POLITECNICO DI TORINO

Corso di Laurea Magistrale

in **Ingegneria Gestionale**

(Master of Science in Engineering Management)

Tesi di Laurea Magistrale

Impacts of fintech innovations on financial inclusion in developing countries and the challenges they face – A case study on Sierra Leone.

Relatore
prof.ssa Elisa Ughetto

Candidato
Joseph Foday Tarawali

10 December 2020

Table of Contents

Abstract

Fintechs have experienced an expansive growth in many sectors over the last decade as a result of their dynamic business models which provide many unparalleled alternative and complimentary services to those that are being provided by the traditional financial institutions. Their proclivity towards affordability, accessibility, security, and better customer experience has the prospect of broadening the horizons of financial inclusion to incorporate many people who were excluded or underserved in the traditional financial system. Financial exclusion has been much prevalent in developing countries where the traditional financial systems have not adequately met the needs of the masses. Moving from this premise, this thesis seeks to investigate the impacts of fintech innovations on financial inclusion in developing countries and the challenges they face together with a case study on mobile money in Sierra Leone. Many financial benefits are being attributed to the growing adaptation of digitization in the delivery of financial services in developing countries through innovations such as payment cards, fintech applications and mobile money services. Building on theory and past literature, this paper investigated the impacts of fintech on financial inclusion in developing countries using a multivariate regression model and a principal component analysis (PCA) on statistical data. In addition, a survey was done in Sierra Leone to investigate the usage and access to financial services, as well as the barriers that are preventing people from being in the formal financial system.

Based on results of the regression analysis, there was significant evidence that support a positive relationship between fintech indicators and financial inclusion. The results of the PCA show a high contribution of fintech indicators in the quality of representation analysis in the first two dimensions of the PCA. However, indicators that represent access to the traditional financial system have a much more significant influence on the first principal component. This shows that despite of the significant evidence of the impact of fintech on financial inclusion, the fundamental basis of financial inclusion is still the traditional financial system. Furthermore, the results of the Sierra Leone survey show 72% of all respondents do not own an account at a formal financial institution, however, 67% of all respondent indicated that they have used mobile money services in 2019. This shows that with specified financial services, fintech has the potential to broaden the frontiers of financial inclusion to incorporate many who were excluded or underserved.

In addition, many challenges and risks exist which need addressing in order to foster fintech and augment financial inclusion in developing countries. Solving these issues require policy support for fintech growth and regulatory frameworks to maintain financial stability and financial integrity.

Acknowledgements

I would first of all like to express my thanks and appreciation to my supervisor, prof.ssa Elisa Ughetto, for giving me the opportunity to do this thesis under her supervision and for the kindness and support she has given me throughout this work.

Secondly, I would like to show my immense gratitude and recognition to people who have been very crucial to me during this master program. The first of these is Francesca, who has been the most important person in my life in all these years. Reaching this point would have been impossible without her unwavering support to me. Losing both my parents a year into this master program was one of the most difficult experiences, but her support gave me courage, peace, and strength. Next, I would like to show my appreciation to my late parents, Michael A Tarawali, and Alice Tarawali for all the advice, and giving me the courage to take this step in my life. I would also like to express my thanks and appreciation to Rob James, Manya Sadouski and the entire James family for being very supportive to me, treating me like family, and always being there with me in every single step ever since I met them in Canada in 2011. In addition, my life in Italy would have been much more difficult without the support of the Testa and Raviola families. They have always opened their doors to me and have been very helpful to me since I stepped my feet in Italy. I would therefore like to thank Dino, Clara, and Maria as well as Neta and Cia. Furthermore, my family has been a big part in my life over these years. In this regard, I would like to express my thanks and appreciation for the support to my following relatives at home in Sierra Leone and abroad: Henry, Mary, Beatrice, Patricia, Br. Joseph, Alfred, Samson, Bernadette, Mohamed Alie, Mathew, Isatu, Uncle James, and many other relatives and friends that I didn't mention. In addition, many friends and other people also helped me in one way or the other in reaching here. You all played an important role in my life and I am thankful for that.

Abbreviations of Variables in the Regression Analysis & the PCA

Abbreviation/Acronym	Description
NoCBpA	Number of Commercial banks per 100,000 adults
NoCBpK	Number of Commercial Banks per 100,000 square kilometers
NoATMpA	Number of ATMs per 100,000 adults
NoATMpK	Number of ATMs per 100,000 square kilometers
Act	Financial Institution Account
MMAct	Mobile Money Account
DigPay	Made or received a Digital Payment
Sav	Savings
Brwd	Loans
UMIAct	Use of mobile or internet to access an account
FaR	Distance as a barrier
Expensive	Cost of opening an account as a barrier of financial inclusion
Document	Lack of document as a barrier of financial inclusion
Trst	Lack of trust as a barrier of financial inclusion
Religion	Religious beliefs as barriers of financial inclusion
InsFunds	Lack of sufficient funds as a barrier of financial inclusion
Fam	Lack of account because other family member already has one
NoNeed	Lack of need for a financial institution account as a barrier

List of Figures

Chapter 1 - Overview of the Study

1.1 Introduction

Financial Technologies (FinTechs) are increasingly growing in number, geography, and scope as a result of their dynamic business models which seek to deliver unparalleled alternatives and complimentary services to those that are being provided by the traditional financial institutions. Their proclivity towards affordability, accessibility, security, and better customer experience has the prospect of broadening the horizons of financial inclusion to incorporate many people who were excluded or underserved in the traditional financial system. Hitting the road from this premise, this paper seeks to investigate the impacts of fintech innovations on financial inclusion in developing countries and the challenges they face together with a case study on mobile money in Sierra Leone.

The magnitude of financial exclusion is very prevalent among the poor (*Demirgüç-Kunt et al. 2018*), especially in developing economies where poverty rates are extremely high, and the traditional financial systems have not adequately met the needs of the masses. Fintech services are bringing disruptive and incremental innovations as well as creating new market segments in different financial sectors to ameliorate the financial industry. The benefits of fintechs are already felt immensely in the developed countries in diverse sectors. The propensity of fintechs to solve many of the weaknesses of the traditional financial system have created a new avenue towards augmenting financial inclusion in developing countries where exclusion has been most prevalent.

Financial inclusion and access to financial services has captivated the interests of many policymakers - especially in developing countries, who have had a growing concern about the lack of financial diffusion across the population and economic sectors (*World Bank, 2016*). This is evident in Sierra Leone where the government has put in place a national innovation and digital strategy which will establish a digital identity database to help people who strive to get loans to prove their credit history. Furthermore, the implementation of the biometric scan cards in India helped achieved a 2.8 percentage points reduction - (47% relative to the control mean), in leakages of pension funds *(Muralidharan et al., 2014)*. This also helped the government to curb corruption rates and increase efficiency in the delivery of payments to government workers.

The growing adaptation of digitization in the delivery of financial services through innovations such as payment cards, fintech applications and mobile money services is already benefiting many

people. In 2018, the World Bank together with the IMF launched the Bali Fintech Agenda in order to provide a framework to help member states to capitalize on the opportunities and potential benefits of the growing advances in fintech. Different fintech innovations have the capability of expanding the frontiers of financial inclusion especially in developing countries. This is especially true for market-driven fintech innovations, which lay more emphasis on understanding the customer needs (*Cantamessa and Montagna 2018, pp. 247*).

1.1.1 Background and Context of Study

In 2019, Sierra Leone launched the development of a national digital identity database using blockchain technology in a move to support people who struggle to get loans to prove their credit history and to augment financial inclusion in the country. This strategy will help pave the way for the diffusion of new innovative fintech in the country. The state of fintech innovations in Sierra Leone is still at its infant stage and the most common type of financial technology solutions are mobile money services. This case study may be analogous to some other developing countries around the world, however, distinctive factors in the individual countries can influence the state of fintech in those countries. Political, social, cultural, and economic factors are some examples of factors that vary from one country to another and can create differences in the diffusion of fintech in those countries and hence its impacts. Furthermore, the level of technological infrastructure differs greatly from one country to another. In this regard, this paper takes a general outlook on the impacts of fintech on financial inclusion together with a specific case study on Sierra Leone to corroborate or contradict the findings.

Background of Sierra Leone

Sierra Leone is a developing country in Sub-Saharan Africa which has experienced a turbulence of economic growth since independence in 1961. This was fueled mostly by multiple political armed conflicts and an Ebola epidemic that left the country in economic shambles. However, developments in technology have been slowly growing in the nation over the years. Like many developing countries, Sierra Leone is trying to build its digital infrastructure in order to position itself well in the upheaval of the Fourth Industrial Revolution - an epoch defined by the emergence of new digital technologies, with a trajectory into the consolidation of digital technology and physical innovations. Developments in science, technology and innovations have played a great role in driving and shaping the world and has impacted many industries today. According to the DSTI in Sierra Leone, these emerging technological

paradigms has left nations with no options but to prepare the necessary infrastructure to support their diffusion or be left behind in the near future *(James et al. 2019)*. In this regard, Sierra Leone has developed a 10-year National Innovation and Digital Strategy (NIDS) starting from 2019, with the aim of building an infrastructure that will support present and future developments. One of the key aspects of this strategy is to create a national identity database using blockchain in a move to allow people who struggle to get loans to prove their credit history and improve financial inclusion in the country.

1.1.2 Fintech and Mobile Money in Sierra Leone

FinTech in Sierra Leone

The spread of new innovative financial technologies in Sierra Leone has been slower than many developing countries and this is partly due to the level of technological infrastructure to support these new innovations. Some financial technologies, such as mobile money services, are well positioned in the fintech services in the country not only because of the large potential market of those excluded in the formal financial system, but because there is already the infrastructure for mobile service companies to exploit this market segment by using their internal competencies and resources.

The central bank of Sierra Leone has worked in collaboration with different partners to help boost fintech in the country through different frontiers. In 2017, the Bank of Sierra Leone, together with *UNCDF - MM4P*[1] and other international partners, launched "The Sierra Leone Fintech Challenge" in a bid to help bolster and accelerate the development of relevant FinTech solutions that will promote financial inclusion in Sierra Leone. FinTech solutions are expected to bring about disruptive innovations that have the potential of expanding access and delivery of financial services in the country which has a very high unbanked population *(Bindi, 2017)*. According to the IDT Labs, the majority of the unbanked population in Sierra Leone represents a segment which comprises mostly people from rural areas, women, farmers, the youth, and people in marginalized communities. Different approaches and attempts have been made in the past to increase the level of financial inclusion in the country. In 2009, the government of Sierra Leone tried to augment the access to financial services nationally through the *Financial Sector Development Plan 2009*[2]. This plan helped provide licenses to many financial intermediaries. However, due to structural challenges this attempt was ineffectual. This

[1] United Nations Capital Development Fund - Mobile Money for the Poor (UNCDF-MM4P)

[2] Sierra Leone Fintech Challenge 2017

plan had many flaws: increasing supply does not automatically shift the demand. One thing that could have been done is to better understand why there is a high rate of exclusion. Many aspects such as affordability, ease of access and execution, how fast and other personal issues like trust, need for financial services, etc., have to be studied. Then the plan should have tried to address at least some of the key issues raised by the people. According to the Bank of Sierra Leone, despite the steps taken to boost the financial sector, less than 15% of the country's adult population had access to financial services.

Mobile Money in Sierra Leone

Sierra Leone has experienced a significant growth in the use of mobile money as both a substitute and a compliment to the formal financial services and money transfer systems. The increase in the use of mobile money is as a result of the extremely high number of unbanked populations who were excluded from the formal financial services and due to the presence of mobile phones services in almost every part of the country. Many people in Sierra Leone do not own a bank account but own a phone or have access to one. The use of mobile technology for payment or banking helps addresses two issues at the same time. On one hand, it helps create an opportunity for financial inclusion among people that are underserved by the incumbent financial service institutions and on the other hand it helps financial institutions to deliver a wide range of services at low cost for a wide range of clients including the very poor and those in remote areas *(Diniz et al., 2011)*.

Many people in the rural areas of Sierra Leone, for example, used to have problems sending money to their children who are studying in other towns. This is also true for people trying to send remittances to their parents or relatives who live in distant places. The main available methods were through the use of Western Union, MoneyGram or asking someone to deliver the money in person. Western Union and MoneyGram are very expensive, and they only have points of sending or receiving in big towns, mostly at banks. The cost, time, and the distance to a point to send or receive money makes these options not viable for people living in the remote rural areas. Sending by asking someone to deliver is usually time consuming and also risky with respect to trust. To make payments or send remittances to relatives in rural areas requires that you know someone who is trustworthy that is going there, which does not happen very often. The advent of mobile money, therefore, has eased the complications with the existing options by making transfer of money very fast, cheap, secure, and readily available in every corner of the country where mobile service connectivity is available. This has

therefore helped broaden the horizons of financial inclusion to the poor in remote areas and provided them with the opportunity to participate in the financial system. In Sierra Leone, the levels of financial inclusion are very low, with only 19.8% of people above 15 years of age are in possession of an account at a bank or other financial institution (*Demirgüç-Kunt et al., 2018*).

Mobile money has tremendously contributed to expanding financial inclusion in Sierra Leone to reach masses of people who were excluded from the formal financial system in the country. As in many developing countries around the world, mobile money has brought about the possibility of making money transfers and payments relatively cheap, secure, accessible, and reliable for millions of people in the country. However, there also exists challenges and constraints, which, if addressed, can create many economic benefits.

1.2 Purpose of the Study

The objective of this thesis project is to study the impacts of fintech innovations on financial inclusion in developing countries and examine the challenges they face. The thesis will also look into the case of how mobile money is broadening the horizons of financial inclusion in Sierra Leone and will also attempt to identify some strategies for the application of fintech in developing countries.

1.3 Research Objectives

1.3.1 Theoretical Objectives

- To review literature on financial inclusion in developing countries.
- To examine the connection between fintech digital technology and financial inclusion.
- To examine literature on measurement of financial inclusion and the weaknesses they present.
- To study the major challenges and impediments of financial inclusion.
- To study the evolution of fintech, its disruptions together with the risks, challenges, and constraints it faces in developing countries.

1.3.2 Statistical Objectives

- To study the variability caused by fintech indicators on financial inclusion using a multivariate linear regression.
- To study the impacts of fintech financial indicators on financial inclusion using principal component analysis.
- To study the impacts of mobile money on financial inclusion in Sierra Leone.

Chapter 2 – Theoretical Background and Literature Review

2.1 Introduction

Fintech is making significant advances in the financial industry and is poised to help widen the frontiers of financial inclusion especially in developing countries according to the World Bank and various scholars. This is apparent in different types of fintech which are already causing disruptions in many sectors. Different studies have shown that many developmental benefits can be derived from financial inclusion and it is deemed as one of the fundamental issues that need addressing to eradicate endemic poverty in places around the world. Scholarly literature on fintech on the other hand, however, is still very shallow. This may be attributed to the infancy of the last era of financial technology (fintech) whose inception happened after the 2008 financial crisis, and the dynamic nature of fintech which continues to expand every day. On the latter point, what can be said about fintech today, may not be precisely the same in the near future and hence may influence what scholars are willing to publish.

In this section, a brief background on financial inclusion in developing countries will be explored, followed by a brief review of digital technology and financial inclusion in developing countries. Next will be a discussion of fintech, its global landscape and some major disruptions it is causing in the global financial system. Furthermore, literature on mobile money as a driver of financial inclusion in developing countries will be discussed, and some scholarly attempts of measurements of financial inclusion will also be discussed.

2.2 Financial Inclusion in Developing Countries

Financial inclusion is very important for the economic development of nations and its people. It has a great role in reducing poverty and augmenting economic growth opportunities. Economies are stronger with higher financial inclusion, an increase in financial inclusion in a market can increase the real GDP per capita by 3.6 percentage points (*Goyal, 2015*). A financially inclusive economy can enable the smooth going of day-to-day activities and help people and businesses to make future plans and be well prepared in the advent of unexpected emergencies. People who own financial accounts are more likely to use other financial services which can enhance their overall quality of life. Possession of an account does not only give one the opportunity to make or receive payments, but it also gives one access to markets that may be physically unreachable especially for people in remote rural areas.

Policy making on financial inclusion relies on financial data in order to help identify areas that need policy making the most. In this regard, the World Bank Group established the Global Findex

Database in 2011, which provides data on hundreds of financial indicators for regions and countries around the world (*Kumar, 2019*). The Global Findex, which was initially funded by *The Bill and Melinda Gates Foundation*, was established, in an effort, to augment financial inclusion around the world. According to the Gates Foundation, their aim is to make financial data available to governments and the private sector to use in broadening the access of affordable digital financial services for the poor.

Financial exclusion is one of the major factors that contribute to poverty in many developing nations and has drawn the attention of many legislators and global developmental organizations. Different studies have helped broaden the understanding of how people interact with financial services and how they live their lives. A direct correlation between financial exclusion and poverty has been evident in the Global Findex reports of 2011, 2014 and 2017. In regard to this, financial inclusion and access to financial services has captivated the interests of many policymakers - especially in developing countries, who have had a growing concern about the benefits that can be generated through financial intermediation and the lack of market diffusion across the population and economic sectors. Financial exclusion has the potential to cause negative effects on poverty level, growth, and the distribution of income within nations. According to the 2017 Global Findex *(Demirgüç-Kunt et al, 2017),* a quarter of all adults globally live in the poorest 20 percent of households within their country which is about twice the share of those living in the richest 20 percent.

According to the World Bank (*2018*), financial inclusion is when "individuals and businesses have access to useful and affordable financial products and services that meet their needs – transactions, payments, savings, credit and insurance". Lack of access to inclusive financing is very prevalent on underprivileged people and people of low income, most especially in developing countries. In 2017, 1.7 billion adults globally do not have a basic transaction account - either at a financial institution or a mobile money account, according to the 2017 Global Findex report. Different factors and barriers including lack of money, distance from financial services, lack of necessary documents and lack of trust in the financial service providers are key reasons given by people who participated in the survey. The majority of the unbanked adults globally are from the developing countries and half of them live in only seven countries[3]. Among the unbanked, half of them come from the poorest forty percent of the adults globally. Furthermore, gender inequality also exists among the

[3] China, India, Pakistan, Bangladesh, Nigeria, Mexico and Indonesia

unbanked adults. Fifty-six percent of unbanked adults globally are women according to the report. The chart below shows the disparity in account ownership among countries around the world. The chart shows a direct correlation between how developed a country is to the percentage of account ownership.

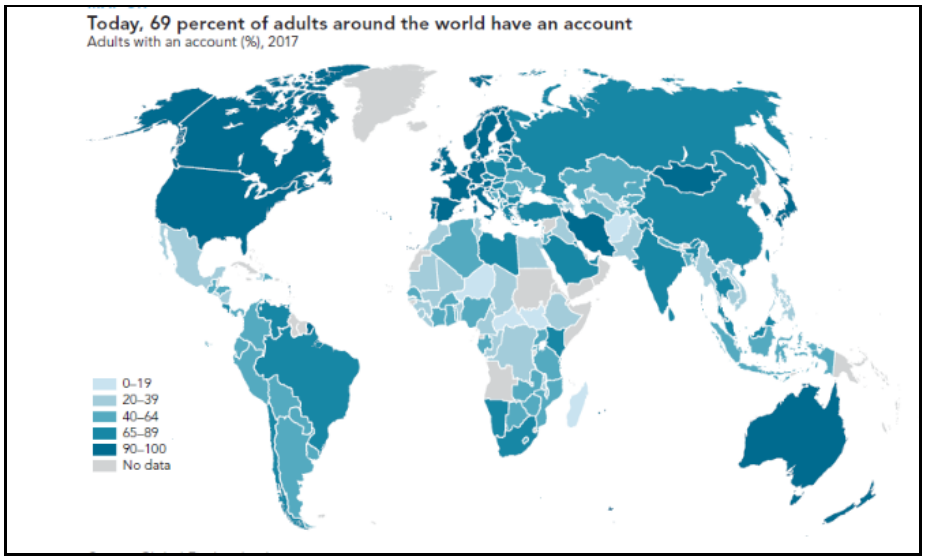


Figure 1 Global Distribution of Account Ownership Among Adults

Source: Global Findex Database

While the effects of financial inclusion differ from one country to another, there are, however, possibilities of positive outcomes if the right services are rendered to the people. A service that works well in one country may not necessarily work well in another due to social issues, economic levels, delivery infrastructure, cultural or religious concerns, services that the people need access to, etc. For example, poor people living in a rural village in Sub-Saharan Africa or in a rural village in India, may not readily have access to the internet, but may have access to and are more likely to be able to acquire an affordable mobile phone. Among these people, a mobile money service may be a better suited service than an internet money service because there is already the infrastructure, accessibility, and familiarity of use. Differently, since mobile services are mostly limited nationally or within economic communities, a mobile money service may not be applicable for people who want to make or receive payments from across borders. However, a credit or debit card connected to a bank can easily make or receive payments from across borders.

2.3 Digital Technology and Financial Inclusion

Digital technology is disrupting the way the traditional financial system works. The growing adaptation of digitization in the delivery of financial services through innovations such as payment cards, mobile payments, fintech applications and mobile money services is already benefiting many people who were earlier excluded in the formal financial system. The advent of blockchain technology and its rapid proliferation is opening many avenues that can promote financial inclusion. Studies have also shown that digital payments in the form of mobile money services can help improve the income earning potential of people, especially for the poor and women in rural areas of developing countries. The case of the M-Pesa in Kenya is found to have created a lot of benefits for women in the rural areas in Kenya (*Buku & Meredith, 2013*). Similarities in social, cultural, economic, occupational, and political demographics of Kenya to other developing countries shows that mobile money can be a successful service in expanding the frontiers of financial inclusion in other developing economies. In Malawi, farmers who saved their earnings in accounts are found to have spent thirteen percent more on farming equipment with a corresponding fifteen percent increase in crop value *(Demirgüç-Kunt et al. 2018)*. Digital payments also help reduce cost and time; in Niger, twenty hours are saved in receiving payments according to the Global Findex report. Digital financial services can also help in the management of financial risk through ease of distant payments. Mobile money services have helped many residents in rural areas to easily send or receive money from friends or family living in distant places.

Fintech is still at its early stages of diffusion as its impending impacts in areas such as blockchain, artificial intelligence, cloud computing and IoT are yet forthcoming in many developing countries. Fintech companies are delving into the value chain of financial services in order to create new innovative solutions and also establish new market segments in developing countries where there is a high population of both unbanked and underbanked. The solutions of FinTech companies are themselves not enough to serve the market without the traditional banks. Hence, many fintech companies are working with banks in order to provide innovative digital banking service in order to integrate and consolidate services such as digital payments, robo-advising, microfinance, etc. into the existing traditional banking system.

The transaction value of digital payment has had a steady growth over the years, and it is projected to continue its growth trajectory. According to a Statista report, the transaction value of Fintech digital payments is estimated to reach 9.5 trillion dollars by 2024.

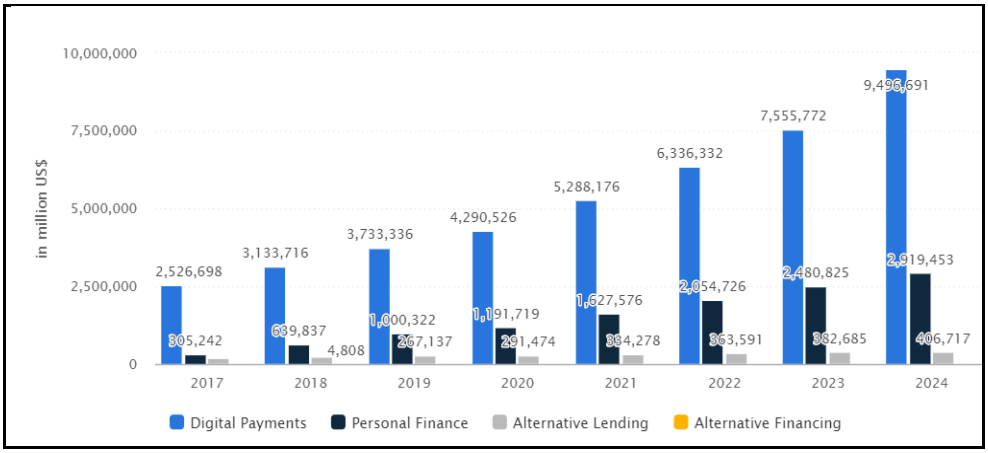


Figure 2 Transaction Value of Fintech Digital Payments

Source: Statista

As fintech continues to expand into different areas of financial services, the number of users of digital technologies continue to increase. This is evident from the multi-purpose Chinese messaging, social media and payment app, WeChat, which accumulated more than 1.2 billion monthly active users in 2020 *(Thomala, 2020)*. According to Statista's market forecast worldwide, digital payments users are estimated to reach 4.6 billion by 2024.

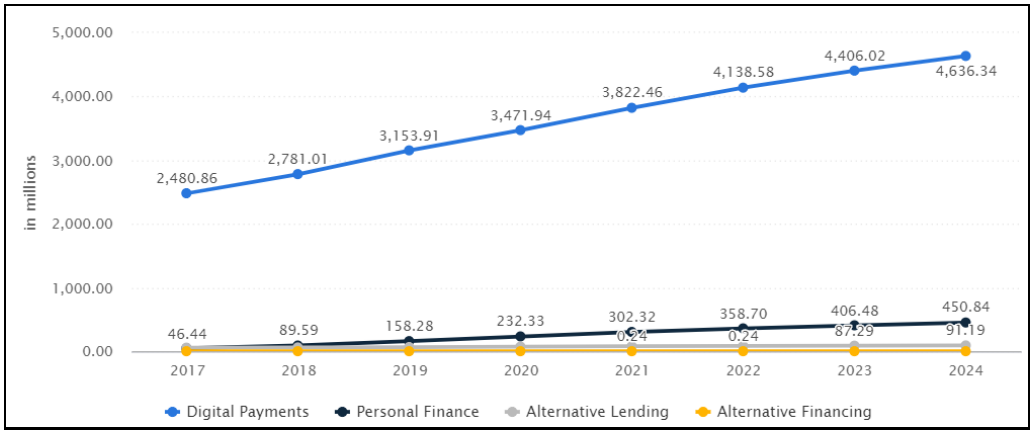


Figure 3 Number of Digital Payment Users Globally

Source: Statista

2.3.1 Blockchain

The term Blockchain has most popularly been associated with bitcoins or other cryptocurrencies. This is because the first person or group of persons to conceptualize the idea of a secured decentralized public ledger for digital transaction, by the pseudonym of Satoshi Nakamoto, implemented the first blockchain in a public ledger for transactions using bitcoin in 2009. In 2008, Satoshi released the white paper which established the model for a blockchain which was later implemented in 2009. Bitcoin helped to establish a form of currency that can be sent in a peer-peer mode without the need for a central intermediary or authority to actualize the transaction. However, blockchain has moved from just a form of cryptocurrency to something more over the years. The potential benefits of blockchain technology in many sectors and industries has prompted the need for more exploration of the potential applications of the technology.

Blockchain has opened a different avenue for SMEs and startups in crowdfunding through ICOs as a digitalized form of crowdfunding. Many startups that has the potential to make a difference cannot readily get the funding the need due to their geographical location. Access to finance from traditional financing tools for SMEs and startups is shaped by geographical proximity (*Ughetto et al., 2019*). However, the emergence of new innovative digital financing platforms like ICOs provide an easier access to capital for SMEs and startups. While ICOs are not completely free from drawbacks, they have helped solved some of the problems that are usually associated with equity crowdfunding. Blockchain is predicted to be adapted in different sectors and industries. In the following section, some details about blockchain and its features are given.

Blockchain is an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way *(Iansiti & Lakhani, 2019)*. The distributed ledger is managed by a peer-peer network that collectively adhere to a protocol for internode communication and the validation of new blocks in the chain. After a transaction has been recorded the data in any given block cannot be altered without the alteration of the subsequent blocks which requires a consensus of the majority of the network. The ledger is basically replicated in a large number of identical databases, each hosted and maintained by an interested party. If changes are entered in one of the nodes, all other nodes will be updated simultaneously. Therefore, as transactions happen, the records of the values and the assets exchanged will be permanently entered in all ledgers. The need for a third-party intermediation to verify the transaction or transfer of ownership is eliminated. With advancements in blockchain technology, there will come a time when contracts can be embedded in digital code which is stored in a transparent, secure, and shared database where it is impossible to alter them.

Below are the five principles on how blockchain works as described by Iansiti and Lakhani *(2019)* in their Harvard Business review article.

- **Distributed Database**

  Every member of the blockchain has access to the entire database and its complete history and also has the ability to verify the records of transaction partners directly without the need for an intermediary. The distributed ledger also ensure that a single member cannot control the data.

- **Peer-to-Peer Transmission**

  The communication between peers is done directly rather than a central node. Each node in the blockchain will store and forward data to all other nodes in the chain.

- **Transparency with Pseudonymity**

  Transactions and their associated values are made visible to anyone with access to the system. Each node or user on the blockchain has a unique address and also has the option to remain anonymous or provide proof of their identity if they wish to. The transaction itself takes place between addresses.

- **Irreversibility of Records**

  The transactions cannot be altered once entered and updated because they are linked to every transaction that happened before them. This is done through complex computational algorithms and approaches that ensure that the database remain permanent, chronologically ordered, and available to all other nodes in the network.

- **Computational Logic**

  The blockchain can be linked to computational logic that are predefined with algorithms and rules that can automatically trigger transactions between nodes.

Types of Blockchain

There are currently four major types of blockchain. However, they will only be listed, and the summary of their features will be shown in the figure below the list. They include the following:

- Public blockchain
- Private blockchain
- Consortium or Federated blockchain
- Hybrid blockchain

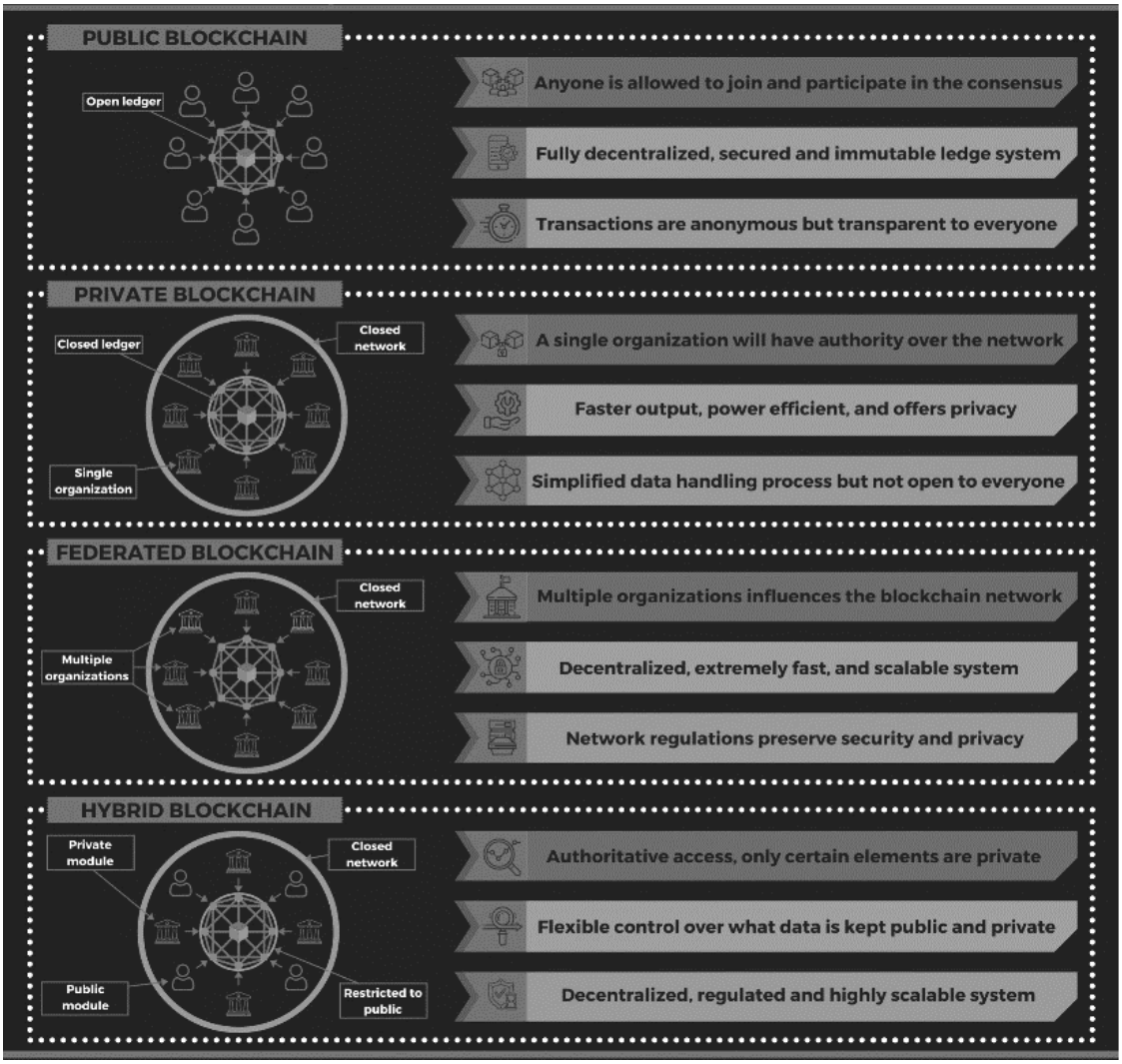


Figure 4 Types of Blockchain

Source: 101 Blockchains

2.3.2 Mobile Money – A Driver of Financial Inclusion in Developing Nations

"Mobile money is a tool that allows individuals to make financial transactions using cell phone technology" *(William & Suri, 2011)*. Mobile money is revolutionizing the financial system in many developing countries and has become very instrumental in stimulating financial inclusion. Many scholars have posited that different benefits can be derived from mobile money services. According to Ngwabe (*2018*) of the UNCDF, mobile money is opening doors to various life-enhancing services in education, health care, financial services, social protections and employment for people who were once underserved or excluded by the traditional financial system. Furthermore, Alexandre and Eisenhart *(2013)* argued that mobile money has the potential to promote both financial inclusion and financial

integrity and observed three tangential points of the two with respect to mobile money. The three tangential points speaks to a reduction of dependency on cash, provision of data and lastly, the acceleration of accounts which forms the main pillar of financial inclusion and financial integrity. Mobile money has been very successful has helped many people who have been excluded by the traditional financial system to have access to financial services.

2.4 Fintech

Financial Technology is the use of innovative technology to augment the efficiency in the delivery of financial services. In general, fintech is used to describe companies that utilize the internet, mobile phones and the cloud to deliver financial services such as peer-to-peer lenders, crowdfunding, blockchain and bitcoin, robo-advising, mobile payment and insurance (*Robinson & Verhage, 2018*). FinTech has mostly been used to refer to small emerging startups, however, the use of financial technologies dates all the way back to the 1800s. The new innovative forms of financial technologies, however, started rising after the 2008 financial crisis and is increasingly being adopted by legacy and incumbent financial services sectors to develop innovative technological solutions.

There are different definitions for fintech depending on the lens one is viewing it from. However, most of the definitions carry the general theme of "*use of technology to deliver financial services*". Some examples of definitions of fintech are as follows. According to the Merriam-Webster Dictionary definition, fintechs are *"*products and companies that employ newly developed digital and online technologies in the banking and financial services industries" and the Oxford Learner's Dictionary defines fintechs as "computer programs and other technology used to provide banking and financial services*"*

2.4.1 Background and Evolution of Fintech

It is very important to understand the evolution of fintech as many people often think about it as a technology that emerged after the 2008 financial crisis. However, financial technology has evolved for more than a century. The trajectory of fintech after the financial crisis can be considered more like a

breakthrough that led to a new technological paradigm[4]. The evolution of Fintech has a history that goes all the way back to 1866 and has been divided into three different eras: the analogue to digital era, between 1866 and 1967; the development of traditional digital financial services, between 1967 and 2008 and the democratizing digital financial services which started after the 2008 financial crisis (*Arner et al, 2015*). These different eras are marked by revolutionary innovations that have contributed to the progresses that we have seen today in the banking and financial industry. Technological innovations continue to emerge and continue to shape the way we carry out our financial activities. Within the different eras themselves, there are different types of technological innovations that have helped financial technology evolve from archaic Morse code to more recent forms of fintech like cryptocurrencies which utilize blockchain technology.

The first era of financial technology unfolded with technologies such as the telegraph which was demonstrated for the first time by Samuel Morse in 1838 and in 1865, Giovani Caselli invented the pantelegraph which started operation between Paris and Lyon, France (*Zimmerman, 2016*). This was followed by the first transatlantic cable which was laid out successfully in 1866 providing an infrastructure that made financial globalization possible. This era later saw the use of Fedwire service in the United States in 1918 which connected the twelve reserve banks in the United States using a Morse code system (*Vardhman, 2019*). In his 1919, British economist, John Maynard Keynes propounded the connection between finance and technology in his book, "The Economic Consequences of Peace". In 1950, the first credit card was issued by the Diners Club to alleviate carrying cash around (*Desai, 2016*). This era constitutes the fundamental basis of the evolution of financial technologies that have grown today to more complex systems but more efficient systems. Other financial technological development during this era includes the Quotron and the global telex network.

The second era was between 1967 and 2008, which marks the revolution from analogue to digital technology and the advent of the 2008 financial crisis. The introduction of the ATM in 1967 by Barclays bank was notably the beginning of the second era of the evolution of fintech. In the early 70s, the Clearing House Interbank Payment System was established to make payments orders in American

[4] A technological paradigm is a mixture of supply-side and demand side elements that blend together in a coherent whole and give birth to a technological trajectory that is at the same time viable for companies, and appreciated by the market (*Cantamessa & Montagna, 2018*)

dollars among some of the big banks around the world possible. This was followed by the birth of the Nasdaq, the first electronic stock market, in 1971. Initially, Nasdaq only provided automated quotations and the automated online trading was only facilitated later (*Kennon, 2019*). The SWIFT[5] was set up in 1973 in order to support international finance and commerce among the user community. Other fintech advancements during this era include online brokerage, the mainframe computer and online banking (*Aldoma, 2019*). In 1993, the term "Financial Technology was coined in place of the Financial Services Technology Consortium, a project that was established by Citicorp to prevail over a reputation of non-technological collaboration with outsiders. This is sometimes misunderstood as the beginning of the evolution of fintech. Furthermore, Wells Fargo introduced the first online checking account in 1995 and the first virtual bank without physical branches was established in 1997 in Canada as a subsidiary of ING Group (*Arner et al. 2015*).

The last era of the evolution of the fintech industry is what is most widely regarded as the emergence of fintech. This era began after the 2008 financial crisis which plummeted the reputation and trust in the traditional banking industry. After the advent of the financial crisis, different solutions on the delivery of financial services started to emerge in order to address the inefficiencies in the traditional banking system. In 2009, the version 0.1 of the Bitcoin cryptocurrency was released which includes a generation system that was planned to create 21 million bitcoins through the year 2040 (*Zimmerman 2016*). Other forms of financial technologies during this era include the establishment of Google Wallet by Google in 2011 and improvements in different forms of mobile and internet banking.

2.4.2 Global Fintech Landscape

The fintech landscape is broad and is becoming more and more pervasive in many financial sectors. However, its impacts are not only limited to financial services, but also on a wide spectrum across financial business processes, educational institutions, and governments. Technology has become inherent in the delivery of financial services. Financial institutions have therefore become very reliant on technologies, especially new innovative ones, in the running of their businesses. As the financial processes of financial institutions increasingly move to the cloud, the need for new technologies and software has become inextricable. Data analytics technologies and artificial intelligence are making a considerable amount of improvements in existing products and also enabling the development of new financial technologies across different financial sectors. Some of the leading financial services sectors

[5] Society for Worldwide Interbank Financial Telecommunication (SWIFT)

that fintech is making a substantial amount of disruptions include payments, banking, lending, insurance, and wealth management among other financial services areas. Furthermore, other emerging fintechs include real estate, regulatory technology (RegTech), health care, financial management, security and authentication and cryptocurrency. It is increasingly becoming difficult to carry out the operations of financial institutions without technology. In the near future, there may be no distinction between financial services and fintech *(McLaughlin, 2020).*

The impacts fintech on financial inclusion may vary on an uneven spectrum that is dependent on different factors such as the type of technology, technological infrastructure and the target market or geographical location. The prevalence of fintech has been more in developed countries and countries with good technological infrastructure and market for fintech services. Many developing countries have had limited penetration of fintech due to many technological barriers. However, while the pace is different, adoption is gradually increasing. However, the impacts of fintech on financial inclusion are felt more in developing countries due to the large amount of unbanked or underbanked populations.

The two following charts show the regional financing volumes of fintech from 2015 to 2019. On the left, the chart with Africa, Middle East, South America, and Oceania is in millions of dollars while the one on the right with North America, Europe and Asia is in billions of dollars. The disparity shows that there is a higher fintech penetration in more developed countries than developing countries. While most Asian countries are considered developing countries, some of them have a high level of technological infrastructure and markets for fintech services, therefore the fintech financing volumes there are also very high.

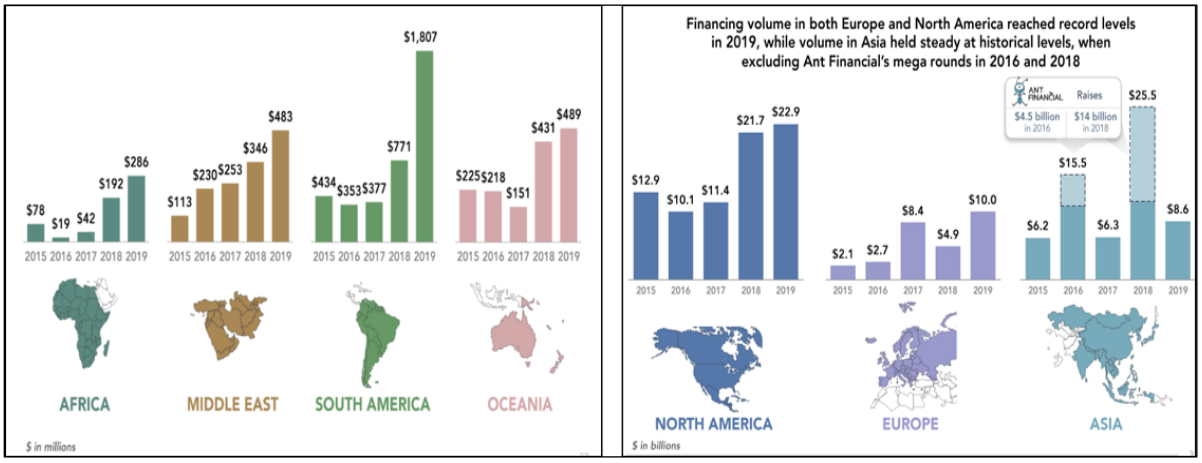


Figure 5 Regional Financing of fintech from 2015 to 2019

Source: FT Partners

A few categories of fintech companies have emerged as key disruptors and competitors of traditional banks and other companies operating in the financial services sector. Barriers to entry in the financial services sector have been very high due to excessive regulations, capital requirements and management of risk and compliance requirements which are complex and costly. Therefore, the financial industry companies also provide services to their clients at elevated costs. In many cases, this causes deteriorating relationships with the customers. This gets even worse in situations wherein a customer with many products and financial service needs has engaged in a long relationship with a company that changing to a new provider becomes inextricable. This dormant relationship coupled by the 2008 financial crisis and a surge of technological innovations struck the financial service industry with an unpleasant reputation which triggered the need for alternatives to the traditional financial services providers. Fintech companies started to identify inefficient segments of the value chain that provided inferior user experience in the traditional financial service system and leveraged them with innovative technology.

2.4.3 Major Fintech Disruptions

Many scholars consider the evolution of fintech as a disruptive innovation with the potential to provide more efficient financial solutions to diverse problems in the financial industry. The argument, however, can be dependent on the sector and how the technology is used. For new fintech companies, their approach is typically disruptive as they present new business models to solve inefficiencies in existing financial industry models that have underserved the market. Incumbents, on the other hand, may utilize technological innovations as sustaining or incremental innovations in order to strengthen their market position and improve their financial services. New innovative financial technologies present many opportunities to be exploited. For the incumbents, these new technological innovations do not only present opportunities, but also threats if they are not exploited.

The adoption of fintech by incumbents are both geared towards exploiting opportunities in the market and also as a defensive strategy to avoid competency traps - that is, their existing competencies

becoming their future rigidities. Different sectors in the financial industry have been bounded by their brick-and-mortar[6] models which hinder them from exploiting other opportunities outside their reach.

Fintech startups are continuously increasing both in number and in the amount of services they provide around the world. According to a Statista report in March 2020, the total number of fintech startups around the world is 20,925, with an increase of 8,794 from 2018 (*Szmigiera, 2020*). Fintech startups are changing the financial industry's business models and setting the future landscape of the industry due to their dynamic business models which seek to understand and recognize different key demographics and customer segments. Fintech startups, especially those entering in banking, payment, and transaction services, create new market segments that increase financial inclusion and lower operational costs through their use of technology in their delivery of services *(Kagan, 2020)*. In comparison to traditional financial services, fintechs are usually more accessible to customers, provide affordable rates and provide a better customer experience in the delivery of their services. Ease of setting up an account, accessibility, affordability and the provision of better online experience and functionality are some of the key reasons for the increase in fintech adoption according to a 2015 EY fintech adoption index (*Gulamhuseinwala, et al. 2017*).

The chart below shows the adoption rate of five grouped categories of fintechs from 2015 to 2019. The data shows the average percentage of consumers who use at least one fintech service. Among the five grouped categories, all showed a steady increase in the rate of adoption between 2015 and 2019. This shows that fintechs are continually gaining traction in the financial industry, sending a strong message to incumbents about the disruptive nature of the new innovative financial technologies. Money transfer and payments showed the highest adoption rate increase from 18% to 75% between 2015 and 2019 followed by insurance which increased from 8% to 48%. The most commonly used services in the money transfer and payments category is peer-to-peer payments which does not require a traditional bank as an intermediary for the transaction to occur (*Hatch et al. pp. 10, 2019*).

[6] Brick-and-mortar refers to businesses that requires the physical presence of an organization or branches. This was typical in the operations of traditional banks wherein services are provided at bank branches. But this is gradually fading out due to innovations in internet and online banking, robo-advising and other fintech innovations.

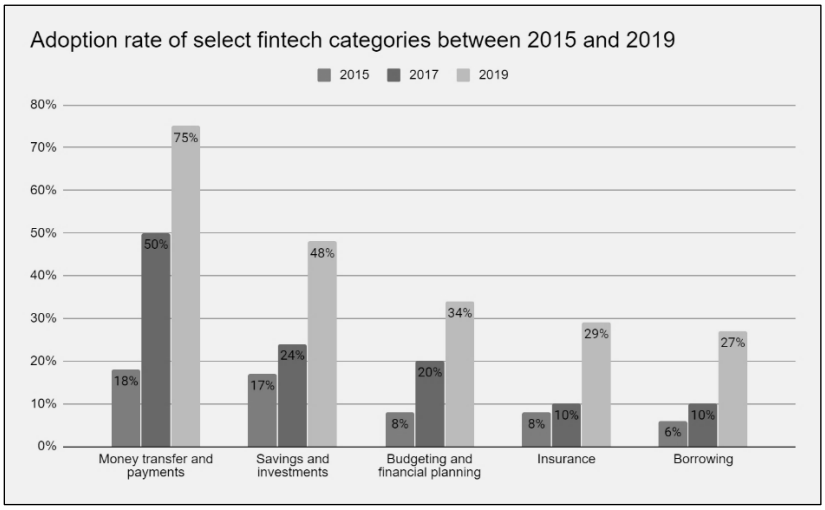


Figure 6 Global FinTech Adoption Index

Source: EY Report - 2019

Fintech is already making a lot of disruptions in many financial sectors. However, this essay will focus on banking, insurance, transaction & payments, investment…

2.4.3.1 Banking

The bank has been the central keystone in the formation of the modern financial services system and can be traced to as far back as the ancient world. The stability of the banks is very important in driving the global economies. It is therefore incumbent on nations to establish the necessary regulations to avoid failure of the banks. The banking industry has had a substantial amount of entry barriers, which include regulations, capital requirements, strengthening of clientele, reputation for solvency and physical assets requirements, such as branches, ATMs, computer equipment and software systems for the delivery of services (*Vives 2016, pp. 71*). These barriers became inherent in the banking industry and promoted monopoly power in many local instances. Inefficiencies and financial exclusions are prevalent and appear to be inextricable in the traditional banking systems.

Prior to the 2008 financial crisis, which crumbled world economies, the banks became an industry that appears to be invulnerable. However, “a chain of misaligned incentives culminated to a catastrophe” (*Vives 2016, pp. 15*). In the United States, a lot of subprime mortgages were granted to families who have limited capacity to pay back the loans. This was primarily due to the permissive credit policy which encouraged some lousy issuance of soaring credit scores by the credit-scoring agencies on very risky products in securities. This led to the economic boom which flourished on very low interest rates, and contributed to the real estate bubble, which ultimately led to the financial

crisis. The 2008 financial crisis, however, exposed the vulnerability of the banking industry and fueled the need for broader and more innovative ways to promote benefits for both the banks and the customers. The lack of trust on the banks, the existing inefficiencies and complications in the banking business models and lack of creative ways to broaden the frontiers of financial inclusion paved the way for the emergence of fintech.

While fintech poses threats to the banking establishment, it also presents many solutions and business models that can help solve some of the inefficiencies in the banking industry. Due to the potential capability of fintech to expand to different financial services sectors, many banks do not only consider fintech companies as competition threat, but they also try to incorporate their new innovative competencies into their business models to try to gain traction in preparation for the forth industrial revolution through research and development internally and mergers and acquisitions of fintech companies. With the fast pace of fintech in the banking sector, some banks are expected to work together and co-invest in some instances in order to mutualize and mitigate costs in areas where they have little or no competitive advantage. Furthermore, to strengthen their market position and fend off of the threats posed by fintechs, many banks are seeking business model expansions and growth opportunities in diverse banking segments. Some banks have sought investments in corporate venture capital funds; however, this is not a very popular move as it tends to strengthen fintechs rather than the banks themselves and integrating fintechs can disrupt the organizational structure of the companies. Hence, many have turned to in-house research and development, while others engage in mergers and acquisitions (M&A) of fintechs to incorporate them as core competencies in their organizational structures to better position themselves with the new emerging technologies.

The chart below shows the global volume and deal count of mergers and acquisitions from 2010 to 2019. The dollar amount in global mergers and acquisitions has fluctuated between 2010 and 2019 with more deals in some years while other years experiences lower amount of deals. 2017 is notably the year with the highest value in M&As with $12.8 billion. The total number of transactions also fluctuated between 2010 and 2014 in the range of 79 and 121 but has had a steady increase since 2015 from 118 to 176 in 2019.

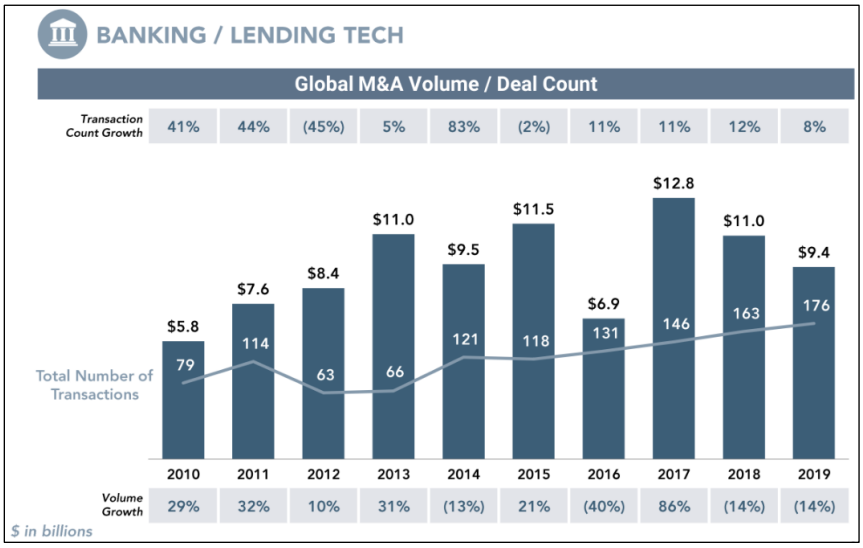


Figure 7 Global Mergers and Acquisitions Volume/Deal Count from 2010 to 2019

Source: FT Partners

The number of fintech financing volume and deal count in the banking and lending technologies sector has significantly increased since 2010. According to Financial Technology Partners, a whipping $17 billion in banking and lending tech was reported in 2019, a $300 million increase from 2018. The top five companies that received the highest amount of financing in 2019 include: Beike, Danke Apartment, Sofi, Chime and OakNorth with a total of $2.74 billion *(McLaughlin, 2020)*. Tencent emerged as the leading investor in a single company with $800 million in financing on Beike in March of 2019. The chart below shows the transaction count growth, total number of transactions, volume growth and the amount of financing in banking and lending from 2010 to 2019.

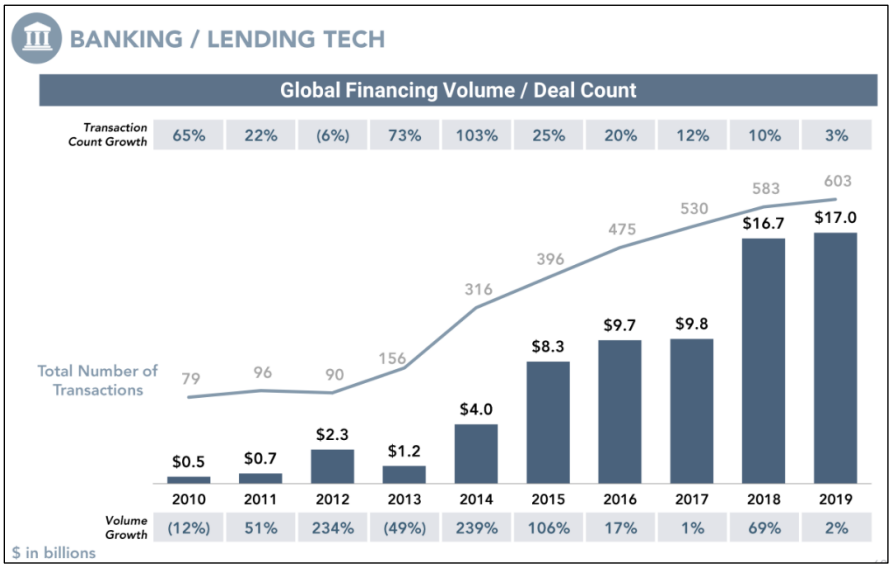


Figure 8 Global Financing Volume/Deal count from 2010 to 2019

Source: FT Partners

2.4.3.2 Insurance

The insurance sector has become an inherent part of our everyday life as many people tend to hedge their financial risk in case of the advent of events that may cause financial losses. Different types of insurance exist for different types of risks. An insurer or an insurance company will provide a guaranteed amount of compensation to the insured depending on the contract agreement. The premium to be paid by the insured is determined by the scope and type of risks that are being hedged. Like the banking industry, the insurance industry has many opportunities that can be exploited by new innovative fintechs in order to augment savings and efficiency in the existing models in the insurance industry. These new technological innovations are now increasingly being referred to as "insuretechs". Insuretechs provide innovative ways of management of risks, streamlining of operations and also helping to develop new business models such as P2P and on demand insurance services that are transforming the insurance industry. Examples of insuretech companies which are seeking to simplify and transform the insurance industry include Oscar, Lemonade and Fabric. Since 2010, the global financing volumes in the insuretech sector as well as the number of transactions have made significant growth. The chart below shows the global financing volumes and deal counts from 2010 to 2019.

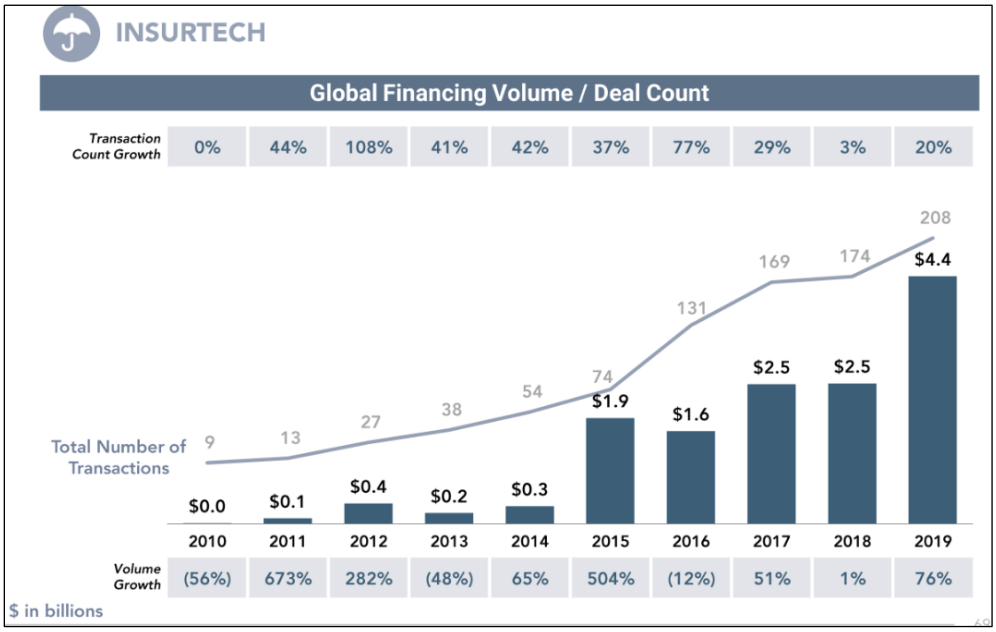


Figure 9 Global Financing Volume / Deal Count

Source: FT Partners

2.4.3.3 Transaction and Payments

Transaction and payments have become one of the focus areas of many innovative fintech. Before the advent of digital payments, trying to send money to someone at distant places was one of the most inconvenient things. You may need to go to the bank and provide details of the receiver and the processing of the transaction may take days. With new fintech innovations, transactions and payments can be done at a faster, easier, cheaper, and more convenient with just a mobile phone. The number of non-cash payments have increase progressively and dramatically over the last decade as a result of the huge rise in adoption of digital payments services in all markets. The transaction and payments sector comprises of different areas that are greatly demanding fintech innovations. These include domestic P2P payments, consumer international remittances, international B2B payments, online retail payments, domestic SME B2B payments and in-store retail payments. The continuous increase in innovation in payment services is creating a lot of competition in the sector where traditionally established players are fighting to defend their market share and expand while new entrants are also trying to get some of the market share. New entrants have not only been new innovative startups, but also tech giants who are using their internal competencies as well as making acquisitions so that they can also operate in the sector.

New fintech innovations in the payment and transaction sector are not only making services more efficient than existing ones but are also paving the way for greater inclusion in the financial system especially in developing countries. A clear manifestation of this is the successes of the bKash mobile financial service in Bangladesh and the M-Pesa mobile money service in Kenya. Mobile money services are already increasing access and circumventing the barriers that prevent many people in the developing world from the financial system. Increase in financial inclusion can help boost the world economy and alleviate poverty around the world.

According to the 2017 Payment Innovation Jury report, the top five trends in the payment and transaction sectors are: the rise in the use of APIs and open banking, data and security, the role of the regulators in fostering innovation, the role of mobile in payment, and the future of cryptocurrencies and distributed ledger technology. Different trends continue to unfold over the years as fintechs continue to search for the most suitable sectors where new innovations will make the most profitability. Payments and transaction are with no question among the top areas where fintech is already disrupting. In some regions, fintechs in payments and transaction are yet to make much marginal profitability especially from casual consumers while purchasing in stores as the opportunity cost of fintech innovations which is cash has no additional cost. However, profitability derived from businesses are encouraging and the very high demand of innovative technologies in payments and transactions makes the case for fintech to pursue the sector and develop business strategies and plans that will maximize profitability in the future. Based on the same report, the best region to start a payment business is Asia and followed by Africa. Asia is more diversified in terms of the types of payments and transaction fintechs. However, in Sub-Saharan Africa, mobile money is more prevalent at the moment.

2.4.3.4 Investment

Since the 2008 financial crisis, fintech has been expanding to many areas of investment management with innovations in robo-advisory, risk analysis, blockchain and the use of algorithms in trading. A number of fintech startups are disrupting and challenging established firms in the investment management industry. These creative innovations are not just seen as threats, but they are being embraced by incumbent firms and investors. According to a Deloitte report, the number of new startups in the investment management industry culminated in 2014 and dramatically started to drop due to the reaction of incumbents. Despite the decrease in new startups, the amount of funding in fintechs in the investment and management industry climaxed in 2018 as incumbents engaged in incorporating these fintechs in their business models through in-house developments and acquisitions of innovative fintechs. Their current market share and competitive strategies together with their diversified services

made many new fintech startups not to be able to gain traction in the industry while they try to lock in their clients.

2.4.3.5 Distributed Ledger Technology (DLT) & Blockchain

A distributed Ledger is a decentralized digital database for recording transactions at multiple locations by multiple participants at the same time. Many companies are still using the old, centralized databases systems which exist at fixed locations. With the advent of DLT, many companies are moving away from the old systems to allow the processing of transactions and data at the same time from different locations. This is very important for companies which have establishments at multiple locations. Instead of having to transfer data to a central clearing house for processing and validation of transactions, a DLT only requires the consensus of the parties involved to store the data. Blockchain and DLT should not be confused with each other because blockchain is just a type of DLT.

The potential benefits of DLT and blockchain are not only economic, but they also extend into political, humanitarian, social and scientific domains and its technological capacity is already being utilized by different groups to address real-world problems *(Swan, 2015)*. There are many possible transformative applications of blockchain technology that are only being explored now mostly by fintech startups and other innovative technology firms. Some transformative blockchain applications include asset management, crowdfunding, insurance, payments, blockchain IoT, blockchain Identity, passports, supply chain management and smart appliances. While DLT and blockchain have made great successes in cryptocurrency, it will take some time to finally know the sector where their greatest utility will be observed. Several governments in developing countries and international organizations are already working on ways of leveraging on DLT to help alleviate financial inclusion.

2.5 Risks, Challenges and Constraints of Fintech in Developing Countries

The global volume of fintech investment has grown dramatically over the past few years and is projected to increase in the coming years as they provide immense opportunities over a wide range of businesses. Despite the increasing adoption of fintech services by traditional financial institutions there are a number of impediments that fintech face. The vast amount of opportunities presented by fintech to the financial industry come along with challenges, risks and constraints which impede the diffusion of fintech, especially in developing countries. These risks and challenges are not only to the fintech companies but can also pose threats to the stability and integrity of the financial system in cases where operations happen outside of the scope of regulations and supervision. In this section, some of the risks, challenges and constraints associated with fintech in developing countries are discussed.

2.5.1 Raising Venture Capital or Strategic Financing

One of the challenges of new innovative fintech startups which present new and disruptive business models that have the ability to make a difference in certain sectors is the difficulty of raising the required financing or venture capital. Venture capitalists use strategic and professional procedures in their due diligence and financing processes. While venture capital firms and investors mostly seek to get good returns, they also ensure that their investments do not go into very risky projects that do not guarantee their exit. This, therefore, makes it very hard for fintech startups who develop technologies or services that are very risky to raise venture capital funds. Financing for fintech startups has been mostly concentrated in fewer places in developed countries. Some developing countries, mostly in Asia, that have the innovative ecosystem to support startups are also on the rise, but the majority of developing countries have little financing for fintech startups. As put forward by Ughetto et al., finance from traditional financing tools for SMEs and startups is influenced by geographical proximity. Furthermore, venture capitals are more interested in making investments at expansion and later stages where there is less risk. Many fintech startups cannot get to those stages, even with very good business proposals, due to the lack of financing. Venture capital firms usually possess value-enhancing abilities other than money that can be very good for fintech companies. They can help provide coaching and advising on competitive intelligence, refinements of marketing plans and customer targets, and opening doors to potential customers, partners, capital investors and potential management team members. However, due to the laborious requirements and strategic processes of cherry-picking of venture capitalists, many fintech companies get stuck on the way.

2.5.2 Regulatory Compliance

As expansion and diffusion in the fintech industry continue to surge, there has been a growing concern among regulators about the future of fintech with regards to regulations. Fintechs are being pressured to ensure that they address both potential and existing regulatory issues in the financial industry. Consumer privacy and data security, together with regulatory schemes related to financial services are increasingly becoming a hurdle for new fintech companies. Abiding to different regulatory schemes for different regions limits the diffusion of fintech companies as well as the scope of their services. In the European union, laws such as the revised Payment Service Directive (PSD2) and the General Data Protection Regulation (GDPR) which regulate payment services and the control of personal data of individuals respectively within the European Union are major impediments for fintechs in the European market. In the United States, fintech companies must work in compliance with both federal and state laws such as the Federal Trade Commission (FTC), the Consumer Financial Protection Bureau (CFPB) and the State Data Breach Notification Law.

In many developing countries around the world, regulations that are similar but specific in scope also apply to fintech companies. Satisfying these regulations requires the services of experts in different professions such as legal and cybersecurity and this can be costly for fintech companies and subsequently becomes a major challenge. This gets even more complex when a fintech company tries to expand to different markets. Furthermore, different countries and states have different laws against money laundering. Fintech companies that provide services in remittances, or transfer of funds are required to follow laws against money laundering and illegal activities. While fintech has a lot of potential to increase financial inclusion, it is also enticing people in the illegal businesses like drug cartels that may abuse the opportunities presented by fintech and hinder financial integrity.

Furthermore, the prevalence of fraudulent acts is also becoming an issue with new innovative technologies. While blockchain is increasingly being used by fintech companies to ensure secure services, fraudulent acts still exist. One of the biggest of frauds in online investment in recent years is the Quadriga fraudulent incident. Over 76,000 clients with a combined sum of $215 million saw their investments disappear just as the founder, Gerald Cotten, died during his honeymoon in India in 2018. The fraud is being referred to as a Ponzi scheme in which Cotten had opened many accounts under different aliases and crediting himself with fabricated currency and crypto assets which he traded with unsuspecting clients *(Deschamps, 2020)*.

2.5.3 Technological Infrastructure

The penetration and diffusion of fintech is greatly dependent on the technological infrastructure in the countries. Lack of good information technology infrastructure can hinder the development of innovative technological-based solutions. The need to deliver global interoperability is steering more interconnection among participants in the fintech industry. This means that the fintech industry requires continuously evolving technological infrastructures to support new innovative technologies.

In developed countries, where basic infrastructures such as electricity supply, access to good internet, access to good mobile networks exist, fintech solutions find it easy to penetrate and become mainstream. Consider the evolution of new fintech payment services - in many developing countries, the rate of diffusion is very low because the financial systems are based on old traditional models and the financial technology infrastructures are more typical of old legacy systems that cannot support new innovative solutions. This therefore creates challenges for fintech solutions in penetrating those markets.

In many developing countries, problems with some of the basic technological infrastructures are still inherent there. For example, a reliable electricity supply fosters all technological solutions, even for those that operate with less advanced features and products, such as mobile phones running on 2G cellular networks. Without reliable electricity supply, delivery of financial services with fintech solutions becomes impossible. The landscape of fintech is very broad and each area of fintech requires some form of infrastructure that supports the fintech solutions in that area.

In many developing nations, continuous access to electricity can be difficult, especially in remote and rural areas. Internet connectivity can also be very challenging in many developing countries and it is fundamental for the operations of fintech solutions. Capital investment by the public administration for some of these infrastructures are needed to ensure reliability and an easy penetration of fintech solutions. Mobile money services are successful in many developing countries where they are operating because there was already the infrastructure. In contrast, mobile wallet payments methods have had little penetration in developing countries in Sub-Saharan Africa because the financial systems there mostly operate with cash and old legacy systems.

Therefore, technological infrastructures to support new innovative financial technologies are necessary to foster and enhance fintech in developing countries.

2.5.4 Cybersecurity

Cybersecurity is the protection of internet-connected systems such as hardware, software, and data from cyber threats *(Rouse, 2020)*. Cybersecurity is one of the biggest issues that even the traditional financial institutions lays a lot of emphasis on. Some cybersecurity issues of concern include data breach, malware attacks, digital identity theft, application risks and third-party security risks. The integration of fintech services in many financial services in traditional banking services is of concern for data security. Traditional banking systems used local servers which makes data breach less vulnerable. The rapid rise in the use of digital platforms, as fintech adoption continues to grow, has made the fintech industry and its customers more vulnerable to different breaches of security. Most of the data processing for fintech services now happens in the cloud and without extreme security measures can be breached by hackers. Overcoming or minimizing these security risks requires experts and very good security systems to protect fintech firms and their customers from cyber threats.

2.5.5 Innovation

Innovation is a continuous process, therefore fintech companies have to ensure that they stay on top of trends. The value of an innovative solution today cannot be guaranteed in the near future which means fintech companies have to continuously work to stay on top of new trends. Innovation helps firms to not only diffuse in the market and gain traction, but also help them with awareness of new trends and innovative solutions so that they can make smart dynamic business models that allow them to keep up with new trends. Meeting dynamic customer needs is another issue for which fintech companies must innovate. Customers are becoming more and more demanding of new and dynamic innovative solutions every day. Financial services firms and businesses depend on customers, it is therefore important to continuously seek to understand their needs and address them to ensure that they do not lose the customers. It is very crucial for fintech companies to build a cordial relationship with customers through quality delivery of services.

2.5.6 Competition and Market Risk

Fintech services have been widely adopted by traditional financial institutions over the last few years. However, while fintech provides complimentary services to the financial institutions, they also act as competitors to them. Traditional financial institutions have a lot of data and knowledge about the customers and the market as well as good human resource personnel with experience in the delivery of financial services. Therefore, fintech companies cannot underestimate the competencies of incumbents

and the lengths they are willing to go to defend their market position. The financial services industry has also experienced an influx of big techs like Google, Apple, Alibaba, Samsung, etc., in the delivery of financial and payment services. With their leverage on capital spending power, human resource capability, platforms, and research and development capability; they possess in-house competencies and capabilities that can easily give them a competitive advantage against small emerging fintech companies. In many cases, it is preferable for emerging fintech to differentiate their products or services and focus on niche segments where they can defend themselves or sell their product to bigger companies.

2.6 Measuring Financial Inclusion

The question of how to measure financial inclusion has been a very important one and yet one of the most difficult to answer. The underlying reason for this is due to the multidimensional nature of financial inclusion. Several attempts have been made to develop models for a universal financial inclusion index. However, an effective index that works for all countries still seems far-fetched. A country may perform very poorly in one dimension but does very well in another due to the unleveled playing ground for the penetration of financial services. The indicators used to measure these dimensions also differ from one country to another. A developed nation may score very high on bank related account ownership while it may score very poorly in mobile money account ownership. This may be the inverse for a developing nation. If account ownership is looked at as a function of owning an account at a financial institution or at a mobile money service, the results of a model that uses this information may not effectively explain how account ownership relates to financial inclusion in a global sense. Maybe, one may also look at other things connected to the type of account one owns: like what markets does your account give you access to, how useful is that account in your region or is there a good infrastructure for you to effectively use that account in your region? The answers to all these questions differ from one region to another and giving more weight to one may give rise to results that do not explain financial inclusion very well in different countries. It is, therefore, important to look at different relevant indicators at country level in order to come up with a better way of understanding the level of financial inclusion in countries around the world. One of the most detailed sources of financial data that provides data on several financial indicators around the world is the Global Findex Database. In this paper, a few attempts from past literature at measuring financial inclusion will be explored.

2.6.1 The Global Findex Database

Due to the lack of a universal way of measuring financial inclusion, the World Bank, with initial funding from the Bill and Melinda Gates foundation, developed the Global Findex, which compiled data from surveys in over 140 countries to give a sense of how different countries perform against different indicators for both formal and informal financial services indicators *(Demirgüç-Kunt et al. 2017)*. This helps governments, non-government, and private entities to track financial access in the different countries. In the Global Findex report, account ownership of adults is used as a measurement of financial inclusion in the different countries that were surveyed. But this is not very correct because it does not account for some informal means through which people in some countries participate in their local financial systems. However, the provision of different financial indicators beyond account ownership for the different countries help provide a better view of the level of financial inclusion in the different countries around the world.

2.6.2 Financial Inclusion Modelling

Modeling financial inclusion is a difficult task and requires a very broad look at different indicators. Several researchers have made different approaches to establish models of financial inclusion by looking at different factors and financial indicators. Some models of financial inclusion indices used supply-side data and demand-side data. In this section, I will look at some models of financial inclusion that look at different indicators to explain the depth of financial inclusion.

A multidimensional model of financial inclusion index by Noelia Cámara and David Tuesta, used both demand and supply side data to develop an index for financial inclusion using a two-stage principal component analysis with three dimensions. The three dimensions used include usage of financial services, access to financial services and barriers to financial services *(Cámara & Tuesta, 2014)*. The model captured different indicators for each dimension to develop regression models for the individual dimensions. According to their report, usage and access are necessary but do not give complete information about financial inclusiveness. It was therefore necessary to add barriers to understand why people are excluded from the financial system. To compute the financial inclusion index, the model employed a second stage principal component analysis in which the dimensions that were computed in the first stage became the variable for the second stage.

This model is a good theoretical model that gives a better understanding about the dimensions of financial inclusion. However, the dimensions do not capture some indicators that are very crucial in explaining the usage patterns, access, and barriers of financial inclusion in the individual countries. For

example, in the usage dimension, savings and loans only capture the percentage of the population that save and have loans at a formal financial institution, respectively. This may therefore misrepresent the level of financial inclusion in countries that use other informal means like mobile money that are not accounted for in the model. This model may not work well in Kenya where the M-Pesa, a mobile money service, is dominant. In my 2019 survey on the use of mobile money in Sierra Leone, most respondents use their mobile money accounts to do transactions and to save. In addition, access is represented as a function of ATMs and number of financial institution branches. This may also underestimate the number of access points of financial services in some countries. For example, there are more mobile money service agents in Sierra Leone than there are banks. Excluding agents will therefore give an underestimate of financial access in the Sierra Leone context.

Another model that attempts to measure financial inclusion is that of Mandira Sarma. The model is adapted from common methods used by the UNDP to model the Human Development Index. The model, however, differs from those used by the UNDP as it utilized the averages of the Euclidean distances between the dimensions and the worst point and ideal point rather than averaging the indices of the dimensions. The model also used three dimensions and several indicators for each dimension. The dimensions are banking penetration, availability of banking services and usage. This model suffers a lot of limitations in both dimensions and indicators which is due to the availability of data for different indicators at the time the model was developed. The indicators used are limited to access and usage. Barriers are not considered in the model, therefore, the limitation in scope will result in a model that is not able to explain why people are excluded in the financial system. However, the model creates a framework that can be easily adapted by just adding more indicators and dimensions of available data.

Chapter 3 – Research Methodology and Data Analysis

3.1 Introduction

This section will start with a description of the research design, then the data collection and sources together with justification of the methods used and the limitations of the methods used will also be discussed. This will be followed by the research methodology for the analysis of the data which will outline the methods used and a description of how they are employed in this paper. The dimensions and the variables used in the data analysis will be explained and finally, data analysis and presentation of results will be carried out based on the laid-out methodology. The latter part will focus on preparing and analyzing the data using statistical tools and presenting the results of the statistical analysis.

3.2 Research Design

To provide a clear picture of the impacts of fintech on financial inclusion in developing countries, both descriptive and correlational research designs methods are utilized. The choice of a dual approach on the design of the research is to be able to provide a broader outlook into financial inclusion using theoretical and previous literature as well as utilizing data to provide analytical methods to show evidence of the impacts of fintech on financial inclusion.

The descriptive aspect will allow the use of past literature and information in this study to describe the situation and provide better insights into the underlying state of financial inclusion and how fintech can help augment it in developing countries. This aspect is important because there are little known methods of calculating financial inclusion with respect to the different components that constitutes it. In addition, existing models tend to be biased since the penetration of variables of financial inclusion differs from one country to another. It is therefore difficult to provide a universal model that works for all countries. Furthermore, the lack of availability of data for all countries makes a descriptive analysis necessary.

The choice of including a correlational design technique is to study the relationship between fintech indicators and financial inclusion and examine the variability of financial inclusion with respect to those indicators of financial technology. To find a relationship between fintech indicators and financial inclusion, a multivariate regression analysis will be carried out together with a principal component analysis in order to summarize and visualize the information on the data set for the different countries as described by the multiple inter-correlation among the financial inclusion indicators used. The results of the correlation analysis may or may not support existing literature about how fintech can augment financial inclusion. However, it will be interesting to see the variations and intercorrelation

between indicators and understand how this contrast or complement literature. Furthermore, the results will depend solely on the data and the statistical techniques utilized to establish the relationship between financial inclusion and fintech indicators. It is worth noting that there is not a specific indicator of fintech or financial inclusion as they are latent variables that can be described by other indicators. However, common indicators that are very representative of fintech will be used to examine the impacts of fintech on financial inclusion.

3.3 Data Collection and Sources

The collection of data in this study draws from different sources. First, secondary data from the World Bank Global Findex and the IMF Financial Access Survey were used to carry out the regression analysis and the principal component analysis on different financial indicators to find a relationship between fintech and financial inclusion. Secondly, a survey was done to collect data on usage and barriers to financial services for the case study in Sierra Leone.

3.3.1 Target Population

The target population for this study is developing economies and Sierra Leone as a case study. Financial exclusion has been most prevalent in developing countries. However, different studies have shown that, with the emergence of different forms of fintech, some nations are already broadening the horizons of financial inclusion. The choice of looking into developing nations is to try to get a specific look at countries that have had more financial exclusion and find out how fintech can help close the gaps in exclusion. While the value of the impacts of fintech in developed countries is extremely high compared to developing nations, it has mostly made little impact on financial inclusion in those countries. This is analogous to the Boeing-Crawford experience curve of product costing in which the relative cost decreases declines hyperbolically because the residual inefficiencies progressively become fewer and harder to spot or solve (*Cantamessa & Montagna, 2018*). In developed countries, the number of people who do not own an account in the formal financial system is very little. Hence, solving the problems that keep them out of the financial system becomes harder to solve as they may depend on personal reasons or other strong barriers. It is, however, worth noting that even for those who are already in the financial system, they also benefit a lot from fintech innovations as they provide both complements and substitutes to the traditional financial services that help improve their experience. It is therefore decided to look into developing countries where it is more likely to find a pattern on the impacts of fintech on financial inclusion.

3.3.2 Sample Size

The sample size for analysis of the impacts of fintech in developing economies is 42 developing countries while a sample of 250 respondents was done for the case study in Sierra Leone. The sample size for developing countries was limited to 42 countries because all data for the financial indicators chosen for the study were only available for the 42. The number of respondents in the survey for the Sierra Leone case study was made 250 in order to get adequate responses from different demographics that can provide a good representation of the use and barriers of formal financial services and mobile money services in the country.

3.3.3 Secondary Data – Global Findex & Financial Access Survey

The data from the Global Findex was collected by Gallup World Poll through surveys that were conducted through face to face or on the telephone. Face to face was done in economies where less than 80 percent of the population have telephone coverage or where it is the customary method. The method of data collection utilized professional methods that minimizes the potential of error. In addition, data weighting was done to ensure nationally representative sample with base sample weights to correct for unequal probability of selection and poststratification weights to correct for sampling and nonresponse error. The IMF Financial Access Survey is a supply side dataset which provide information on access to and use of financial services geared toward supporting policymakers to measure and monitor financial inclusion and benchmark the progress of other economies. The data is based on administrative data collected by central banks and other financial regulators in the different countries. However, while this data is reliable, there are lot of missing data for many indicators. This also limited the number of indicators used because I found that the more, I increased the number of indicators, the less the number of countries that have data for all those indicators. This was impacting more on developing countries which are the countries of my primary interest. Therefore, the number of indicators were limited to ensure that there are sufficient number of observations that represent different strata of countries among the developing countries.

3.3.4 Primary Data – Sierra Leone Financial Services Usage and Barriers – Survey

The data on the usage and barriers to financial services and mobile money in Sierra Leone was collected through an in-person survey between December 2019 and January 2020. The survey was made on several respondents from different cities and towns in Sierra Leone to collect data on several indicators about barriers and usage of financial services.

3.3.5 Survey Design

The survey design was aimed at collecting data from both people that are banked and those that are unbanked. The first part of the survey collected data on basic demographics like gender, age, level of education and city/town of respondents. This was followed by questions related to whether respondents are banked or not. For the unbanked, a list of common reasons for not being in the formal financial system were asked to be rated on a scale from 0 to 4 with 0 being unrelated and 4 being a strong reason. For the banked respondents, further questions about their use of financial services are also asked. The next part explores the use of mobile money - reasons why or why not were asked to respondents who are using it and those that are not respectively, Further questions on how often respondents use mobile money services and also if they use it for savings were asked. In addition, the survey also asked respondents if they have borrowed/ taken loans from formal financial services. The design of the questionnaire is primarily to investigate how fintech has open the doors of financial inclusion to people who were not included in the formal financial system. The survey questions were mostly guided by using closed ended questions which help to avoid opinions and responses that are difficult to incorporate in the data analysis. The survey questionnaire will be attached in the appendix.

3.3.6 Justification of using an In-Person Survey

An in-person survey method was utilized in order to reduce nonresponses and to ensure that respondents understand the questions in instances where they need clarifications. Also, some questions in the survey only need to be answered if correspondents choose a specific answer in the preceding question(s). Furthermore, I assumed that not all respondents may be able to read and correctly understand the questions in the survey in English as a result of their low level of formal education, familiarity of terms used, and/or language barriers. Also, the rate of responses is usually very high in an in-person survey compared to other methods of data collection.

3.3.7 Limitations of the survey

While a lot of data was able to be collected on barriers and usage of financial services from respondent. Data on financial access statistics were unavailable. I made efforts to obtain data on some financial access data from the UNDP, Bank of Sierra Leone and the Sierra Leone Commercial Bank on statistics about number of financial institutions, access mobile points, number of ATMs, number of mobile money services agents and number of mobile money accounts in the country, but I never received the data. The lack of these data limited the mobile money case study in Sierra Leone to a descriptive analysis, contrary to the correlational analysis with regression and principal component analysis for developing countries in general.

3.4 Theoretical Dimensions and Variables

Financial inclusion is made up of different dimensions which can be defined by several indicators. Different models of financial inclusion utilize different indicators for measurement. In this study, several relevant financial indicators were used as variables. Different studies have put forward different theoretical dimensions for financial inclusion. However, in this paper three theoretical dimensions for usage, access and barriers are considered with several indicators for each of the theoretical dimensions. According to Cámara and Tuesta *(2017)* an inclusive financial system is said to be one that maximizes the usage and access of financial services while minimizing involuntary financial inclusion. Therefore, indicators that speak to these three dimensions were used to do the analysis. To estimate the variability caused by the different indicators on financial inclusion, a regression analysis and a principal component analysis are done. Although usage, access and barriers are used as theoretical dimensions, the principal component analysis, in practice, does not have a predefined set of dimensions. This is because the number of dimensions can be as many as there are variables. The number of dimensions is dependent on the data and a linear combination of the different variables used, to associate components that produce the maximum variations in the data. Among the indicators used in the analysis are indicators that represent the use of fintech. A closer look into the variability caused by these indicators will be done to assess the impacts of fintech on financial inclusion.

For the regression analysis, since financial inclusion is a latent variable, it requires a dependent variable to be regressed against financial indicators. Account ownership was therefore chosen to be the dependent variable since it is most representative of financial inclusion. In addition, ownership of an account from the Global Findex database is considered as being financially included. While financial inclusion is more than just owning an account, it was thought to be the most representative of financial inclusion, it is therefore used as the dependent variable for the regression analysis. The three theoretical dimensions: access, usage and barriers to financial inclusion used will be discussed in the following section. The names of the indicators are abbreviated or coded to shorten them. The full description of each variable is attached in the list of Abbreviations and Acronyms.

3.4.1 Access

Adequate financial access is very important to having a financially included society. To model this dimension, the access points of formal financial institutions were utilized. First, I considered the number of commercial banks per 100,000 adults and the number of commercial banks per 100,000 square kilometers for each country used in the study. Then number of ATMs per 100,000 adults and

number of ATMs per 100,000 square kilometers were also used as indicators for the access dimension. These indicators are very important because they show geographical proximity of financial services access points within different economies and account for both population size and geographical size. However, this dimension lacks some vital indicators that could have improved the model. For example, in many developing nations, access points for financial services are largely mobile money agents and other financial points of services that are not commercial banks. Unfortunately, data for these indicators is unavailable for most of the countries in the study. The data for the indicators used was obtained from the IMF financial access survey.

3.4.2 Usage

The usage of financial services was modelled as a function of several indicators that describes different modes in which people use financial services. First, I assumed that ownership of an account is in most cases the first step in using financial services. However, this is not enough as it does not provide enough information about other usage modes. I considered mobile money account ownership which tends to be a trend that has been gaining traction in many developing countries. Then savings or loans from a financial institution are considered as other modes of usage of financial services. Finally, the use of digital payment and use of internet or mobile to access an account are also considered as use of financial services. It is necessary to point out that, in many financial inclusion models, the use of mobile money, the use of digital payments and use of mobile or the internet are not considered as usage indicators. This is partly because fintech are still in the diffusion stage and many academic studies have failed to mention them due to their little or no existence in the past. But these indicators are included in this model to be able to see how these fintech indicators influence the usage patterns of financial services. The data for these indicators were obtained from the Global Findex database.

3.4.3 Barriers

Different barriers of financial inclusion are utilized in this study. The reason being because the use of formal financial services and the availability of access points do not fully describe financial inclusion from the point of view of all the actors involved. Usage and access lean more towards the supply side of financial services while barriers describe the stumbling blocks that prevent financial inclusion in the demand side. This is important because to fully understand the issue, it is necessary to look from both sides of the aisle. The usage of financial services can be impacted by socioeconomic factors like cultural barriers, legal barriers, proximity, and economic status. The usage of financial services happens if one doe does not have barriers that prevent that individual to using it. So, in theory, usage is an out. Access, on the other hand, also provide infrastructure that help one to use financial

services, however, one must have overcome barriers first before one can use those services. It is therefore necessary to include this dimension as it speaks to the impediments that prevent people from being financially included. For the barriers dimension, demand side data on the following indicators were obtained from the Global Findex database.

Physical proximity, cost of opening and account, document requirements, lack of trust in financial institutions, religious beliefs, lack of sufficient funds, lack of need to open an account and lack of an account because a family member already has one were all considered as barriers that prevent one from getting an account.

3.5 Research Methodology

For the purpose of this research, two statistical methods will be employed in the analysis of fintech with respect to financial inclusion in developing countries in general. First, a multivariate regression analysis will be performed to examine the correlation of different financial indicators on financial inclusion. Secondly, a principal component analysis will be performed on the data set to create a predictive visual model of the different indicators with respect to the major dimensions of the model. Furthermore, for the mobile money case study in Sierra Leone a survey/questionnaire methodology was done to collect data. The collected data for the case study on the usage and barriers to financial services in Sierra Leone will be analyzed and presented in a more descriptive form.

3.5.1 Multivariate Linear Regression Analysis

As already stated, the primary objective of this research is to study the impacts of fintech innovations on financial inclusion in developing countries and the challenges they face. Regression analysis is one of the statistical techniques that is more often used to investigate or evaluate the relationship between a dependent variable and other independent explanatory variables. A regression analysis is a quantitative research methodology that is used when the study involves an analytical model with several variables. In a nutshell, it is a quantitative method that is used to examine the relationship between a dependent variable and one or more independent variables.

For the purpose of this study, a financial inclusion variable will be established and will be regressed against other indicators of financial inclusion that speak to access, usage, and barriers of financial inclusion dimensions. To find the relationship between fintech and financial inclusion, a number of financial indicators which are typical of the usage and access of fintech products and services are used in the model. For this reason, a multivariate linear regression analysis will be

performed on several observations and the variations on the dependent variable with respect to the fintech indicators will be examined. For simplicity in this analysis, observations and countries will be used interchangeably while variables and indicators will also be used interchangeably. The number of observations used is dependent on the number of countries for which data for the different indicators used could be found. In the regression model for this study, the dependent variable is established as account ownership. Since a universal financial inclusion index is not available, account ownership which is more representative of financial inclusion is used to establish a dependent variable. Furthermore, account ownership is regarded as being financially included according to the World Bank.

Assuming that Y_i, which represent the dependent variable, is a function of n independent variables x_i and an unknown parameter β with an additive error term ε_i our regression model will follow the given format shown below.

$$Y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_n x_{in} + \varepsilon_i$$

In the regression model for this paper, Y_i is the financial inclusion variable which is assumed to be account ownership, β_0 represents the intercept, whereas β_1, $\beta_2 \ldots, \beta_n$ represent the coefficients of the 17 variables (x_i) which are regressed against account ownership and the number subscripts 1, 2, …, n, correspond with the number of variables used in the model. A more detailed procedure of the regression model used in R is given in the data analysis section.

3.5.2 Principal Component Analysis

Principal Component Analysis (PCA) is utilized in this study to create a predictive model of financial inclusion in developing countries with special focus on how financial technology indicators impact financial inclusion. The PCA is a method used to extract important information from a multivariate dataset and decompose the information as a set of fewer new variables that form the principal components *(Kassambara, 2017).* The new variables are proportionate to a linear combination of the original indicators used. The goal of PCA is to identify components that give the maximum variations in the data. Mathematically, PCA is dependent on the eigen-decomposition of semi-definite matrices and upon the singular value decomposition of rectangular matrices (*Abdi & Williams, 2010*).

Since financial inclusion is a hypothetical concept, measurement through direct quantitative means like standard regression is quite impracticable. Therefore, to get a more applicable method of measurement will require the study of the interaction of casual variables that are representative of financial inclusion. In this regard, PCA can provide a better analysis than standard regression analysis.

However, the selection of relevant variables is very important in the determination of components. To address these issues, relevant financial inclusion indicators on access, barriers and usage of financial services are selected from the Global Findex database and the Financial Access Survey from the World Bank and IMF, respectively. Furthermore, since principal component analysis can be biased with respect to the weights of variables that are highly correlated *(Mishra, 2007)* it is important to minimize biases through standardization of the data.

The first step in the analysis involves the calculation of the covariance matrix of the original indicators in each financial dimension. To do this, let's consider a data matrix X of several variables $j = 1, 2, 3, \ldots m$ which have several observations $i = 1, 2, 3, \ldots m$. The data matrix can be represented as shown below.

$$X = \begin{pmatrix} X_{11} & X_{12} & X_{13} & \cdots & X_{1m} \\ X_{21} & X_{22} & X_{23} & \cdots & X_{2m} \\ X_{31} & X_{32} & X_{33} & \cdots & X_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & X_{n3} & \cdots & X_{nm} \end{pmatrix}$$

where X_{ij} is the $j-th$ variable collected from the $i-th$ observation. The observations which represent the developing countries used in the analysis are rows and the variables which represent the financial inclusion indicators are columns. With all the variables and different observations, the covariance matrix of the data can be found. This can be done automatically with R using the function 'cor()'. One can also specify which correlation coefficient to use between pearson, kendall or spearman. However, for this analysis, A pearson correlation coefficient will be used because it measures the linear dependency between two variables while kendall and spearman are non-parametric ranked based correlation tests. Mathematically, the covariance matrix can be calculated by using the vector of the variable means and a centering matrix. Below is the simplified structure of the covariance matrix.

$$S = \begin{pmatrix} s_1^2 & s_{12} & s_{13} & \cdots & s_{1m} \\ s_{21} & s_{22} & s_{23} & \cdots & s_{2m} \\ s_{31} & s_{32} & s_{33} & \cdots & s_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ s_{m1} & s_{m2} & s_{m3} & \cdots & s_m^2 \end{pmatrix}$$

Where:

- $s_1^2 = \frac{1}{n}\sum_{i=1}^{n}\left(x_{ij} - \bar{x_j}\right)^2$ is the variance of the $j-th$ variable
- $s_{jk} = \frac{1}{n}\sum_{i=1}^{n}\left(x_{ij} - \bar{x_j}\right)\left(x_{ik} - \bar{x}_k\right)$ is the covariance between the $j-th$ and the $k-th$ variables.

- $\bar{x_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$ is the mean of the $j - th$ variable

The second step is to perform the computation of the eigenvectors and the eigenvalues of the covariance matrix to identify the principal components. To find the eigenvalues and the eigenvectors from the covariance matrix, it must be noted that the eigenvector is a vector which when multiplied by the eigenvalues gives the same result as when multiplied by the matrix. This can be represented mathematically as shown below.

$$S\vec{x} = \lambda\vec{x}$$

Where S is the covariance matrix derived from the first step, $\vec{x}$ is the eigen vector and λ is the eigen value. The right part of the equation can be transferred to the left and multiplying an identity matrix I with the eigenvalue and leaving a zero vector on the right side.

$$(S - I\lambda)\vec{x} = \vec{0}$$

$$det|S - I\lambda| = 0$$

By solving the resulting equation, the values of λ represent the eigenvalues. The eigenvectors for each eigenvalue can then be found by substituting the eigenvalues into the equation and solve. The higher the number of columns and rows of the matrix, the higher the level of difficulty of computing the eigenvalues and the eigenvectors. However, several computational programs, including R which is used for this paper, can easily do the computation.

The total variation on the model will be represented by two orthogonal parts which are the variation caused by the indicators and the variation caused by the error, that is the correlation matrix and the p-values matrix, respectively. With a well specified model, with a relatively small variance on the error term with respect to the latent variable in question, and sufficient number of explanatory variables, the total variation in financial inclusion can be largely explained by the variation in the indicators. By minimizing the variation caused by the error through standardizing the data and using relevant indicators the impacts of fintech on financial inclusion can be explained by the variation caused by the fintech indicators.

3.5.3 Survey on Financial Services Usage and Barriers in Sierra Leone

The survey took a closer look into usage of financial services – both formal and informal, and the barriers that prevent those that are not using financial services in order to study the impacts of fintech in the form of mobile money on financial inclusion. The survey was conducted between December 2019 and early January at different geographic locations in Sierra Leone. The responses

obtained from the 250 respondents presented a lot of disparities in different demographics and some intriguing statistics on the use of formal financial services. The response rate to the different questions in the survey was excellent as the survey was done in a face to face manner and the survey employed mostly closed ended questions. This face to face approach helped respondent to clarify doubts in the questions that they do not understand and also not to respond to questions they are not supposed to answer to because of their responses to previous questions. Also, some people would likely not complete the survey if they were to take the questionnaire away or may not even read the questions properly. The results of the survey will be discussed in the data analysis section.

3.6 Data Analysis

In this section, the focus is to analyze the data using statistical tools, present and discuss the results of the statistical analysis. This will include cleaning of data, selection of relevant variables and application of statistical tools to process the data. Finding the impacts of fintech on financial inclusion cannot be found directly by using a formula because there is no universal formula to do that. However, it is possible to look at different variables that are representative of fintech and find a relationship with financial inclusion using data. For the purpose of this study, the impacts of financial indicators which are representative of fintech will be utilized to establish a relationship with financial inclusion. As already indicated in the research methodology, the analysis will employ two statistical tools to investigate the relationship between fintech and financial inclusion. The two are: a multivariate regression analysis and a principal component analysis. Furthermore, a descriptive analysis was done on the Sierra Leone survey results, hence, will only be included in the discussions section.

3.6.1 Data Preparation

In order to use the data, significant amount of cleaning, sorting and selection of relevant variables was done to the data. The data for many developing countries were not available for the different variables. This may create inaccuracies in the model if the said countries are considered. Therefore, it was thought fit to consider developing countries that have complete information for the different variables used. This was a hard choice, especially because of the lack of complete data for Sierra Leone. However, to be able to sufficiently describe the variation caused by fintech on financial inclusion, a sufficient number of indicators must be used. It must also be noted that

The selection of data variables was based on some theoretical information on the dimensions of financial inclusion which include, access, usage, and barriers. However, none of the previous models utilized explicit variables of financial technology to measure the variability fintech causes on financial inclusion. This therefore prompted the addition of financial inclusion indicators that are typical of the access and usage of innovative fintech products and services. Based on the availability of data on the Global Findex database, mobile money account ownership ($MMAct$), digital payments ($DigPay$), and usage of mobile and internet account ($UMIAct$) were designated as indicators of use of fintech. Selection of variables was limited to relevance and availability of data. The data was then sorted with excel based on countries that are categorized as developing countries. Among the developing countries, those that do not have information for the different variables selected for the model were removed from the list. The list of the countries used in the statistical analysis will be attached in the Appendix section.

Furthermore, for the PCA, a standardization of the data was applied to transform the data into the same scale by calculating the z-scores for all the data. This is important because it helps reduce the sensitivity of the variances of the initial variables due to large differences in scales. For example, some variables are given in percentages while others are given in absolute values that are in thousands. The differences in scales can lead to biased results. Therefore, by transforming the data into a similar scale will avoid such biases and prevent the exaggeration of results. The standardization was done by subtracting the mean from the value and dividing by the standard deviation as shown below.

$$z = \frac{x - \bar{x}}{\sigma}$$

Where x, $\bar{x}$ and σ represent the original value, the mean value, and the standard deviation for each variable.

3.6.2 Multivariate Regression Model

In this model, the different financial indicators data collected from the Global Findex database and the Financial Access survey were used to carry out a multivariate regression analysis in which account ownership among adults is the regressor and 17 other variables that are considered as indicators of access, usage or barrier to financial inclusion are used as predictors. To carry out the regression analysis, the data was first sorted and cleaned using excel to ensure all data are available for the different variables and countries used in the study. This was important because a model can be just as good as the data, incomplete data can cause unanticipated outcomes and errors in the analysis. The open software program, R, was used for the regression analysis because it provides flexibility for the use of multiple variables in the regression. Other software such as SPSS and Excel could be used as an option for the regression analysis, however Excel[7] was limited to only 16 independent variables. Also, it was better to use a single software to carry out both PCA and the regression analysis.

Procedure

The sorted data is first imported and loaded onto the RStudio console. The linear modelling method used required the installation of the R packages “tidyverse” “corrplot” and “Hmisc” which make manipulation of data and visualization possible. To ensure that the data is correctly loaded and all variables and observations are within the loaded dataset, the data is first of all viewed through the RStudio console and all the different variables and observations in the final sorted file from excel are present. Next is to do the linear modeling. A linear model (lm) was chosen over a generalized linear

[7] Excel in the Microsoft 365 MSO (16.0.1321.20110) 32-bit package is only limited to 16 independent variables.

model (glm) because it is more reliable in maintaining control over type-1 errors in tests where there are no association (*Warton et al., 2016*). The modeling in R is very simple with little syntax to be applied. The formula used for the lm regression is given below with the syntax used in R.

$$FIModel = lm(Act \sim MMAct + DigPay + Sav + Brwd + UMIAct + NoCBpA + NoATMpK + NoCBpK + NoATMpA + FaR + Exp + Doc + Trst + Rel + InsFunds + Fam + NoNeed, data = Standardized\_CountryData)$$

On the left side of the equation, the $FIModel$ is just the name given to the model and it can be named differently. On the right side, the lm indicates linear modeling and inside the bracket, the account ownership among adults (Act), is regressed against 17 predictor variables from $MMAct$ to $NoNeed$. The syntax "$data = Standardized\_CountryData$" only indicate the file from which the different variables used are to be extracted from.

Extraction of Data Analysis

To extract the analysis of the regression model of the $FIModel$, the syntax "$summary(FIModel)$" is used which provide a summary of some key information that explains the model. These information include the intercept, the residual standard error, the multiple R-squared, the adjusted R-squared, the F-static and the $p - value$ for the regression model. Also, a summary of the coefficients of the variables, their standard error, $t - values$, and the $p - values$ of the different predictor variables used are given. Furthermore, other important information about the Pearson correlation, confidence intervals and different plots can be extracted to explain the model.

Summary Results of the Multivariate Regression Model

The results of the regression analysis of the $FIModel$ will be elaborated on in the discussion of results section. Below is a summary of the residuals, coefficients, and other linear regression results.

```
> summary(FIModel)

Call:
lm(formula = Act ~ MMAct + DigPay + Sav + Brwd + UMIAct + NoCBpA +
    NoATMpK + NoCBpK + NoATMpA + FaR + Exp + Doc + Trst + Rel +
    InsFunds + Fam + NoNeed, data = Standardized_CountryData)

Residuals:
     Min       1Q   Median       3Q      Max
-0.36531 -0.15443 -0.01264  0.16158  0.43580

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.153e-17  4.219e-02   0.000 1.000000
MMAct        8.519e-02  1.630e-01   0.523 0.605996
DigPay       7.036e-01  1.680e-01   4.187 0.000328 ***
Sav          2.770e-01  1.019e-01   2.717 0.012020 *
Brwd        -1.036e-01  7.881e-02  -1.314 0.201220
UMIAct      -8.817e-02  1.798e-01  -0.490 0.628365
NoCBpA      -2.759e-01  9.755e-02  -2.828 0.009294 **
NoATMpK     -5.749e-01  1.346e-01  -4.271 0.000265 ***
NoCBpK       6.195e-01  1.279e-01   4.844 6.17e-05 ***
NoATMpA      3.416e-01  1.147e-01   2.977 0.006554 **
FaR         -4.673e-02  8.045e-02  -0.581 0.566730
Exp         -9.815e-02  9.340e-02  -1.051 0.303810
Doc          5.060e-02  6.240e-02   0.811 0.425382
Trst         3.220e-02  8.359e-02   0.385 0.703504
Rel         -1.532e-01  5.047e-02  -3.035 0.005709 **
InsFunds     1.360e-01  6.371e-02   2.134 0.043267 *
Fam          3.914e-01  9.923e-02   3.944 0.000606 ***
NoNeed       4.914e-02  6.409e-02   0.767 0.450671
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2734 on 24 degrees of freedom
Multiple R-squared:  0.9562,    Adjusted R-squared:  0.9252
F-statistic: 30.85 on 17 and 24 DF,  p-value: 2.916e-12
```

Firstly, the F-statistic and the associated p-value of the results of the $FIModel$ summary will be examined. According to the results, the F-statistic is 30.85 on 17 and 24 degrees of freedom which is significantly higher than 1. Also, the p-value of the F-statistic, which tests the hypothesis that all the model coefficients are equal to zero, is very small with a value of 2.916×10^{-12}. This shows that a relationship between account ownership and at least one of the indicators used in the model exists. Based on the results of F-Statistic and the p-value, we can therefore reject the null hypothesis that there is no relationship between account ownership and the independent variables. Secondly, both the multiple R-squared and the adjusted R-squared values which show the percentage of variance in account ownership that the financial indicators used in the model can collectively explain have values of 0.9562 and 0.9252, respectively. This high coefficient of multiple determination shows that the model explains most of the variation in the indicators used around the mean. Since a high R-squared value does not always indicate a good model, further information about the model will be delved into from different plots of the model to examine any discrepancies that may have influenced the model.

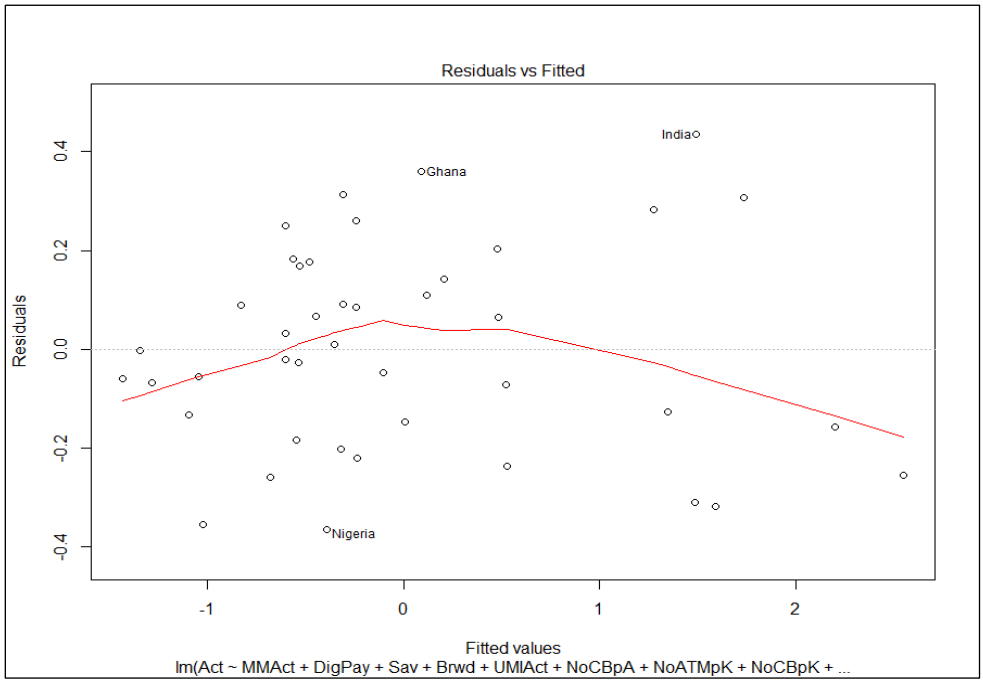
From the p-values of nine of the predictor variables, there is a significant relationship with account ownership at 95% confidence interval. However, the p-values on some of the indicators do not show a statistically significant level to show that a relationship exist between them and account

ownership at the 95% confidence level. The standard error of the coefficients of those variables can be seen to be very high. The very high standard error values may be associated with the many variables used in the model. Another thing that may have influenced this can be due to discrepancies in the data that may have been influenced by the differences in the financial structures, cultural and social constructions in the different countries used in the analysis. In addition, while the data was collected by a professional data collection organization, there could still be issues with methods used, processing and preparation of the data that may impact the data. To see which predictor variables are significant, the coefficients table which shows the estimate of the regression beta coefficients and the associated t-statistic and p-values can be examined. Based on the result summary, we can associate a unit change in the indicators with a change of the coefficient estimate in account ownership adjusting or controlling for the other variables. Digital payment, savings, number of commercial banks per 100,000 square kilometers, number of commercial banks per 100,000 people, number of ATMs per 100,000 square kilometers, number of ATMs per 100,000 people, religion as a barrier, lack of funds as a barrier and lack of account because a family member already has one, all showed p-values that are statistically significant at the 95% confidence level. Therefore, there exist a statistically significant relationship between those indicators and account ownership.

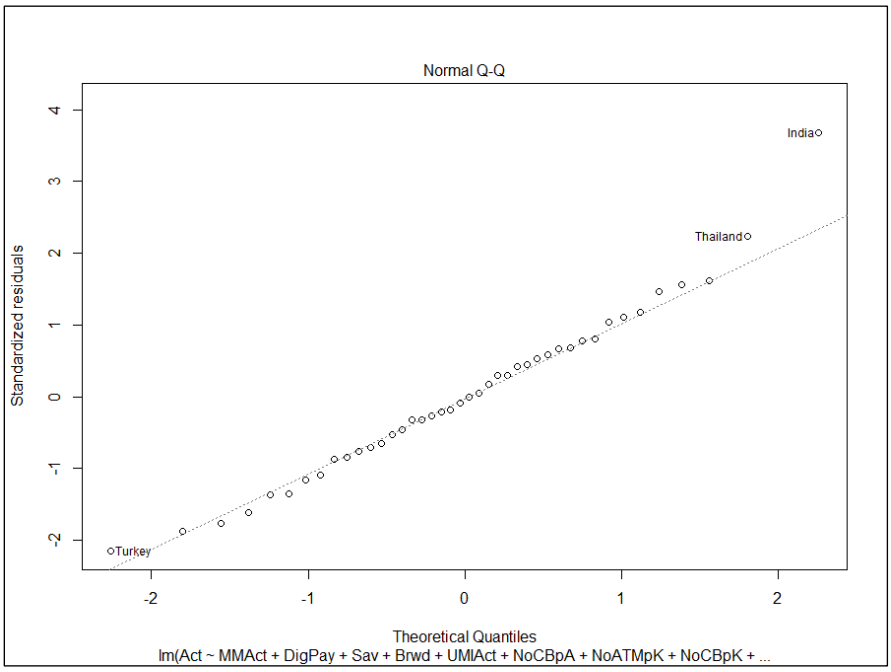
Among the indicators that are deemed as new innovative fintech variables, mobile money account and digital payments showed a positive correlation with account ownership, while the use of mobile and internet accounts showed a negative correlation to account ownership. However, only digital payment is statistically significant at the 95% confidence level.

Diagnostic Plots of the Model

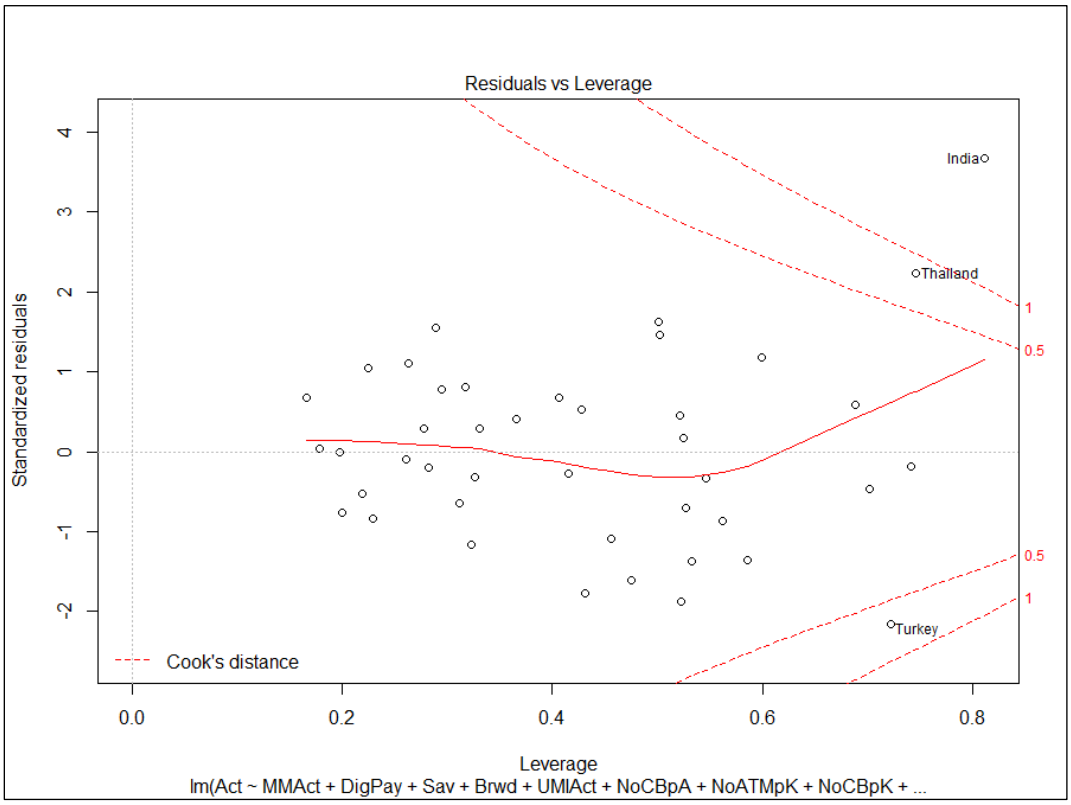
Regression results such as the coefficients of the variables, the p-values R-Squared values usually provide important information about how well the model is, but in some case, they do not provide all the information about the model. However, to see a bigger picture of the model about some things that may not have been explained by the aforementioned results, it is important to make some diagnostic plots to get more information about the model. In this regard, multiple plots were looked into in order to understand further details about the model and other things that may have impacted it. In the following, the plots of the residual vs fitted values, the normal Q-Q, the scale-location, and the residuals vs leverage values are examined.



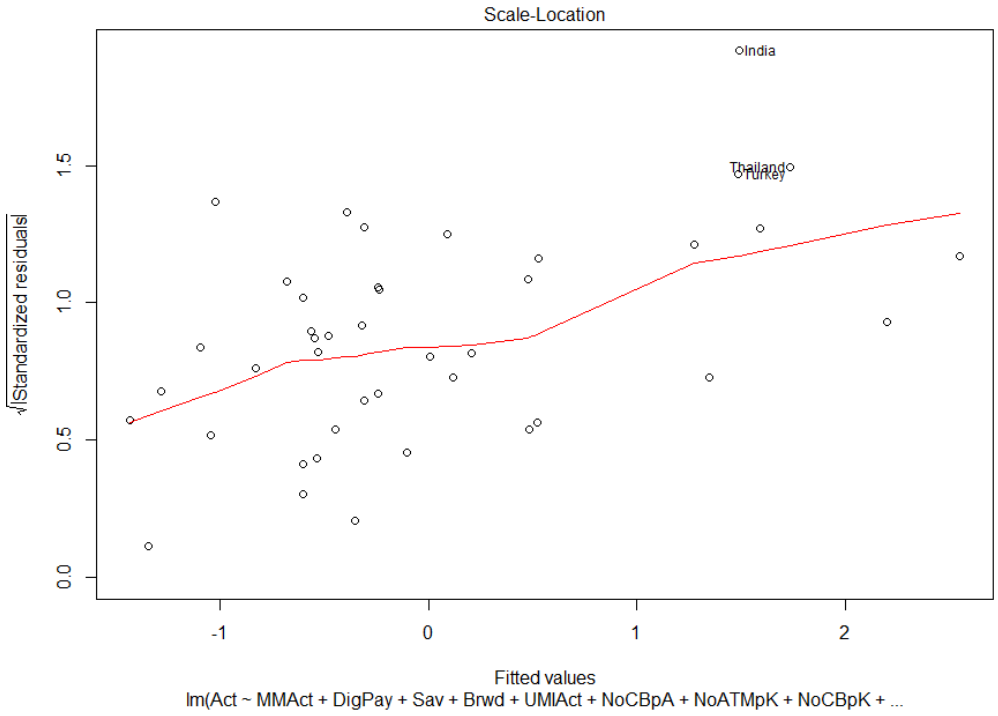
The residuals vs fitted values is used to detect nonlinearity, unequal error variances and outliers in the model. From the graph, the plot of residuals vs fitted values started from negative and increased linearly but flatten at the middle and started decreasing gently again to negative values. Since a linear regression model was used in the analysis, the non-linearity in the residual vs fitted values plot may indicate that a nonlinear model may be better for the given data. However, a closer look into the other diagnostic plots can provide further information about the behavior of the model.



The Normal Q-Q plot shows whether the residuals are normally distributed or not. Based on the graph, there is a linear plot between the standardized residuals and the theoretical quantities with a few outliers. In a perfect model, the points will on a straight line. The outliers that are way off the linear plot should be examined and their influence on the model should be assessed.



The residual vs leverage plot helps to understand the observations that are more influential in the model. Observations that lie outside a Cook's distance of 1 are said to be influential and needs to be removed. Observations that lie within a Cook's distance between 0.5 and 1 may have some influence, but do not necessarily need to be removed. The choice to remove them depends on how much they influence results if removed and when used. In this case, India has about 3.23 which was way off the accepted limit of 1 and therefore needs to be eliminated. Other observations like Turkey and Thailand needs to be examined but not necessarily be eliminated. However, the influence of Turkey grew higher after the removal of India and skewed the plot downwards. Hence, this was also eliminated. However, none of the remaining observations created any more influence that goes above the acceptable Cook's distance limit.



The scale location shows if the residuals along the predictors are equally spread. In this case, the spread started wider and narrows along the x-axis. However, the plot does not create much alarm as the slope is not very steep.

Elimination of Observations

According to the results of the diagnostic plots, it was evident that there is a need to remove India from the countries used in the data. India had a very high value that exceeded the acceptable Cook's distance for non-influential observations. In addition, Turkey and Thailand were also outliers that were within the acceptable Cook's distance of less than 1. However, upon removal of India, the influence of Turkey was amplified, but after its removal, all other observations fell within acceptable locations on the plots. The revised model therefore took the same approach with all observations with the exception of India and Turkey due to the influence on the model which exceeded acceptable levels.

```
> summary(Model2)

Call:
lm(formula = Act ~ MMAct + DigPay + Sav + Brwd + UMIAct + NoCBpA +
    NoATMpK + NoCBpK + NoATMpA + FaR + Exp + Doc + Trst + Rel +
    InsFunds + Fam + NoNeed, data = RevisedData)

Residuals:
     Min       1Q   Median       3Q      Max
-0.34627 -0.08850  0.00514  0.06016  0.39582

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.032770   0.029591  -1.107  0.28008
MMAct        0.122082   0.117953   1.035  0.31191
DigPay       0.703729   0.115724   6.081 4.03e-06 ***
Sav          0.219661   0.064200   3.422  0.00244 **
Brwd         0.005610   0.054673   0.103  0.91921
UMIAct      -0.112232   0.112045  -1.002  0.32739
NoCBpA       0.015953   0.076540   0.208  0.83682
NoATMpK     -0.116247   0.114132  -1.019  0.31949
NoCBpK       0.034933   0.126023   0.277  0.78422
NoATMpA      0.120095   0.080127   1.499  0.14814
FaR         -0.005758   0.051316  -0.112  0.91167
Exp         -0.111938   0.060735  -1.843  0.07884 .
Doc          0.015361   0.039744   0.386  0.70284
Trst         0.050222   0.052848   0.950  0.35228
Rel         -0.027025   0.037931  -0.712  0.48366
InsFunds     0.091283   0.040800   2.237  0.03572 *
Fam          0.220278   0.092540   2.380  0.02639 *
NoNeed      -0.013040   0.041147  -0.317  0.75430
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1703 on 22 degrees of freedom
Multiple R-squared:  0.9821,    Adjusted R-squared:  0.9683
F-statistic: 71.07 on 17 and 22 DF,  p-value: 2.617e-15
```

Figure 10 Regression model without India & Turkey

After the elimination of the two countries from the model, the results changed with some variables flipping from negative to positive whereas, the level of significance of the coefficients of the variable were not improved. The standard error for the coefficients of some of the variables deteriorated. However, other than use of mobile and internet to access accounts (UMIAct) and number of ATMs per one hundred thousand people (NoATMpK), all the other indicators of access and usage of financial services shows a positive relationship with account ownership.

3.6.3 Principal Component Analysis

To carry out the principal component analysis, the correlation matrix for the different variables was first computed and was followed by the eigen decomposition which transformed the original variables into dimensions from which the principal components are found. The dimensions represent the maximum variations in the data. Most of the variation in the data is usually explained in the first

few principal components. Therefore, using the first few principal components to analyze the data can result to more significant results and will minimize the amount of error which was magnified in the regression analysis.

Eigenvalue decomposition of dimensions

Eigenvector is a matrix of values that shows direction, and an eigenvalue is a value specifying the amount of variance in data in that direction. The standard deviation and the total variance on each principal component, together with eigenvectors of the different indicators on the principal components were computed. Based on the eigen decomposition of the principal components, different graphical analyses were carried out including the percentage of explained variance, the contribution of the indicators on each principal components, the quality of representation of the indicators and the performance of the observed countries in the analysis on each principal component.

Table 1 Eigen Values and Variance Percentage for All Dimensions

Dimensions	***Eigenvalues***	***Variance %***	***Cumulative Variance %***
1	4.46387	24.80%	24.80%
2	3.92290	21.79%	46.59%
3	2.68839	14.94%	61.53%
4	1.66432	9.25%	70.77%
5	1.16283	6.46%	77.24%
6	0.91765	5.10%	82.33%
7	0.66763	3.71%	86.04%
8	0.58797	3.27%	89.31%
9	0.46030	2.56%	91.87%
10	0.40644	2.26%	94.12%
11	0.34165	1.90%	96.02%
12	0.23597	1.31%	97.33%
13	0.20104	1.12%	98.45%
14	0.12374	0.69%	99.14%

15	0.07121	0.40%	99.53%
16	0.03672	0.20%	99.74%
17	0.03378	0.19%	99.92%
18	0.01359	0.08%	100.00%

The table above shows the distribution of eigenvalues, the variance percent and cumulative variance percent associated with each dimension in the principal component analysis. Just as mentioned table shows 18 dimensions which also corresponds to the number of variables used. The aim of PCA is to find the direction of the maximum variance in a multi-dimensional data set and projects it onto a new subspace with equal or less dimensions as there are variables *(Li, 2019).* In PCA, the *eigenvalues* measure the amount of variation retained by each principal component (Kassambara, 2017). The eigenvalues decrease from the first principal component to the subsequent ones. The eigen value associated with a component is the sum of the squared factor scores for the component. The importance of an observation can be found by the ratio of the squared factor score of the observation to the eigenvalue associated with that component (Abdi & Williams, 2010).

The scree plot below shows the percentage of explained variances for the first ten principal components. The value of each bar corresponds to the percentage of variance as given by the eigenvalue for each dimension.

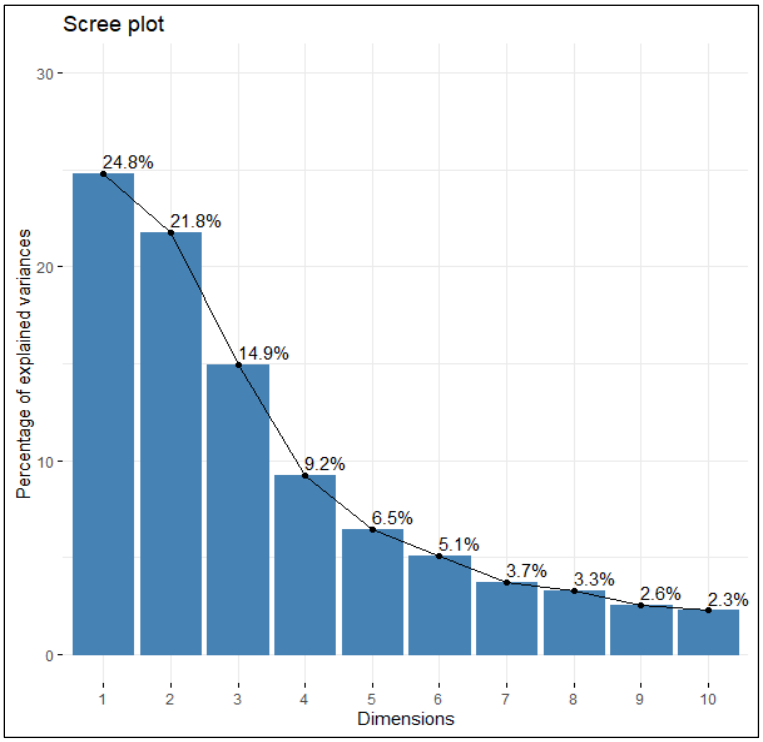


Figure 11 Percentage of Explained Variance for the First 10 Dimensions

From the plot, it can be seen that the first four PCs explains more that 70% of the total variation in the data. Since the goal of PCA is to extract the important information from the dataset and decompose it into fewer dimensions, the first few principal component can be chosen and the remaining discarded. However, it must be noted that, it is possible to have certain variables in the original data that contribute very little in the first few PCs and score higher in a PC that is discarded. But the tradeoff of discarding the lower dimensions is better results where error is minimized. Choosing too many dimensions can lead to overfitting which may give rise to misleading results.

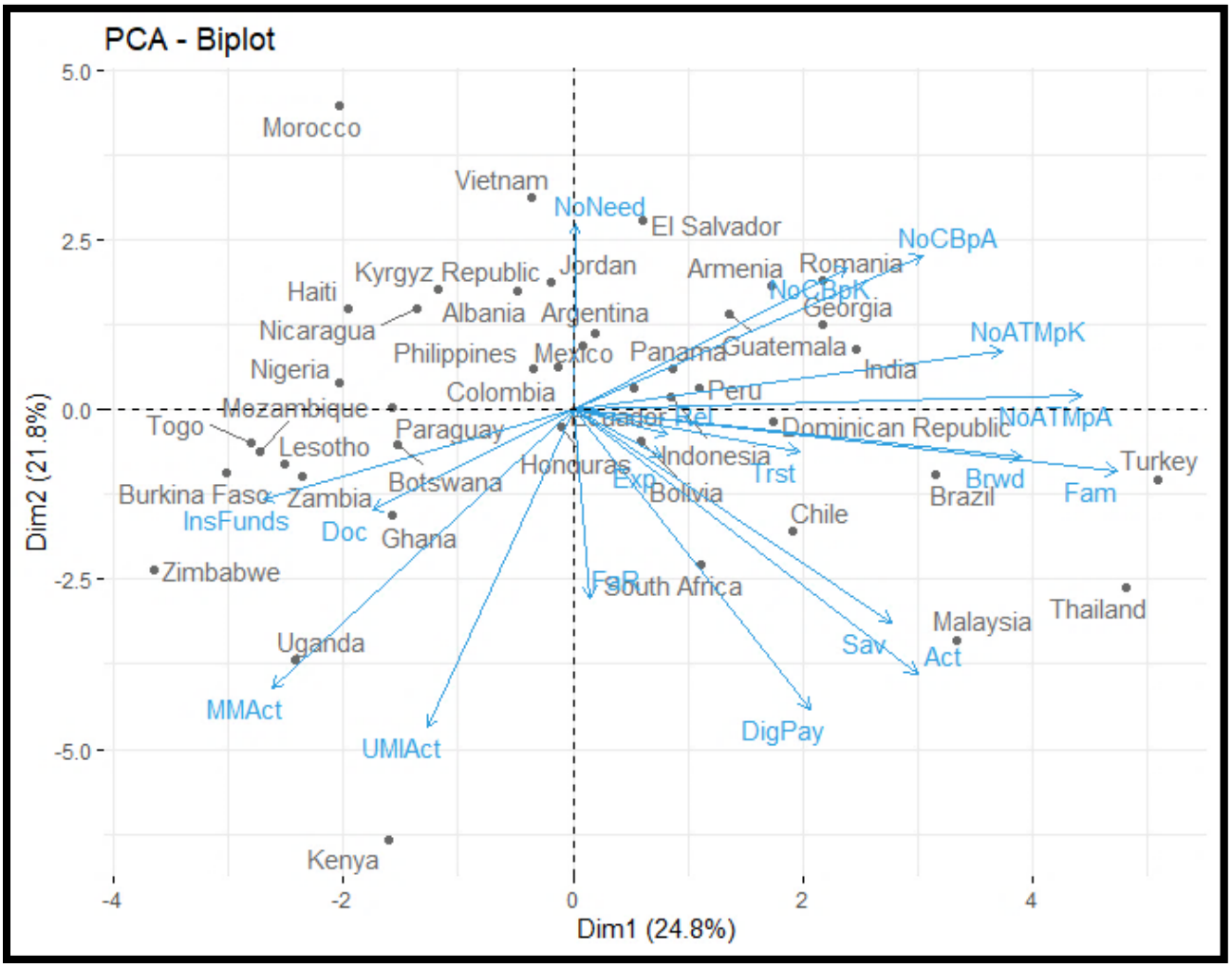


Figure 12 PCA Biplot of Indicators and Countries

The PCA biplot above shows both the variables (indicators) and the observations (countries) used in the analysis and their contributions to the first two dimensions. Dimension 1 (horizontal) and dimension 2 (vertical) are used because only two dimensions can go into a 2D graph. However, up to three dimensions can be plotted with a 3D graphing software. To understand the plot, the closer a variable or observation is to the axis, the higher its contribution to that axis. For example, the contribution of "*NoNeed*" to Dimension 1 is almost zero while the contribution of "*NoATMpA*" to Dimension 2 is also very low. The contributions of the variables are proportional to the absolute length of the arrows. In the following plot, the overall contribution of the variables on the first two dimensions is shown. In the plot, the indicators that made significant contributions to the two dimensions are those that are higher than the red dotted line.

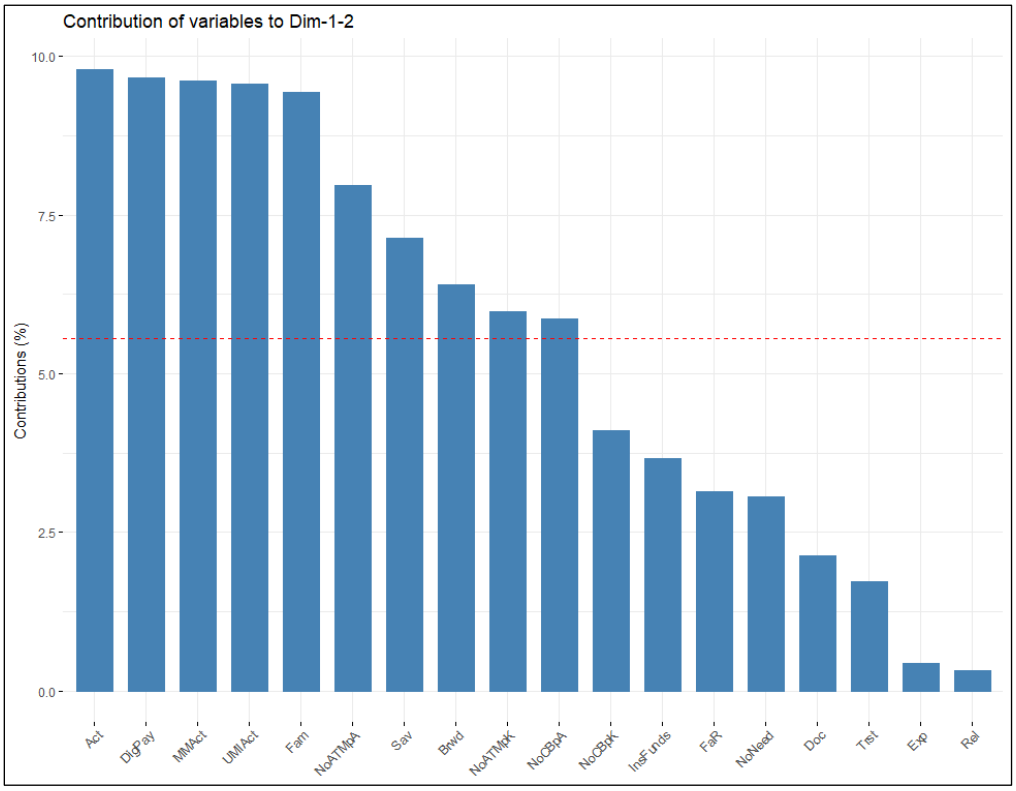


Figure 13 Contribution of Variables to Dimensions 1 & 2

One notable observation from the biplot is the cluster formed by Sub-Saharan African countries in the third quadrant of the plot. This shows that these countries have something common. This is not only geographical location, but something that has to do with the financial system structures. First of all, most of the African countries scored very low in the percentage of people with accounts at a formal financial institution according to the 2017 Global Findex database. However, Sub-Sharan African countries also have the highest use of mobile money services globally where it has surpassed the use of formal financial services. This is clearly shown in the graph as this cluster of countries sits in the same quadrant with mobile money. Another common issue that many people give as a reason for not an account is lack of sufficient funds. In the survey in Sierra Leone on the use of financial services, 94% of people of the people who reported that they do not have an account at a financial institution attributed it to lack of sufficient funds. The cluster of countries from Sub-Saharan Africa on the plot of the quality of representation (cos2) of individual observations is shown below.

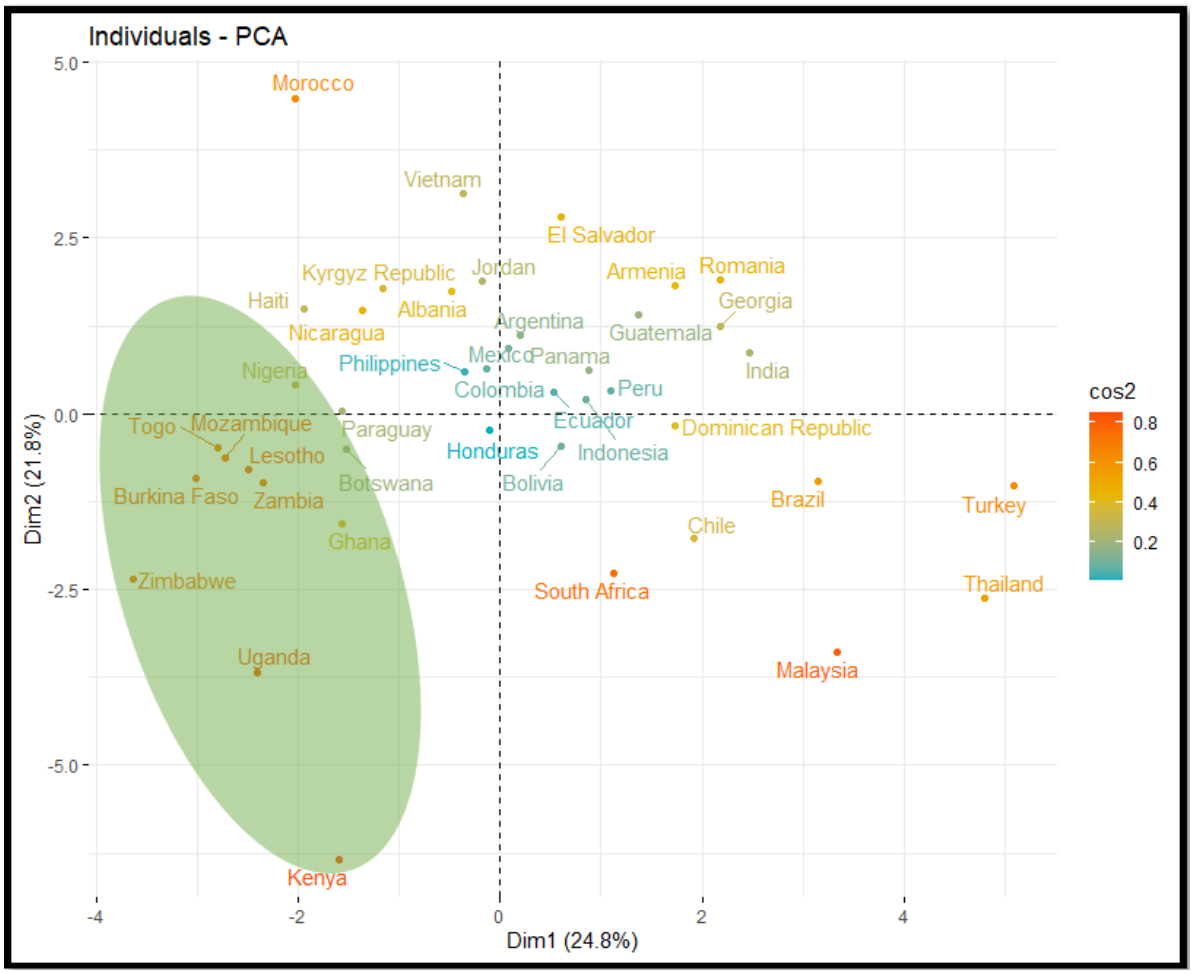


Figure 14 Quality of Representation of Countries Showing Cluster of Sub-Saharan African Countries

Analysis of Results of Quality of Representation

Analysis of the quality of representation (also referred to as the squared cosine) was performed and is shown graphically using R to visualize the contribution of the different variables. The squared cosine indicates the contribution of a component to the squared distance of the observation to the origin *(Abdi & Williams, 2010)*. The squared cosine is used to show the importance of a component for a given observation or set of observation. This is mathematically computed using Pythagorean theorem using the sum of all values of the factor score of the observation. The higher the value of the squared cosine for a variable in the principal component analysis, the greater its relative contribution towards the total distance. Therefore, if a variable has a higher value relative to the other variables, it shows that it is more important for that dimension.

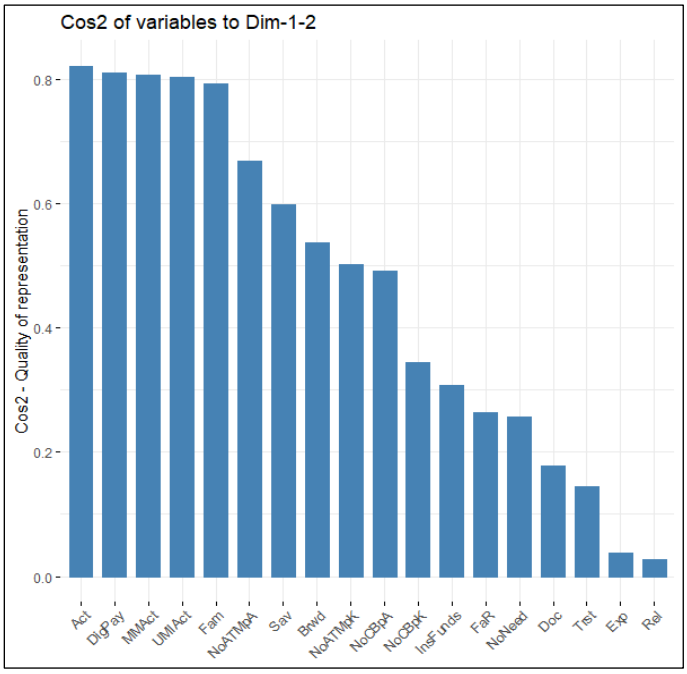


Figure 15 Quality of Representation of the Financial Indicators

From the analysis of the quality of representation of the variables on the factor map for the first two principal components, it can be seen that ownership of an account at a financial institution make the highest contribution toward the first two dimensions relative to the other variables. However, it is followed by digital payment, mobile money account and use of mobile or internet accounts by just a little margin. These three variables were in fact the variables identified as fintech variables. Their combined contribution on the first and second dimensions shows that they are very important towards financial inclusion since the first two dimensions give the highest percentages of the explained variance of the principal component analysis. Furthermore, the barriers to financial inclusion for people who are not in the financial system do not make a lot of contribution to the model. The only exception is the lack of an account because a family member already has one.

In addition, according to *Abdi and Williams (2010)*, the distance to the center of gravity is defined for supplementary observations and the squared cosine is very meaningful. It can therefore help to find the components that are important to interpret both active and supplementary observations. It can be drawn that despite the insignificant confidence level for the correlation between account ownership and mobile money account and use of mobile and internet accounts in the regression analysis, their contribution to financial inclusion cannot be underestimated. Their performance on the

quality of representation for the first two dimensions is evidence that they can have an impact on financial inclusion.

3.6.4 Revised Regression Model Based on the Dimensions of the PCA

The revised model utilizes the dimensions from the results of the principal component analysis as independent variables which are regressed against account ownership. New variables (dimensions) were established based on their percentage contribution on the amount of explained variation on the data set. Principal components (PCs) with low eigenvalues were omitted from the analysis. In this regard, the PCs with eigen values less than one were excluded and this resulted to a remainder of five principal components. The five PCs forms the dimensions which will be used as variables for the revised regression analysis. Based on the contributions of the indicators on the dimensions, the following inferences were derived.

1. The first dimension received its highest contributions from variables that describe access and usage in the traditional financial system. These include number of ATMs, borrowing from formal financial institutions, account ownership, number of commercial banks savings. While lack of account because a family member already has one is categorized as a barrier to financial inclusion, people in this category still have access to the financial system through their family members.
2. The second dimension received its highest contributions from variables that are related to the use of fintech. These variables include use of mobile or internet to access an account, digital payments, mobile money accounts and ownership of an account.
3. The third dimension received its highest contributions from indicators that describe barriers of financial inclusion according to the Global Findex. These include lack of account because it is expensive, because of trust, lack of documents, distance from financial institutions, religion, and lack of need for financial services.
4. The fourth dimension also received some of its highest contributions from variables associated with the traditional financial system and barriers to financial inclusion.
5. The fifth dimension received its highest contributions from a mixture of variables and a clearly defined theoretical explanation about their common characteristics is unknown. However, it had an eigen value that is greater than 1.

In a nutshell, the first three dimensions which explain most of the variations in the data can be considered as the traditional financial system, fintech and barriers to financial inclusion based on the contributions of the variables on the respective dimensions. The fourth dimension also received contributions from variables associated with the traditional financial system and other barriers while the fifth is a little vague. Below are the contributions of the indicators on the first 3 dimensions.

Indicators	Contribution to Dim.1
Fam	17.04515253
NoATMpA	15.71833738
Brwd	13.41217316
NoATMpK	9.701224876
Act	7.287753929
NoCBpA	6.449590558
Sav	6.220783788
DigPay	4.794429424
InsFunds	4.774964644
MMAct	3.956416863
NoCBpK	3.450064668
Trst	3.23847654
Doc	1.985076443
Exp	0.698615653
Rel	0.605232963
UMIAct	0.585528875
FaR	0.074518661
NoNeed	0.001659038

Indicators	Contribution to Dim.2
UMIAct	19.05338607
DigPay	15.35162091
MMAct	15.26054557
Act	13.64450018
Sav	7.63724329
NoNeed	6.180400858
FaR	5.924253209
NoCBpK	5.734814239
NoCBpA	5.429343228
Doc	1.850783065
InsFunds	1.662869245
NoATMpK	1.073179628
Fam	0.45433881
NoATMpA	0.254282775
Exp	0.20032384
Trst	0.123228616
Brwd	0.121414981
Rel	0.043471486

Indicators	Contribution to Dim.3
Exp	26.29621462
Trst	16.28818162
Doc	14.01200429
FaR	10.58699623
NoNeed	10.46862726
Rel	6.654956781
UMIAct	3.563720401
Sav	3.499961501
InsFunds	2.014081082
NoATMpK	1.846743031
NoCBpA	1.084677387
MMAct	1.084594127
DigPay	1.054881327
Act	0.884970083
Brwd	0.290818237
NoCBpK	0.173349908
NoATMpA	0.10127143
Fam	0.09395069

New Financial Inclusion Model

Based on the results of the PCA, the first five dimensions were used to carry out a new regression analysis. With fewer variables, the model avoids overfitting which gave misleading results in the first regression model due to the many variables used and lack of sufficient observations. In this model, the standard error is minimized, and the results are much more significant at the 95% confidence level compared to the first model.

$$New\ FIModel = \beta_0 + \beta_1 Dim.1 + \beta_2 Dim.2 + \beta_3 Dim.3 + +\beta_4 Dim.4 + \beta_5 Dim.5 + \varepsilon_i$$

```
> summary(DimsModel)

Call:
lm(formula = Dims$Act ~ Dims$Dim.1 + Dims$Dim.2 + Dims$Dim.3 +
    Dims$Dim.4 + Dims$Dim.5)

Residuals:
      Min        1Q    Median        3Q       Max
-0.245337 -0.061868  0.002246  0.080916  0.199578

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.436726   0.029905  14.604  < 2e-16 ***
Dims$Dim.1   0.024237   0.006066   3.995 0.000306 ***
Dims$Dim.2   0.011996   0.004030   2.977 0.005180 **
Dims$Dim.3  -0.016159   0.005767  -2.802 0.008127 **
Dims$Dim.4   0.013794   0.004688   2.942 0.005667 **
Dims$Dim.5  -0.003159   0.005755  -0.549 0.586402
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1097 on 36 degrees of freedom
Multiple R-squared:  0.5291,    Adjusted R-squared:  0.4637
F-statistic: 8.089 on 5 and 36 DF,  p-value: 3.398e-05
```

Based on the results of the model, the R-squared and the adjusted R-squared are 0.4383 and 0.3914, respectively. These values seem low but are acceptable looking at the variables used to get the dimensions for the analysis. According to Jim Frost (*2019*), studies that attempt to predict human behavior tend to have R-Squared values that are not very high. Based on the model, ownership of an account is influenced by different dimensions, some of which has to do with human behavior, cultural, social, and economic factors. Therefore, an R-squared value of 52.9% is a reasonable one. The F-statistic is 8.089 on 5 and 36 DF which is higher than the critical F-value of 2.944 for the same degrees of freedom at $\alpha = 0.5$. The p-value is very small with a value 3.398×10^{-3} showing that there is a relationship between account ownership and at least one of the dimensions in the analysis. Since the F-Statistic is higher than the critical value and the p-value is less than $\alpha = 0.05$ the null hypothesis that there is no relationship between account ownership and the other variables can be rejected. The standard errors of the coefficients are very low which is in contrast to the first regression model where the standard errors were significantly high.

Chapter 4 – Discussions

4.1 Introduction

This section will cover discussions of both statistical and theoretical findings on the impacts of fintech on financial inclusion in developing countries. The study incorporates both findings from literature and statistical analyses to find the impacts of financial technologies on financial inclusion. The first part will focus on findings from past literature and trends that show evidence of impacts of fintech on financial inclusion. The second part will focus on the findings from the regression analysis, the principal component analysis, and the Sierra Leone survey on the use of financial services. Furthermore, a discussion on some strategies for the application of fintech in developing countries will be carried out.

4.2 Discussion of Findings

4.2.1 Literature Findings

Over the last decade, fintech has been creating many disruptions in the financial system and continue to augment different financial services. Its impacts are already felt in many sectors like artificial intelligence, digital payments, financing, investments, insurance, asset management, cryptocurrency, etc. and continues to expand to different sectors in different geographical areas. According to findings, fintech has the potential to expand financial inclusion and different forms of fintechs have different ways they do so. Some fintech types increase access and encourage usage while also reducing the barriers that make access to the financial system difficult. The target of these types of fintech are mostly people who are in the financial system and those that are underserved. Some other types of fintech target a completely different market segment that includes the underserved and the excluded. This latter type of fintech services are the ones that are expanding the confines of financial inclusion the most. The rapidity of adoption of many forms of fintech have been much easier in developed countries where the infrastructures that support their growth exists. In developing countries on the other hand, adoption has been slower, fintech type specific and are influenced by different factors. Based on findings from literature, some fintech innovations are already expanding financial inclusion in different developing countries.

According to Buku and Meredith (*2013*), the M-Pesa in Kenya significantly increased financial inclusion and created many benefits for women and the poor people in rural areas. Sy, et al. (2019) also showed that while access to the traditional financial system continues to be a challenge for most Africans, mobile money accounts have surpassed the amount of bank accounts in the region, propelling

financial inclusion among the unbanked and underserved. The successes of mobile money in the Sub-Saharan region is as a result of the presence of telecommunications infrastructure and the access to affordable mobile phones. Other forms of fintech have not successfully found their way through in the region as mobile money does. Many innovative fintech applications that are very common in developed nations struggle to diffuse in many developing nations. Innovative fintech services such as Apple Pay, Samsung Pay, Satispay, WeChat Pay, etc. which have made payments very easy through mobile phones are not very popular in many developing countries. These services are only available for smartphones and requires internet connectivity. People with simple affordable mobile phones that do not have internet connectivity capability cannot access these services. Many people in developing countries do not have access to internet or can afford a smart phone which can be expensive for the poor and lower income earners. These services also require a bank account which means users are already in the formal financial system, however, they still promote financial access. Mobile money services on the other can be accessed with a simple phone that has text messaging capability which is pretty much available for all phones connected to a telecommunication network. In many developing countries, you can easily get a sim card for your phone from the street without even having to provide elaborate identification documents.

Fintech innovations are also bringing many benefits that are increasing financial inclusion as well as creating beneficial spillovers. Muralidharan et al. (*2014*), showed how the implementation of the biometric scan cards helped improve financial inclusion and reduce leakages of pension funds in India. Many developing countries continue to see high rates of corruption in many aspects of the everyday life of the people. When payments such as salaries, pensions and other governmental projects can be done directly with digital technology, this helps reduce the chain through which monies travel before they reach the final beneficiary and subsequently reduces the potential of corrupt activities. Also, it makes it easier to hold people who engage in corrupt activities accountable. According to the UN, the annual cost of corruption in 2018 is about $2.6 trillion, or 5% of the global GDP. Corruption has many negative consequences of which poverty is one of the biggest. When people are very poor, they are more likely to be excluded in the financial system and usually face more barriers that prevent them from being included. With fintech innovations such as the biometric scan cards in India, there is a higher chance of curbing corruption and expanding financial inclusion.

Fintech has also been growing rapidly in Latin America especially after the 2018 Bali Fintech Agenda which put forward some blueprint considerations for policy makers with regards to fintech. The opportunities that fintech presents to the region are enormous, but still remains vastly unregulated.

Fintech can reduce transaction costs, enhance competition in the financial sector, reduce poverty and help strengthen financial inclusion in the region. According to an Inter-American Development Bank survey in 2017, about 1,166 startups operates in 18 countries in the region with most of them situated in Brazil, Mexico, and Columbia. The majority of the startups in Latin America focus on payments and alternative financing and in the Caribbean, several governments are considering the use of distributed ledger technology (DLT) to enhance financial inclusion (*Berkman et al. 2019*). By facilitating the use of mobile money and DLT, payments systems can be improved, and credit history can be made possible for people who are not active in the formal financial system.

4.2.2 Regression Discussions

The objective of the regression analysis was to use statistical data to find out how indicators that are considered as fintech affect account ownership in developing countries. The model used data on 18 financial variables from the World Bank Global Findex and the IFM financial access survey for 42 developing countries across all regions. The regression analysis was carried out multiple times to examine how different observations in the data were influencing the model. After the principal component analysis, the first three dimensions which explain the most variation in the model were used to create a new model to see the relationship of these dimensions to account ownership.

The results of the first model were mixed and a bit counterintuitive. The output of the model showed a very high R-squared as well as the adjusted R-squared with 95.6% and 92.5% respectively. While this seems like a good thing, however, just over half of the variables used were explained by the model at the 95% confidence level. This therefore rings a bell about problems that may exist in the model. Further diagnostics plots were carried out on model to examine the results of the residuals. The diagnostic plots revealed some issues with some data for some countries as the caused a lot of influence on the model. It therefore became necessary to remove two of those country data as they exceeded the acceptable Cook's distance of 1 in the residual vs leverage plot. India, Turkey, and Thailand happen to be outliers in the different diagnostic plots. India was out of the acceptable tolerance while Turkey and Thailand were within the cautionary level between 0.5 and 1. The influence of Turkey however increased after the removal of India. Thailand, on the other hand, while it was within the same cautionary interval, it influences on the model was not too much. Therefore, the data for India and Turkey were excluded to create another model.

However, even after their removal, both the R-squared and adjusted R-squared are very high. For this kind of study which utilized data that are influenced by human behavior, culture, social constructs, etc., high R-squared values or adjusted R-squared values are not expected. But with a closer examination on the model and the standard error values what was noticed was there may have been an overfitting in the model. Overfitting is a condition in which a statistical model begins to describe the random error in the data rather than the relationship between the variables (*Frost, 2019*). According to Frost, this situation usually occurs when a model is too complex and one of the consequences of an overfitted model is a very high R-squared values. Furthermore, while adjusted R-squared usually try to correct the R-squared value, it is not designed to detect when an overfitting occurs. This regression model does not have sufficient observations and the number of variables was many. Unfortunately, there were not enough data for other developing countries to increase the number of observations. In addition, even if all developing countries were to be used, the required amount of observations may still not be sufficient. Improvements can be made by increasing the number of observations or reducing the number of variables. An option to reducing the number of variables is to do a principal component analysis of the many variables and choose only the first few principal components that explains most of the variation in the model. The total number of components are less than or equal to the number of variables used. However, the principal component analysis transforms the variables into dimensions that explain the most variations in the data. In some cases, the first few principal components may explain over 90% of the total variation in the model. Therefore, those few principal components that forms the first few dimensions can be used as variables to model a new regression analysis. The dimensions themselves only explain certain behaviors that are described in the model based on the variations they cause. They receive contributions from all the variables. Some variables contribute high in one dimension and then score low in the others. Some variables will contribute almost equally among the first few dimensions. In some cases, it may not be obvious to identify what characteristics the dimension is describing, while in other cases, one can identify the behavior or commonality in the variables that is explained by a dimension. While the first few principal component usually explains the highest variation in the data, some variables may contribute very little in those components and score higher in dimensions that may be excluded. This could be an issue if the variation caused by that specific variable is of interest. However, while this can be a drawback for some specific cases, the majority of the variation in the data will still be explained in the model if a sufficient number of principal components are used to create a new regression model.

4.2.3 PCA Findings & Discussions

The principal component analysis method became a very useful tool as the results of the regression analysis were initially ambiguous. The presence of many variables with few observations made the regression to be overfitted. However, by using PCA, it was possible to create hypothetical variables (dimensions) that optimizes the maximum variations in the dataset from which the dimensions that explains the most variations were used to recreate a regression model with fewer variables. The PCA was done by the calculation of the covariance matrix and the eigen decomposition of the principal components. Based on the results of the eigen decomposition, different analyses were carried out including the percentage of explained variance, the contribution of the indicators on each principal components, the quality of representation of the indicators and the performance of the variables and the countries used in the analysis on each principal component.

First, the correlation matrix was computed to find the association between each variable to the other variables used in the analysis. The correlation matrix for the variances of the variables used and the correlation matrix for the p-values at 95% confidence level are given in the appendix section. The two orthogonal matrices represent the variations by the indicators and the variations caused by the error term. Based on the results of the correlation matrix, account ownership (*Act*) is positively correlated to all the variables except three: lack of documents (*Doc*), insufficient funds (*InsFunds*), religion (*Rel*), and No need for financial services (*NoNeed*). However, these indicators are barriers to financial inclusion, which means they are expected to be negatively correlated to account ownership. Some barriers that are expected to have a negative impact on account ownership shows a relatively low positive correlation that are not significant. Lack of account because a family member already has one shows a positive correlation to account ownership even though it is considered as a barrier by the Global Findex.

The eigen decomposition resulted to 18 principal components in which the first few constitute the majority of explained variance in the data. The first five principal components explained about 77% of the total variation in the data. Therefore, since the aim is reducing the number of variables into few dimensions that explain the most variation, the first five were chosen to be used for a revised regression analysis. This method has both advantages and disadvantages, but the former supersedes the latter. It significantly minimizes the error in the analysis and helps avoid issues of overfitting which are common in regression analyses of many variables and insufficient number of observations. The disadvantage is mostly common in cases where the dimension of interest is not explained in the principal components chosen. For example, if the dimension we are interested is found in the 15th

principal component. In such situations, even if the dimension received its only contributions from the indicators that describe that dimension, we can infer that the amount of variation caused by that component is not very significant with respect to the entire dataset.

The graphical analyses of the PCA is only limited to two dimensions for this paper, there is a possibility of plotting three dimensions with a 3D software program. Based on the results of the PCA biplot of the countries and the indicators, one of the most notable clusters is that of the Sub-Saharan African countries. The cluster also aligns with indicators that represent the use of mobile money services and use of mobile and internet to access accounts as well as barriers of financial inclusion such as documents and insufficient funds. The spread of the use of mobile money services has been more popular in Sub-Saharan African countries, so it is no coincidence for this observation. In addition, poverty rates are very high in most African countries, therefore having lack of funds as a barrier to owning an account is not surprising either. However, the presence of these two indicators in this cluster does not only show how much these countries score on those indices, but also shows that with increase in mobile money services usage, there is a chance of reducing poverty in the region.

Furthermore, the quality of representation of the variables on the first two principal components showed that indicators that are deemed fintech like digital payments, mobile money accounts, use of mobile and internet to access accounts scored the highest after ownership of an account. The performance of these indicators on the quality of representation indicates their importance and shows evidence that they can have an impact on financial inclusion.

4.2.4 Sierra Leone Survey on Mobile Money and Financial Services

Data analysis of the survey responses was done in a descriptive manner, unlike the regression analysis and the principal component analysis. This was due to lack of sufficient data to carry out a statistical analysis to explain the variations in the data effectively. The discussions on this section will cover findings from the survey on the basic demographics of the respondents, account ownership, the unbanked, reasons for being unbanked, From the survey results, the respondents are unevenly distributed on the different demographics. The demographics on gender, geographic location and educational level are given below. The demographic information help understand what may have influenced the responses from the respondents especially geographic and level of education of the correspondents.

Table 2 Gender Distribution

Male	Female
60.8%	39.2%

Table 3 Distribution based on Level of Education

Level of Education	Number of respondents	% of Total Respondents
Did not go to school	36	14.4%
Primary	8	3.2%
Secondary	81	32.4%
Technical/Vocational	57	22.8%
College	26	10.4%
University	42	16.8%

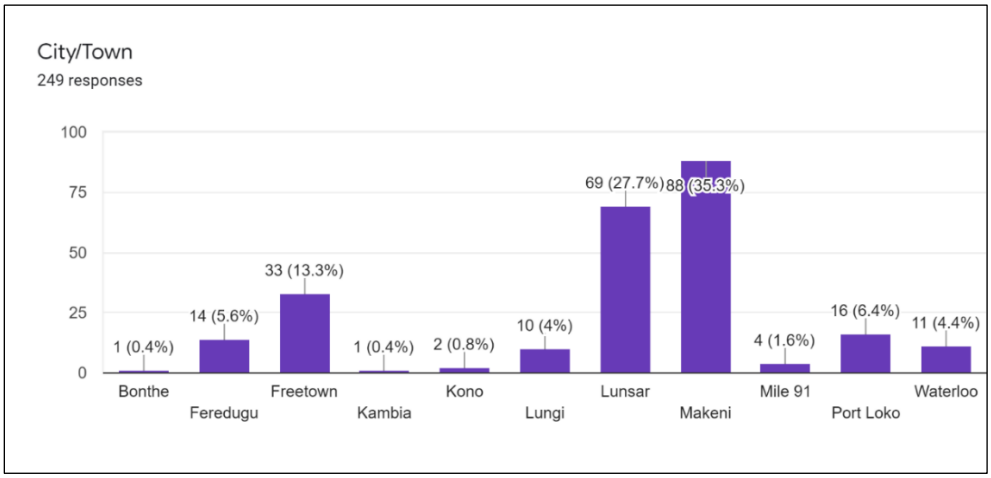


Figure 16 Distribution of Correspondents based on Geographic Location

From the distribution of respondents based on level of education, over 80% of our respondent are people who have achieved at least a secondary school education. Gender came out to be 60.8% to 39.2% for males and females, respectively. During the interviews, it was more likely for males to voluntarily respond to the questionnaire than females when approached. This may have contributed to the difference in distribution, but no target number of females or males was set before the interviews. The respondents are mostly from the Northern and Western parts of Sierra Leone. However, the

distribution between urban and rural is almost even. Freetown and Makeni are urban while the rest are predominantly rural towns.

Account Ownership and Usage

Based on the results of the survey, 72% of the survey respondents do not own an account at a formal financial institution. This is an improvement from the 2017 Global Findex estimate which was 80.2%. However, among the 28% that own an account at a formal financial institution, only 75% of them (or 20% of total survey respondent) have used those accounts either for deposits, payments, or withdrawals in the last 12 months. Account ownership was found to be directly correlated with the level of education. Respondents who have achieved a university level of education were found to be in possession of accounts at a formal financial institution the most with 40.6%. None of the respondents who did not go to school own an account at a formal financial institution and those who achieved a primary education account only for a total of 4.3%. Furthermore, 40% of those with accounts are women despite only representing 39% of the total respondent. By applying weights based on the proportion of gender representation, gender does not seem to affect account ownership among women in Sierra Leone compared to the global gender inequality in account ownership in the Global Findex report. Among the women in the survey, 30% of them own an account at a formal financial institution compared to only 28% of men.

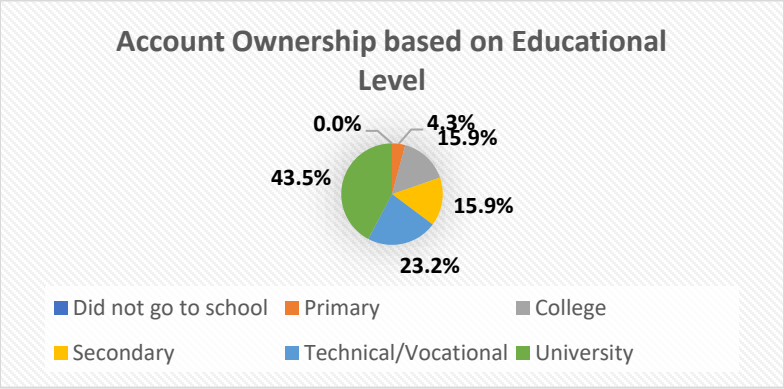


Figure 17 Distribution of Account Ownership Based on Educational Level

Among those who reported that they own a bank account, only 44% (or 12.4% of total correspondents) have a debit card. Deposits of money or withdrawals are mostly done through over the counter service among those who own accounts at financial institutions. This shows that there has been a lower penetration rate of basic innovative financial technologies in the traditional banking system in

Sierra Leone which could have helped augment financial access and encourage usage. One may decide not to put money at the bank just because they may have to go to the bank to withdraw it for use. Also, only 35% of those who own a debit card have used it in 2019. Furthermore, out of those who own an account at a formal financial institution, only 7% own a credit card. This represents only 2% of the total number of respondents.

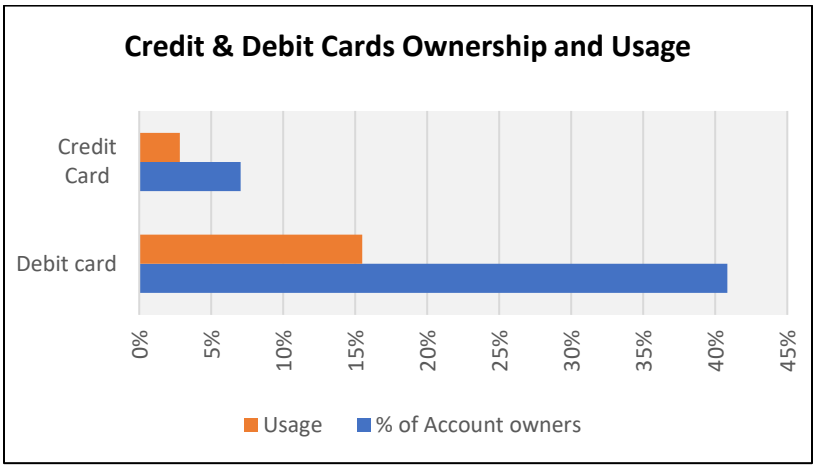


Figure 18 Ownership and Usage of Credit and Debit Cards Among Account Owners

Borrowing money from financial institutions is also not a popular activity in Sierra Leone as in Western countries. This is partly due to the difficulty in the financial institutions to efficiently calculate and assign credit scores to customers whose credit history is unknown. This is one of the key reasons why the government is trying to implement a blockchain identity database that could help with credit history to citizens. According to the survey only 12.3% of all respondents have ever taken a loan from a financial institution. However, 69% of those who indicated that they have borrowed money from financial institutions are above 35 years of age despite only representing 30% of the total respondents. Therefore, it is believed that if the survey targeted stratified age categories of an even distribution, the percentage of borrowers will be higher. The chart below shows those who have taken loans from a financial institution and those who have not.

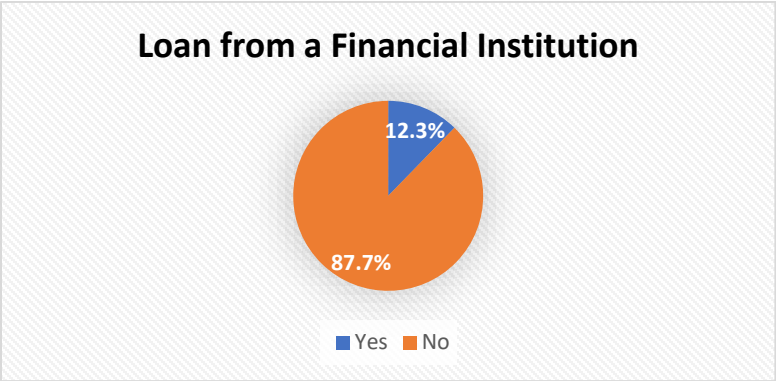


Figure 19 Loans from a Financial Institution

The Unbanked

From the result of the survey, 72% of the respondents are unbanked. This is an extremely high number compared to the world average of 22.6% in 2017. The majority of the unbanked population came from those who have achieved a secondary education followed by those who have achieved a technical or vocational education. However, it can be seen that their high representation among the unbanked is due to their high representations in the total correspondents in the survey if weights are applied. But an intriguing aspect is that of those who did not go to school. All of those who responded that they never went to school do not have an account at any formal financial institution. Therefore, even though they form only 20% of the unbanked, it can be deduced that lack of an education may have a great influence on financial exclusion. The chart below shows the distribution of the unbanked based on their educational levels.

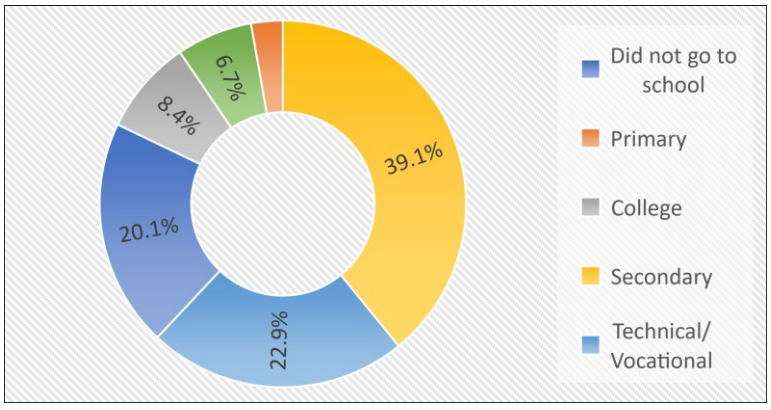


Figure 20 Unbanked Population Based on Educational Level

The highest concentration of the unbanked in the survey are between 25 and 34 years old. However, applying weights based on the total number of correspondents from their different categories, the most unbanked age category is between 15 and 24 for which 86% of the total age category are

unbanked followed by 25 and 34 with 70% of the age category reporting that they are unbanked. The chart below shows the percentage of the unbanked based on age categories in the survey.

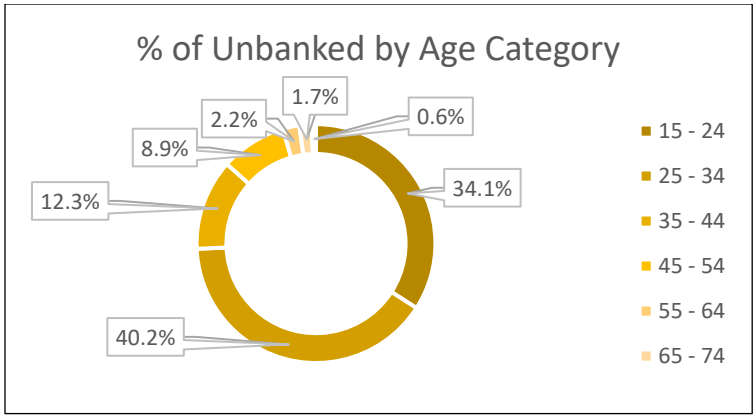


Figure 21 Percentage of Unbanked Based on Age Categories

Reasons for being Unbanked

According to the survey, a total of 72% are unbanked, an 8 percentage points less from the 2017 Global Findex report. In order to better understand the reasons that are preventing those that are excluded from the formal financial system, questions on the barriers that prevent them from having an account were asked. The questions were organized such that the respondent can choose any reason that applies to them on a scale between 0 to 4 with 4. 0 is given if a reason doe does not apply and 4 is given for a strong reason.

The most popular barrier that most of the respondents cited was insufficient money. 94% of respondents who do not have an account at a formal financial institution said they do not have an account because they do not have sufficient money with 60% of respondents citing it as their only reason for not having an account. The second most popular reason is cost. 21% of unbanked respondents said it is too expensive to open an account. The chart below gives the summary of the percentage of unbanked respondents on the different reasons for being unbanked.

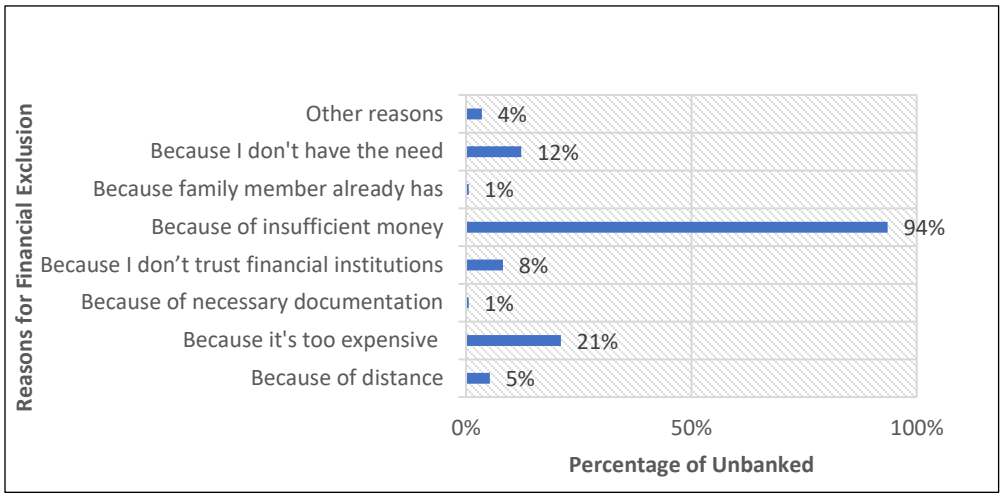


Figure 22 Barriers of Financial Inclusion from Unbanked Respondents

Based on the barriers given by the respondents, the two most popular reasons for being unbanked are lack of sufficient money and the cost of opening an account. It is therefore evident that poverty is the main driver of financial exclusion according to the survey responses. Lack of necessary documentation and because a family member already has an account scored very low. To get a basic bank account in Sierra Leone, one only needs a government issued ID which could be a passport or a national Identity card for documents. Furthermore, most of the respondents when asked if they do not have an account because a family member already does, responded no, but cited other reasons.

Mobile Money

In the 2017 Global Findex report, only 20% of adults own an account at a financial institution. However, over the following years, there has been significant improvements in the digital financial services, especially mobile money, which have incorporated many who were not included in the traditional financial system. According to the UNCDF, the percentage of adults using digital financial services in 2017 was 9% and by the end of 2018, it increased to 14%. However, while digital financial services are increasingly diffusing in Sierra Leone, providers continue to struggle with customer retention. Account registration increased by 81% in 2017 alone, but the number of active customers only increased by 39%. In 2018, one of the key challenges of the providers was how to augment usage of a wider range of financial services among activated customers *(Ngwabe, 2019).*

The increase in mobile money services has provided an alternative to the traditional financial system for people who were excluded as well as those that are currently in the formal financial system. According to the survey, 67% of respondents said they have used mobile money service in 2019. Usage is evenly distributed among all educational levels and age categories. On gender, 77% of women in the

survey said they have used mobile money services in 2019 while only 61% of men said the same. This agrees with the 2017 Global Findex report and the increase in financial inclusion among women in Kenya.

Users of mobile money services were asked on the reasons why they use mobile money services. More than 87% said they use it because it is fast, 57% said because it is cheap. About 47% of respondents who use mobile money services said it is the only way available to them while 38% said it is the only way available to the people, they send money to.

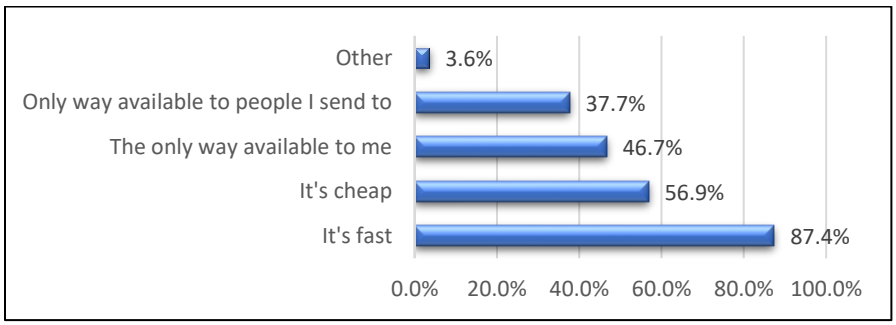


Figure 23 Reasons for Using Mobile Money According to Correspondents

Since mobile network service is available to almost the entire country, operators are able to leverage on their coverage span to deliver financial services with just a click of a button, which could take days for banks to do the same. In addition, some respondents said mobile money is the only available option to them while some indicated that it is the only available option to those, they send money to. Furthermore, since most of the unbanked population indicated that they remain unbanked due to insufficient money, providing a service that is cheap has helped capture a large market segment of the unbanked into using mobile money services.

Since usage of financial services is very important in measuring financial inclusion, the frequency of usage of mobile money services was also surveyed. About 44% of respondents said they use mobile money services less than 3 times a month while 35% said they use it 3 to 5 times a month. Just above 5% use mobile money services more than 10 times a month. Among them are mostly business owners and mobile money agents.

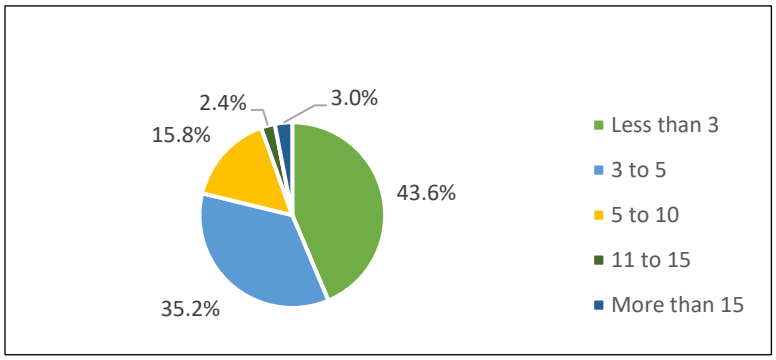


Figure 24 Frequency of Monthly Usage of Mobile Money Services

While the use of bank account for savings is very low, many people are using Mobile Money services as an alternative for saving their money. Many people can now keep their money digitally in their phones without any fear of being robbed by thieves. It is also very easy for people to easily transfer money to relatives or friends in times of emergencies without needing to go to the bank to withdraw and send money in cash. This can be even more challenging in situations where banks are not very close or not open. According to the survey results, 66% of people who use mobile money services indicated that they use it also to for saving or keeping their money.

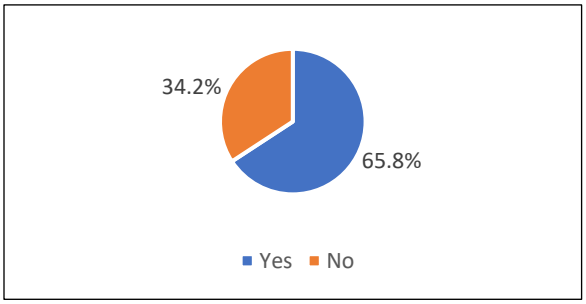


Figure 25 Use of Mobile Money Account to Save Among Mobile Money Users

In the chart below, people who do not use mobile money services indicated that the barrier preventing them from using mobile money are lack of a phone or a phone number, not knowing how to use it, the cost, trust in the service and because the people they usually send to or receive money do not use the service.

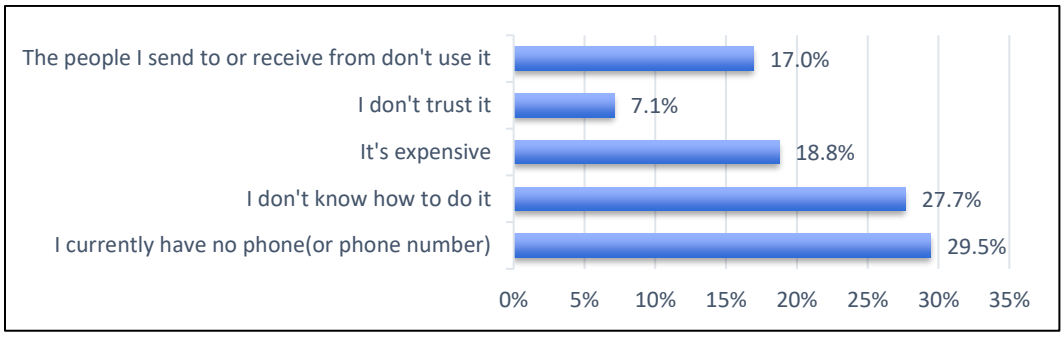


Figure 26 Barriers Preventing Non-users of Mobile Money from Using it

Mobile network operators have used different business models that help make the experience of users better. These include allowing users to go negative on their calls or text messages credits as well as mobile data and pay later when they recharge. This has helped many people who find themselves in an emergency situation where they cannot readily recharge their phone credit or mobile data. However, the amount someone can go negative is dependent on how active a user has been, how much mobile credit history he or she has accumulated and frequency of use. This form of credit scoring if replicated on the mobile money services can capture a huge market segment that has been underserved by the traditional banking system. Mobile network operators will already have enough data on the financial activities of the users and with more information on user identity and other personal information on possessions or asset for collateral in the case of a default. They therefore have the platform and potential to tailor financial services to their existing models and disrupt the traditional banking industry. During the survey, all the correspondents were asked if they will use mobile money services if the mobile operators create a business model that provide credit scoring that can help them to be able to take loans and 86% of the correspondents said they will be willing to use the mobile money service.

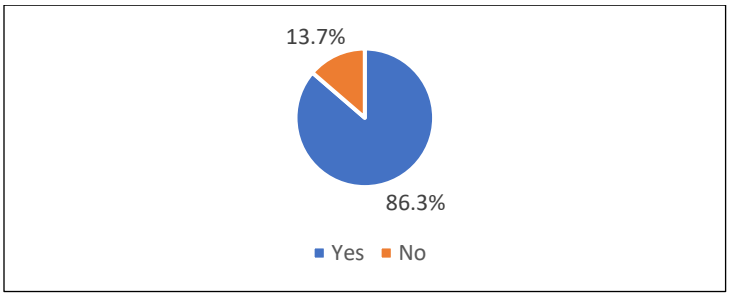


Figure 27 Willingness to Use Mobile Money Service if Credit Scoring is Implemented

4.3 Limitations

This paper used both past literature and data to find evidence of impacts of fintech on financial inclusion. However, some limitations exist as a result of scope, availability of data and methods used in survey and data analysis. The focus of this paper is developing countries and therefore the evidence found here that supports the impacts of fintech on financial inclusion may not necessarily be applied in developed countries. The difference in contexts and differences in their performance on the different financial indicators can make results completely different. Nevertheless, empirical evidence shows that fintech is also increasing usage and access of financial services while reducing many barriers of financial inclusion. The impacts of fintech will undoubtedly create more impacts on financial inclusion in developing countries where exclusion is more prevalent. In developed countries where there are high rates of financial inclusion, the major impacts are more on issues such as making efficiencies in existing financial services, creating alternative and complimentary services, and improving customer experience.

There was a limitation with regards to the available data also. Many developing countries do not have data for several of the different financial indicators used in the analyses. They were therefore excluded from the analyses therefore the final dataset had fewer observations. Furthermore, with the number of financial indicators used, even if all developing countries were to be used, the number of observations will still be very small for a good statistical analysis.

Finally, there were also some flaws with the methodology used. A regression analysis cannot produce reliable results with the number of variables and observations used in the analysis. However, this was made better by applying the principal component analysis to reduce the number of variables into few principal components that explains the most variations. But limitations exist because only the first few principal components were used in the revised model. If certain variables in the original data contribute only to the PCs that are excluded, this means that the new regression model does not explain the variations caused by that variable.

4.4 Discussion on Strategies for Fintech Application in Developing Countries

In order for fintech to make the greatest impacts on financial inclusion in developing countries, specific strategies must be put in place in order to get the best utility. Strategies must address both local and international contexts in order to support and promote the innovative solutions presented by fintech and minimize risks and challenges that they face. While local strategies will vary from one country to

another, there is a need for international strategies to address issues of standards, regulations, competition, cybersecurity, etc. in order to support financial inclusion and maintain financial integrity across the globe. In 2018, the International Monetary Fund and the World Bank rolled out 12 policy elements at the Bali Fintech Agenda for countries to consider in their domestic policy discussion. This was an important step because at the pace with which fintech is expanding, lack of international guidelines and standards will not only create challenges for fintech but may also lead to abuse of fintech services which can hinder financial integrity.

Different developing countries have different necessities that need to be addressed in order to establish a smooth growth of fintech in those respective countries. One of these key things is the infrastructures to support fintech. Many developing countries that are adopting mobile money services, for example, should consider building strong telecommunication networks on to the remotest areas across their countries since mobile money services rely on telecommunication networks. Other forms of fintech requires internet connectivity or satellite connection in order to transmit data. To foster these types of fintech, good internet connectivity networks needs to be put in place. Many developing countries lack good internet connectivity. Internet use in these regions mostly rely on mobile network data which can be very slow in many cases. Government can help intervene in the provision of such necessities because the social benefits that can be derived from it is very high.

Another major issue is the lack of digital identity systems in many developing countries. Digital identity has many benefits. For example, many people in developing countries do not have access to finances because they do not have a credit history. This issue can be salvaged through the establishment of digital identity for everyone and setting up of secure information sharing systems. With these in place credit scoring can be made simple if financial institutions can have access to people's credit history and subsequently give them more access to financing.

Governments can also directly get involved in the development of fintech services by providing sandbox programs that will give fintech startups a real-life environment to develop and test their innovative solutions. By this government can also provide guidelines on innovations that they think can create impacts on financial inclusion and make competitions in which startups with good solutions can be given access to real life data for testing a d developing the fintech innovations.

That been said, individual countries must work very hard to establish rules and legal frameworks to prevent cybersecurity issues, fraud, money laundering and identity theft. Many people are concerned that with the rapid growth of fintech, it can also be an avenue for the transaction of

illegal funds and money laundering. This is possible, but if governments are working with fintech startups, financial institutions and their legislative arms to roll out rules, legal frameworks, legal checks, etc. to ensure that there are effective monitoring systems and that financial services providers as well as users conform to legal frameworks.

Chapter 5 – Conclusions and Recommendations

5.1 General Conclusions

The principal aim of this paper is to investigate the impacts of fintech on financial inclusion in developing countries. The paper looked into evidence based on different studies, statistical analysis, and survey data to examine the effects of fintech on financial inclusion. Exclusion from the financial system has been closely linked with poverty in developing countries. Different studies have shown that financial inclusion is very important for the economic development of a nation and its people. It has a great role in reducing poverty and augmenting economic growth opportunities. The rapid growth of fintech which presents numerous unparalleled alternatives and complimentary services to the financial industry has become an opportunity to tackle endemic poverty through financial inclusion. Recent studies have shown that, fintech is already making positive impacts on financial inclusion and by all indications within the scope of this study, it has the potential to further broaden the frontiers of financial inclusion to meet the needs of many who were excluded or underserved by the traditional financial systems in developing countries. Evidence shows that some developing nations that had high levels of exclusion were able to significantly increase financial inclusion by adopting digital financial technologies like mobile money services. Financial inclusion is also projected to increase more in many developing countries that are adopting and building infrastructure for the use of distributed ledger technologies which can help keep track of the credit history of people and will help them have more access to financing.

Based on the statistical analysis, individual fintech indicators showed a positive correlation with account ownership in financial institutions. The regression analysis of the different financial indicators against account ownership was however not sufficient due to limitations in the data which resulted to overfitting. Notwithstanding, the weaknesses of the regression analysis were improved by the principal component analysis by reducing the number of variables and replacing them with the principal components which explain the majority of the variations in the dataset. The results of the PCA showed that first principal component received its highest contributions from financial indicators that are associated with the traditional financial system. The second principal component gets its highest contributions from indicators associated to fintech and the third principal component received its highest contributions from indicators associated with barriers that prevent people from being in the financial system. The highest contributions to the fourth are also from traditional financial system indicators while the highest contributions for the fifth principal components, showed a mix of

indicators defined by barriers, traditional financial system. A revised regression analysis which utilized the first five principal components showed that the second principal component which received the highest and majority of its contributions from fintech indicators is positively correlated with account ownership. In addition, the principal components that received their majority of contribution from traditional financial system indicators are also positively correlated with account ownership. The principal component which received its majority of contributions from indicators of barriers showed a negative correlation with account ownership. Based on the results of the analysis, there is evidence that fintech has a positive impact on financial inclusion.

Furthermore, the results of the survey on the use and barriers of financial services in Sierra Leone showed that fintech is already making significant impacts in the lives of the people in the country. Account ownership among respondents of the survey is 28% about eight percentage points higher than the 19.8% of the 2017 Global Findex report. Among those who own an account, only 75% of them have used that account within the previous 12 months. Debit and credit cards ownership is 41% and 7% respectively and their usage withing the previous 12 months among respondents is only 15% and 4% respectively. Many barriers to access and usage of traditional financial services exist which has left many people excluded from the financial system. However, the rapid growth of mobile money in the country over the few years shows that fintech has the potential of augmenting financial inclusion in the country. According to the survey, 67% of respondents have used mobile money services within the previous 12 months. Respondents attributed their use of the service due to ease of access, affordability, fastness and because it is the only way available to them or the person, they are transacting finances with. The Sierra Leone case is specific, but similarities of context with many developing countries shows that with the right type of fintech services, access and usage of financial services can be significantly increased.

However, many challenges and risks also exist which need addressing in order to obtain the most benefits from fintech. Countries need to establish technological infrastructures that support the proliferation of fintech services and their diffusion in order to foster financial inclusion. Both national and international regulatory frameworks need to be put in place in order to maintain financial stability and financial integrity. Furthermore, international cooperation can help pave the way for greater financial inclusion through fintech. In a nutshell, the opportunities presented by fintech are numerous and diverse and with proper strategies to integrate new innovative fintech services into the financial system, financial inclusion can be augmented, and endemic poverty reduced significantly.

5.2 Recommendations

Based on the results of this study, the following are some recommendations that can help improve results of findings. The first is a focus on few financial indicators that have a more significant impact on financial inclusion for the analysis. This is because, some theoretical financial indicators may have an insignificant correlation, but they can significantly increase the standard error in the model. Also, since the number of available observation for developing countries can only be as large as the total number of developing countries if all data is available, having a fewer variables can help offset the proportion of variables to observations for a good statistical model.

Secondly, I will recommend a 2-step principal component analysis (PCA) in which the indicators are divided into theoretical dimensions and a PCA is done on each of those dimensions. Then the top principal components that explain the majority of the variations for each dimension are chosen. Then a second PCA can be done to the chosen PCs from the different PCA results. The PCs that explain the most variations in the second PCA can then be used for the regression analysis. This can help minimize the potential for error which was magnified in the first regression analysis of this paper.

Citations and Bibliography

Abdi, Hervé, and Lynne J. Williams. "Principal Component Analysis." *Wiley Online Library*, John Wiley & Sons, Ltd, 30 June 2010, onlinelibrary.wiley.com/doi/abs/10.1002/wics.101.

Abdi, Hervé, and Lynne J. Williams. "Principal Component Analysis." *Wiley Online Library*, John Wiley & Sons, Ltd, 30 June 2010, onlinelibrary.wiley.com/doi/abs/10.1002/wics.101.

Aldoma, Cristina. "Evolution of Fintech." *ZIGURAT Innovation & Technology Business School* , 3 July 2019, www.e-zigurat.com/innovation-school/blog/evolution-of-fintech/.

Alexandre, Claire, and Lynn Chang Eisenhart. *Mobile Money as an Engine of Financial Inclusion and Lynchpin of Financial Integrity*. Washington Journal of Law, Technology & Arts, 2013, digitalcommons.law.uw.edu/wjlta/vol8/iss3/7/.

Arner, Douglas W, et al. "The Evolution of Fintech: A New Post-Crisis Paradigm?" *SSRN*, 20 Oct. 2015, papers.ssrn.com/sol3/papers.cfm?abstract_id=2676553.

Berkman, P, et al. "Fintech in Latin America and the Caribbean: Stocktaking ." *IMF*, 26 Mar. 2019, www.imf.org/~/media/Files/Publications/WP/2019/WPIEA2019071.ashx.

Bindi, Thomas J. "Sierra Leone Fintech Challenge 2017." *Bank of Sierra Leone*, 2017, www.bsl.gov.sl/FinTech.html.

Buckley, Ross P, and Sarah Webster. "Fintech in Developing Countries: Charting New Customer Journeys." *SSRN*, 11 Oct. 2016, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2850091

Buku, Mercy W, and Michael W Meredith. "Safaricom and M-PESA in Kenya: Financial Inclusion and ..." *UW Law Digital Commons*, 2013, digitalcommons.law.uw.edu/cgi/viewcontent.cgi?article=1183&context=wjlta.

Cámara, Noelia, and David Tuesta. "Measuring Financial Inclusion: a Multidimensional Index." *BIS*, 14 July 2017, www.bis.org/ifc/publ/ifcb47p.pdf.

Cantamessa, Marco, and Francesca Montagna. *Management of Innovation and Product Development Integrating Business and Technological Perspectives*. Springer London, 2018.

Ccmara, Noelia, and David Tuesta. "Measuring Financial Inclusion: A Muldimensional Index." *SSRN Electronic Journal*, 2014, doi:10.2139/ssrn.2634616.

Collins, Sean. "Report on Fintech Startups Focusing on Invest-Tech." *Deloitte*, 14 Jan. 2020, www2.deloitte.com/us/en/pages/financial-services/articles/fintech-startups-focusing-on-invest-tech.html.

Demirguc-Kunt, Asli, and Leora Klapper. "Measuring Financial Inclusion: The Global Findex Database." *Policy Research Working Papers*, 2012, doi:10.1596/1813-9450-6025.

Demirguc-Kunt, Asli, et al. “Global Findex Database 2017.” *Open Knowledge Repository*, Washington, DC: World Bank, 19 Apr. 2018, openknowledge.worldbank.org/handle/10986/29510.

Demirgüç-Kunt, Asli, et al. “The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution.” *Global Findex*, 2018, globalfindex.worldbank.org/.

Desai, Falguni. “The Evolution Of Fintech.” *Forbes*, Forbes Magazine, 9 Feb. 2016, www.forbes.com/sites/falgunidesai/2015/12/13/the-evolution-of-fintech/#761348047175.

Desai, Falguni. “The Evolution Of Fintech.” *Forbes*, Forbes Magazine, 9 Feb. 2016, www.forbes.com/sites/falgunidesai/2015/12/13/the-evolution-of-fintech/#761348047175.

Deschamps, Tara. “Quadriga Crypto Exchange Was a Fraud Perpetrated by Founder, OSC Says | CBC News.” *CBCnews*, CBC/Radio Canada, 11 June 2020, www.cbc.ca/news/business/osc-quadriga-gerald-cotten-1.5607990.

Diniz, Eduardo Henrique, et al. “Mobile Money and Payment: A Literature Review Based on Academic and Practitioner - Oriented Publications (2001 - 2011).” *SSRN Electronic Journal*, 2011, doi:10.2139/ssrn.2924669.

Elisa Ughetto, Marc Cowling & Neil Lee “Regional and Spatial Issues in the Financing of Small and Medium-Sized Enterprises and New Ventures.” *Taylor and Francis Online*, 2019, doi.org/10.1080/00343404.2019.1601174.

Frost, Jim. “Overfitting Regression Models: Problems, Detection, and Avoidance.” *Statistics By Jim*, 30 Mar. 2019, statisticsbyjim.com/regression/overfitting-regression-models/.

Goyal, Udayan. “Financial Inclusion in the Information Age .” *Youtube*, Tedx Talks, 9 July 2015, www.youtube.com/watch?v=fdn9OyWbu2E.

Gulamhuseinwala, Imran, et al. “FinTech Is Gaining Traction and Young, High-Income Users Are the Early Adopters.” *SSRN*, 8 Dec. 2017, papers.ssrn.com/sol3/papers.cfm?abstract_id=3083976.

Hatch, Matt, et al. “EY Global FinTech Adoption Index 2019.” *EY*, 2019, www.ey.com/en_gl/ey-global-fintech-adoption-index.

Iansiti, Marco, and Karim R. Lakhani. “The Truth About Blockchain.” *Harvard Business Review*, 21 Aug. 2019, hbr.org/2017/01/the-truth-about-blockchain.

IMF, and World Bank. “Fintech : The Experience So Far.” *IMF*, 27 June 2019, www.imf.org/en/Publications/Policy-Papers/Issues/2019/06/27/Fintech-The-Experience-So-Far-47056.

Jack, William, and Tavneet Suri. “Mobile Money: The Economics of M-PESA.” *NBER*, 27 Jan. 2011, www.nber.org/papers/w16721.

James, Mohamed, et al. “Sierra Leone National Innovation & Digital Strategy (2019 – 2029).” *DSTI*, 4 Nov. 2019, www.dsti.gov.sl/sierra-leone-national-innovation-digital-strategy-2019-2029/.

Kagan, Julia. “Financial Technology – FintechDefinition.” *Investopedia*, Investopedia, 29 Jan. 2020, www.investopedia.com/terms/f/fintech.asp.

Kassambara, Alboukadel. “PCA - Principal Component Analysis Essentials.” *STHDA*, 23 Sept. 2017, www.sthda.com/english/articles/31-principal-component-methods-in-r-practical-guide/112-pca-principal-component-analysis-essentials/.

Kennon, Joshua. “What to Know About the NASDAQ, the World's Second-Largest Stock Market.” *The Balance*, The Balance, 8 Dec. 2019, www.thebalance.com/what-is-the-nasdaq-356343.

Ketabchi, Natasha. “State of Fintech.” *Toptal Finance Blog*, Toptal, Dec. 2019, www.toptal.com/finance/market-research-analysts/fintech-landscape.

Kumar, Shefali. “The Global Findex: Financial Inclusion for Developing Countries.” *The Borgen Project*, 19 July 2019, borgenproject.org/financial-inclusion-for-developing-countries/.

Li, Lorraine. “Principal Component Analysis for Dimensionality Reduction.” *Medium*, Towards Data Science, 27 May 2019, towardsdatascience.com/principal-component-analysis-for-dimensionality-reduction-115a3d157bad#:~:text=PCA%20helps%20us%20to%20identify,dimensions%20than%20the%20original%20one.

McLaughlin, Steve. “2019 Annual FinTech Almanac.” *DocSend*, Financial Technology Partners, Feb. 2020, ftpartners.docsend.com/view/9849q93.

Mishra, Sudhanshu K. “A Comparative Study of Various Inclusive Indices and the Index Constructed By the Principal Components Analysis.” *SSRN Electronic Journal*, June 2007, doi:10.2139/ssrn.990831.

Muneeza, Aishath, et al. “The Application of Blockchain Technology in Crowdfunding: Towards Financial Inclusion via Technology.” *International Journal of Management and Applied Research*, 2018, doi.org/10.18646/2056.52.18-007.

Muralidharan, Karthik, et al. “Building State Capacity: Evidence from Biometric Smartcards in India.” *NBER*, 20 Mar. 2014, www.nber.org/papers/w19999.

Muralidharan, Karthik, et al. “Building State Capacity: Evidence from Biometric Smartcards in India.” *NBER*, 20 Mar. 2014, www.nber.org/papers/w19999.

Nagar, Anirudh L, and Sudip Ranjan Basu. “Statistical Properties of a Composite Index as Estimator of a Single Latent Variable.” *Journal of Quantitative Economics*, vol. 2, no. 2, 2004, pp. 19–27., doi:10.1007/bf03404606.

Ngwabe, Wycliffe. “State of the DFS Market in Sierra Leone 2018 .” *UN Capital Development Fund (UNCDF)*, 16 Aug. 2019, www.uncdf.org/article/4814/state-of-the-dfs-market-in-sierra-leone-2018.

Robinson, Edward, and Julie Verhage. “Fintech.” *Bloomberg*, 26 Nov. 2018, www.bloomberg.com/quicktake/financial-technology-companies-disrupt-comfy-banks-quicktake.

Rouse, Margaret. “What Is Cybersecurity? Everything You Need to Know.” *SearchSecurity*, TechTarget, 3 Apr. 2020, searchsecurity.techtarget.com/definition/cybersecurity#:~:text=Cybersecurity%20is%20the%20protection%20of,centers%20and%20other%20computerized%20systems.

Sarma, Mandira. “Index of Financial Inclusion – A Measure of Financial Sector Inclusiveness.” *Central Data Catalog*, July 2012, catalog.ihsn.org/index.php/citations/49252.

Singh, Manish. “Fintech Startups Raised $34B in 2019.” *TechCrunch*, TechCrunch, 22 Feb. 2020, techcrunch.com/2020/02/22/fintech-startups-raised-34b-in-2019/.

Swan, Melanie. “Currency, Contracts and Applications beyond Financial Markets.” *Blockchain: Blueprint for a New Economy*, 2015.

Sy, Amadou N, et al. “FinTech in Sub-Saharan African Countries : A Game Changer?” *IMF*, 26 Mar. 2019, www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2019/02/13/FinTech-in-Sub-Saharan-African-Countries-A-Game-Changer-46376.

Szmigiera, M. “Number of Fintech Startups Globally by Region 2020.” *Statista*, 20 Mar. 2020, www.statista.com/statistics/893954/number-fintech-startups-by-region/.

Thomala, Lai Lin. “WeChat: Active Users Worldwide.” *Statista*, 20 Aug. 2020, www.statista.com/statistics/255778/number-of-active-wechat-messenger-accounts/.

Upadhyay, Parijat, and Saeed Jahanyan. “Analyzing User Perspective on the Factors Affecting Use Intention of Mobile Based Transfer Payment.” *Internet Research*, Emerald Group Publishing Limited, 1 Feb. 2016, www.emerald.com/insight/content/doi/10.1108/IntR-05-2014-0143/full/html.

Vardhman, Raj. “Growth of Fintech: From the First Wire Transfer to Blockchain.” *Carsurance*, 7 Sept. 2019, carsurance.net/blog/growth-of-fintech/.

Vardhman, Raj. “Growth of Fintech: From the First Wire Transfer to Blockchain.” *Carsurance*, 7 Sept. 2019, carsurance.net/blog/growth-of-fintech/.

Warton, David I., et al. “Three Points to Consider When Choosing a LM or GLM Test for Count Data.” *Besjournals*, John Wiley & Sons, Ltd, 8 Apr. 2016, besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.12552.

Zimmerman, Eilene. “The Evolution of Fintech.” *The New York Times*, The New York Times, 6 Apr. 2016, www.nytimes.com/2016/04/07/business/dealbook/the-evolution-of-fintech.html.

“Financial Access.” *World Bank*, 2016, www.worldbank.org/en/publication/gfdr/gfdr-2016/background/financial-access.

“Financial Access.” *World Bank*, www.worldbank.org/en/publication/gfdr/gfdr-2016/background/financial-access.

“Financial Inclusion.” *IDT Labs*, idtlabs.xyz/financial-inclusion/.

“Financial Inclusion.” *World Bank*, 2 Oct. 2018, www.worldbank.org/en/topic/financialinclusion/overview.

“Financial Services for the Poor.” *The Bill & Melinda Gates Foundation*, 2019, www.gatesfoundation.org/What-We-Do/Global-Growth-and-Opportunity/Financial-Services-for-the-Poor.

“FinTech - worldwide: Statista Market Forecast.” *Statista*, 2020, https://www.statista.com/outlook/295/100/fintech/worldwide.

“Technological Paradigms.” *Management of Innovation and Product Development Integrating Business and Technological Perspectives*, by Marco Cantamessa and Francesca Montagna, Springer London, 2018, pp. 34–35.

“The Analysis of Competition in Banking: Theory and Empirics.” *Competition and Stability in Banking: the Role of Regulation and Competition Policy*, by Xavier Vives, Princeton University Press, 2016, pp. 70–105. *JSTOR*, www.jstor.org/stable/j.ctt1q1xs80.9.

“The Bali Fintech Agenda.” *IMF*, 11 Oct. 2018, www.imf.org/en/Publications/Policy-Papers/Issues/2018/10/11/pp101118-bali-fintech-agenda.

“The World Bank Annual Report 2019: Ending Poverty, Investing in Opportunity.” *World Bank Annual Report*, 2019, doi:10.1596/978-1-4648-1470-9.

Appendix

Regression & PCA Tables and Plots

```
> summary(FIModel)

Call:
lm(formula = Act ~ MMAct + DigPay + Sav + Brwd + UMIAct + NoCBpA +
    NoATMpK + NoCBpK + NoATMpA + FaR + Exp + Doc + Trst + Rel +
    InsFunds + Fam + NoNeed, data = Standardized_CountryData)

Residuals:
     Min       1Q   Median       3Q      Max
-0.36531 -0.15443 -0.01264  0.16158  0.43580

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.153e-17  4.219e-02   0.000 1.000000
MMAct        8.519e-02  1.630e-01   0.523 0.605996
DigPay       7.036e-01  1.680e-01   4.187 0.000328 ***
Sav          2.770e-01  1.019e-01   2.717 0.012020 *
Brwd        -1.036e-01  7.881e-02  -1.314 0.201220
UMIAct      -8.817e-02  1.798e-01  -0.490 0.628365
NoCBpA      -2.759e-01  9.755e-02  -2.828 0.009294 **
NoATMpK     -5.749e-01  1.346e-01  -4.271 0.000265 ***
NoCBpK       6.195e-01  1.279e-01   4.844 6.17e-05 ***
NoATMpA      3.416e-01  1.147e-01   2.977 0.006554 **
FaR         -4.673e-02  8.045e-02  -0.581 0.566730
Exp         -9.815e-02  9.340e-02  -1.051 0.303810
Doc          5.060e-02  6.240e-02   0.811 0.425382
Trst         3.220e-02  8.359e-02   0.385 0.703504
Rel         -1.532e-01  5.047e-02  -3.035 0.005709 **
InsFunds     1.360e-01  6.371e-02   2.134 0.043267 *
Fam          3.914e-01  9.923e-02   3.944 0.000606 ***
NoNeed       4.914e-02  6.409e-02   0.767 0.450671
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2734 on 24 degrees of freedom
Multiple R-squared:  0.9562,    Adjusted R-squared:  0.9252
F-statistic: 30.85 on 17 and 24 DF,  p-value: 2.916e-12
```

Figure 28 Regression model results after elimination of India and Turkey

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC15	PC16	PC17	PC18
St.Dev	2.1128	1.9806	1.6396	1.2901	1.0783	0.9579	0.8171	0.7668	0.6785	0.6375	0.5845	0.4858	0.4484	0.3518	0.2668	0.1916	0.1838	0.1166
Variance	4.4639	3.9229	2.6884	1.6643	1.1628	0.9176	0.6676	0.588	0.4603	0.4064	0.3416	0.236	0.201	0.1237	0.0712	0.0367	0.0338	0.0136
Act	0.2615	-0.3626	0.1048	-0.0183	0.1114	-0.1753	0.0166	-0.0267	0.1764	-0.1096	0.3967	-0.2203	0.0619	-0.0487	0.4846	-0.0145	-0.0404	-0.5027
MMAct	-0.2292	-0.3820	0.1175	-0.0779	0.0987	-0.2018	0.1239	-0.1412	-0.0676	0.0505	-0.3025	-0.2096	0.2488	-0.0830	-0.0758	0.4760	0.5020	0.0173
DigPay	0.1803	-0.4118	0.1053	-0.2367	0.0769	-0.1906	-0.0092	0.0221	-0.0491	-0.0935	-0.0212	0.0104	0.0154	-0.0818	-0.0767	-0.6654	0.2023	0.4240
Sav	0.2424	-0.2926	0.2001	0.2487	-0.0948	0.1684	-0.1095	-0.2093	0.0835	0.0059	0.1418	0.4781	-0.4944	-0.1672	-0.0097	0.2811	0.1741	0.1519
Brwd	0.3412	-0.0660	0.0391	-0.3357	-0.0136	-0.0777	0.0524	0.1268	-0.2876	0.6625	-0.1557	0.2954	0.1057	0.1641	0.1891	0.1103	-0.1371	-0.0459
UMIAct	-0.1102	-0.4366	0.2034	0.0513	0.0803	-0.0274	0.0459	-0.0802	-0.1292	-0.1838	-0.2660	0.0260	-0.0002	-0.0151	-0.2586	0.0663	-0.7325	-0.0863
NoCBpA	0.2655	0.2125	-0.1144	-0.0633	0.3546	-0.4374	-0.2068	0.0831	0.1037	-0.3165	-0.1158	0.4525	0.1790	-0.0864	-0.2578	0.0871	0.0771	-0.2278
NoATMpK	0.3262	0.0815	0.1386	0.4070	0.1314	0.1299	0.1680	0.0062	-0.3360	0.0665	-0.3144	-0.2200	-0.2063	0.0346	-0.2051	-0.2612	0.2339	-0.4079
NoCBpK	0.2089	0.1948	-0.0177	0.4650	0.2476	-0.3376	0.2436	-0.3025	0.0827	0.1134	-0.0761	-0.1140	0.1191	-0.0467	0.2835	0.0578	-0.1975	0.4452
NoATMpA	0.3864	0.0193	-0.0465	-0.1673	0.0199	0.2205	-0.1407	0.3685	-0.0535	-0.4153	-0.3442	-0.2548	-0.1353	0.0551	0.2990	0.2787	-0.0320	0.2594
FaR	0.0133	-0.2587	-0.3125	0.2903	0.1046	0.4845	-0.0979	-0.1145	-0.0205	-0.0946	-0.0900	0.2920	0.5238	0.2388	0.1698	-0.1136	0.0817	-0.0088
Exp	0.0680	-0.0649	-0.5169	-0.1621	0.2235	0.2216	-0.0126	-0.1332	0.0472	0.2040	-0.0857	-0.1316	-0.0916	-0.6994	-0.0483	-0.0163	-0.0924	-0.0607
Doc	-0.1526	-0.1379	-0.3652	0.1755	-0.0717	-0.2063	0.4103	0.3787	-0.5131	-0.1903	0.2536	0.1850	-0.0988	-0.0990	0.0883	0.0776	0.0254	0.0458
Trst	0.1722	-0.0566	-0.4126	-0.3033	0.0687	-0.0217	0.2756	-0.4633	0.0211	-0.1340	0.0775	-0.0874	-0.2739	0.5117	-0.1841	0.0777	0.0104	-0.0159
Rel	0.0720	-0.0341	-0.2579	0.1177	-0.6056	-0.3309	-0.4702	-0.2963	-0.2546	-0.0532	-0.1718	-0.0903	0.0196	-0.0538	0.1023	-0.0510	-0.0178	-0.0792
InsFunds	-0.2352	-0.1236	-0.1316	0.1463	0.5103	-0.1024	-0.5706	0.1159	-0.2003	0.2097	0.1501	-0.1660	-0.2674	0.2571	0.0139	0.0340	-0.0010	0.0876
Fam	0.4137	-0.0840	-0.0248	0.1294	-0.1363	0.0627	-0.0965	0.1530	-0.0399	0.1050	0.4401	-0.2817	0.3282	-0.0068	-0.5280	0.2159	-0.0528	0.1664
NoNeed	0.0014	0.2560	0.3059	-0.2471	0.1877	0.1886	-0.0860	-0.4060	-0.5910	-0.2272	0.2601	0.0169	0.1557	-0.1683	0.1007	0.0487	0.0007	0.0544

Figure 29 Performance of Indicators on each PCs

	Act	MMAct	DigPay	Sav	Brwd	UMIAct	NoCBpA	NoATMpK	NoCBpK	NoATMpA	FaR	Exp	Doc	Trst	Rel	InsFunds	Fam	NoNeed
Act	1.000	0.322	0.865	0.705	0.441	0.518	0.069	0.221	0.048	0.363	0.209	0.018	-0.074	0.207	-0.002	-0.068	0.611	-0.267
MMAct	0.322	1.000	0.533	0.132	-0.162	0.866	-0.526	-0.416	-0.419	-0.461	0.177	-0.101	0.231	-0.133	-0.113	0.374	-0.376	-0.247
DigPay	0.865	0.533	1.000	0.580	0.515	0.671	-0.015	0.010	-0.266	0.312	0.156	0.055	-0.024	0.232	0.006	-0.025	0.382	-0.229
Sav	0.705	0.132	0.580	1.000	0.300	0.487	-0.112	0.460	0.102	0.265	0.318	-0.164	-0.205	-0.058	0.083	-0.164	0.556	-0.186
Brwd	0.441	-0.162	0.515	0.300	1.000	-0.082	0.335	0.313	0.034	0.578	-0.136	0.155	-0.261	0.332	0.043	-0.371	0.574	0.062
UMIAct	0.518	0.866	0.671	0.487	-0.082	1.000	-0.495	-0.136	-0.361	-0.229	0.303	-0.204	0.141	-0.199	-0.124	0.276	-0.122	-0.237
NoCBpA	0.069	-0.526	-0.015	-0.112	0.335	-0.495	1.000	0.310	0.534	0.489	-0.219	0.171	-0.181	0.286	0.049	-0.094	0.312	0.139
NoATMpK	0.221	-0.416	0.010	0.460	0.313	-0.136	0.310	1.000	0.689	0.497	0.053	-0.150	-0.233	-0.084	-0.049	-0.289	0.597	0.118
NoCBpK	0.048	-0.419	-0.266	0.102	0.034	-0.361	0.534	0.689	1.000	0.096	-0.058	-0.052	-0.091	0.038	0.046	-0.133	0.320	0.012
NoATMpA	0.363	-0.461	0.312	0.265	0.578	-0.229	0.489	0.497	0.096	1.000	0.046	0.223	-0.268	0.326	0.061	-0.398	0.657	0.034
FaR	0.209	0.177	0.156	0.318	-0.136	0.303	-0.219	0.053	-0.058	0.046	1.000	0.515	0.374	0.260	0.148	0.296	0.191	-0.477
Exp	0.018	-0.101	0.055	-0.164	0.155	-0.204	0.171	-0.150	-0.052	0.223	0.515	1.000	0.325	0.720	0.162	0.207	0.113	-0.332
Doc	-0.074	0.231	-0.024	-0.205	-0.261	0.141	-0.181	-0.233	-0.091	-0.268	0.374	0.325	1.000	0.207	0.221	0.285	-0.149	-0.497
Trst	0.207	-0.133	0.232	-0.058	0.332	-0.199	0.286	-0.084	0.038	0.326	0.260	0.720	0.207	1.000	0.234	-0.150	0.228	-0.172
Rel	-0.002	-0.113	0.006	0.083	0.043	-0.124	0.049	-0.049	0.046	0.061	0.148	0.162	0.221	0.234	1.000	-0.098	0.247	-0.325
InsFunds	-0.068	0.374	-0.025	-0.164	-0.371	0.276	-0.094	-0.289	-0.133	-0.398	0.296	0.207	0.285	-0.150	-0.098	1.000	-0.365	-0.161
Fam	0.611	-0.376	0.382	0.556	0.574	-0.122	0.312	0.597	0.320	0.657	0.191	0.113	-0.149	0.228	0.247	-0.365	1.000	-0.159
NoNeed	-0.267	-0.247	-0.229	-0.186	0.062	-0.237	0.139	0.118	0.012	0.034	-0.477	-0.332	-0.497	-0.172	-0.325	-0.161	-0.159	1.000

Figure 30 Correlation Matrix of Indicators

	Act	MMAct	DigPay	Sav	Brwd	UMIAct	NoCBpA	NoATMpK	NoCBpK	NoATMpA	FaR	Exp	Doc	Trst	Rel	InsFunds	Fam	NoNeed
Act		0.0375	0.0000	0.0000	0.0035	0.0004	0.6653	0.1602	0.7645	0.0182	0.1840	0.9088	0.6410	0.1879	0.9913	0.6707	0.0000	0.0875
MMAct	0.0375		0.0003	0.4052	0.3069	0.0000	0.0003	0.0062	0.0057	0.0021	0.2619	0.5250	0.1406	0.4019	0.4760	0.0148	0.0142	0.1142
DigPay	0.0000	0.0003		0.0001	0.0005	0.0000	0.9255	0.9484	0.0890	0.0441	0.3227	0.7314	0.8791	0.1397	0.9710	0.8764	0.0125	0.1454
Sav	0.0000	0.4052	0.0001		0.0539	0.0011	0.4784	0.0022	0.5220	0.0893	0.0403	0.2991	0.1922	0.7141	0.5997	0.2982	0.0001	0.2391
Brwd	0.0035	0.3069	0.0005	0.0539		0.6040	0.0302	0.0433	0.8296	0.0001	0.3897	0.3285	0.0944	0.0318	0.7868	0.0157	0.0001	0.6951
UMIAct	0.0004	0.0000	0.0000	0.0011	0.6040		0.0009	0.3916	0.0189	0.1451	0.0513	0.1944	0.3741	0.2074	0.4342	0.0768	0.4400	0.1313
NoCBpA	0.6653	0.0003	0.9255	0.4784	0.0302	0.0009		0.0461	0.0003	0.0010	0.1639	0.2780	0.2508	0.0659	0.7594	0.5542	0.0440	0.3806
NoATMpK	0.1602	0.0062	0.9484	0.0022	0.0433	0.3916	0.0461		0.0000	0.0008	0.7394	0.3428	0.1381	0.5948	0.7587	0.0630	0.0000	0.4581
NoCBpK	0.7645	0.0057	0.0890	0.5220	0.8296	0.0189	0.0003	0.0000		0.5441	0.7151	0.7454	0.5646	0.8126	0.7722	0.3994	0.0389	0.9403
NoATMpA	0.0182	0.0021	0.0441	0.0893	0.0001	0.1451	0.0010	0.0008	0.5441		0.7742	0.1553	0.0860	0.0353	0.6993	0.0091	0.0000	0.8320
FaR	0.1840	0.2619	0.3227	0.0403	0.3897	0.0513	0.1639	0.7394	0.7151	0.7742		0.0005	0.0146	0.0964	0.3506	0.0571	0.2260	0.0014
Exp	0.9088	0.5250	0.7314	0.2991	0.3285	0.1944	0.2780	0.3428	0.7454	0.1553	0.0005		0.0357	0.0000	0.3066	0.1879	0.4779	0.0317
Doc	0.6410	0.1406	0.8791	0.1922	0.0944	0.3741	0.2508	0.1381	0.5646	0.0860	0.0146	0.0357		0.1885	0.1587	0.0678	0.3463	0.0008
Trst	0.1879	0.4019	0.1397	0.7141	0.0318	0.2074	0.0659	0.5948	0.8126	0.0353	0.0964	0.0000	0.1885		0.1364	0.3425	0.1472	0.2773
Rel	0.9913	0.4760	0.9710	0.5997	0.7868	0.4342	0.7594	0.7587	0.7722	0.6993	0.3506	0.3066	0.1587	0.1364		0.5383	0.1151	0.0357
InsFunds	0.6707	0.0148	0.8764	0.2982	0.0157	0.0768	0.5542	0.0630	0.3994	0.0091	0.0571	0.1879	0.0678	0.3425	0.5383		0.0176	0.3086
Fam	0.0000	0.0142	0.0125	0.0001	0.0001	0.4400	0.0440	0.0000	0.0389	0.0000	0.2260	0.4779	0.3463	0.1472	0.1151	0.0176		0.3146
NoNeed	0.0875	0.1142	0.1454	0.2391	0.6951	0.1313	0.3806	0.4581	0.9403	0.8320	0.0014	0.0317	0.0008	0.2773	0.0357	0.3086	0.3146	

Figure 31 P-value matrix of Indicators

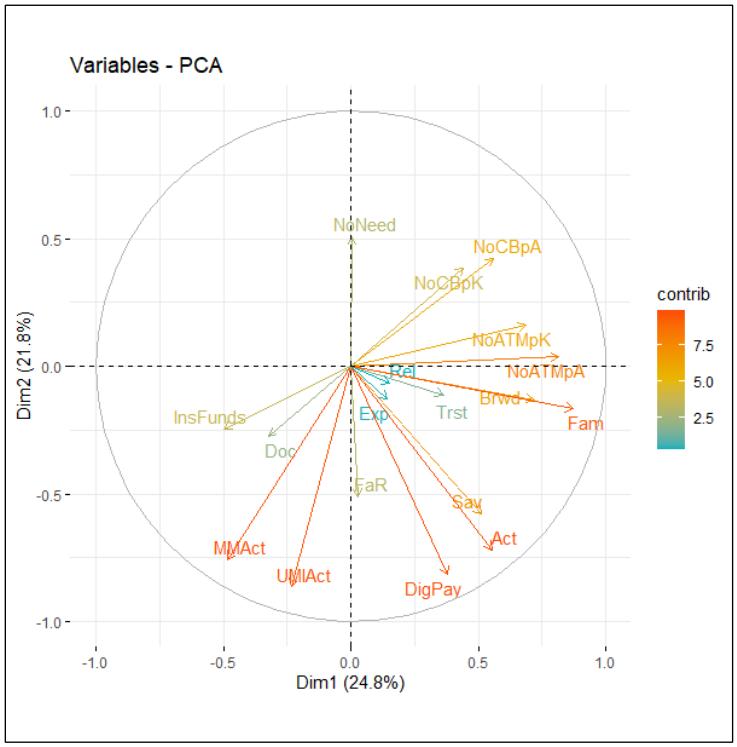


Figure 32 Contribution of Variables to Dimensions 1 & 2

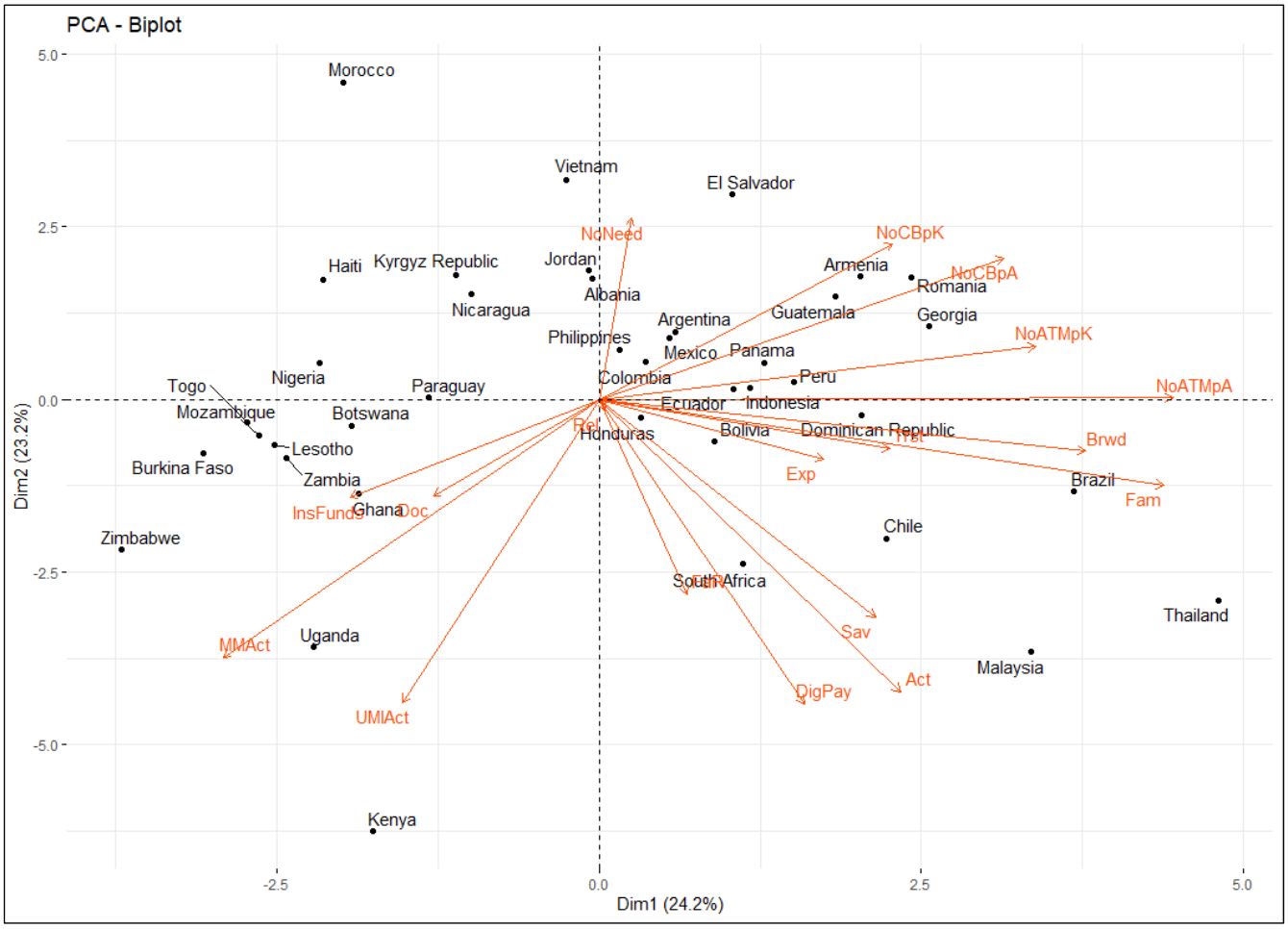


Figure 33 Revised Biplot of Variables and Countries

Questionnaire

IMPACTS OF FINTECH INNOVATIONS ON FINANCIAL INCLUSION IN DEVELOPING COUNTRIES – A CASE STUDY ON MOBILE MONEY IN SIERRA LOENE.

1) Gender □ Male□ Female 2) Age _____ City/Town: _____

3) What is your level of education?

□ Did not go to school □ Primary □ Secondary □Technical/Vocational □ College □ University

4) Do you, either by yourself or together with someone else, currently have an account at a bank or another type of formal financial institution? □ Yes □ No

UNBANKED (If No to 4 answer 5 and skip to 11)

5) Which of the following is a reason why you, personally, do not have an account at a bank or any another formal financial institution? On a scale of 0 to 4, with 0being unrelated and 4 being a strong reason, rate the following:

- Because financial institutions are too far away
- Because financial services are too expensive
- Because I do not have the necessary documentation
- Because I do not trust financial institutions
- Because you do not have enough money to use financial institutions
- Because someone else in the family already has an account
- Because you have no need for financial services at a formal institution
- Other (please specify)

BANKED (If Yes to4 answer 6, 7, 8, 9, 10 & 11)

6) Has money been DEPOSITED into your account(s) within the last 12 months? This can be cash or electronic deposits, or any time money is put into your account(s) by yourself, someone else or another institution.

□ Yes □ No

7) Do you, personally, have an ATM (debit) card? □ Yes □ No

8) **If yes to 7**, in the last 12 months, have you used your own **ATM (debit)** card directly to make a purchase or to pay someone?

□ Yes □ No

9) Do you, personally, have a **CREDIT** card? □ Yes □ No

10) **If yes to 9**, within the last 12 months, have you, personally, used your credit card? □ Yes □ No

MOBILE MONEY

11**)** Within the last 12 months, have you, personally, used a mobile money service to buy things, or to send or receive money? This can be services such as Africell Money or Orange Money.

□ Yes □ No

If No to 11, answer 12 then skip to 15)

12) Why not?

a) I currently have no phone (or phone number) b) I do not know how to do it c) It is expensive d) I do not trust it

d) The people I send or receive money from do not use it.

If Yes (answer 13, 14, 15)

13) Why do you use mobile money to send or receive money? Please choose all that apply.

a) It is fast b) Cheap c) The only way available to me d) It is the only way available to the people I send/receive money from e) Other (please specify)

14) On average, how many transactions do you do a month (or year), either sending or receiving? (please specify with M or Y for month or year)

□ Less than 3 □ 3 to 5 □ 5 to 10 □ 11 to 15 □ more than 15

15) Have you ever borrowed money from a bank or any other formal financial institution to buy/make a home or apartment, to start a business, for medical reasons or for personal use? □ Yes □ No

16) Do you usually save/keep money in your phone account? □ Yes □ No

17) If a mobile carrier increases your credit score (please explain what is a credit score) based on the amount of transactions you do, how much you save on your account, etc., will this encourage you to use their service more? □ Yes □ No (Please specify reason) _____

Thank you for your help

The information given in this questionnaire is completely confidential and will only be used for academic purpose.