*	0.238*	
		(1.068)		(1.024)	(0.127)	
GDPpc (ln)			0.376*	0.551**	0.084**	
			(0.193)	(0.262)	(0.043)	
Donations	−0.301	−0.137	−0.147	0.409	0.000	
	(0.360)	(0.364)	(0.408)	(0.469)	(0.064)	
WOR	−5.134	12.734	−6.369	15.680*	1.468	
	(6.501)	(10.248)	(6.577)	(8.285)	(1.271)	
Rural	0.057	−0.085	−0.036	0.256	0.022	
	(0.586)	(0.531)	(0.557)	(0.660)	(0.086)	
MFI type						
Credit Union/Cooperative	0.900	1.070*	0.425	2.246***	0.267*	0.167
	(0.708)	(0.605)	(0.650)	(0.832)	(0.161)	(0.234)
NBFI	0.772	0.834	0.679	1.459**	0.281**	0.243
	(0.523)	(0.512)	(0.484)	(0.611)	(0.123)	(0.186)
NGO	1.455**	1.184**	1.190**	1.617**	0.351***	0.602***
	(0.567)	(0.573)	(0.546)	(0.720)	(0.134)	(0.199)
DOMCRE						−0.003
						(0.002)
Dispute						−0.343**
						(0.159)
Diamonds						
Low						0.331*
						(0.184)
High						0.384**
						(0.181)
Observations	105	105	105	105	105	984
Pseudo R^2	0.180	0.232	0.135	0.384		

Model specifications (1)-(4) are probit model with *Digital* as dependent variable. Model (5) presents the results of Heckman estimations with *Answer* and *Digital* being dependent variables in the first and second stage of the Heckman model, respectively. Variables are defined in Table 4.1.

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

These findings confirm our evidence concerning the relationship between an MFI's social performance and the adoption of digital tools (H1). To investigate whether institutions using digital solutions have lower operating expense, we additionally run estimations for which *OEA* is added as an explanatory variable (model specification (3) and (6)). The coefficients of interest show negative signs that are significant at the 5% level, suggesting that MFIs that are good at controlling their expenses tend to engage more frequently in digital solutions.

Second, we use two alternative digital solutions proxies, namely the variables *Apps* and *Software* (see Table 4.1 for detailed definitions). Descriptive statistics through the use of Apps and Smartphones are provided in Table 4.9 through Table 4.12. The regression results are shown in the Table 4.13. Indeed, we find no significant changes in the relationship between the variable *Female* and our dependent variables. In other words, MFIs with better social performance are more likely to be involved in the use of digital tools, confirming the robustness of our results when using different measures for digital solutions. Furthermore, the results illustrate the absence of significant coefficients among the variables *ROE*, *Yield* and *GDPpc (ln)* and the two dependent variables of interest. One possible explanation for this is that in the case of more advanced digitized products such as apps/software for tablets or smartphones in the fields, performance risks or the resources for the adoption becomes less important (Kim et al., 2017).

4.5   Conclusion

Although the remarkable innovation in digitizing microfinance as a whole and its important role in financial inclusion are increasingly gaining the attention of scholars and policymakers, this area of research appears to remain under-documented. The purpose of the article is to unveil the global trends regarding the adoption of digital solutions in the microfinance sector and to understand the internal engines that motivate MFIs toward digitization. We have considered the linkage between the social performance of an MFI and its introduction of digital solutions. We have also investigated the role of an MFI's profitability, measured by return on equity, in the digitization of the microfinance industry. Additionally, we have seen how the level of economic development of the specific country can have an influence on the digital transformation of an MFI. By utilizing the results from the Yapu Solutions survey and the probit regression technique, we find that the adoption of digital tools is positively related to the social performance of an MFI. In particular, the number of female borrowers and the real yield on gross loan portfolio manifest a significant correlation with the integration of digital tools. Moreover, our findings regarding the profitability of MFIs support the argument that performing digital solutions is a costly process that poses a need for financial sustainability. Our investigation provides no evidence to support a mission drift of MFIs, i.e., the

Table 4.8: Robustness tests for *Digital solutions*

| | Probit model | | | Heckman model | | | | | |
| | (1) | (2) | (3) | (4) | | (5) | | (6) | |
				Digital	Answer	Digital	Answer	Digital	Answer
Age	0.000	0.002	0.003	−0.001	0.002	−0.001	0.003	−0.001	0.002
	(0.025)	(0.023)	(0.024)	(0.003)	(0.006)	(0.003)	(0.006)	(0.003)	(0.006)
Assets (ln)	0.342**	0.290**	0.300**	0.028	0.025	0.033*	0.026	0.028	0.026
	(0.139)	(0.121)	(0.133)	(0.017)	(0.030)	(0.018)	(0.030)	(0.018)	(0.030)
DTE	−0.120***	−0.096***	−0.091**	−0.019**		−0.018**		−0.017*	
	(0.034)	(0.037)	(0.037)	(0.008)		(0.008)		(0.009)	
ALBGNI	−0.391	−0.621**	−0.284	−0.064	−0.102	−0.118*	−0.106	−0.054	−0.101
	(0.308)	(0.290)	(0.296)	(0.058)	(0.080)	(0.064)	(0.081)	(0.059)	(0.080)
Female	2.654***		2.420**	0.295*				0.319**	
	(0.939)		(0.945)	(0.155)				(0.153)	
Yield (r)	−4.908***	−3.928***		−0.659***		−0.621**			
	(1.454)	(1.444)		(0.238)		(0.243)			
OEA			−4.456**					−0.662**	
			(2.197)					(0.287)	
ROE	1.726*	1.570*	0.527	0.238*		0.281**		0.120	
	(1.024)	(0.831)	(0.726)	(0.127)		(0.116)		(0.112)	
GDPpc (ln)	0.551**	0.363	0.503*	0.084**		0.049		0.080*	
	(0.262)	(0.225)	(0.268)	(0.043)		(0.036)		(0.044)	
Donations	0.409	0.220	0.276	0.000		−0.021		0.001	
	(0.469)	(0.403)	(0.484)	(0.064)		(0.062)		(0.067)	
WOR	15.680*	10.327	11.907	1.468		1.194		1.341	
	(8.285)	(6.728)	(8.921)	(1.271)		(1.208)		(1.252)	
Rural	0.256	0.159	0.288	0.022		0.019		0.026	
	(0.660)	(0.637)	(0.608)	(0.086)		(0.092)		(0.088)	
MFI Type									
Credit Union/Cooperative	2.246***	1.503**	1.905**	0.267*	0.167	0.215	0.164	0.251	0.168
	(0.832)	(0.649)	(0.836)	(0.161)	(0.234)	(0.159)	(0.235)	(0.169)	(0.234)
NBFI	1.459**	1.248**	1.177**	0.281**	0.243	0.268**	0.243	0.254**	0.244
	(0.611)	(0.544)	(0.530)	(0.123)	(0.186)	(0.131)	(0.187)	(0.125)	(0.186)
NGO	1.617**	1.564**	1.491**	0.351***	0.602***	0.368**	0.607***	0.341**	0.605***
	(0.720)	(0.673)	(0.636)	(0.134)	(0.199)	(0.144)	(0.199)	(0.134)	(0.199)
DOMCRE					−0.003		−0.004*		−0.003
					(0.002)		(0.002)		(0.002)
Dispute					−0.343**		−0.356**		−0.338**
					(0.159)		(0.159)		(0.159)
Diamonds									
Low					0.331*		0.325*		0.324*
					(0.184)		(0.182)		(0.186)
High					0.384**		0.380**		0.376**
					(0.181)		(0.179)		(0.183)
Observations	105	105	105	105	984	105	984	105	984
Pseudo R^2	0.384	0.316	0.332						

Variables are defined in Table 4.1.
Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4.9: Frequency table by the use of Apps

	No		Yes		Total	
	Obs	%	Obs	%	Obs	%
Region						
Africa and MENA	16	27.59	7	14.89	23	21.90
EAP	7	12.07	8	17.02	15	14.29
EECA	9	15.52	4	8.51	13	12.38
LAC	18	31.03	16	34.04	34	32.38
South Asia	8	13.79	12	25.53	20	19.05
Type						
Bank and others	6	10.34	4	8.51	10	9.52
Credit Union/Cooperative	7	12.07	3	6.38	10	9.52
NBFI	19	32.76	16	34.04	35	33.33
NGO	26	44.83	24	51.06	50	47.62
Diamonds						
Unrated	7	12.07	1	2.13	8	7.62
Low	23	39.66	15	31.91	38	36.19
High	28	48.28	31	65.96	59	56.19
N	58		47		105	

Table 4.10: Frequency table by the use of Software

	No		Yes		Total	
	Obs	%	Obs	%	Obs	%
Region						
Africa and MENA	17	23.94	6	17.65	23	21.90
EAP	11	15.49	4	11.76	15	14.29
EECA	10	14.08	3	8.82	13	12.38
LAC	23	32.39	11	32.35	34	32.38
South Asia	10	14.08	10	29.41	20	19.05
Type						
Bank and others	7	9.86	3	8.82	10	9.52
Credit Union/Cooperative	8	11.27	2	5.88	10	9.52
NBFI	24	33.80	11	32.35	35	33.33
NGO	32	45.07	18	52.94	50	47.62
Diamonds						
Unrated	7	9.86	1	2.94	8	7.62
Low	27	38.03	11	32.35	38	36.19
High	37	52.11	22	64.71	59	56.19
N	71		34		105	

Table 4.11: Descriptive statistics of metric variables by the use of Apps

	No		Yes		Total	
	Mean	SD	Mean	SD	Mean	SD
Age	18.55	8.50	23.06	9.69	20.57	9.28
Assets (ln)	15.76	1.57	17.42	1.86	16.50	1.89
DTE	4.18	4.32	4.53	3.94	4.34	4.14
Female	0.61	0.23	0.76	0.20	0.68	0.23
ALBGNI	0.53	0.62	0.32	0.36	0.44	0.53
Yield (r)	0.25	0.13	0.27	0.16	0.26	0.14
OEA	0.18	0.11	0.18	0.11	0.18	0.11
ROE	0.03	0.24	0.12	0.30	0.07	0.27
GDPpc (ln)	7.55	0.95	7.82	0.79	7.67	0.89
DOMCRE	46.96	26.75	56.26	25.65	51.12	26.54
Dispute	0.69	0.35	0.75	0.36	0.72	0.35
WOR	0.02	0.03	0.02	0.02	0.02	0.02
Rural	0.58	0.26	0.58	0.27	0.58	0.26
Observations	58		47		105	

Table 4.12: Descriptive statistics of metric variables by the use of Software

	No		Yes		Total	
	Mean	SD	Mean	SD	Mean	SD
Age	19.46	9.07	22.88	9.44	20.57	9.28
Assets (ln)	16.10	1.73	17.34	1.96	16.50	1.89
DTE	4.48	4.71	4.03	2.59	4.34	4.14
Female	0.63	0.23	0.77	0.20	0.68	0.23
ALBGNI	0.48	0.57	0.34	0.40	0.44	0.53
Yield (r)	0.25	0.14	0.26	0.16	0.26	0.14
OEA	0.18	0.11	0.18	0.11	0.18	0.11
ROE	0.06	0.30	0.09	0.20	0.07	0.27
GDPpc (ln)	7.63	0.92	7.76	0.84	7.67	0.89
DOMCRE	48.91	27.33	55.74	24.57	51.12	26.54
Dispute	0.70	0.36	0.76	0.33	0.72	0.35
WOR	0.02	0.03	0.02	0.02	0.02	0.02
Rural	0.59	0.25	0.57	0.29	0.58	0.26
Observations	71		34		105	

Table 4.13: Robustness checks: Analyzing with different measures of Digital Solutions

	Probit model				Heckman model			
	(1)	(2)	(3)	(4)	(5)		(6)	
Dependent variable	Apps		Software		Apps	Answer	Software	Answer
Age	0.014	0.016	0.003	0.003	0.004	0.002	0.000	0.002
	(0.020)	(0.018)	(0.019)	(0.018)	(0.006)	(0.006)	(0.006)	(0.006)
Assets (ln)	0.526***	0.481***	0.296***	0.299***	0.117***	0.024	0.086***	0.025
	(0.110)	(0.099)	(0.085)	(0.083)	(0.022)	(0.030)	(0.023)	(0.030)
DTE	−0.002	0.026	−0.037	−0.021	0.002		−0.009	
	(0.038)	(0.036)	(0.034)	(0.032)	(0.011)		(0.009)	
ALBGNI	−0.454	−0.954**	−0.147	−0.505	−0.112	−0.092	−0.047	−0.091
	(0.315)	(0.403)	(0.311)	(0.340)	(0.086)	(0.078)	(0.091)	(0.077)
Female	2.588***		1.954**		0.705***		0.577***	
	(0.779)		(0.791)		(0.197)		(0.217)	
Yield (r)	1.850	1.609	0.552	0.571	0.337		0.172	
	(1.291)	(1.219)	(1.036)	(1.050)	(0.274)		(0.319)	
ROE	−0.209	0.196	−0.482	−0.244	−0.027		−0.148	
	(0.561)	(0.547)	(0.518)	(0.507)	(0.155)		(0.165)	
GDPpc (ln)	0.105	−0.151	0.026	−0.175	0.058		0.021	
	(0.215)	(0.183)	(0.205)	(0.180)	(0.055)		(0.057)	
Donations	0.420	0.259	0.040	−0.091	0.134		0.025	
	(0.365)	(0.329)	(0.337)	(0.317)	(0.096)		(0.103)	
PAR30	−0.019	−1.048	−0.474	−1.290	−0.050		−0.041	
	(1.436)	(1.674)	(1.464)	(1.770)	(0.293)		(0.282)	
WOR	−4.048	−4.082	−0.428	−1.933	−0.786		−0.431	
	(7.416)	(6.429)	(5.984)	(5.813)	(1.722)		(1.750)	
Rural	−0.510	−0.516	−0.464	−0.476	−0.057		−0.095	
	(0.591)	(0.587)	(0.546)	(0.544)	(0.168)		(0.172)	
MFI Type								
Credit Union/Cooperative	0.991	0.542	0.384	0.130	0.260	0.166	0.172	0.171
	(0.774)	(0.769)	(0.714)	(0.706)	(0.188)	(0.231)	(0.175)	(0.232)
NBFI	0.380	0.218	0.226	0.096	0.097	0.242	0.065	0.249
	(0.569)	(0.579)	(0.559)	(0.553)	(0.159)	(0.184)	(0.158)	(0.185)
NGO	0.181	0.190	0.299	0.322	−0.042	0.604***	0.054	0.610***
	(0.599)	(0.612)	(0.583)	(0.585)	(0.182)	(0.195)	(0.195)	(0.198)
DOMCRE						−0.003		−0.003
						(0.002)		(0.002)
Dispute						−0.265*		−0.269*
						(0.149)		(0.156)
Diamonds								
Low						0.305		0.303
						(0.188)		(0.199)
High						0.389**		0.363*
						(0.185)		(0.191)
Observations	105	105	105	105	105	984	105	984
Pseudo R^2	0.337	0.278	0.178	0.136				

Variables are defined in Table 4.1.

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

action of increasing profit through the rise in lending rate in order to finance for the digital transformation process. Furthermore, our analysis places a new emphasis on the impact of the growth of the economic health on an MFI's engagement in digital applications. Our findings are further confirmed by estimation results obtained from Heckman regression.

As our article provides one of the very first insights into the decision of integrating digital solutions into the core business and service delivery of MFIs, we hope that future research will dedicate more efforts to stimulating and supporting the eradication of poverty and financial inclusion through the evolvement of microfinance digitization. To add to this, potential research should employ panel data to account for the continuing impact of digital evolution and the increasing change in the microfinance sector. Since we are only able to consider the influence from the supply-side, the demand-side drivers should also be taken into account, because striving for better outreach to customers remains one of the key pillars in the performance of MFIs.

Acknowledgments

4.A Appendix: Rural lending and IT solutions survey

Here we display those original questions and answer options of the employed questionnaire that are related to the variable *Digital solutions*.

Digital solutions

"By digital solutions we mean any software support that contributes to digitalise the processes and/or activities of your financial institution: collection of client's information, credit assessment, credit management, monitoring, reporting, etc. Examples are dedicated software solutions for desktop computers, Apps for tablets or smartphones, etc.

...

Does your institution use any digital support solutions for data collection, analysis, reporting on lending activities? (multiple answers are possible)

- No

- Yes, desktop: excel

- Yes, specialized desktop software (not excel)

- Yes, software/App. for tablets or smartphone in the field

- Yes, tablets in the field

- Yes, smart phones in the field

- Other (please specify)"

Chapter 5

Mobile money for women's economic empowerment: The mediating role of financial management practices

This chapter is based on a joint work with Gregor Dorfleitner. The paper has been submitted to the *Journal of Banking and Finance*.

Abstract: This article examines whether mobile money adoption contributes to women's economic empowerment, and considers the mediating effect of financial management behavior. Cross-sectional data analysis is conducted utilizing a sample of women in seven countries across South Asia and Sub-Saharan Africa. We also investigate whether these effects vary between rural and urban areas. Three measures of mobile money adoption are considered to reflect the process of engaging in mobile money services. We find supportive evidence for the impact of mobile money adoption on women's economic empowerment and the influencing mechanism of financial management behavior for the whole sample and the rural sub-sample. Moreover, the results are consistent for three alternative measures of mobile money adoption. Our findings suggest that mobile money can be harnessed to promote women's economic empowerment; however, the impact appears to be greater if women are equipped with proper financial management skills.

5.1   Introduction

Financial inclusion, particularly digital financial services, is known to foster an increase in women's income and helps to reduce poverty, which are important elements for women's economic empowerment (Hendriks, 2019). However, approximately 1.7 billion people are reported to be unbanked (Demirgüç-Kunt et al., 2018), which poses several challenges to sustainable development. Furthermore, women account for 56% of the unbanked population and are over-represented in some countries, such as China, Bangladesh and India. With the penetration of cell phones and the Internet, mobile-enabled financial services have been perceived as one of the most important engines for further financial inclusion and the flourishing of social development.

Mobile money is a modern innovation which utilizes mobile phones to deliver financial services and has evolved dramatically in recent years. Starting with the successful launch of M-Pesa in Kenya in 2007, the mobile money industry is now actively engaged in by more than one billion registered mobile money accounts and 750 operators in 95 countries, with the total value of transactions being nearly \$2 billion a day (GSMA, 2019). Mobile money has opened up a huge opportunity to access financial services for unbanked communities and people who live in remote and rural areas, where a very few or no bank branches or other formal financial institutions are available.

Mobile money shows its importance in several aspects. Despite remarkable achievements of the financial system, progress towards sustainable development seems to be hindered in some countries due to the insufficient financial inclusion of women. Inequality in access to finance remains severe in developing economies, since the percentage of women owning an account is reported to be 9% less than that of men (Demirgüç-Kunt et al., 2018). Closing this financial gap is important, as a greater financial inclusion of women will contribute substantially to positive changes in their financial health, such as increased income, a higher purchasing power and better business opportunities (Siddik et al., 2017, Hendriks, 2019). The impact of access to finance on women's empowerment, however, depends on the question of how effective and sustainable financial services are (Kabeer, 2001). Mobile money can be an innovative and efficient model for delivering financial services with several desirable benefits such as convenience, low costs and security (Donovan, 2012). Therefore, mobile money appears to be a crucial enabler for enhancing women's ability to make life-determining financial decisions. Additionally, a positive change in financial behavior due to the usage of mobile-based financial services is another advantage of mobile money. According to Ouma et al. (2017) individuals tend to save more and with higher values when they use mobile money. The significant association between better financial management behavior and greater financial access is also documented in the study of Birkenmaier and Fu (2019).

The existing body of literature provides a wide range of qualitative and quantitative analyses on mobile money services, financial management behavior and women's economic empowerment aligned with financial inclusion. The linkages among these three topics have been considered in a number of academic papers that draw some reasonable conclusions regarding their influence on each other (Donovan, 2012, Buvinić and Furst-Nichols, 2016, Yen and Wu, 2016, Dorfleitner et al., 2019a). However, those studies do not investigate the impact of mobile money on women's economic empowerment through the influencing mechanism of financial management practices. [1] Furthermore, the dominance of single-country-level studies and M-Pesa case-study analyses in the literature creates a demand for more comprehensive studies regarding broader aspects. Our study, to the authors' knowledge, provides the first empirical evidence to tackle these issues.

The emphasis of the current paper is to investigate how the adoption of mobile money helps empower women economically and how financial management practices mediate this relationship. For this purpose, we run several regressions for a sample of women in seven developing countries whose total inhabitants account for more than one-fourth of the global population. Three measures of mobile money adoption are employed to capture the more restricted definitions, namely, mobile money user, mobile money account owner and active mobile money account owner. For robustness checks, we further conduct regressions on rural and urban sub-samples, as previous literature on mobile financial services indicates different results between the two areas (Jack and Suri, 2011, Lyons et al., 2020b). In addition, models with an appropriate instrumental variable are estimated to avoid the potential problem of endogeneity.

The main findings of our paper show that the use of mobile money can promote women's economic empowerment. Moreover, better financial management practices contribute to explaining this linkage as the mediating effect. The results hold for all measures of mobile money adoption. Regarding our robustness tests, the obtained results indicate significant differences between rural and urban areas. While the effects of mobile money on women's financial empowerment remain positive in the case of rural women, these effects turn out to be insignificant when considering the sub-sample of urban women. However, the sign and significance of the coefficients between financial management behavior and women's economic empowerment do not vary across sub-samples.

The remainder of this article is organized as follows: Section 2 reviews the related literature and develops our hypotheses. Section 3 describes the data sample, methodologies and detailed variables, while section 4 reports descriptive analysis and empirical results. A brief conclusion is presented in section 5, along with several suggestions for future studies.

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[1]In this study, the terms "financial management behavior" and "financial management practices" are interchangeable.

5.2   Literature

Mobile money refers to the application of mobile phones in delivering financial services, which allows users to store or transfer money, make a payment, withdraw cash at legal physical agents and to access other possible financial services. While mobile banking services facilitated by traditional banks have undergone a long path of growth, mobile money has recently emerged extensively as a new alternative to deliver financial services for unbanked segments. Mobile money is different from mobile banking in the way that it can be offered by a network of mobile money agents and/or their partners. For example, M-Pesa, which offers flagship microfinancing services through mobile phones, was established in 2007 with the cooperation of two famous mobile network agents in Kenya, namely, Vodafone and Safaricom (Morawczynski, 2009). In this case, a bank account is not a mandatory prerequisite since money is stored in a digital account operated through a mobile phone account. Another model of mobile money highlights the partnership between banks and mobile money operators to launch a mobile money business (Weber and Darbellay, 2010). For this service, the electronic money account linked to a bank account is accessible through mobile telephones.

Mobile money is an innovative financial model for the poor and the unbanked to overcome the problem of access to affordable and sustainable financial services, especially for those who are living in regions where bank exclusion remains persistent (Donovan, 2012). Due to their lack of creditworthiness and low collateral, financially disadvantaged groups of people have borrowed mainly from the informal financial sector to complement their exhausted internal sources of finance, which are commonly unreliable, uncertain and high cost. Some examples of informal finance are pawnbrokers, private moneylenders, rotating savings and credit associations.

According to data from Demirgüç-Kunt et al. (2018), mobile money is increasingly prevalent, especially in countries with a low level of financial accessibility. A possible explanation could be that mobile money agents are relatively easier and more convenient to access, and hence this financial service is more likely to attract customers. By 2019, the number of mobile money agents was 20 and seven times more than that of bank branches and ATMs (GSMA, 2019). As suggested in the previous literature on mobile financial services, the customer's perception of ease of use is one of the key determinants in the adoption decision Lee et al. (2012). Thus, the rapid growth of mobile money possibly lies in its simple operational mechanism through mobile network agents. Customers need only a basic mobile phone with an active SIM card in order to use mobile money services. In addition, the lower cost of mobile money services' usage in comparison with other alternatives could be another reason why individuals are keen on mobile money (Donovan, 2012). Lastly, mobile money services appear to be more secure and safer than cash finance (Suri,

2017).

Various aspects of mobile money have been extensively investigated in the literature. One of the important strands of research is the determinant of mobile money adoption. While some studies highlight the importance of supportive regulations for the telecommunications sector and market conditions (Lashitew et al., 2019), socio-demographic characteristics, such as gender, education level and income, are also shown to influence the adoption of mobile money (Amoah et al., 2020). Furthermore, some factors associated with the development of mobile money services have been examined extensively. Della Peruta (2018) and Rewilak (2017) argue that countries with low access to formal financial services exhibit more mobile money evolvement. Donovan (2012) and Weber and Darbellay (2010) suggest that a proper regulation system and adequate policies can support mobile money deployment. Benefits accompanying the adoption of mobile money have also been of interest to scholars. The clearest impacts are the improvements of livelihood and poverty reduction (Kikulwe et al., 2014, Suri, 2017). Better shock management is another highlight that has emerged from mobile money adoption (Jack and Suri, 2011, Afawubo et al., 2020). To be more specific, households with access to mobile money services are less likely to be vulnerable to shock events like droughts and floods than those without such access.

The above review demonstrates that mobile money can be an important financial tool to accelerate financial inclusion, and thus helps to achieve sustainable development. Within the scope of this study, we empirically investigate the impact of mobile money on women's economic empowerment, an area of study which remains sparse in the existing body of literature. Following this, we also explore its influencing channel through financial management practices.

Links between mobile money and women's economic empowerment

Women's empowerment is an important issue as it is one of the main goals to achieve a sustainable development according to the United Nations (2015). [2] The term *empowerment* refers to the process in which individuals become more involved in making decisions (Kabeer, 2005). Accordingly, women are economically empowered if they have control over their resources such as savings, expenditures and business investment (Pereznieto and Taylor, 2014).

The relationship between mobile money and women's economic empowerment has recently been discussed in several scholarly contributions. Buvinić and Furst-Nichols (2016) review several existing studies to determine the factors that promote

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[2]The Sustainable Development Goal 5 is called "Achieve gender equality and empower all women and girls".

women's economic empowerment. The authors conclude that using mobile phones to provide capital in-kind or conduct transactions helps women overcome social constraints and invest in businesses. In another study, Wieser et al. (2019) perform an experimental analysis to examine the impacts of rolling out mobile money agents in the rural region of Northern Uganda. Their findings reveal that the agent rollout helps spread self-employed businesses significantly. Meanwhile, Riley (2019) examines the potential impact of microfinancing through mobile money on female-led microenterprises in Uganda. The author finds that an increase of 15% in profits and 11% in the level of capital results from the microloan disbursement through mobile money accounts instead of cash outs. These outcomes are driven by the privacy and safety of mobile money, which gives women more control over their funds. Likewise, Aker et al. (2016) assert that cash transfer through mobile money increases the intra-household bargaining power of women.

Recent studies show that the gender gap in access to finance remains persistent in most of the countries (Demirgüç-Kunt et al., 2018). However, in some countries such as Kenya and Côte d'Ivoire, where the deployment of mobile money is frequent, the proportion of female mobile money account owners is at least equal to that of males. Thus, it is reasonable to argue that mobile money provides an effective tool to include more women in the financial system, which in turn possibly induces positive impacts on women's welfare and financial health. Among the existing literature on mobile-based financial services, Suri and Jack (2016) is one of the few studies employing panel data at the household level. The findings from their study emphasize the long-run impact of the use of the mobile money system M-Pesa on Kenyan households' financial welfare. Most importantly, the effects are more significant for female heads of household, which implies access to mobile money services lifting women up economically. With the focus on financial inclusion–related projects, Hendriks (2019) summarizes existing evidence to draw lessons on financial inclusion. The author asserts that closing the gender financial gap through the usage of mobile money is a key strategy to empower women. Based on the arguments from the above-mentioned literature, we formulate the following hypothesis:

Hypothesis 1 (H1) *The use of mobile money is positively and significantly linked to women's economic empowerment.*

Mobile money adoption and women's economic empowerment: the mediating effect of financial management practices

Financial management behavior is generally defined as individuals' practices of seriously managing their resources, such as budgeting, saving, spending, manag-

ing risks and investing (Xiao et al., 2009, Dew and Xiao, 2011). The existing body of knowledge recognizes financial knowledge as a crucial determinant for women's empowerment (Bijli, 2012, Johnson et al., 2016). In addition, Robb and Woodyard (2011) present findings that confirm the close relationship between financial knowledge and financial behavior. Thus, it is likely that women equipped with good financial practices and financial knowledge tend to exhibit better economic development. On another note, financial management behavior can have a positive influence on financial inclusion (Birkenmaier and Fu, 2019) and financial well-being (Gutter and Copur, 2011), which subsequently contributes to an enhancement in the economic power of women (Hendriks, 2019). Other studies provide evidence on the importance of financial management behavior in women's socioeconomic status. For instance, financial management skills are shown to be the key driver of women's engagement in business in rural Bangladesh (Afrin et al., 2010). Moreover, Stavins (2021) argues that good financial management practices help individuals prepare for future unwanted economic events, as they can avoid financial distress through these practices. With the focus on working women in Pakistan, Haque and Zulfiqar (2016) conduct a study to investigate how financial attitudes (i.e. financial management, spending tendency, risk attitude and attitudes to financial knowledge) have impacts on the economic empowerment of women. The results show supportive evidence for the argument that there is a positive and significant relationship between these two variables.

Additionally, several studies have indicated that the relationship between access to finance and the economic empowerment of women is possibly affected by the ability to manage financial resources. For example, Suri and Jack (2016) illustrate the positive impact of mobile money on the financial welfare of poor women. The authors further suggest that the ability of financial management rather than the increase of capital results in better financial outcomes for women, conditionally on access to finance. Moving on to the next study, Samineni and Ramesh (2020) examine the relationship between microfinance and the economic enhancement of women in India. Their findings suggest that further management skills and economic activities are necessary for the economic empowerment of women who have access to finance.

Altogether, it can be proposed that the practices of financial management are crucial for the positive change in women's economic power. Furthermore, financial management behavior appears to have a mediating effect on the relationship between mobile money and women's financial empowerment. Therefore, we propose the following hypotheses:

Hypothesis 2 (H2) *Financial management practices are positively associated with women's economic empowerment .*

Hypothesis 3 (H3) *Financial management practices mediate the relationship between mobile money adoption and women's economic empowerment.*

5.3 Data and methodology

5.3.1 Data

The individual cross-sectional data are taken from the 2017 InterMedia Financial Inclusion Insights (FII) survey which was undertaken in seven countries: Bangladesh, India, Kenya, Nigeria, Pakistan, Uganda, and Tanzania. The FII survey has been carried out every year from 2013 to draw meaningful insights about the current stages of financial inclusion in eight South Asian and Sub-Saharan Africa economies. [3] Up to now, six rounds of surveys have been undertaken. However, the countries included in each round are different, to an extent. Although the 2018 FII survey provides the most recent data, we choose the 2017 FII survey for a broader coverage due to seven out of eight countries being included in it instead of only two countries in the 2018 round. To obtain data, face-to-face interviews under close supervision are conducted in the respective local languages or English in each country. The survey samples are selected randomly using a stratified multi-stage design. In each region of each country, the survey data proportionally cover inhabitants aged 15 and older in rural and urban areas. Sampling weights were used to make the sample nationally representative. [4]

The FII survey collects information on various aspects, including the respondent's socio-demographic profile, the adoption and usage of different types of financial services, especially digital financial services (DFS), and the driving factors of and obstacles to financial inclusion, financial behaviors and the individual's well-being. Apart from a few metric variables, such as age, the reported responses are mostly categorical and dummy variables. The survey data are appropriate for this study for the following reasons. Firstly, the total population of participating countries accounts for more than one-fourth of the global population. Secondly, the respondents are selected randomly from all regions of each country; hence, the data set is nationally representative. Thirdly, the survey contains comprehensive information on the usage and adoption of mobile money, which is the main focus of the study. Lastly, the information on respondents' characteristics is rich, which allows us to control for more important variables.

In total, the number of respondents who took part in the 2017 FII survey was 74,346, of which 59,132 people were from South Asia and 15,232 people were from Sub-Saharan Africa. Due to the focus on women, the sample of male respondents is excluded. Furthermore, observations with missing values for relevant variables are dropped. The final sample size is 30,549 observations for seven developing economies across South Asia and Sub-Saharan Africa.

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[3]Indonesia is excluded from the 2017 FII survey.

[4]For more detailed information on the used method as well as the FII program, please visit the website: http://finclusion.org.

5.3.2 Variable construction

Main variables

Women's economic empowerment (*EMP*) is our dependent variable which we observe on an individual level. The women's economic empowerment index contains 10 items related to the decisions of the answering person about income spending and control over financial resources and services (see Table A1 in the Appendix for more detailed information). The scale is constructed by summing up the scores across all items and ranges from 10 to 50. Higher scores mean better women's economic empowerment. Cronbach's alpha test and factor analysis are applied to test for the reliability of the index. The value of Cronbach's alpha indicates the internal consistency of the index ranging from 0 to 1. An acceptable value of alpha is commonly suggested to be higher than 0.5. In our test, the resulting coefficient of alpha is 0.8707, which is relatively reliable.

The main explanatory variable in this paper is the adoption of mobile money. In order to reflect the process of adoption, three measures of mobile money adoption are employed: mobile money (MM) user, MM account owner and active MM account owner. The variable *MM user* takes the value of 1 if the respondent has used mobile money services for financial activities and otherwise 0. Meanwhile, the variable *MM account owner* indicates whether individuals who have an MM account registered in their name or not. If yes, this variable value equals to 1 and otherwise 0. The variable *active MM account owner* with the value of 1 defines those respondents who conduct financial activities using their registered MM account in the past 90 days. Otherwise, its value equals to 0.

To measure the mediator variable, financial management practice (*FMP*), we construct an index based on the idea of Dew and Xiao (2011) on financial management behavior scale. Due to the dependence on the available questions related to financial management practices in the survey, our index includes fewer items than the domains of financial management suggested by Dew and Xiao (2011). Ten items from the survey are adopted to measure the FMP index about the respondent's ability to manage savings, consumption, cash flow and debts (see Table A2 in the Appendix for more detailed information). The values of this scale are an aggregation of the scores of each item ranging from 10 to 50. The higher the scores means the more the involvement of respondents in financial management practices. Similar to the construction of the women's economic empowerment index, Cronbach's alpha test and factor analysis are performed to test the suitability of the index. Although our measure of the financial management behavior index is based on less information, the internal consistency of the index data is acceptable with the Cronbach's alpha value of 0.8623.

Control variables

In this part, we briefly summarize the employed variables and the construction of the index variables. More detailed information is provided in the Table A3 in the Appendix.

The mobile phone usage variable (*Phone usage*) reflects how the respondents use mobile phones to perform specified functions in the past 90 days. The functions used to compute this index include: (1) send or receive a text message; (2) send/receive photo messages; (3) use/browse the Internet; (4) download music, video or games; (5) make a financial transaction; (6) use Facebook, Whatsapp, Twitter, Instagram or another social networking site; (7) take a color picture; and (8) download/use any other mobile application. Each task performed is assigned to the value of 1, otherwise 0. The scale scores range from 0 to 8. The value of α is 0.9083 for Cronbach's alpha test, and factor analysis shows reliable results for the internal consistency.

The financial literacy index is computed to measure the respondent's ability to correctly answer questions related to financial concepts. Each correct answer is assigned to the value of 1, otherwise 0. The respondents were asked about compound interest, inflation and diversification. The final scores for this scale range from 0 to 5. Similar to the other indices, Cronbach's alpha test and factor analysis are conducted to determine for the reliability of this index. The obtained results reveal that the index is internally consistent with $\alpha = 0.5711$, and the results of the factor analysis are suitable.

The control variables related to respondents' socio-demographic profile encompass age, working status, marital status, education level and residential status. Other household characteristics and respondents' information are also included: household head; main income earner; poverty status; smartphone ownership; insurance; perceptions about the future, life and financial situation; shock experience; and the use of bank and non-bank financial services. An additional categorical variable representing the countries in which the respondents live is also included. These variables have been employed in a range of literature in regard to mobile money, for instance Ouma et al. (2017) for Sub-Saharan African countries and Afawubo et al. (2020) for the case of Togo.

5.3.3 Econometric model

To evaluate the impact of mobile money adoption on women's economic empowerment, several OLS regressions are estimated. The basic equation is expressed as follows:

$$EMP_i = \beta_0 + \beta_1 MM_i + \beta_2 X_i + \epsilon_i, \tag{1}$$

where EMP_i represents the women's economic empowerment index for woman i. MM_i refers to one of the measures of the MM adoption, namely, MM user, MM account owner and active MM account owner. The symbol X_i represents a set of control variables, including the respondents' characteristics, financial literacy, and the subjective well-being. ϵ_i is the random error term.

To explore the mediating effect of financial management practices, the following specifications are employed:

$$FMP_i = \alpha_0 + \alpha_1 MM_i + \alpha_2 X_i + \epsilon_i \qquad (2)$$

$$EMP_i = \gamma_0 + \gamma_1 MM_i + \gamma_2 FMP_i + \gamma_3 X_i + \epsilon_i, \qquad (3)$$

where FMP_i represents the financial management practices index for woman i. To investigate whether the linkage between mobile money adoption and women's economic empowerment is mediated by financial management practices, we perform the following steps as described by Baron and Kenny (1986). After performing Model (1), we run a regression with *FMP* being the dependent variable (Model (2)), *MM* being the independent variable and keep a series of control variables as in Model (1). The coefficient α_1 represents the total effect of mobile money adoption on financial management practices. Subsequently, the explained variable in Model (3), i.e. *EMP*, is regressed on the mediating variable *FMP*, the main explanatory variable *MM* and the same set of control variables (Model (3)). The coefficient γ_1 measures the effect of the adoption of mobile money under the influencing mechanism of financial management practices. The coefficient γ_2 measures the impact of *FMP* in this case. In order for a certain degree of the mediating effect (partial mediation) to exist, the coefficients α_1, β_1, γ_1 and γ_2 must be significant. Furthermore, the absolute value of γ_1 must be smaller than that of β_1. In other words, the coefficient of the variable *MM* when paired with the variable *FMP* must be smaller than in the model without the variable *FMP*. If α_1, β_1 and γ_2 are significant, but γ_1 is insignificant, the relationship between mobile money adoption and economic empowerment for women is fully mediated through the variable *FMP* (i.e. full mediation).

5.4 Results

5.4.1 Descriptive analysis

The results in Table 5.1 and Table 5.2 show the frequency of categorical variables by the adoption of MM and the usage of MM by country respectively. Table 5.3

presents the data description for the employed index and metric variable. At first glance, the data in Table 5.1 indicate the dominance of married and rural female residents who have used MM with 56.73% and 63.12%, correspondingly. Married women possibly have more control over their decision-making, and thus engage more in using MM services. Meanwhile, the high usage of MM in rural areas could be due to the low level of access to banking services as previously discussed. The percentages of rural women who own an MM account and are active users also are approximately 1.5 times higher than their non-owner counterparts. In addition, women who own smartphones tend to actively use MM services. One possible reason for this could be that smartphones are more convenient for managing their mobile money account.

As can be seen in Table 5.2, the tendency of using mobile money services varies across countries. While the percentages of women who have used mobile money services are at least higher than 30% in Bangladesh, Uganda, Tanzania and Kenya, these proportions remain low in the rest of the countries, which is lower than 5%. One possible explanation could be the prevalence of mobile money in these countries, as shown in several studies (GSMA, 2019, Demirgüç-Kunt et al., 2018). Furthermore, there are significant differences between the percentages of MM user, MM account owner and active MM account owner in all countries. For example, 84.83% and 57.90% of female respondents in Kenya and Uganda have used MM services, respectively; however, just approximately two-thirds of them have registered for an MM account.

5.4.2   Empirical results

5.4.2.1   Main results

Table 5.4 illustrates the empirical findings on the linkage between mobile money adoption and women's economic empowerment and the mediating effect of financial management practices. The estimation results in model specifications (1), (4) and (7) reveal that all the measures of mobile money adoption have significant and positive impacts on the change in women's economic power. In other words, the deployment of MM proves to empower women economically, no matter in which way the deployment of MM is measured. Our hypothesis 1 on the impacts of MM on women's economic empowerment is therefore supported by the evidence. Furthermore, we observe that employed and well-educated women tend to be involved in economic decision making to a larger extent, as the coefficients are significantly positive. These findings are consistent with a previous study on women's economic empowerment (Kabeer, 2005). As expected, women who are equipped with financial knowledge tend to make their own financial decisions. On the contrary, there is no difference in the decision of using MM between the poor and non-poor

Table 5.1: Frequency table of categorical variables

	MM user		MM account owner		Active MM owner	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**
Married						
No	26.14	43.27	26.74	45.37	26.95	45.90
Yes	73.86	56.73	73.26	54.63	73.05	54.10
Household head						
No	87.74	77.73	87.77	72.60	87.64	71.54
Yes	12.26	22.27	12.23	27.40	12.36	28.46
Main income earner						
No	90.44	74.72	90.33	68.25	90.12	67.10
Yes	9.56	25.28	9.67	31.75	9.88	32.90
Smartphone						
No	92.59	76.92	92.27	72.67	92.18	70.45
Yes	7.41	23.08	7.73	27.33	7.82	29.55
Poverty						
No	37.32	51.44	37.30	58.44	37.31	61.90
Yes	62.68	48.56	62.70	41.56	62.69	38.10
Rural						
No	12.06	36.88	12.98	39.31	13.21	41.05
Yes	87.94	63.12	87.02	60.69	86.79	58.95
Life satisfaction						
No	24.04	31.91	24.23	33.78	24.43	32.90
Yes	75.96	68.09	75.77	66.22	75.57	67.10
Financial satisfaction						
No	33.47	49.58	33.90	52.91	34.25	51.76
Yes	66.53	50.42	66.10	47.09	65.75	48.24
Worry						
No	26.28	35.87	26.40	39.21	26.57	39.29
Yes	73.72	64.13	73.60	60.79	73.43	60.71
Death						
No	92.59	85.40	92.22	85.81	92.12	85.95
Yes	7.41	14.60	7.78	14.19	7.88	14.05
Illness						
No	69.26	45.20	67.97	46.95	67.62	47.68
Yes	30.74	54.80	32.03	53.05	32.38	52.32
Floods						
No	88.06	71.08	87.56	68.11	87.29	68.04
Yes	11.94	28.92	12.44	31.89	12.71	31.96
Insurance						
No	86.74	80.32	86.98	74.80	86.93	73.31
Yes	13.26	19.68	13.02	25.20	13.07	26.69
Bank account owner						
No	43.42	75.04	45.55	68.19	46.03	66.23
Yes	56.58	24.96	54.45	31.81	53.97	33.77
NBFI account owner						
No	91.80	85.85	91.73	83.67	91.70	82.69
Yes	8.20	14.15	8.27	16.33	8.30	17.31
N	26.294	4.255	27.543	3.006	27.957	2.592

Note: All the data reported as percentages are weighted.

Table 5.2: MM usage by country

	Bangladesh	India	Kenya	Nigeria	Pakistan	Tanzania	Uganda	Total
MM user								
No	68.88	98.66	15.17	98.18	95.28	45.31	42.10	86.95
Yes	31.12	1.34	84.83	1.82	4.72	54.69	57.90	13.05
MM account owner								
No	88.93	98.80	30.64	98.09	99.53	53.93	62.65	91.21
Yes	11.07	1.20	69.36	1.91	0.47	46.07	37.35	8.79
Active MM account owner								
No	91.46	98.90	35.27	98.94	99.56	66.81	68.37	92.49
Yes	8.54	1.10	64.73	1.06	0.44	33.19	31.63	7.51
N	2,584	18,940	1,794	2,289	2,298	984	1,660	30,549

Note: All the data reported as percentages have been weighted.

Table 5.3: Descriptive statistics for indices and metric variables

	Mean	S.D.	Min	Median	Max
Age	35.32	14.28	15.00	32.00	100.00
Women's economic empowerment	33.86	8.50	10.00	35.00	50.00
Financial management practices	27.99	8.84	10.00	28.00	50.00
Financial knowledge	1.78	1.44	0.00	2.00	5.00
Mobile phone proficiency	1.02	2.02	0.00	0.00	8.00
Observations	30,549				

women, which is opposed to the argument on the linkage between poverty and the adoption of MM (Wieser et al., 2019).

Regarding the influencing mechanism of financial management practices, we first run the model specification (2), (5) and (8) to investigate the linkage between the practices of financial management and the adoption of MM. The results from our estimations show significant and positive coefficients for different variables representing MM adoption. The positive effect of MM adoption means that the use of mobile money is positively related with the practices of more financial activities such as savings and budget planning. Relevant literature on financial inclusion also considers access to financial services as a driving factor of the engagement in financial management behavior such as the habits of saving or the use of credit. For example, mobile money proves to boost the probability and amount of savings of households in several Sub-Saharan African countries (Ouma et al., 2017). Furthermore, based on the data from Uganda rural households, Munyegera and Matsumoto (2018) investigate whether financial innovation, i.e. mobile money, leads to a change in financial behavior. The results show that mobile money users tend to save and borrow more than their non-user peers. Hence, our findings are in line with findings from previous studies.

Subsequently, estimations which consider the mediating effect of the variable *FMP* are conducted. The results reported in the model specification (3), (6) and (9) provide favorable evidence for our hypothesis 2. We first realize that practices of financial management are positively related with women's economic empowerment, which indicates that better financial management skills are closely connected with the greater roles of women in household finances. This finding shows supportive evidence for the study by Sarban and Hassanzadeh (2014), which affirms that less skilled rural women are constrained to attain economic empowerment.

The main focus of this analysis is the linkage between MM adoption and women's economic empowerment under the influencing channel of financial management behaviors. We find that this relationship remains unchanged since the coefficients on all three measures of MM adoption are positive. In addition to that, the magnitude of the impact of MM adoption is smaller than in the models without the inclusion of *FMP*. This finding supports our hypothesis 3 that financial management practices mediate the impact of MM adoption on women's economic empowerment. In other words, the mediating effect of financial management enhances the explanatory power of mobile money usage on the economic empowerment of women. Indeed, a recent study by Buvinić and O'Donnell (2019) shows that financial services are not gender-neutral and the inclusion of program designs can yield more positive outcomes such as higher decision-making power for women. Supporting women with skill training and technical assistance in accompanied with access to finance is a key point of these program designs.

Table 5.4: Estimation results for the mediation model utilizing different measures of MM adoption

Dependent variable	(1) EMP	(2) FMP	(3) EMP	(4) EMP	(5) FMP	(6) EMP	(7) EMP	(8) FMP	(9) EMP
MM user	1.113***	0.824***	0.883***						
	(0.286)	(0.236)	(0.275)						
MM account owner				1.148***	0.596**	0.982***			
				(0.317)	(0.255)	(0.307)			
Active MM account owner							1.043***	0.548**	0.890***
							(0.329)	(0.228)	(0.326)
FMP			0.279***			0.279***			0.279***
			(0.007)			(0.007)			(0.007)
Age	0.042***	0.036***	0.032***	0.041***	0.036***	0.031***	0.041***	0.036***	0.031***
	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Married	2.874***	1.737***	2.390***	2.866***	1.736***	2.382***	2.868***	1.736***	2.383***
	(0.164)	(0.142)	(0.158)	(0.164)	(0.142)	(0.158)	(0.164)	(0.142)	(0.158)
Household head	2.988***	−0.177	3.038***	2.985***	−0.177	3.034***	2.983***	−0.179	3.033***
	(0.230)	(0.200)	(0.218)	(0.230)	(0.200)	(0.218)	(0.230)	(0.200)	(0.218)
Main income earner	2.840***	0.317	2.751***	2.822***	0.313	2.735***	2.830***	0.316	2.741***
	(0.258)	(0.216)	(0.250)	(0.256)	(0.215)	(0.248)	(0.256)	(0.216)	(0.248)
Work									
Employed, regular salary	0.518**	1.300***	0.155	0.519**	1.307***	0.154	0.520**	1.308***	0.155
	(0.222)	(0.186)	(0.211)	(0.222)	(0.186)	(0.211)	(0.222)	(0.185)	(0.212)
Employed, irregular salary	1.376***	−0.110	1.407***	1.381***	−0.108	1.411***	1.384***	−0.106	1.413***
	(0.208)	(0.198)	(0.203)	(0.208)	(0.198)	(0.203)	(0.208)	(0.198)	(0.204)
Self-employed	2.231***	2.052***	1.658***	2.232***	2.064***	1.656***	2.241***	2.068***	1.663***
	(0.290)	(0.262)	(0.273)	(0.290)	(0.263)	(0.274)	(0.289)	(0.262)	(0.274)
Looking for jobs	−0.482	−0.690	−0.290	−0.494	−0.691	−0.301	−0.501	−0.695	−0.307
	(0.509)	(0.477)	(0.505)	(0.508)	(0.477)	(0.504)	(0.508)	(0.478)	(0.504)
Education									
Primary school	0.599***	1.100***	0.292**	0.601***	1.102***	0.293**	0.600***	1.101***	0.292**
	(0.150)	(0.150)	(0.140)	(0.150)	(0.150)	(0.140)	(0.150)	(0.150)	(0.140)
Secondary school	0.359*	1.801***	−0.143	0.369*	1.811***	−0.136	0.369*	1.810***	−0.137
	(0.189)	(0.173)	(0.177)	(0.190)	(0.173)	(0.177)	(0.189)	(0.172)	(0.177)
Higher education	1.400***	3.008***	0.560*	1.399***	3.013***	0.558*	1.411***	3.019***	0.567**
	(0.303)	(0.305)	(0.289)	(0.303)	(0.305)	(0.289)	(0.303)	(0.305)	(0.289)
Smartphone	1.072***	0.833***	0.839***	1.059***	0.825***	0.829***	1.064***	0.827***	0.833***
	(0.248)	(0.260)	(0.229)	(0.260)	(0.260)	(0.230)	(0.248)	(0.260)	(0.230)
Poverty	−0.198	−0.075	−0.177	−0.192	−0.076	−0.171	−0.195	−0.077	−0.174
	(0.124)	(0.127)	(0.114)	(0.124)	(0.127)	(0.114)	(0.124)	(0.127)	(0.114)
Rural	−0.213	−0.473***	−0.081	−0.225	−0.492***	−0.088	−0.229	−0.494***	−0.091
	(0.181)	(0.175)	(0.170)	(0.181)	(0.174)	(0.170)	(0.181)	(0.174)	(0.170)
Mobile phone proficiency	−0.202***	0.219***	−0.263***	−0.199***	0.227***	−0.263***	−0.198***	0.227***	−0.261***
	(0.037)	(0.037)	(0.035)	(0.037)	(0.037)	(0.035)	(0.038)	(0.037)	(0.035)
Financial knowledge	0.373***	0.497***	0.234***	0.374***	0.498***	0.235***	0.375***	0.499***	0.236***
	(0.043)	(0.041)	(0.042)	(0.043)	(0.041)	(0.042)	(0.043)	(0.041)	(0.042)
Insurance	0.521***	1.408***	0.128	0.515***	1.410***	0.121	0.518***	1.412***	0.124
	(0.200)	(0.158)	(0.192)	(0.199)	(0.158)	(0.192)	(0.199)	(0.158)	(0.191)
Life satisfaction	−0.131	0.910***	−0.385***	−0.130	0.910***	−0.384***	−0.132	0.909***	−0.386***
	(0.141)	(0.139)	(0.137)	(0.141)	(0.139)	(0.137)	(0.141)	(0.139)	(0.137)
Financial satisfaction	−0.524***	2.541***	−1.234***	−0.517***	2.546***	−1.229***	−0.520***	2.545***	−1.231***
	(0.143)	(0.131)	(0.136)	(0.143)	(0.131)	(0.136)	(0.143)	(0.131)	(0.136)
Worry	0.138	−1.278***	0.495***	0.141	−1.275***	0.497***	0.141	−1.275***	0.498***
	(0.130)	(0.121)	(0.125)	(0.130)	(0.121)	(0.125)	(0.130)	(0.121)	(0.125)
Death	−1.029***	0.126	−1.064***	−1.027***	0.134	−1.064***	−1.022***	0.136	−1.060***
	(0.299)	(0.262)	(0.283)	(0.299)	(0.262)	(0.283)	(0.298)	(0.262)	(0.283)
Illness	−0.184	−0.890***	0.064	−0.174	−0.883***	0.072	−0.175	−0.884***	0.072
	(0.140)	(0.130)	(0.134)	(0.140)	(0.130)	(0.134)	(0.139)	(0.130)	(0.134)
Floods	−0.920***	−1.207***	−0.583***	−0.917***	−1.201***	−0.582***	−0.911***	−1.198***	−0.577***
	(0.183)	(0.173)	(0.176)	(0.183)	(0.172)	(0.176)	(0.183)	(0.172)	(0.176)
Bank account owner	1.634***	0.662***	1.449***	1.624***	0.662***	1.440***	1.630***	0.665***	1.444***
	(0.140)	(0.137)	(0.133)	(0.139)	(0.137)	(0.132)	(0.139)	(0.136)	(0.132)
NBFI account owner	1.110***	−0.204	1.168***	1.101***	−0.201	1.157***	1.107***	−0.198	1.162***
	(0.179)	(0.183)	(0.178)	(0.178)	(0.184)	(0.177)	(0.177)	(0.183)	(0.177)
Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549
R^2	0.133	0.134	0.206	0.133	0.134	0.206	0.133	0.134	0.206

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.4.2.2   Robustness checks

Sub-sample rural and urban areas

According to (Rewilak, 2017), mobile money appears to be used more in countries with an underdeveloped financial system or lower income per capita. Therefore, we assume that there can be a significant difference in the tendency to adopt mobile money services between rural and urban areas due to their financial and development gaps. Our study sample is divided into two sub-samples of women by geographical areas, namely, rural and urban sub-samples. For the purpose of simplicity, we report only the results for our main variables: *MM user*, *MM account owner* and *active MM account owner*. All the coefficients of other variables are subtracted from the table of results, but are available upon request.

The empirical findings for the sub-samples are presented in Table 5.5. The results for the rural sub-sample are consistent with our previous findings, which confirms the significance of MM money adoption in women's economic empowerment and the influencing mechanism of financial management behaviors. Meanwhile, observed coefficients of MM adoption are found to be insignificant across model specifications for the case of the urban sub-sample. We find only the supportive evidence for hypothesis 2, which is the impact of financial management behaviors on women's economic empowerment. The lower prevalence of MM in urban areas is a possible explanation for this finding.

Control for endogeneity

It is noteworthy that our regression results may be biased due to a possible reverse causality problem. It could be the case that women who have control over their financial resources also have more chances to access mobile money services than those who are not economically empowered. Similarly, women who exhibit more practices of managing their money might make use of mobile money due to its features of low transaction costs and security. To control the problem of endogeneity, we follow the approach introduced by Lyons et al. (2020b). To be more specific, *time to the nearest bank* is employed as an instrumental variable in several two-stage least square (2SLS) estimations. This variable is an appropriate instrument, since the further away the bank branches are located, the more incentives the respondents have for using an alternative financial service, for example mobile money. The variable time to the nearest bank has five categories: 15 minutes or less; 15-30 minutes; 30-60 minutes; more than 1 hour; and do not know. The based category is "do not know", which indicates that this person does not know the time to the nearest bank. In the first-stage of the 2SLS model, we regress mobile money adoption on the variable *time to the nearest bank*. Subsequently, the observed values are included in the three stated baseline models as the second stage.

Table 5.5: Estimation results for the mediation model utilizing different measures of MM adoption: Rural and urban sup-samples

	Rural			Urban		
Dependent variable	(1) EMP	(2) FMP	(3) EMP	(4) EMP	(5) FMP	(6) EMP
MM user	1.782***	0.782***	1.571***	−0.112	1.060***	−0.472
	(0.358)	(0.291)	(0.345)	(0.446)	(0.385)	(0.417)
FMP			0.269***			0.340***
			(0.007)			(0.018)
R^2	0.122	0.121	0.192	0.235	0.241	0.321
MM account owner	1.934***	1.057***	1.649***	−0.048	−0.459	0.108
	(0.420)	(0.329)	(0.407)	(0.463)	(0.415)	(0.435)
FMP			0.269***			0.340***
			(0.007)			(0.018)
R^2	0.121	0.121	0.191	0.235	0.240	0.321
Active MM account owner	1.896***	1.041***	1.615***	−0.145	−0.494	0.023
	(0.447)	(0.275)	(0.447)	(0.464)	(0.421)	(0.435)
FMP			0.269***			0.339***
			(0.007)			(0.018)
R^2	0.121	0.121	0.191	0.235	0.240	0.321
Observations	25 516	25 516	25 516	5033	5033	5033

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
All the other control variables are also included in the models but skipped to present in the table.

The results are shown in Table 5.6, in which model specifications (4), (8) and (12) present the first-stage regressions by measures of MM adoption. Meanwhile, the remaining model specification reports the impact of MM adoption on women's economic empowerment under the mediating effect of financial management practices. As expected, the instrumental variable –*time to the nearest bank*–has a positive influence on the likelihood of adopting MM. In other words, respondents who live far from bank branches are better motivated to use MM. Furthermore, we also perform control tests for the validity of the instrument. As can be seen, the estimated F-statistics are larger than the minimum commonly accepted value of 10. Accordingly, our instrumental variable does not suffer from the problem of weak statistics. Moreover, the results from the endogeneity tests show that the null hypothesis of having no endogenous problem is rejected. It is worth noting that the results reported in Table 5.6 affirm the reliability of our previous findings.

5.5   Conclusion

Our investigation represents the first study regarding the topics of mobile money providing empirical evidence on the women's empowerment effect of different measures of mobile money adoption and the mediating effect of financial management practices. For this purpose, we conduct a study using cross-sectional data of women in seven countries across South Asia and Sub-Saharan Africa in 2017. Three measures of mobile money adoption are employed to reflect the process of using digital services, ranging from having used MM services to having an actively used personal MM account in the past 90 days. Additionally, to capture the multi-dimensionality of women's economic empowerment and financial management practices, we construct two indices to measure these two variables. To gauge the reliability of the findings, robustness tests for endogeneity and sub-samples of rural and urban areas are also conducted.

The empirical findings from our study confirm the conjecture that the use of digital finance represented by mobile money contributes to the economic empowerment of women. Moreover, financial management practices appear to stimulate economic empowerment and mediate the influence of mobile money adoption. This finding implies that equipping women with financial management skills helps them take the advantage of financial services to gain independence in making financial decisions. It is noteworthy that while the obtained results are significant in the case of the whole sample and the rural women sub-sample, the regression coefficients present no explanatory power in the case of the urban women sub-sample. By analyzing the influence of mobile money adoption and financial management behavior on women's empowerment, we can identify necessary practices and provide enabling environments to improve the role of women in contributing to economic decisions. To this end, trainings of financial management skills are proven to be necessary as

Table 5.6: Results for IV estimations

Dependent variable	MM user				MM account owner				Active MM account owner			
	(1) EMP	(2) FMP	(3) EMP	(4) MM	(5) EMP	(6) FMP	(7) EMP	(8) MM	(9) EMP	(10) FMP	(11) EMP	(12) MM
MM user	3.270***	3.727***	2.233***									
	(0.717)	(0.667)	(0.679)									
MM account owner					3.319***	3.867***	2.241***					
					(0.704)	(0.655)	(0.666)					
Active MM account owner									2.997***	3.357***	2.060***	
									(0.683)	(0.632)	(0.647)	
FMP			0.278***				0.279***				0.279***	
			(0.007)				(0.007)				(0.007)	
IV: Time to the nearest bank												
15 minutes or less				0.287***				0.321***				0.398***
				(0.087)				(0.102)				(0.085)
15-30 minutes				0.226***				0.276***				0.355***
				(0.073)				(0.085)				(0.073)
30-60 minutes				0.178**				0.165*				0.238***
				(0.074)				(0.085)				(0.073)
More than 1 hour				0.073				0.149*				0.175**
				(0.073)				(0.084)				(0.070)
F-test				1114.77				1457.38				1625.00
Observations	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549	30 549
R^2	0.130	0.129	0.205		0.130	0.128	0.205		0.131	0.130	0.205	

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
All models are weighted

an accompaniment of the increasing use of mobile money services.

One of the limitations of our research lies in the employed dataset. The sample data comprise a large number of observations which allows for drawing reliable findings. However, these results only reflect the situation in one specific year. Further research is encouraged to utilize panel data to find more predictive findings rather than the current validity as our study does. In addition, our research focuses solely on the effect of mobile money on women's economic empowerment without considering the impact of other financial services. Last but not least, future studies could consider other aspects of women's empowerment such as social and psychological empowerment. In conclusion, we hope that this analysis partly contributes to this interesting field of research and can serve as a stepping stone for future deeper and broader investigations.

5.A   Appendix: Additional tables

Here we display the questions and answers in the 2017 FII survey related to the construction of the EMP and FMP indices, and detailed definitions of the control variables.

Table A1: Questions and answers used to construct the *EMP* index

Question	Values
In your best estimate, about how much of your households income do you provide each month?	1=None; 2=A little; 3=About half; 4=Most; 5=Almost all; 98=Refused; 99=DK
About how involved or uninvolved are you typically in deciding how to spend your households income?	1=Very uninvolved; 2=Somewhat uninvolved; 3=Neither uninvolved, nor involved; 4=Somewhat involved; 5=Very involved; 98=Refused; 99=DK
About how involved or uninvolved are you typically in deciding how your households income is spent on basic needs like food and clothing?	1=Very uninvolved 2=Somewhat uninvolved; 3=Neither uninvolved, nor involved; 4=Somewhat involved; 5=Very involved; 98=Refused; 99=DK
About how involved or uninvolved are you typically in deciding how your households income is spent on other things beyond basic needs?	1=Very uninvolved 2=Somewhat uninvolved; 3=Neither uninvolved, nor involved; 4=Somewhat involved; 5=Very involved; 98=Refused; 99=DK
If you were to speak your mind on a decision regarding how to spend your households income, about how much influence do you think you would have on the final decision?	1=None; 2=A little; 3=A fair amount; 4=Most; 5=Almost all; 98=Refused; 99=DK
If you happened to disagree with a decision about how your households income is spent, how likely would you be to voice disagreement?	1=Very unlikely; 2=Somewhat unlikely; 3=Neither unlikely, nor likely; 4=Somewhat likely; 5=Very likely; 98=Refused; 99=DK
If you voiced disagreement about a decision about how your households income is spent, how likely do you think it would be to change the final decision?	1=Very unlikely 2=Somewhat unlikely; 3=Neither unlikely, nor likely; 4=Somewhat likely; 5=Very likely; 98=Refused; 99=DK
To what extent do you typically agree or disagree with the final decisions about how your households income is usually spent?	1=Strongly disagree 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree; 98=Refused; 99=DK
To what extent do you agree or disagree with the following statements regarding the money you personally earn or receive? You make the final decision on how your money is spent or saved	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree; 98=Refused; 99=DK
How involved are you in deciding what kind of financial services you use?	1=Very uninvolved; 2=Somewhat uninvolved; 3=Neither uninvolved, nor involved; 4=Somewhat involved; 5=Very involved; 98=Refused; 99=DK
To what extent do you agree with the following statement related to financial service providers? I am concerned that financial service providers may share my personal information with others without my consent	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree; 97=N/A; 98=Refused; 99=DK

Note: Observations with the values of "99", "98", "97" are treated as missing values

Table A2: Questions and answers used to construct the *FMP* index

Question	Value
About how much do you agree or disagree with the following statements when considering your personal financial situation? I have enough money to pay for my living expenses	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I spend less money than I make each month	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I pay my bills on time and in full	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I have an emergency fund that is large enough to cover unplanned expenses	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I am confident that my income will grow in the future	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I earn enough money to pay back debt and also pay for my living expenses	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? Friends and family rely on me to help with their finances	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I have savings or assets that will keep me financially secure in the future	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
About how much do you agree or disagree with the following statements when considering your personal financial situation? I have the skills and knowledge to manage my finances well	1=Strongly disagree; 2=Somewhat disagree; 3=Neither disagree, nor agree; 4=Somewhat agree; 5=Strongly agree
If you had an emergency and urgently needed to pay a sum equal to one year of your income, how likely is it that you could gather sufficient funds?	1=Very unlikely; 2=Somewhat unlikely; 3=Neither unlikely, nor likely; 4=Somewhat likely; 5=Very likely; 99=DK

Note: Observations with the value of "99" are treated as missing values

Table A3: Definitions of the controls variables

Variable	Definition
Age	The number of years that the respondent has lived
Married	Dummy variable refers to the marital status of the respondent. It equals to 1 if the respondent has married and 0, otherwise.
Work status	Categorical variable refers to the employment status of the respondent. Unemployed is the reference category, the other four categories are employed, regular salary; employed, irregular salary; self-employed; and looking for jobs.
Education	Categorical variable indicates the respondent's level of education. There are four groups: no formal education (the based category); primary school; secondary school; and higher education.
Poverty	Dummy variable indicates whether the respondent's household live under the poverty line of $2.5 per day. If yes, it takes the value of 1 and otherwise 0.
Rural	Dummy variable indicate the respondent's residential location. It equals to 1 if the respondent live in rural area. Otherwise, it equals to 0.
Household head	Dummy variable indicates whether the respondent is household head. If yes, it equals to 1 and 0 otherwise.
Main income earner	Dummy variable indicates whether the respondent is the main income earner in the household. If yes, it equals to 1 and 0 otherwise.
Smartphone	Dummy variable indicates whether the respondent has a smartphone or not. If yes, it equals to 1 and 0 otherwise.
Insurance	Dummy variable indicates whether the respondent has insurance. If yes, it equals to 1 and 0 otherwise.
Life satisfaction	Dummy variable indicates whether the respondent satisfies with his life as a whole recent days. It takes the value of 1 if the respondent's answer is "very satisfy" or "somewhat satisfy". It equals to 0 otherwise.
Financial satisfaction	Dummy variable indicates whether the respondent satisfies with his financial situation presently. It takes the value of 1 if the respondent's answer is "very satisfy" or "somewhat satisfy". It equals to 0 otherwise.

(Resumed on next page)

Table A3 – Definitions of controls variables (cont)

Variable	Definition
Worry	Dummy variable indicates whether the respondent is worried about the future. It takes the value of 1 if the respondent's answer is "very worried" or "somewhat worried". It equals to 0 in otherwise.
Death	Dummy variable indicates whether the respondent experiences a shock from the death of a household member in the past 12 months. If yes, it equals to 1 and 0 otherwise.
Illness	Dummy variable indicates whether the respondent experiences a shock from the illness of a household member in the past 12 months. If yes, it equals to 1 and 0 otherwise.
Floods	Dummy variable indicates whether the respondent experiences drought/floods in the past 12 months. If yes, it equals to 1 and 0 otherwise.
Bank account owner	Dummy variable indicates whether the respondent owns a bank account. If yes, it equals to 1 and 0 otherwise.
NBFI account owner	Dummy variable indicates whether the respondent owns an account in a non-bank financial institution (NBFI). If yes, it equals to 1 and 0 otherwise.
Phone proficiency	An index includes 8 items focusing on question about whether the respondent perform several mobile phone functions in the past 90 days. The functions are: (1) send or receive a text message; (2) send/receive photo messages; (3) use/browse the Internet; (4) download music, video or games; (5) made a financial transaction; (6) use Facebook, Whatsapp, Twitter, Instagram or another social networking site; (7) took a color picture; and (8) download/use any other mobile applications. Each item has a score of 1 if the respondent uses the relevant function in the past 90 days, and 0 otherwise. The index scale is a summation of the scores ranging from 0 to 8.
Financial literacy	An index includes five items focusing on the respondent's ability to correctly answer the questions about financial concepts, namely, compound interest, Inflation, and diversification. Each item has a score of 1 if the respondent correctly answers the questions, and 0 otherwise. The index scale is a summation of the number of the scores ranging from 0 to 5. The questions are:

(Resumed on next page)

Table A3 – Definitions of controls variables (cont)

Variable	Definition
	(1) Is it safer to put your money into one business or investment, or to put your money into multiple businesses or investments? The correct answer is "Multiple businesses or investments".
	(2) Suppose over the next 10 years the prices of the things you buy double. If your income also doubles, will you be able to buy less than you can buy today, the same as you can buy today, or more than you can buy today? The correct answer is "The same".
	(3) Suppose you need to borrow 100 units of national currency. Which is the lower amount to pay back: 105 units or 100 units plus 3 percent? The correct answer is "100 units plus 3 percent".
	(4) Suppose you put money in the bank for two years and the bank agrees to add 15 percent per year to your account. Will the bank add more money to your account the second year than it did the first year, or will it add the same amount of money both years? The correct answer is "More".
	(5) Suppose you had 100 units in a savings account and the bank adds 10 percent per year to the account. How much money would you have in the account after five years if you did not remove any money from the account? The correct answer is "More than 150 units".
Country	Categorical variable indicate the country in which the respondent live in. There are seven countries namely Bangladesh, India, Kenya, Nigeria, Pakistan, Uganda, and Tanzania. The reference category is Bangladesh.
Time to the nearest bank	Categorical variable indicates the time that the respondent has to travel to reach the nearest bank branch. There are five categories: 15 minutes or less; 15-30 minutes; 30-60 minutes; more than 1 hour; and do not know. The reference category is "do not know".

Chapter 6

Conclusion

In conclusion, this doctoral thesis contributes to the improvement of knowledge on new approaches to inclusive financing. The main focus is on digital and green energy finance which are empirically investigated throughout four research papers comprising this dissertation.

The first paper provides an empirical investigation on the provision of MFS by microfinance service providers. The findings illustrate that the integration of mobile technology is not relevant to the trade-off between the social and financial mission of MFIs, as increased probability of MFS provision is associated with a high rate of financial expenditure but does not appear synonymous with having simultaneously low social performance. Furthermore, the results from this research project show that several MFI-specific characteristics, namely maturity, legal status and size, have significant impacts on the probability of offering MFS. The second analysis illustrates the driving factors of green energy lending by MFIs. We find evidence that the MFI's maturity and borrower retention rate are identified as crucial determinants towards the involvement in green energy lending. Furthermore, the analysis highlights the relationship between the MFI's green energy loan provision and the level of its country's development. The findings obtained about the certain MFI's characteristics contribute to the materialization of necessary practices which support the dissemination of green energy system financed with microcredit. The third examination focuses on the MFI's motives for digitalization and highlights the positive link between the MFI's social performance and profitability, suggesting that digital solutions do not necessarily foster mission drift. We also identify that the prevalence of digital solution adoption is associated with the country's economic development. In addition, the findings for alternative measures of digital solutions show supportive evidence for the associations with the MFI's social performance. The fourth study provides quantitative evidence on the linkages between the practices of financial management, the usage of mobile money and the economic empowerment of women. The findings show that the practices

of financial management meditate the effects of various measures of MM adoption on women's economic empowerment. Additionally, we find that the results vary across sub-samples of rural and urban areas, in which the former reveals several significant and positive coefficients supporting the findings from the whole sample.

In summary, this dissertation provides empirical evidence on different approaches to financial inclusion with particular emphasis on the implementation of mobile-based financial services, digital tools and green energy microcredit. Regarding the introduction of technology-based financial services, the studies in this doctoral thesis reveal the high relevance of social objectives and do not identify any detrimental effects from financial performance. As the involvement in green energy finance for the poor requires a certain level of MFI's business sustainability, advanced technology in finance can help meet this requirement in the long run. Identifying certain microfinance-specific characteristics that exhibit significant impacts on the implementation of these initiatives can smooth out the pathway for the combination of green energy finance and financial technology. Furthermore, financial knowledge and behavior prove to facilitate the effectiveness of digital finance, and thereby could have the potential to positive impact financial inclusion.

These findings may motivate a strand of research that seeks to investigate the efficiency and effectiveness of these new methods for greater financial inclusion achievement. Insights from this doctoral thesis may be of special interest for not only microfinance service providers and stakeholders but also regulators, microfinance practitioners and academic researchers who look for a broad picture of mechanisms for positive spillovers into inclusive finance.

As the studies in this dissertation are only able to exploit cross-sectional data, future research should employ panel data sets or even better, with longitudinal ones. In addition, our samples are limited to a small set of MFIs; therefore, it would be better if a large number of MFIs could be covered in the data sets. Although no evidence of mission drift is observed following the introduction of digital and green finance, the question of how to better achieve social and financial objectives using these new approaches still persists. As digital and green finance are examined separately in this dissertation, further studies could focus on the green digital finance. Furthermore, many countries have shown increasing concerns towards digital and green finance through regulations and policies, future analysis should also investigate to which extent these actions could influence the effectiveness of the mentioned new approaches to inclusive financing.

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