Impact of Over-the-top Services, Pricing, and Equity on the Digital Divides in Sub-Saharan Africa

Submitted in partial fulfillment of the requirements for

the degree of

Doctor of Philosophy

in

Engineering and Public Policy

Erezi Ruth Ogbo

B.Tech., Information Technology, Bells University of Technology
MSc., Management and Information Technology, University of St Andrews
MSc., Engineering and Public Policy, Carnegie Mellon University

Carnegie Mellon University
Pittsburgh, PA

December, 2019

Acknowledgements

Udhe-ędę ukriri kęria,	No matter how long it will take,
Orę seba ęgba ha	destiny must come to pass
~ Isoko proverb	

During my PhD orientation, I was told the maximum number of years I had to complete my PhD was 10 years. Thankfully, it didn't take that long! As I finish writing my dissertation, I am honored to acknowledge the many mentors, friends, and family that supported me and contributed to my academic and personal growth over the past four years.

First, thank you to my primary advisor and co-chair of my committee, Doug Sicker. From early on, you allowed me to take control of my research and that has made me into the independent researcher I am today. Throughout my time here at Carnegie Mellon, you have offered me unwavering support: as a research advisor, mentor, and a friend. You are a role model to me and I am indeed thankful for the opportunity to work with you. I also want to thank my co-advisor and co-chair of my committee, Tim Brown. You have continually pushed me to take a step back and critique my work as well as think about the wider policy implications of my research. Given that you are in Rwanda most of the year, I am particularly grateful for the times you were willing to meet with me and talk about my research on a weekend, or at 10 pm your local time. Next, I want to thank my other committee members: Alex Davis and Jon Gant. Thank you for all your guidance on how to conceptualize the different aspects of my research, critiquing my research, and guidance in developing the statistical modeling skills I needed to complete this thesis.

My work here was primarily funded by the Petroleum Technology Development Fund, Nigeria. Special thanks to Gbenga Wahab who facilitated my funding payments. Additional funding was provided by the Carnegie Mellon University's Department of Engineering and Public Policy, the

Carnegie Mellon University's GSA/Provost GuSH Grant, and the Carnegie Mellon University's GSA Conference Funding. Without your generous support, I would not be submitting this dissertation. Thank you.

I am also very grateful for the support of the Engineering and Public Policy Staff: Vicki Finney, Debbie Kuntz, Adam Loucks, and Kim Martin, who have made navigating the PhD program seamless. Special thanks to Patti Steranchak, whose kindness, support, and words of inspiration are priceless.

I am very grateful to the friends I have made here in Pittsburgh whose friendship, banter, encouragement, and academic support have helped make it a second home to me. In particular, I would like to thank Tobi Adekanye, Travis Carless, Judith Odilli, Logan Warberg, Daniel Sun, Vanya Britto, Nicole Racine, Erin Mayfield, Rianne Laurejis, Ana Ceceres, Mihloti and Nathan Williams, Abi and Babatunde Fapahounda, Julia Chelen, Sarah Riordan, Corey Harper, Sam Jones, Sarah Gilmer, Brian Sergi, Matt Babcock, Octavio Mesner, Sinnot Murphy, Nyla Khan, Emily Grayek, Allante Whitmore, and Chukky Udeani. I also want to say thank you to my old friends: Onome Sotu, Fisayo Tunde, Dara Ogun, Afoma Ikhigbe, Onome Taylor, Oche Ejembi, and Misan (+Maro) Sebiotimo for your consistent support, affection, and optimism.

I have been blessed with an amazing family. You have been my biggest cheerleaders and I will not be writing these final pages of my dissertation without your unwavering support. First, I want to say thank you to my parents, Chief Enoch Ogbo and Mrs. Felicia Ogbo. You both taught me the value of education and hard work. Thank you for being available when I needed someone to talk to and being patient on the days I only cared about my research. Thank you for your unconditional love, support, and never-ending words of encouragement. I also want to say thank you to all my siblings, Elo Akin-Agunbiade, Enakeno Ogbo, Odeomaero and Ufuoma Ogbo,

Iteye Ogbo, Obaro Ogbo, Utejiro Ogbo, Ewoma and Martins Oloye, Oruaro Ogbo, Ruona Ogbo, and Oteruo Ogbo. Also, thank you to my grownup niece and nephew, Yums and Kit Akin-Agunbiade. Your love and encouragement have meant the world to me and I am very grateful I have been able to stay in touch with all of you while living in a different continent for the past four years. I also want to say a special thank you to my baby nieces and nephews, Eloho and Temisan Oloye, Rugba Ogbo, and Osiwi Ogbo. You have been a constant source of joy in my life, and I will not forget the days of long-distance babysitting and singing nursery rhymes over WhatsApp video calls.

Thank you to my village, listed here and everyone else that I did not mention, that have supported me throughout this PhD journey.

Finally, I give all glory to God Almighty, for blessing me with the mental and physical ability and all the support I needed to complete this PhD program.

Abstract

With the convergence within the digital ecosystem today, access to digital technology is now a multilevel phenomenon closely tied to the access to one or more of the following: a compatible device, the Internet, and a facilitating service/application. This makes it difficult to disentangle mobile services and Internet services in studies on the digital divide. As countries in Sub-Saharan Africa (SSA), which have the lowest adoption rates globally, look to leverage digital technologies as a tool to drive economic and social development, there is a need for continued and novel approaches to understanding the digital divide. This thesis proposes a new approach to conceptualizing the digital divide and characterizes the three levels of the digital divide: inequalities in access, use, and benefits from use in SSA, using Nigeria as a case study. This work also critically examines the effect of recent pricing policies in Nigeria on the digital divide, as well as the effect of other sociodemographic, socioeconomic, and behavioral factors at the individual level.

In Chapter 2, I run a choice-based conjoint experiment to understand the impact of access to over-the-top (OTT) services on individual preferences for different mobile services – cellular calls, text, or the different services on the Internet – or not using any mobile service (the first-level digital divide). I find that when OTTs are introduced into the market, mobile users are less likely to go without mobile services or to use a traditional service. I also find that this effect is significant in a market with a pay-as-you-go business model. The results also reveal that mobile users are price sensitive, therefore pricing policies may aid in bridging the first and second levels of the digital divide. The findings indicate that customers' preferences in the mobile market are changing and OTT access could be a tool in closing the first-level digital divide. Therefore, I recommend that policies to drive Internet access, especially OTT, should be explored.

In Chapter 3, I use a panel data approach to estimate the effect of reduction in the prices of mobile Internet plans on the volume of use of the Internet, cellular calls, and text messaging services (the second-level digital divide). I find that the reduction in the prices is associated with an increase in the volume of data used and a decrease in the volume of texts sent by an individual. However, reducing the prices of mobile Internet plans does not "close" the second-level digital divide across socioeconomic groups. I did not see a convergence in the volume of use of any of the mobile services across any demographic subgroups. These findings suggest that more robust policies that are targeted at specific subgroups are needed to reduce the existing second-level mobile technology digital divide that exists in developing countries.

In Chapter 4, I draw on the Uses and Gratifications Theory, the Unified Theory of Acceptance and Use of Technology, and factor analysis to examine the differences in the frequency and type of Internet use (second-level digital divide) and the differences in outcomes from Internet use (third-level digital divide). I find that females, the older population, and individuals with a lower level of education are the digitally disadvantaged subset of the population. I also find that high technical skills are associated with high frequency of use of the Internet for personal development, social, and business activities. I also find that encouragement from family and friends as well as intention to increase Internet use in the future are associated with increased frequency of use of the Internet for consuming news content and social interaction respectively. This supports arguments in an earlier work that improving access to over-the-top applications such as WhatsApp could increase Internet use. In examining the determinants of the third-level digital divide, I find that using the Internet for social activities such as using social networks and communicating with family and friends have the greatest impact on offline outcomes. I also find that individuals with a high level of education are more likely to get positive health outcomes

and less likely to get personal development outcomes, such as getting a job or completing an online training, from the Internet.

In Chapter 5, I discuss this work's contribution to the literature and some of the policy implications of the findings in Chapters 2 through 4. Findings in Chapters 2 through 4 suggest that supporting the use of OTT and social networks in developing countries would have benefits. These Internet activities, although they may not directly contribute to personal development or economic gains, typically require little technical skills. Therefore, by engaging with these Internet activities, the digitally disadvantaged subset of the population would be able to develop the required skills to achieve benefits from Internet use. In Chapter 3, I learn that addressing the affordability barrier in a developing country is not enough to bridge the second-level digital divide. More robust policies are needed to bridge the second-level digital divide in developing countries. In Chapter 4, I learn that the digital disadvantage may simply be a reflection of societal inequalities in the online space. Therefore, in order to bridge the digital divide, target policies that address these preexisting inequalities are recommended.

Table of Contents

Acknowledgements ..... *iii*
Abstract ..... *vi*
Table of Contents ..... *ix*
List of Tables ..... *xii*
List of Figures ..... *xiv*
Glossary of Acronyms ..... *xvii*
1. Introduction *1*

1.1 The Concept of the Digital Divide **2**

1.2 Research Context: History of Digital Technologies in Nigeria **4**

1.3 Thesis organization **7**

2. The Impact of Access to Over-the-top Services on Preferences for Mobile Services: A Conjoint Analysis of Mobile Users in Nigeria *8*

2.1 Introduction **8**

2.2 Literature Review **11**

2.2.1 The Relationship Between OTT and Traditional Mobile Services 11

2.2.2 The Determinants of the Individual's Preferences for Mobile Services 13

2.2.3 The Digital Divide in the Nigerian Mobile Market 14

2.3 Methods **16**

2.3.1 Experiment Design 17

2.3.2 Experiment Protocol 20

2.3.3 Sample 20

2.3.4 Preference Modeling and Analysis 21

2.3.5 Modeling Willingness to Pay 24

2.4 Results **24**

2.4.1 Main Results 24

2.4.2 Uncertainty Analysis 29

2.5 Discussion **31**

2.5.1 Implications for the Regulator 32
2.5.2 Implications for the Mobile Carriers 33
2.5.3 Limitations and Future Research 34
2.6 Conclusion 35
3. The Effect of Pricing Policies on the Second-Level Digital Divide in a Developing Country: Evidence from Nigeria 37
3.1 Introduction 37
3.2 Literature Review 40
3.2.1 The Second-Level Digital Divide 40
3.2.2 Drivers of the Digital Divide in SSA 41
3.2.3 State of the Mobile Market in Nigeria 44
3.3 Methods 47
3.3.1 Sample Generation 47
3.3.2 Measurement Variables 49
3.3.3 Statistical Modeling 53
3.4 Results 53
3.5 Discussion 56
3.5.1 Implications of Main Findings 56
3.5.2 Limitations and Future Work 59
3.6 Conclusion 60
4. When Being Connected is not Enough. An Analysis of the Second and Third Levels of the Digital Divide in a Developing Country 62
4.1 Introduction 62
4.2 Theoretical Background 65
4.2.1 The Concept of the Digital Divide 65
4.2.2 Classifications of the Second and Third Levels of the Digital Divide 67

4.2.3 The Unified Theory of Acceptance and Use of Technology 69

4.3 Methods 71

4.3.1 Sample 71

4.3.2 Measures 73

4.3.3 Data Analyses 75

4.4 Results 77

4.4.1 Second-Level Digital Divide 77

4.4.2 Third-Level Digital Divide 83

4.5 Discussion 85

4.5.1 Main Findings 85

4.5.2 Policy Implications 88

4.5.3 Limitations and Future Research 90

4.6 Conclusion 90

5. Conclusion 93

Bibliography 97

Appendix A: Supplementary Information for Chapter 2 108

Appendix B: Supplementary Information for Chapter 3 120

Appendix C: Supplementary Information for Chapter 4 123

List of Tables

Table 1. Factors that determine consumers' preference for traditional mobile or OTT services. . 14

Table 2. Characteristics of the urban and rural samples with a comparison to the Nigerian population [56], [58], [73]. 21

Table 3. Variables and levels of attributes for the alternative mobile plans. 22

Table 4. Description of the mobile Internet attribute and its levels. 22

Table 5. Estimation results of the multinomial, nested logit and mixed logit models. The baseline mobile service plan is the “none” option. 25

Table 6. General demographic and mobile market distribution of Nigeria in comparison to South Africa and Kenya [Data sources: MTN Group Limited, ITU, Nigerian Communications Commission, GSMA] 46

Table 7. Distribution of monthly mobile Internet megabytes, outgoing call minutes, and sent text messages averaged per customer over seven months. 49

Table 8. Distribution of the individual demographic characteristics of the sample. Sources: National Population Commission, National Bureau of Statistics, World Bank 52

Table 9. Estimation results of the Fixed Effects models 55

Table 10. Distribution of the individual demographic characteristics of the sample 72

Table 11. UTAUT Measures 74

Table 12. Rotated matrix of the factor loadings of the Internet activities (In the past year, how often did you use the Internet for…) 78

Table 13. Rotated matrix of the factor loadings of the Internet outcomes (In the past year, through the use of the Internet...) 79

Table 14. Regression coefficients of adoption factors for behavioral intention to use the Internet 80

Table 15. Estimations results of the linear regression models showing the determinants of the second-level digital divide..... 82

Table 16. Estimations results of the logistic regression models showing the determinants of the third-level digital divide..... 84

Table 17. Comparing the fit of a 1-factor model and a 5-factor model for Internet activities.... 126

Table 18. Scale intercorrelations corrected for attenuation raw correlations below the diagonal, alpha (bolded) on the diagonal, and corrected correlations above the diagonal 126

Table 19. List of all measures of Internet activities included in the survey instrument (In the past year, how often did you use the Internet for…) 127

Table 20. List of all measures of Internet outcomes included in the survey instrument (In the past year, through the use of the Internet...) 128

Table 21. Regression results of the Internet outcomes with only user demographics as the predictor variables..... 129

Table 22. Regression results of the Internet outcomes with only Internet activities as the predictor variables..... 130

List of Figures

Figure 1. Percentage of mobile users on the major mobile carriers in Nigeria in 2019. Data source: The Nigerian Communications Commission 5

Figure 2. Distribution of the number of Internet subscriptions on the major mobile carriers 6

Figure 3. Mobile networks coverage in Nigeria, by all networks. From left to right, 2G, 3G, and 4G. [Data source: GSMA] 6

Figure 4. Example choice screen for a respondent. Each task was displayed on a separate screen/page. 18

Figure 5. Comparing the choice probabilities of traditional services and no service across scenarios with OTT as an alternative and when it is not. Price is set to $10, and the levels of the traditional services are shown in the upper x-axis. 27

Figure 6. Boxplot showing the willingness to pay ($/Month) for different mobile services. The x-axis shows the different attribute levels of the mobile services and the WTP is shown in the y-axis. 28

Figure 7. 95% confidence intervals of the conditional individual coefficients of the first 50 respondents. 29

Figure 8. Comparing the effect of introducing OTT into the market given the highest and lowest conditional individual coefficients 30

Figure 9. Mobile subscriptions per 100 people [Data source: ITU] 45

Figure 10. Percentage of individuals using the Internet. [Data source: ITU]. 47

Figure 11. Total active users for cellular calls, text, and Internet mobile services in each month 50

Figure 12. Average volume of use for cellular calls, text, and Internet mobile services in each month 50

Figure 13. Theoretical framework of the study hypotheses. Adapted from the UTAUT model [106] 75
Figure 14. Comparing the impact of access to different Internet plans on preferences for traditional mobile services 116
Figure 15. Comparing across different age groups, the impact of OTT on the choice probabilities of different traditional services and going with mobile service 117
Figure 16. Comparing across college educated and non-college educated mobile users, the impact of OTT on the choice probabilities of different traditional services and going with mobile service 118
Figure 17. Comparing the choice probability of OTT and no service across urban and rural areas at a price of $10. The upper x-axis shows the different traditional mobile services 118
Figure 18. 95% confidence intervals of the individual willingness to pay for OTT. 119
Figure 19. Log transformed scale of the volume of use of data, calls, and text over the 7 months observed in the study 120
Figure 20. Distribution of active users in the dataset across the states in Nigeria 120
Figure 21. Distribution of the average volume of use of the Internet (measured in megabtyes) across the states in Nigeria 121
Figure 22. Distribution of the volume of use of cellular calls (measured in outgoing minutes) across the states in Nigeria 121
Figure 23. Distribution of the volume of use of text (measured in outgoing count) across the states in Nigeria 122
Figure 24. Heatmap showing the correlation between the raw Internet activities 123
Figure 25. Heatmap showing the correlation between the raw Internet outcomes 124

Figure 26. Scree plot showing the recommended number of factors for Internet activities 125

Figure 27. Scree plot showing the recommended number of factors for Internet outcomes 125

Glossary of Acronyms

AVE	Average Variance Extracted
BI	Behavioral Intention
CAPI	Computer Aided Personal Interviewing
CBC	Choice-Based Conjoint
EE	Effort Expectancy
FC	Facilitating Condition
GB	Gigabyte
GDP	Gross Domestic Product
ICT	Information and Communication Technology
ITU	International Telecommunication Union
ML	Mixed Logit
MNL	Multinomial Logit
NCC	Nigerian Communications Commission
NL	Nested Logit
OTT	Over-the-top
PAF	Principal Axis Factoring
PC	Personal Computer
PE	Performance Expectancy
SCT	Social Cognitive Theory
SI	Social Influence
SIM	Subscriber Identification Modules
SSA	Sub-Saharan Africa
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UGT	Uses and Gratifications Theory
UTAUT	Unified Theory of Acceptance and Use of Technology
VoIP	Voice Over Internet Protocol
WTP	Willingness to Pay

1. Introduction

The Internet has the potential to drive economic and social development by improving communication and facilitating innovation. Unfortunately, developing countries, which are most in need of these benefits, are faced with low penetration and adoption rates. Data published by the International Telecommunication Union (ITU) showed that in 2016, over 80% of individuals in developed countries used the Internet, compared to 40% in developing countries [1]. This challenge is exacerbated in rural communities, where, in addition to other barriers to Internet adoption and use, there is a struggle to keep up with the rapid developments in broadband connectivity. This is a significant challenge in Sub-Saharan Africa (SSA), where over 60% of the population live in a rural community[1] and only 25% of the population used the Internet in 2016. It has been argued that to compensate for their remoteness, rural areas are more in need of improved digital connectivity [2]. However, remoteness is a key factor driving the urban/rural digital divide. Other factors such as low language and digital literacy, the high cost of a device and access, as well as lack of access remain a barrier to Internet adoption and use [3].

In SSA, the Internet is predominantly accessed via mobile devices, reducing some of the limitations associated with using a computer, such as advanced technical skills and cost. Over the past few years, Internet access, adoption, and use have increased significantly in SSA. Between 2012 and 2016, the average Internet adoption rate in the region increased from 9% to 29% [1]. This growth is expected to continue, with rates increasing from 26% to 38% between 2016 and 2020; driven mostly by increased adoption by the rural, below 20 years, and women population sub-groups [4]. Still, significant differences among individuals, households, businesses and

[1] https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG

geographic areas at different socio-economic levels with regard to both their opportunities to access digital technologies and to their use of the Internet for a wide variety of activities exists. These differences are defined as the *digital divide*.

Over-the-top (OTT) applications, "apps", that support calling and sending messages over the Internet such as WhatsApp, Viber and Skype, could have a significant impact on the digital divide. These apps, due to the low digital literacy needed to use them, could drive Internet adoption and use. Furthermore, the comparatively low cost of communication using OTT apps compared to cellular calling/texting could have broader implications on the digital divide beyond access to and use of Internet technologies.

1.1 The Concept of the Digital Divide

Since the 1990s, as Internet access and the use of Personal Computers (PCs) increased, the digital divide has been studied extensively [5]–[11]. Prior works have explored the differences in the access and use of digital technologies across nations worldwide [12], geographical locations within nations [6], [13]–[17], select regions e.g. countries with high market penetration [9], [18]–[20], and individuals within nations [10], [21], [22].

Initially, research on the digital divide followed a simplistic and dichotomous view focused on the difference in access; studying the difference between those connected to the Internet and those who were not. This type of digital divide is referred to as the first-level digital divide [7], [16], [23], [24]. Understanding the first-level digital divide assisted in developing policies to drive Internet adoption. Studies of the first-level digital divide have shown that individual characteristics such as age, gender, socioeconomic status, and geographical location affect Internet adoption [5], [25]. However, the first-level digital gap between men and women was

found to be entirely as a result of existing socioeconomic differences between the genders [10], [26], suggesting that closing gender inequalities need to be addressed in order to close gender digital divides. In general, high-income and highly educated individuals were the early adopters of the Internet [7], [20], [27].

Over the past two decades, as Internet penetration increased, the first-level digital divide has been gradually closing [12], [28], [29]. Internet users are increasingly crossing socioeconomic lines. Thus, rather than clear divides limited to between areas or individuals with access and those without, access has become a spectrum with evolving bandwidth and capacity [28], [30], [31]. These changes support arguments to shift from studying the differences between the "connected" and "unconnected", to studying the extent and pattern of Internet use. This difference in Internet use by the connected population is described as the second-level digital divide [5], [18], [29].

The Internet service used by an individual is largely dependent on having the required skills. For example, skills to operate the required hardware and software, information literacy to process the online content, as well as social skills and creative skills to create content and connect with other individuals online. Up to half of the variance in having the required skills, and thus Internet use, are accounted for by sociodemographic factors [18]. Researchers have studied how the Internet services used by active users vary. Some of these studies examined the frequency of Internet use and how it varies across demographic groups [10], [32]. Others explored how the type of service or content accessed, such as information seeking or commercial transaction, varies across demographic groups [18], [21]. These studies, while informative, have predominantly been limited to high penetration mobile markets, which significantly differ from the growing markets in developing countries.

While a lot of research has explored the first-level digital divide, and increasingly explored the second-level digital divide, very little work has been done on studying the difference in the impact of Internet access and use. This difference in the impact of Internet use, where some individuals do not have beneficial outcomes, is described as the third-level digital divide [5], [33], [34]. Some researchers argue that studies on the digital divide need to focus on this third-level divide; examining the economic, social, cultural and human capital that could be attained through Internet use [18]. However, existing literature on the third-level digital divide have focused on developed markets, where penetration rates are high. Countries in the global south, such as Nigeria, face all three levels of the digital divide. This creates a need for new approaches to understanding and addressing the digital divide.

1.2 Research Context: History of Digital Technologies in Nigeria

Since mobile communications were introduced in Nigeria in 2001, it has dominated the telecommunications industry where fixed telephony penetration rates have remained consistently below 0.2% [35]. Mobile penetration rates, on the other hand, have grown rapidly to over 140 million subscriptions in the fourth quarter of 2017; which is 74% of the population[2] [36]. However, unique penetration was at only 49% as – due to an attempt to take advantage of price arbitrage in calling different networks or network unreliability – each subscriber has an average of 1.5 phone lines, also called subscriber identification modules (SIMs) [37].

Similarly, fixed broadband is underdeveloped in Nigeria; driving the dependence on mobile as the primary means of Internet access. In contrast to the rapid adoption and use of mobile as a substitute to fixed telephone, the use and adoption of mobile Internet has been low, with

[2] Using the 2017 estimate of 190 million as the population of Nigeria.

significant differences in access and adoption across the country. In the fourth quarter of 2017, the national regulator, Nigerian Communications Commission (NCC), reported there were 100 million Internet connections in Nigeria, which, if they were unique users, would be equivalent to 53% of the population. This penetration rate, referred to in this work as the *connection penetration rate*, differs significantly from the *subscriber penetration rate*; 26% of Nigerians use the Internet [36], [38]. The distribution of active Internet users and the penetration rates within each state varies significantly. Lagos State, which accounts for the greatest share of the national Internet subscriptions (14%), has a connection penetration rate of 113%. On the other hand, Bayelsa State, which has the smallest share of the national Internet subscriptions (less than 1%), has a connection penetration rate of 30% [39].

Mobile and Internet access is concentrated to a few providers. Over 99% of mobile and Internet connections are served by the four major mobile carriers, MTN, Glo, Airtel, and 9Mobile, as shown in Fig. 1 and 2. Among the big four carriers, market share is largely driven by the quality of service, the coverage area, and the prices of the services offered on the network.

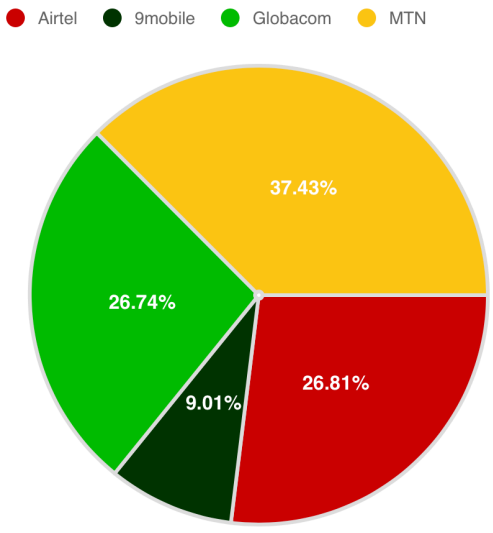


Figure 1. Percentage of mobile users on the major mobile carriers in Nigeria in 2019. Data source: The Nigerian Communications Commission

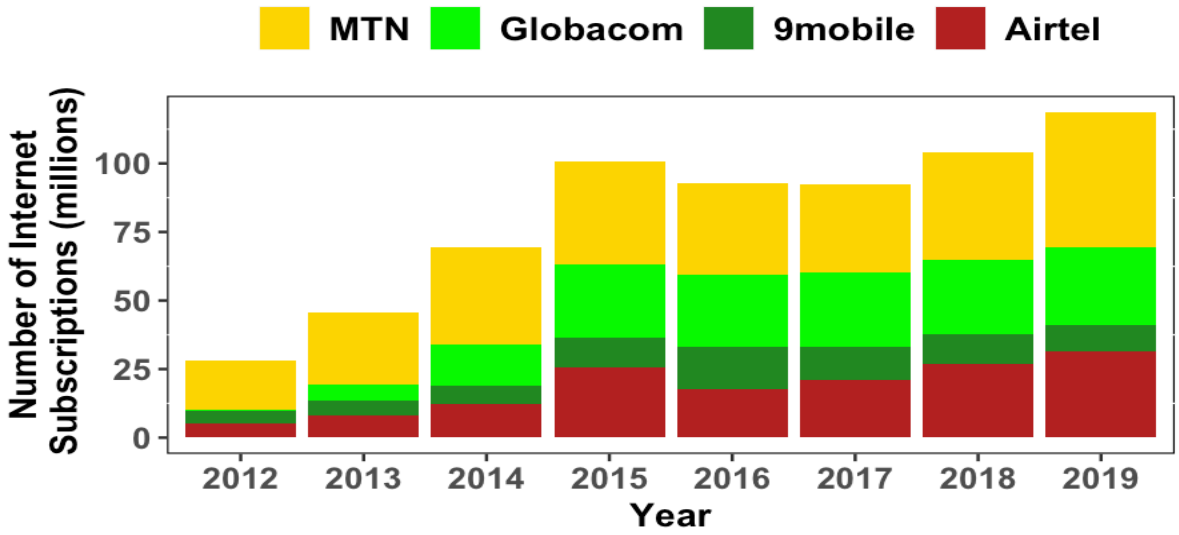


Figure 2. Distribution of the number of Internet subscriptions on the major mobile carriers

While users across the country have access to good GSM (2G) coverage, UTMS (3G) and LTE (4G) coverage are more limited. Fig. 3 shows that big cities such as Lagos, Abuja, and Kano benefit from access to high quality signals while rural areas struggle with connectivity. Figures from the NCC in 2017 show that only 15% of the base stations in Nigeria support 4G LTE networks.

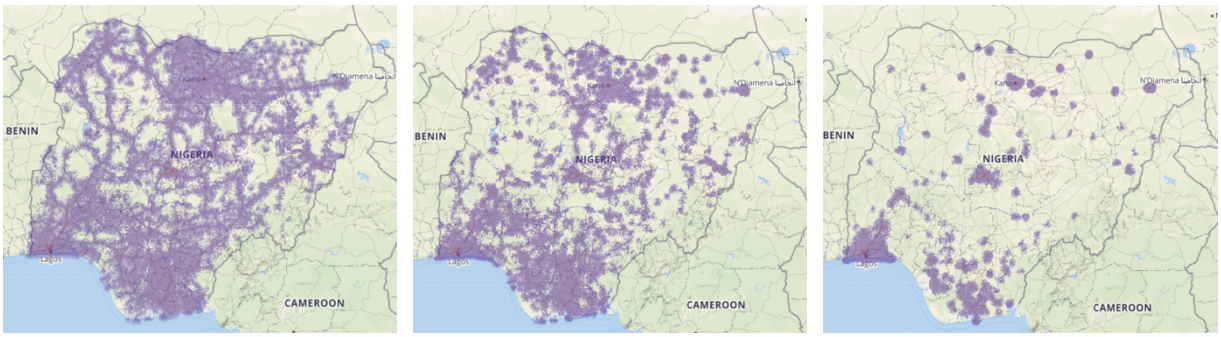


Figure 3. Mobile networks coverage in Nigeria, by all networks. From left to right, 2G, 3G, and 4G. [Data source: GSMA]

1.3 Thesis organization

This thesis presents findings from three studies I conducted while at Carnegie Mellon University with the overarching goal of characterizing the three levels of the digital divide in Sub-Saharan Africa. In Chapter 2, to understand the first-level digital divide, I apply a choice-based conjoint (CBC) experiment to investigate the impact of access to OTT services on users' preferences for traditional services such as cellular calls and texting. In Chapter 3, I use a panel data of historical customer billing records, retrieved from a major mobile carrier in Nigeria, to examine the effect of reductions in the prices of mobile Internet plans on the use intensities of the Internet, cellular calling, and text messaging (the second-level digital divide). In Chapter 4, drawing on the Uses and Gratifications Theory (UGT), the Unified Theory of Acceptance and Use of Technology (UTAUT), and factor analysis, I identify the key Internet activities Internet users engage with (second-level) and the key outcomes they experience through Internet use (third-level digital divide) as well as the determinants of these divides. Finally, in Chapter 5, I summarize all these studies and discuss their contribution to the literature on the digital divide and their implications in closing the first, second, and third levels of the digital divide in Sub-Saharan Africa.

2. The Impact of Access to Over-the-top Services on Preferences for Mobile Services: A Conjoint Analysis of Mobile Users in Nigeria

Abstract

African mobile carriers are faced with increasing uncertainties in revenues due to changing customer preferences for mobile services. This has led to different strategies to protect their revenues, from bundling voice, text, and data services to pushing national regulators to ban OTT services. This paper examines the first-level digital divide by analyzing the impact of access to OTTs on the differences in individual preferences for different mobile services – voice, text, or the different services on the Internet – or not using any mobile service. A choice-based conjoint experiment run on a sample of mobile users in Nigeria is used to understand this impact. The results suggest that when OTTs are introduced in the market, the choice probabilities – the probability of choosing a particular service given certain alternatives – of a traditional mobile service and no service are significantly reduced. This impact is determined by the business model in place and the affordability of the mobile plans offered in the market. User demographics is not found to be a significant predictor of user preferences or the impact of OTTs on preferences. The results suggest that policies that encourage access to OTTs could potentially reduce the first-level digital divide in the mobile industry.

2.1 Introduction

Early research on the digital divide typically followed a simplistic and dichotomous approach. This, termed the first-level digital divide, compared the differences in the sociodemographic characteristics between those that have access to Information and Communication Technologies (ICTs) and those that don't have access [5], [7], [10]. More recent research on the digital divide, largely driven by the high adoption rates and near-universal use of ICTs in developed countries, shifted to investigating the differences in the use patterns of ICTs (second-level digital divide) [5], [18], [29] and the differences in the outcomes from these use patterns (third-level digital

divide) [33], [40], [41]. The digital divide research has been largely limited to sociodemographic and socioeconomic determinants [5]. However, in developing countries, where the mobile markets are still developing, adoption rates are still low, and the use of mobile devices cuts across sociodemographic and socioeconomic groups, there is a need for continued and novel approaches to understanding the first-level digital divide.

The early approach to the first-level divide, examining the binary choice of ICT use, is no longer suitable for today's markets. In these markets, with the convergence within the digital ecosystem, the binary choice of technology adoption is more complex and differs significantly from in the 1990s and early 2000s when most of the first-level digital divide studies were conducted. Today, multiple services/applications can be located on a single mobile device. The applications that support traditional mobile services such as voice and text may sit next to OTT applications such as WhatsApp, Viber, and Skype that enable low-cost services such as Voice Over Internet Protocol (VoIP[3]) calling and instant messaging. These OTT services can be a direct substitute to traditional mobile services i.e. voice and/or text, thus creating competition for subscribed end-users between mobile carriers and OTT providers. Therefore, it can be argued that a second related binary choice is *does the end-user use a particular class of application?*

Access to digital technology is now a multilevel phenomenon. For example, access to telecommunications infrastructure is no longer limited to physical access to a network or a hardware system. Rather, with the disruption of the mobile industry by OTT applications, access to remote telecommunications infrastructure could be facilitated through a service/application on a smartphone and Internet access. Therefore, access to digital technology is closely tied to access

[3] In this paper, VoIP refers to voice calls over the Internet that use an OTT application.

to one or more of the following: a compatible device, the Internet, and a facilitating service/application. With this, we argue that studies on the first-level digital divide should apply a two-part approach; (1) mobile device and Internet access divide, and (2) application access divide. The mobile device access and Internet access can be seen as tightly-coupled facilitating conditions for the first-level adoption of competing applications for cellular calls, text, VoIP, and instant messaging services. Conversely, application access can be a determinant for the first-level adoption of mobile and/or the Internet.

In Nigeria, the largest mobile market in SSA, mobile cellular use has grown rapidly albeit unevenly. In 2016, Nigeria ranked 22nd (out of 46 countries in SSA) in mobile penetration with 86 million unique subscribers; 45% of the population [4]. Internet subscription, which is predominantly via mobile, has grown significantly in Nigeria with over 90 million subscriptions in 2016; 49% connection rate. However, given that the average Nigerian has 2.4 SIMs, the subscriber penetration rate is 26% and consists of mostly the educated and urban population [42]. To reduce this digital divide, improving affordable access to ICTs in urban and rural areas is a key policy objective to the Nigerian government. The proliferation of cheaper smartphones and reliable high speeds has facilitated the adoption of the Internet and the use of OTT communication services in Nigeria. Therefore, the mobile industry is now faced with increasing uncertainties on changing customer preferences, industry growth, and future revenues. In Nigeria and the wider SSA mobile market, these uncertainties have led to mobile carriers adopting various strategies to protect their revenues. These strategies range from bundling voice, text, and data services to banning OTTs. More broadly, Nigeria plays an important role in the wider SSA mobile market. Future trends in the SSA mobile market is expected to be largely driven by Nigeria; accounting for 18% of 168 million additional subscribers between 2015 and 2020 [43].

These expected changes in the Nigerian mobile industry raise a number of important questions, such as: how does access to OTT impact users' preferences for traditional services? How does affordability affect users' preferences? And finally, what are the effects of demographic factors on users' preferences? Answering these questions would inform policy recommendations such as: to what extent can public policies and mobile carriers' decisions in Nigeria foster the reduction of the first-level digital divide by (1) fostering access to devices and the Internet? (2) simultaneously diversifying options to meet heterogeneous preferences for access to devices and Internet services as well as options for voice, data, and text services over traditional services?

Using stated preferences from a sample of young and educated mobile Internet users in Nigeria in a CBC experiment, this paper attempts to answer these questions. We define mobile as a device that can connect to a cellular network and is used for voice and/or text services over this network. Mobile services in this study are limited to voice (cellular calls), text (text messaging over a cellular network), VoIP (using Internet applications such as WhatsApp and Skype), and general mobile Internet use.

The paper is organized as follows. In Section 2, we summarize existing relevant literature. In Section 3, we outline our methodology and describe our sample. In Section 4, we discuss our results. In section 5, we present the discussions and policy implications.

2.2 Literature Review

2.2.1 The Relationship Between OTT and Traditional Mobile Services

To understand the impact of OTT services on the mobile industry, existing literature has explored the relationship between mobile Internet use and voice and/or text. Gerpott classified this literature along three conceptual lines; (1) rational decision making under uncertainty, (2)

UGT, and (3) social exchange and hedging theory [44], [45]. Gerpott's extensive work on understanding the interdependencies of usage intensities of different mobile services have been majorly along the first conceptual line which emphasized that customers' use of different mobile services is constrained by time and budget. As a result, the use of one service can be compensated by a reduction in the use of other services [44]. In multiple studies between 2010 and 2017, Gerpott used existing billing records of consumers of a major telecommunication company in Germany, and more recently in an Arabian Gulf Corporation Council GCC country to explore this topic [44]–[48]. The earlier work from 2010 in Germany suggests that mobile Internet use had a significantly negative effect on text traffic and no effect on voice traffic. However, he concluded that these effects, although significant, and their relevance to mobile carriers – effect on revenue – were very small. His later works between 2014 and 2016, also in Germany, suggest that the use of mobile Internet and voice are complementary, and correlated with a significant increase in text.

In the European Union, the mobile Internet could not only potentially disrupt the mobile industry, but because fixed connections are still widely used, could disrupt the telecommunications market as a whole. While mobiles have been found to be a strong substitute for fixed-lines [49], a more recent study, using panel data from 20 European countries between 2008 and 2011, show that VoIP could also be a substitute for fixed-lines [50]. Findings from studies that rely on data collected through survey support the findings using historical data. Using data on Italian consumers collected through a survey in 2006, it was found that the use of VoIP is negatively correlated with voice calling, and has a complementary relationship with non-voice (Internet-based) services [51].

Notwithstanding the extent of the disruption OTT services has on the mobile market, little attention has been given to the preferences of consumers while controlling for the rapidly changing industry. In developed countries, where most of the existing studies have been focused, the mobile market is saturated and the impact of changes in service quality/access on subscription are expected to be minimal with insignificant effects. On the other hand, the mobile market in emerging countries is still growing rapidly and the impact of changes in service quality and access could be significant, with practical relevance to mobile users, carriers, and regulators. While the use of historical data allows an investigation into the correlation between two or more trends/variables, it creates a gap in understanding the preference of the population that does not have access to a service. It also limits the understanding of how users would respond to future trends in the market. For example, a good quality VoIP call requires between 90 kbps to 156 kbps, which is within the limit for 3G speeds. However, Internet speeds could fluctuate due to environmental and network factors, and users may not rely on VoIP for communication if the service is unreliable. In addition, with 4G being prevalent in developed countries and 5G expected to roll out in 2020, analysis using only 3G would provide a limited understanding and be irrelevant in a few years.

2.2.2 The Determinants of the Individual's Preferences for Mobile Services

Heterogeneity in demand for different mobile services among German mobile users in 2015 was found to be large [47]. Age, gender, and educational qualifications have been found to drive the use and adoption of mobile phones [52]. Existing literature, using surveys, on the factors that influence consumers to switch from voice and text to using OTT services for communication can be structured into three: (1) service attributes, (2) user attributes, and (3) existing business model. These factors are summarized in Table 1. Using an extension of the Technology Acceptance

Model, Shin found that the call and service quality, as well as the mobility and coverage (service attributes) of VoIP significantly affected its adoption [53]. Nikou et al administered a conjoint survey to 82 respondents in the Netherlands, France, and Spain, and found that reliability, security, and interoperability of OTT services were considered important [54]. Across his studies, Gerpott found several user-attributes that could explain their interdependencies pattern for OTT and voice and/or text. Subscribers who are more likely to substitute across the services are those that have been with the mobile carrier for a long period, use other Internet services, are older and have recently purchased a new phone [45], [47]. While his work in 2015 found that females are more likely to reduce their text volume in parallel to their increase in mobile Internet use, the study in 2016 shows that males are more likely to substitute voice with mobile Internet. Also, users are more likely to switch to OTT if a pay-as-you-go business model exists [44].

Table 1. Factors that determine consumers' preference for traditional mobile or OTT services.

Service Attributes	**Individual-Specific Attributes**	**Industry Attributes**
Mobility, coverage, and quality of service	Current technical skills, age, income, type of phone, familiarity with web platforms, and use of other Internet-based communication services	No additional cost of data for OTT, and a pay-as-you-go model

2.2.3 The Digital Divide in the Nigerian Mobile Market

With an estimated population of 190 million in July 2017, Nigeria is the most populous country, the second largest economy and largest mobile market in SSA. Mobile has dominated the telecommunications industry as access to fixed telecommunications has remained consistently less than 0.2% [35], [55]. Since its inception in 2001, the Nigerian mobile market has grown significantly to over 154 million subscriptions in 2016; a connection rate of 82% [56], [57]. The

penetration in Nigeria is only at 45% given that, on average, each subscriber has 1.8 SIMs. Furthermore, significant variation in penetration exists within the country. Across the 36 states in the country, mobile subscription ranges from 40% to 170% with an estimated 33% of users concentrated in 5 states [58]. In the first quarter of 2016, there were 92 million Internet connections in Nigeria, with 70% of the connections via mobile (42% via feature phones, and 28% via smartphones) [59]. Similar to mobile penetration, there is a wide variation in the adoption of mobile Internet across Nigerian states; subscription ranged from 20% to 110% across states [58]. Furthermore, there are significant differences in Internet use across Nigeria.

In Nigeria, and the wider SSA region, the literature on the digital divide is limited. In Nigeria, early research on the digital divide identified demographic factors such as gender, age, education, and marital status [60] and the initial cost of PCs [61] as key determinants of the divide. More recent work examining the contributors to the divide among the low-income population found that affordability continues to be a key determinant, as well as the lack of Internet access, and lack of computer skills [3]. Research on the digital divide in the region has also shifted to understanding how Internet activities vary across countries and demographic groups. Survey data from six countries in SSA show that although Internet use is growing, majority of the population is still offline, with the young, more educated, and wealthy more likely to use the Internet, and most likely to use the Internet for social and entertainment activities [62]. In Angola, applying the extended unified theory of acceptance and use of technology (UTAUT2) to explore the role of values in ICT acceptance found that habit, ICT skills, and benevolence are key factors that influence ICT use [63].

The presence of competition, the introduction of 3G services in 2007 and regulatory reforms have been identified as a few key drivers of the rapid growth in the mobile industry in the past

decade [64]. Internet speeds remain a key factor determining the volume of Internet use. Although independent mobile Internet Service Providers (such as Smile and Spectranet) offered 4G LTE dating back to 2014, the major mobile carriers only introduced it in Nigeria in 2016. The rapid growth in the adoption of the mobile Internet, increasing access to 3G and 4G networks, and falls in the cost of smartphones – MTN Nigeria offers the MTN Sm@rt2 smartphone for less than $35 – would enable more Nigerians to access key Internet applications and services. Considering that data is the future and mobile markets will be moving to 5G networks, this increases the possibility of improved Internet and data use. Therefore, the volume of voice and text are expected to decline as OTT platforms grow. Indeed, this has been seen in other emerging markets such as Brazil and China – the largest market in Latin America and Asia respectively, where 59% and 67% of respondents respectively use OTT more than text [43].

2.3 Methods

A CBC experiment was designed and administered to elicit stated preferences for mobile services. Conjoint analysis is the theory and method of designing, implementing and analyzing judgment data experiments involving multi-attribute alternatives [65]. An important underlying theory in using this method is that consumers have predetermined preferences that are not dependent on the choices available; either in the experiment or in the current market [66]. By asking respondents to choose a preferred alternative, which is similar to the selection process in the market, CBC methods have been shown to closely match the estimates of demand in the market [67]–[69]. Within telecommunications, CBC has been used in analyzing the preferences

of consumers for different communication technologies as a function of its security, privacy, ease of use and extension of its functionality as a device or as a service [54], [70]–[72][4].

2.3.1 Experiment Design

Participants in the experiment are asked to choose between two different mobile bundled plans or going without mobile service under the assumption that their current mobile plan ends the next day and the plans offered are the new options available. Each mobile plan is characterized by a combination of four attributes which represent the cost of the plan and the mobile services (Internet, voice calls, and text) that can be offered on a mobile plan. A sample CBC interface shown to the respondents is shown in Fig. 4.

The first attribute is the economic cost of the mobile plan to the user, presented as the *monthly price*. To select the levels of the monthly price that is displayed to the respondents, we used the self-reported monthly expense estimates on mobile Internet, voice calling and text from the survey pretest. We also computed the cost of the mobile services using the chosen levels in the experiment as well as the current market price. These cost estimates are then used to inform the cost levels included in the experiment. The second attribute is *mobile Internet*, which is described using the volume of data, Internet network speed and Internet service access, which refers to what websites or Internet applications can be accessed under the plan. The levels included in the experiment represents Internet plans that already exists in the market (e.g. 3.5GB volume of data, 2G network speed, and access to all websites and applications) and plans that consists of a combination of services that exists in the Nigerian market and other markets (e.g. unlimited GB volume of data, 4G network speed, and access to only OTT applications). In the

[4] CBC has been used in analyzing different mobile devices; such as smartphones versus feature phones [71]. It has also been used to study the preferences for different applications; OTT apps offered by Internet companies versus those offered by mobile carriers [54].

experiment, OTT access is presented to the respondents as "Internet access: IM & VoIP", which is Internet access that is restricted to instant messaging and Voice over IP. The blocks were carefully selected to ensure realistic attribute combinations within blocks; for example, a 4G speed and no Internet access cannot exist within a block. The third attribute is *voice*, which is described to respondents as the minutes of outgoing calls in the mobile plan. Finally, the fourth attribute is *text* via a cellular connection and is described to the respondents as the number of SMS sent in a month. The levels of voice and text were informed by the price levels to ensure realistic combinations could be created.

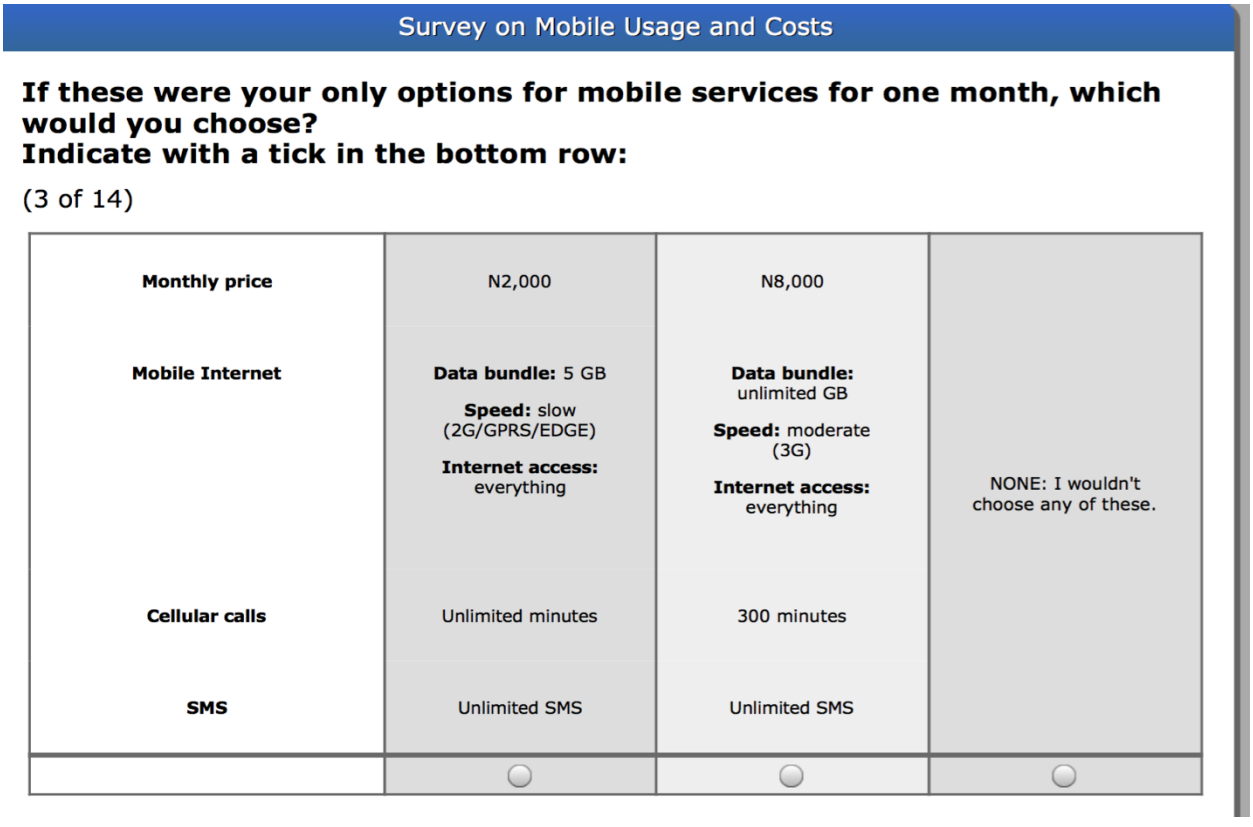


Figure 4. Example choice screen for a respondent. Each task was displayed on a separate screen/page.

While the levels of the attributes were carefully selected to mirror the current market, to better understand future trends in the mobile market, some levels not offered in Nigeria but offered in other markets, were also included. For example, 4G LTE, unlimited voice, unlimited text, and bundling of services were not widely available in Nigeria when this study was conducted.

The survey was designed and administered using Sawtooth Software[5], and respondents completed the survey online, using local hosts on tablets, or paper and pencil. The survey consists of four parts with a total of fifty-one questions, see Appendix A. First, the participants were introduced to the context of the study by providing background information on mobile and OTT use. The second part consisted of fourteen choice questions. Each choice task was made up of three alternatives; two mobile plan alternatives and a "none" option – which meant the respondent would rather go without mobile service than choose any of the mobile plans[6]. The none option indicates the participant is unable to make calls or send messages but can receive calls and text messages. This was designed to closely model the current market in Nigeria where there is no access fee for mobile users. In the third part of the questionnaire, respondents were asked their perceived importance for different mobile services based on their current usage, their current cost, and usage for different mobile services. The last part of the survey consisted of demographic and follow-up questions.

---

[5] Sawtooth Software is the most widely used program to design, collect and analyze choice based survey data. (www.sawtoothsoftware.com)

[6] Advantages of the none option is that it makes the choice decision more realistic and therefore leads to better predictions of preferences. A disadvantage however, is that participants may select none to avoid difficult choices and this would affect the validity of preference predictions. Another disadvantage is that the survey taker may consider "none" to mean that they could choose some other option in the actual market. i.e. they may be thinking of an option offered by MTN as an alternative and if they prefer the MTN option they select "none" among the options. In our experiment, the none option was selected in 8% of the choice tasks, and at least once by 55% of the respondents.

2.3.2 Experiment Protocol

To understand the relative importance of cost savings information, as well as economic cost savings on users' preferences, a between-subjects experiment was designed. Participants were randomly assigned to two experimental groups and had no pre or post-experiment knowledge of the different groups. A comparison of the value for money of OTT, voice and text services are presented to one group, and the control group had no added information.

We used a combination of checks to determine if the participants were paying attention to the choice tasks. Prior to completing the choice tasks, we provided information on OTT applications and then asked follow-up questions on the information given to see if the respondent understood OTT applications. We also included two fixed choice tasks with a dominant option in the conjoint choices to test if the respondents were randomly selecting their choices.

2.3.3 Sample

Respondents were recruited between June and August 2016 from Lagos[7] and Delta[8] States in Nigeria using a site-based sampling method (N = 390). Participants were recruited from across these locations to represent users in urban and rural regions. Within each location, in order to recruit the target participants with diverse socio-economic and employment backgrounds, sampling took place in higher educational institutions and public places near shopping malls and markets. Participation in the study was limited to mobile phone users in these locations that could read and write in the English Language. This provided a convenience sample that is neither

[7] A mega city and also the economic hub of the country with a population density of between 6,400 (based on the 2006 population census) to 15,000 people/square mile (based on 2016 population estimate by the National Population Commission of Nigeria).

[8] Recruitment took place in Warri, a medium sized metropolitan city in the underdeveloped south of Nigeria with an estimated population density of 200 people/square mile based on the 2006 population census, and also in a cluster of remote villages in southern Nigeria with an estimated population density of 60 people/square mile.

representative of the Nigerian population, nor the population of mobile users. However, the sample is representative of mobile users that have been identified as likely to use OTT – young and educated. Therefore, this sample is used to provide insights on the preferences of the potential users of OTT, and its results used to inform further studies using a more representative sample. Table 2 presents the summary statistics of the self-reported demographic characteristics of the sample, comparing respondents in urban and rural areas.

Table 2. Characteristics of the urban and rural samples with a comparison to the Nigerian population [56], [58], [73].

Demographic variable	**Nigeria (2015)**	**Urban**	**Rural**
Female	49.4%	51%	44%
Monthly income under $160	-	28%	37%
Bachelor's degree	-	87%	66%
Mobile Internet use	65%	97%	80%
Monthly ARPU	$4.6	$17	$10
Mean age (years)	18 (median age)	32 (SD= 7)	36 (SD = 12)
Total respondents	-	174	214

2.3.4 Preference Modeling and Analysis

The responses to the CBC experiment were analyzed using a random utility model in which, for each individual *n,* with *J* alternatives, the utility, U_{nj}, derived from an alternative *j* is derived as a sum from two components; (1) an observable part, V_{nj}, which is a function of the attributes of the choice-based conjoint questions, X_{nj}, and the individual-specific attributes, S_{nj}, and (2) an unobserved part, ε_{nj}, which is assumed to be random and independently, identically distributed. A model that is linear in parameters and is assumed to have the basic form:

$$U_{nj} = \beta_0 + \beta_1 X_j^{PRICE} + \beta_2 X_j^{INT} + \beta_3 X_j^{CCALLS} + \beta_4 X_j^{TEXT} + \varepsilon_{nj} \quad 1$$

where each β represents the coefficient for each attribute X, with the attribute and its levels described in Tables 3 and 4.

Table 3. Variables and levels of attributes for the alternative mobile plans.

Attribute	Description	Value
X_j^{PRICE}	Monthly price for the bundle of mobile services	\$6.3/\$12.7/\$25.3[9]
X_j^{INT}	Bundle of mobile Internet attributes; speed, data limit, and application/web access	Described in Table 4
X_j^{CCALLS}	Minutes of cellular calls made in a month	0/300/500/unlimited
X_j^{TEXTS}	Number of text messages sent in a month	0/300/500/unlimited

Table 4. Description of the mobile Internet attribute and its levels.

Mobile Internet	**Levels**		
Value	**Volume of Data**	**Network Speed**	**Available Access**
None	0GB	None	None
FastLowOTT	3.5GB	4G	IM & VoIP
SlowLowAll	3.5GB	2G	Everything
SlowHighAll	Unlimited	2G	Everything
ModModOTT	5GB	3G	IM & VoIP
ModHighAll	Unlimited	3G	Everything
SlowModAll	5GB	2G	Everything

We used three random utility models; the multinomial logit (MNL), mixed logit (ML) and nested logit (NL) models. The MNL model assumes all alternatives have equal weight and participants do not discriminate between them. To more closely model how we assume people make choices, we estimate the NL model; where participants would make choices by first deciding if they want

[9] The price was displayed to the participants in Nigerian Naira. The Nigerian official exchange rate of 316 Naira/$ is used. However, it is significantly different from the volatile black-market rate which reached a maximum of ~480 Naira/$ between January to November 2016.

a mobile plan or not. If they want a mobile plan, then they make a selection from the two available bundles [74]. The nested logit consists of two nests; one nest consisting only of the "none" option, and a nest consisting of the "real" mobile plans with varying attribute levels. The ML model relaxes some of the assumptions of the NL model and was estimated using 1000 draws to allow for individual heterogeneity across the preferences for the services.

Directly comparing the logit coefficients provides little insight into users' preferences for different mobile services and the tradeoffs of their choices. To improve the interpretation of these coefficients, we present the results as conditional probabilities that respondents select a mobile bundle plan with a specified combination of attributes. Following the technique derived in [74], [75] the conditional choice probability[10] of a mobile service is computed for an NL model using:

$$P_{(nm)} = P_n * P_{(m|n)} \quad 2$$

where there are *n* nests and each nest contains *m* alternatives. The probability of a nest *n* being chosen is given as $P_{(n)} = exp(\lambda V_n) \,/\, \sum_{n'=1}^{N} exp\ (\lambda V_{n'})$ and the probability of an alternative *m* chosen from within the nest n is given as $P_{(m|n)} = exp\left(\frac{\beta^T X_{nm}}{\lambda}\right) / exp\ (V_n)$. λ is the dissimilarity coefficient, β is the coefficient of the regressor *X* and V_n is the inclusive value for nest *n* and is given as $V_n = \log\ (\sum_{m=1}^{N_n} \exp(\beta^T X_{nm}))$.

[10] Conditional choice probability is the probability that a particular service is chosen given certain alternatives.

2.3.5 Modeling Willingness to Pay

Following the method applied in the literature [76]–[78] an estimate of the willingness to pay (WTP) for each mobile service is computed using the coefficients of the logit model – the ratio of the coefficient of that service to the coefficient of the price:

$$WTP = \beta_{SERVICE} \div \beta_{PRICE} \quad (3)$$

2.4 Results

In this section, the analyses and results are described.

2.4.1 Main Results

The estimation results for the MNL, ML and NL models are reported in Table 5. The MNL model is the simplest and easiest to interpret. A likelihood ratio test between the MNL model and the NL model gives $\chi^2(2) = 7.42$ and $p = 0.02$. Conducting a similar test between the NL model and the ML model gives $\chi^2(11) = 19.20$ and $p = 0.06$. The dissimilarity coefficient is significantly close to 1 for the NL model, which indicates IIA does not hold and the NL model differs significantly from the MNL model. The NL and ML models address the effects of linear attributes by capturing the none option in a different nest. Considering the statistical significance from the likelihood ratio test and the results from the AIC test, the ML is a better fitting model. However, for ease of interpretation of the results, we suggest the use of the NL model for further analysis of the data.

2.4.1.1 Conditional Choice Probabilities

Fig. 5 compares across two scenarios, the conditional choice probabilities of a traditional service and going without mobile service. The scenarios are: (1) *the base scenario* -- two options of the same traditional mobile service and a none option, and (2) *the OTT scenario* -- a traditional

mobile service, OTT service and a none option. In the base scenario, both traditional mobile services are identical; hence their choice probabilities are equal. In the OTT scenario, OTT service refers to the mobile Internet service with the FastLowOTT value – 3.5GB of data, 4G LTE speed and access to only IM & VoIP. In Fig. 2, "None" means no service and "Trad" represents the traditional services.

Table 5. Estimation results of the multinomial, nested logit and mixed logit models. The baseline mobile service plan is the "none" option.

	MNL Model	**NL Model**	**ML Model (Mean)**	**ML Model (Std. D)**
Price	-0.05 (0.00) ***	-0.04 (0.00) ***	-0.08 (0.00) ***	
Internet: None	-0.56 (0.10) ***	-0.22 (0.15)	-1.15 (0.22) ***	2.11 (0.21) ***
Internet: SlowModAll	0.27 (0.09) **	0.46 (0.10) ***	0.59 (0.13) ***	0. 63 (0. 22)**
Internet: SlowLowAll	0.34 (0.09) ***	0.50 (0.10) ***	0.57 (0.14) ***	1.21 (0.18) ***
Internet: SlowHighAll	0.54 (0.09) ***	0.67 (0.09) ***	0.90 (0. 13)***	1.04 (0.17) ***
Internet: ModModOTT	0.63 (0.09) ***	0.75 (0.08) ***	1.08 (0.13) ***	1.11 (0.15) ***
Internet: FastLowOTT	0.75 (0.09) ***	0.82 (0.08) ***	1.24 (0.14) ***	1.20 (0.14) ***
Internet: ModHighAll	1.06 (0.09) ***	1.10 (0.07) ***	1.79 (0.15) ***	1. 46 (0.16) ***
Calls: 300	0.65 (0.06) ***	0.53 (0.07) ***	0.81 (0.10) ***	1.12 (0.11) ***
Calls: 500	0.76 (0.06) ***	0.61 (0.07) ***	1.05 (0.11) ***	1.46 (0.12) ***
Calls: unlimited	0.83 (0.06) ***	0.67 (0.08) ***	1.08 (0.11) ***	1.40 (0.13) ***
Texts: 300	0.16 (0.06) **	0.14 (0.05) **	0.18 (0.10)·	1.09 (0.10) ***
Texts: 500	0.08 (0.06)	0.07 (0.05)	0.08 (0.11)	1.07 (0.14) ***
Texts: unlimited	0.35 (0.06) ***	0.29 (0.05) ***	0.38 (0.10) ***	1.05 (0.11) ***
iv.mobile	-	0.77 (0.08) ***	-	-
Log-likelihood	-5238.5	-5234.8	-4774.7	-
AIC	10504	10501	9603	
Respondents	390	390	390	-
Observations	5398	5398	5398	-

Note: ** p<0.05 ** p<0.01 *** p<0.001*

At a price of $10, participants showed OTT access has the greatest impact on text services. The choice probability of 300 texts reduced by 64% when OTT is made available. However, when compared with higher value traditional services, OTT has a lesser impact. The choice probability of the combination of unlimited voice and text reduced by 47% when OTT is made available. Furthermore, unlimited voice and text had a higher choice probability, 37%, 95% CI [35%, 38%], than the OTT service, 33%, 95% CI [25%, 41%]. Introducing OTT service reduced the choice probability of no service, and this was significant when the traditional mobile service is text. When the combination of unlimited voice and text was the traditional service alternative, the effect of OTT was not statistically significant.

The impact of the other Internet plans on user preferences were also examined. While the overall trend of the impact remains the same, the effect varies across the plans, see Figure 14 in Appendix A. As seen with the OTT plan, introducing an Internet plan has a higher impact on user preferences on text services compared to voice or a combination of voice and text. However, the effect of this impact is highest for the ModHighAll Internet plan (3G, unlimited GB, and access to all websites), followed by the OTT plan, and lowest for SlowModAll Internet plan (2G, 5GB and access to all websites). The OTT plan had similar effect as ModModOTT (3G, 5GB and access to only IM & VoIP). On the other hand, the college-educated participants showed a reduction in the choice probability of no service by up to 25%, and a reduction in the choice probability of traditional services by up to 65%. Examining the effects of gender and location type, in the base scenario, the choice probabilities where similar across the different subgroups. However, when OTT is introduced as an option, females experienced lower impact compared to males, and the choice probabilities of the traditional service and no service reduced significantly for urban users compared to rural users.

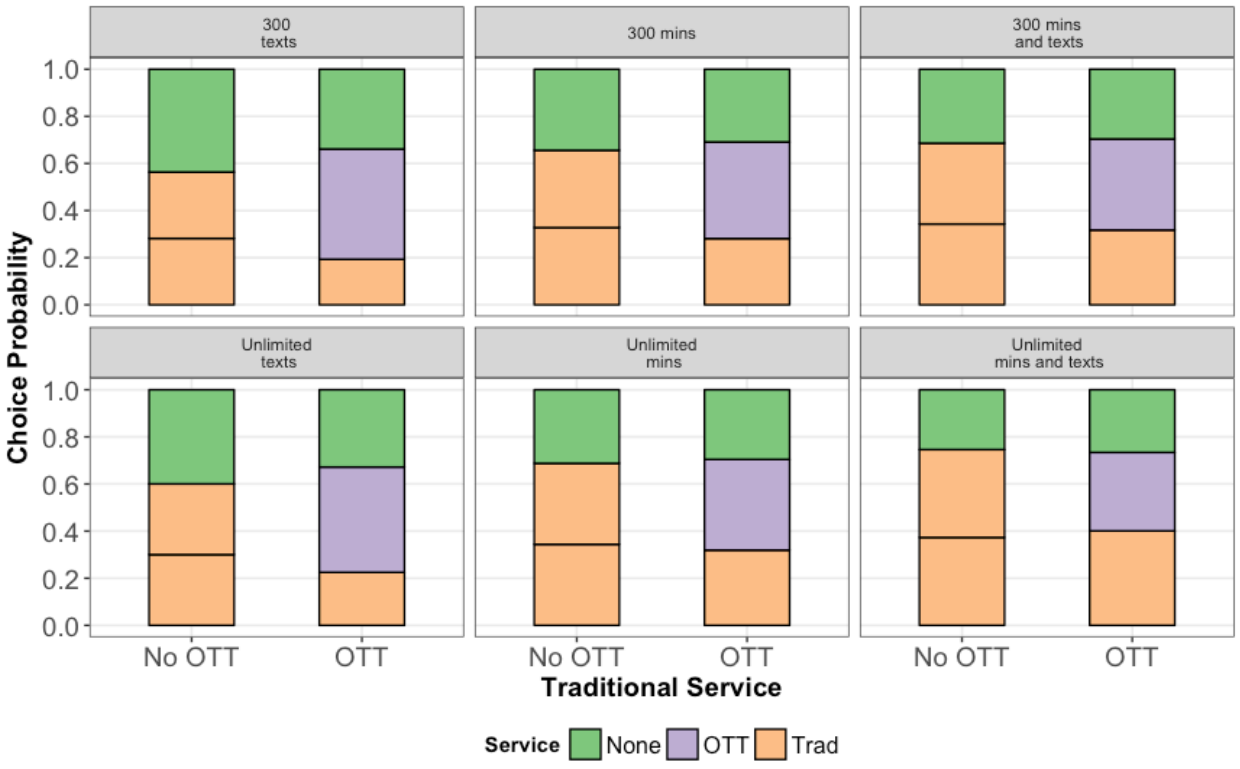


Figure 5. Comparing the choice probabilities of traditional services and no service across scenarios with OTT as an alternative and when it is not. Price is set to $10, and the levels of the traditional services are shown in the upper x-axis.

By conducting a between-subjects experiment, the possible effect on mobile users' preferences of added information on the reduced cost of communication due to substituting traditional mobile services with OTT service was examined. The results showed that the group that received additional information had lower conditional choice probabilities for OTT than the group with no information. Analyzing the data from the attention checks show that 66% of all participants passed all the attention checks, and 99% passed the check in the conjoint choice tasks. The conditional choice probabilities of the group that passed the attention checks were, on average, similar to those of the entire sample.

2.4.1.2 Affordability and Willingness to Pay for Mobile Services

To examine the effect of affordability on users' preferences, the price was increased to $30. This increased the choice probability of no service to at least 50% for all services and service levels (except for unlimited voice calling and text, where it increased to 43%). Participants had a significantly higher choice probability for no service than the other available alternatives in both scenarios. The WTP for the services was computed and select results are plotted in Fig. 6. The results show that the WTP for Internet services are significantly higher than the WTP for voice calling and text services. The individual estimates for the WTP have higher variation for the Internet services compared to the traditional services. Furthermore, the higher levels of the traditional services have a higher WTP, all other things being equal. Participants indicated a highest WTP for access to ModHighAll (3G, unlimited GB and access to all websites) and the lowest WTP for a plan offering 300 texts in a month.

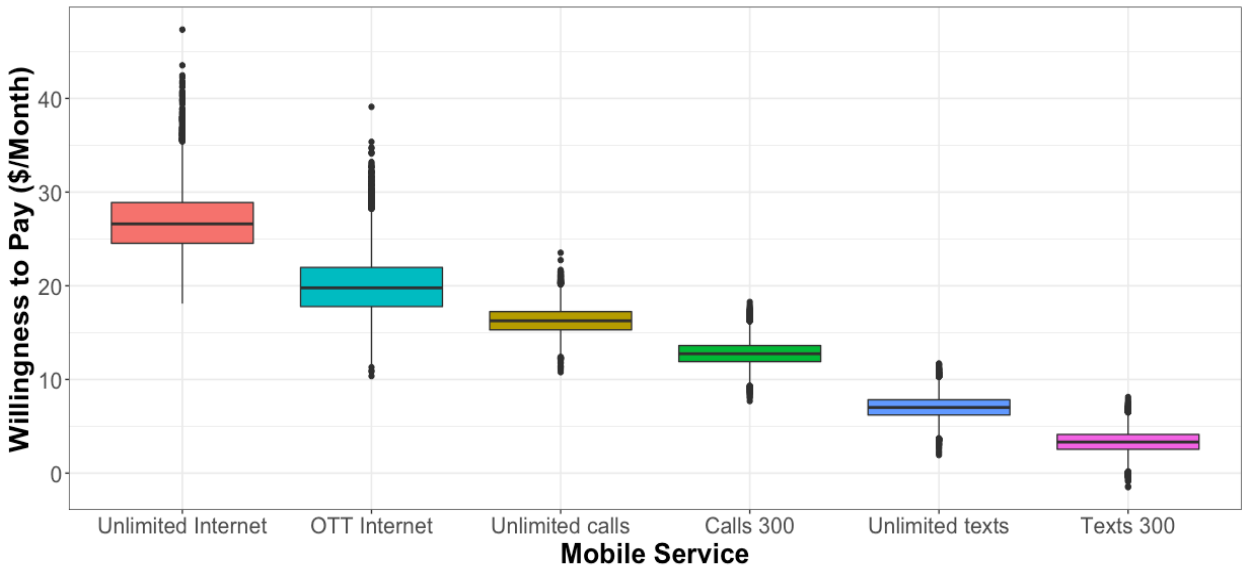


Figure 6. Boxplot showing the willingness to pay ($/Month) for different mobile services. The x-axis shows the different attribute levels of the mobile services and the WTP is shown in the y-axis.

2.4.2 Uncertainty Analysis

To understand how users' preferences differed relative to one another, the 95% confidence intervals for the coefficient estimate for OTT was computed and plotted in Fig. 7. This showed that users' preferences do not significantly differ from one another. However, the long whiskers show there is significant variation in the preferences of a single individual.

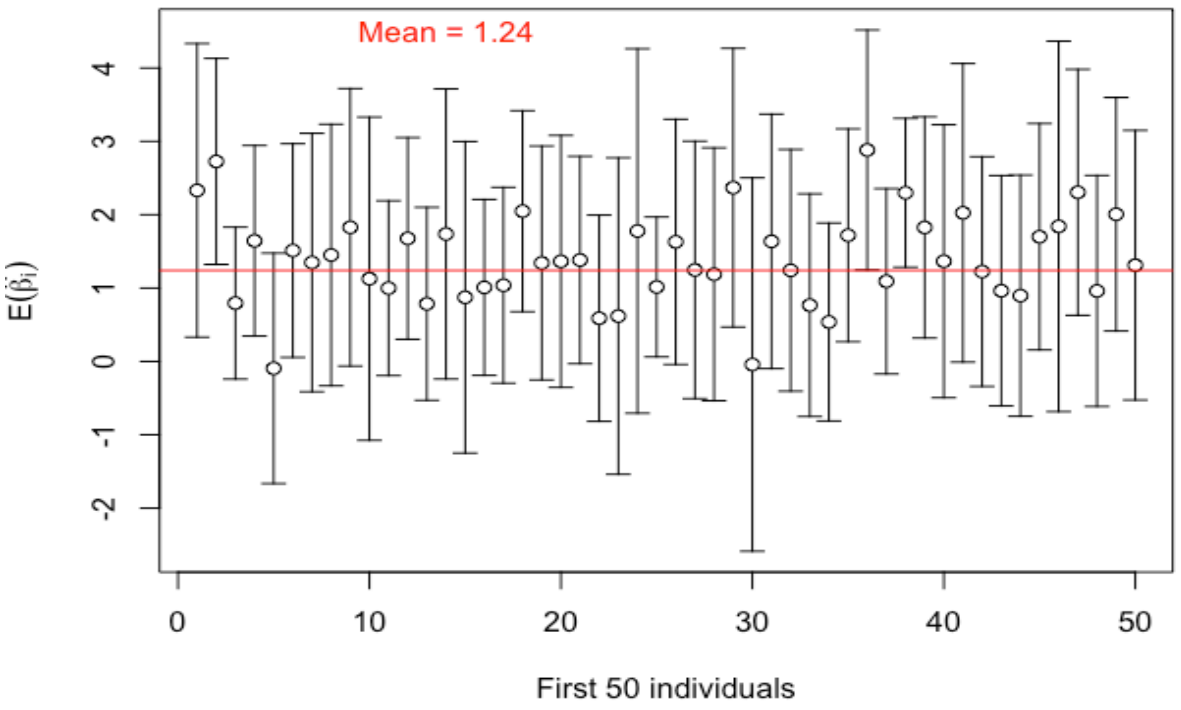


Figure 7. 95% confidence intervals of the conditional individual coefficients of the first 50 respondents.

Fig. 8 showed that at the extreme expected conditional individual coefficients, the impact on the choice probabilities of existing traditional services is significant; increasing the choice probability of no service with a less than 50% decrease in the choice probability of the traditional service in the least coefficient estimate. At the highest coefficient estimate, the choice

probabilities of no service and the traditional service decrease to less than 5% respectively for all traditional services.

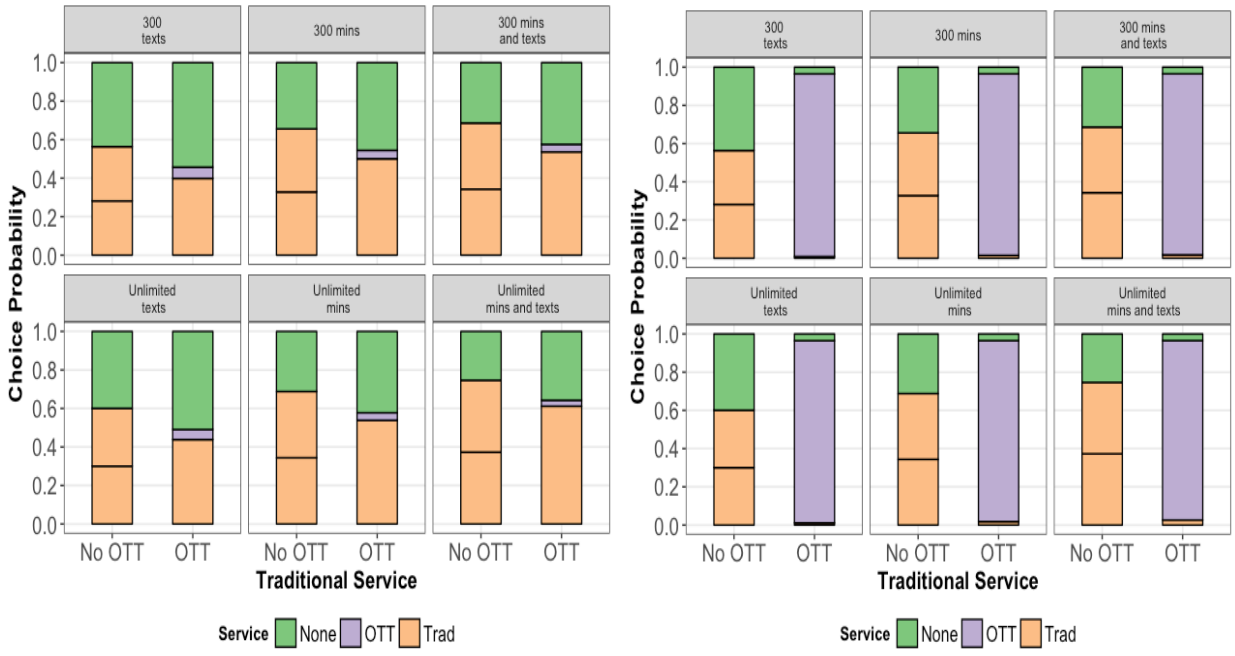


Figure 8. Comparing the effect of introducing OTT into the market given the highest and lowest conditional individual coefficients.

The individual mean WTP for different mobile services, using the results from the ML model, shows significant heterogeneity across the users in the study. Although negative WTP values are seen for all the mobile services (indicating some individuals would need to be paid to use these services), some individuals are willing to pay over $40 for access to unlimited calls, unlimited Internet or OTT Internet. Plotting the 95% confidence intervals of each individual's WTP for OTT (see Figure 18 in Appendix A) , shows most individuals have a positive mean WTP, with wide confidence intervals that overlap the zero point. This indicates that significant variability exists in the WTP of a given user for OTT.

2.5 Discussion

The results indicate that access to OTT can be a tool for closing the digital divide. However, it is important to highlight that there is a large variation in consumer preferences, which could affect the expected benefits of access to OTT on the digital divide. The implications of the results, for the regulator of the mobile industry and the mobile carriers, are discussed in this section. The contributions of this work to existing theory as well as limitations of the study are also highlighted.

In this paper, the focus is on answering three research questions: (1) *How does access to OTT impact users' preferences for traditional services?* (2) *How does affordability affect users' preferences? and* (3) *What are the effects of demographic factors on users' preferences?*

In answering the first research question, the results show that users' preferences within the mobile industry could be shifting to Internet communications. This is consistent with earlier findings that access to mobile Internet significantly reduce the number of text sent and received in a month [46], [47]. Generally, access to an Internet plan changes users' preference. While the effect was higher with access to all websites and applications, the effect of access to only OTT applications was comparable. Access to OTT largely reduced the choice probabilities - the probability of choosing a particular service given certain alternatives – of a traditional mobile service and no service. In Nigeria, where the mobile market has not been saturated, this reduction in the choice probability of no service could indicate a driver of penetration growth; increasing the number of active customers on a network. This supports previous studies that show mobile Internet is a leapfrogging tool that reduces the digital divide [79]. Furthermore, this indicates that providing the digitally disadvantaged population with access to OTT could increase their use of mobile technologies. The results also indicate that the business model (pay-as-you-go versus all-

you-can-eat) is an important determinant of the impact of OTT on user preferences, a finding consistent with previous work [44]. Interestingly, the results show that with access to OTT, there was a slight increase in the choice probability of no service in an all-you-can-eat business model. This suggests that users do not have a strong preference for traditional services over OTT. A possible explanation is that the perceived benefit (cost savings) from the use of OTT in a pay-as-you-go market is a driver for the choice of a mobile plan.

The results also indicate an answer to the second research question. In terms of affordability, the results show that mobile users are price sensitive. In general, users are willing to spend more on Internet services (up to 30% of their income) than on traditional mobile services (up to 10% of their income)[11]. Increasing the price from $10 to $30 significantly increased the choice probability of no service. These results provide new insight into the findings from previous studies that found the economic cost is one of the key barriers to Internet use in Nigeria and other SSA countries [3], [61]. The results suggest that economic cost as a barrier can be addressed strategically, by offering different Internet services/plans at different price brackets.

The third result is partially answered in this paper. Although the results suggest there are differences in preferences across demographic groups, the effect on individual preferences are not significant.

2.5.1 Implications for the Regulator

Reducing the digital divide by increasing Internet access and adoption remains a key policy objective in Nigeria. Policies that improve the facilitating conditions for OTT access will likely

[11] Computed using the 2016 GDP per Capita in Nigeria ($2500)

aid in the reduction of the digital divide. Therefore, contrary to recent policies in other developing mobile markets, the policymakers should dismiss any call to ban OTT. Furthermore, it is recommended that any regulation of OTT does not discourage its adoption and/or use. To improve the facilitating conditions needed for OTT adoption (mobile and Internet access), policies that drive investment in broadband technologies in underserved areas should be explored. For example, the government could enter into a public-private partnership to drive investment in target locations. Given that the users are price sensitive, the regulator should consider policies that reduce the recurring cost of mobile services to mobile users such as; granting tax breaks to mobile carriers, promoting fiercer competition, or imposing a price ceiling.

2.5.2 Implications for the Mobile Carriers

The switch in demand for mobile services, from traditional services to Internet services, could lead to a reduction in mobile carriers' revenue. In response to the expected changes in the mobile market, mobile carriers will need to prioritize the provision of Internet access and services. However, around the world, there have been lobbies to regulate OTTs in a bid to avoid market erosion and loss of revenues in the mobile industry. In Nigeria, where Internet access is predominantly via mobile broadband, mobile carriers can substitute the lost revenues from traditional mobile services with new revenues generated by providing Internet access. In line with the business strategies implemented by a number of mobile carriers across Africa, it is recommended that mobile carriers embrace OTTs and use it as a tool to increase market share. By offering competitive Internet plans with access limited to social networks and specific OTT communication apps such as WhatsApp and Facebook Messenger, a carrier could dominate the low-income subset of the population. Another recommended strategy is offering new mobile plans in a bundled all-you-can-eat business model. By setting the desired price on the plans and

providing close to unlimited voice and text, bundled with a limited gigabyte of Internet data, mobile carriers would limit the impact of OTT on revenues. However, given that mobile users are found to be price sensitive, the price will need to be strategically determined.

2.5.3 Limitations and Future Research

Some of the limitations encountered during the study are mentioned in this section. First, generalization of the results may be limited as the sample is not representative of the general population; 76% are college graduates and the average age is 34, compared to 9% that were college educated according to the last census in 2005 and a median age of 18 years in 2015 [73]. However, OTT has been found to be largely used by the young and educated population [51], [52], therefore the results allow conclusions and inferences that could be drawn to the target population. Future research can be built by testing the model with different groups.

Second, individuals' preferences were measured using a conjoint experiment. While this has been found to be better than directly asking respondents for their preferences, there is possible cognitive bias due to the use of surveys. The choices of the participants could be affected by their past experience with their mobile carrier or mobile services. For example, if a participant used VoIP in the past and it had a lot of noise due to slow connection speed, then they could decide to not choose it regardless of if it is offered with 4G speed. Furthermore, the effect of demographics such as age, gender, location, and education could not be determined as they have been found to often have a low correlation with choice preferences [80]. Future work should use historical customer records to compare the impact of mobile Internet use on the use of traditional mobile services and control for the effect of demographic factors.

Third, mobile services are modeled as a bundle. In Nigeria, prepaid, pay-as-you-go plans are the norm, therefore there may have been cognitive bias; the participants may interpret the conjoint choices differently from what was intended. However, this is not considered a substantial threat.

2.6 Conclusion

With the rapid advancements in technology and the convergence of applications within the digital ecosystem, the binary choice of technology adoption is more complex. Inequalities of access no longer refer to only the network or a hardware device, but also includes applications on devices. This study uses a choice-based conjoint experiment to analyze the impact of access to OTTs on the individual preferences for different mobile services – voice, text – or not using any mobile service. The study was conducted in Nigeria, contributing to the body of research on the digital divide in Africa. The results show that when OTT is introduced in the market, the choice probabilities – the probability of choosing a particular service given certain alternatives – of a traditional mobile service and no service are found to be significantly reduced. In explaining this impact of OTTs on preferences for mobile services, the business model in place and affordability were the most important determinants.

What differentiates this paper is: 1) a new approach to studying the first-level digital divide is proposed and applied; 2) a conjoint analysis was used, which allowed the investigation of the impact of access to OTT on voice and/or text without the limitation of the ability to pay; and 3) a nested logit approach to our analysis was used which closely models the way users make buying decisions, thus improving the reliability of our findings.

This research can be extended by testing the model with larger samples from Nigeria or other developing countries. While this work is predictive using estimated preferences, future work

should use historical customer records to investigate the impact of mobile Internet use on the use of traditional mobile services in Africa, controlling for the effect of demographic factors.

3. The Effect of Pricing Policies on the Second-Level Digital Divide in a Developing Country: Evidence from Nigeria

Abstract – In September 2015, the national regulator of the telecommunications industry in Nigeria removed the price floor of mobile Internet plans, leading to a reduction in prices across the mobile industry. Using a panel data of the billing records of a sample of approximately 18,000 mobile users over seven months, this paper investigates the impact of this reduction in prices on the use intensities of mobile Internet, cellular calling, and text messaging. The findings show that the reduction in the prices is associated with an increase in the volume of data used and a decrease in the volume of texts sent by an individual. However, reducing the prices of mobile Internet plans does not "close" the second-level digital divide across socioeconomic groups. We do not see a convergence in the volume of use of any of the mobile services across any demographic subgroups. This suggests that more robust policies that are targeted at specific subgroups are needed to reduce the existing second-level mobile technology digital divide that exists in developing countries.

3.1 Introduction

Affordability remains a key barrier exacerbating the first-level (differences in adoption) and second-level (differences in use patterns) of the digital divide in developing countries. In Nigeria, where approximately 50% of the population live in extreme poverty, addressing the affordability barrier could significantly address these levels of the digital divide.

Figures published by the ITU show that in 2016, the mobile subscription rate in developing countries was 94% (80% in Africa) compared to 127% in developed countries. On the other hand, 40% (25% in Africa) of the population in developing countries used the Internet, compared to over 80% in developed countries [1]. Furthermore, there are significant differences in Internet adoption and use – which are closely related to economic differences – across countries in SSA. 60% of the Internet users in SSA are concentrated in five countries; Nigeria, Kenya, South

Africa, Tanzania, and Ethiopia, that represent 36% of the population [81]. While seventeen countries (such as the Democratic Republic of Congo and Eritrea) make up less than 10% of the Internet penetration in SSA. This geographical and socioeconomic differences in adoption rates also exists within countries, with the offline population largely in the low-economic rural areas [82]. In SSA, mobile phone adoption is unprecedented; cutting across location, gender and socioeconomic levels. As a result, mobile phones have been identified as a leapfrogging tool to bridge the digital gap between developed and developing nations [83], [84]. More broadly, mobile technology is seen as a central tool in achieving the United Nations' Sustainable Development Goals – which includes ending extreme poverty, combating climate change, and fighting against inequality. However, the Internet, which is central in achieving these development goals and is primarily accessed via mobile [59], [85] is still considered a luxury in SSA and, as noted above, lags behind other global mobile markets [86].

Reducing the digital divide is a priority for the governments in SSA. African governments have implemented various policies to drive the adoption and use of digital technologies such as the Internet, PCs, and mobile phones. For example, in Rwanda, the government entered into a public-private initiative to drive investments in broadband infrastructures in underserved areas and increase uniform access to the Internet across the country. Taking a different approach in Nigeria, the national regulator of the telecommunications industry, the NCC, removed the price floor for Internet services in September 2015, driving competitive pricing among the Internet providers. This led to a fall in the prices of the major mobile carriers in a bid to cannibalize customers from other carriers.

Early studies on the digital divide examined the difference between the connected and the unconnected, known as the first-level digital divide [5]. However, as adoption rates increased,

researchers shifted to studying the differences in the extent and type of use of different digital technologies among the connected population, referred to as the second-level digital divide [5], [21], [87]. In SSA, a mobile phone is a facilitating condition for Internet use and accessing the Internet using a mobile phone is often the only alternative. Furthermore, a mobile phone is often used in unprecedented ways in SSA, such as to complete tasks (on GSM networks) that are typically completed through the Internet in developed countries. For example, in Kenya, through the use of Mobile Money[12] on their phones, individuals are able to complete bank transfers within minutes without the use of the Internet. This can be viewed as a substitute for completing a bank transfer online using an Internet application on a mobile phone. As argued in the Chapter 2 of this thesis, this makes it difficult to disentangle mobile services and Internet services in studies on the digital divide in SSA. Therefore, studies on the second-level digital divide in SSA should not examine the extent and pattern of Internet use in isolation. We propose that to understand the second-level digital divide, researchers should examine the extent and use pattern of the Internet in the context of the use pattern of other mobile services such as cellular calling and text messaging.

The literature on the digital divide in SSA indicate that the cost of a compatible device and/or an Internet plan is a significant barrier to Internet adoption and/or use [3], [61]. However, there is limited empirical evidence on whether the digital divide is reduced by pricing policies or business strategies to increase affordability. By applying our proposed approach to studying the second-level digital divide, this paper estimates the effectiveness of pricing policies on the use intensities of different mobile services before and after the reduction of the prices of the

[12] The use of a mobile phone in order to transfer funds between banks or accounts, deposit or withdraw funds, or pay bills.

available mobile Internet plans. In this study, we attempt to answer the following research question: what is the effect of the reduction in the prices of mobile Internet plans on the use intensities of mobile Internet, cellular calling, and text messaging? To this end, we used a panel data of the billing records of a sample of approximately 18,000 customers over 7 months in 2016 from a major mobile carrier in Nigeria. The data includes the volume of traffic consumed for each service per customer at monthly intervals during the period as a measure of the second-level digital divide. Some demographic characteristics of each customer are also captured in the dataset. The findings from this work would provide insight on the effectiveness of this policy and contribute to the broader discussion on affordability as a factor exacerbating the second-level digital divide in Africa.

In this paper, we measure "extent" of use by the volume of use of different services: megabytes (Internet), outgoing minutes (calls), and outgoing count (text). The second-level digital divide In Section 2, we summarize existing relevant literature. In Section 3, we outline our methodology and describe our sample. In Section 4, we present our results, and in section 5, we present our discussion and the policy implications of this research.

3.2 Literature Review

In this section, the literature on the second-level digital divide and the drivers of the digital divide in SSA are summarized and an overview of the Nigerian mobile market is presented.

3.2.1 The Second-Level Digital Divide

As the adoption of digital technologies increased over the past two decades, the first-level digital divide – the difference between the connected and unconnected populations – has been gradually closing [12], [28], [29] and users are increasingly crossing socioeconomic lines. Thus, rather

than clear divides limited to between areas or individuals with access and those without, access has become a spectrum with evolving capacity [28], [30]. These changes support arguments to shift from studying the differences between the "connected" and "unconnected", to studying the extent and pattern of use of digital technologies. This new approach to studying the digital divide by investigating the difference in use by the connected population is described as the second-level digital divide [5], [18], [29].

The use of a digital technology by an individual is largely dependent on having the required skills. For example, the use of the Internet is dependent on having the skills needed to operate the required hardware and software, information literacy to process the online content, as well as the social and creative skills to create content and connect with other individuals online. The literature on the second-level digital divide have applied different approaches to studying the difference in the use of digital technologies. The majority of these studies examined the difference in Internet use across demographic groups [5] by investigating the differences in the type of Internet activity, such as information seeking or commercial transaction [18], [21], [52], [62] or the differences in the frequency of Internet use [10]. Some applied a broader approach and examined how the type of activities carried out on other ICTs such as PCs varied across socioeconomic groups [88]. Others examined the relationship between the use of the Internet on the use of text messaging and cellular calls [45], [46], [48]. These studies, while informative, have predominantly been limited to high penetration mobile markets, which significantly differ from the growing markets in developing countries.

3.2.2 **Drivers of the Digital Divide in SSA**

The majority of studies on the digital divide in SSA have been focused on the first-level digital divide. In 2005, with only one submarine cable reaching SSA and Internet access predominantly

through costly satellite links, adoption rates were well under 5%. The slow speeds and high-cost of connections in most parts of the region were identified as key factors that limited adoption growth [89]. The literature addressing the slow rate of Internet adoption identified determinants which can be structured into three groups: (i) country-level determinants, (ii) structure of the telecommunications industry, and (iii) characteristics of the individuals.

While there are a plethora of studies investigating factors that drive Internet adoption at a macroeconomic level, using country and/or industry data, those focusing on Africa are only a handful. Using data on all 54 African countries, adoption was found to be significantly affected by: the official language of the country, economic development and the level of competition in the Internet Service Provider market [90]. Using a sample of 39 African countries, Internet adoption rates were found to be associated with economic development [19]. In addition, the spread of country and industry infrastructure [19], [91], as well as the urbanization of the country [91] were also identified as key forces driving the diffusion of the Internet [19]. While the level of competition in the mobile market has been found to drive penetration of infrastructure, on its own, competition alone has been shown to not be sufficient to achieve universal access and adoption [92].

Up to half of the variance in Internet use, are accounted for by sociodemographic factors which affect whether individuals have the required skills to use the Internet [18]. The individual characteristics that influence Internet adoption and affect the digital divide have been studied in Africa using surveys. Individual characteristics such as gender [52], [60], [91], age and level of education [9], [60], [91], [93] have a significant impact on Internet adoption. Males, young people between 16 to 30 years or individuals with at least secondary school education are more likely to adopt the Internet [91]. Tayo et al. investigated the perceptions of low-income

individuals in Nigeria to the Internet and found that lack of access, cost of PCs and data bundles as well as lack of computer skills contributed to the digital divide [3]. Using interviews, Oyelaran-Olayinka & Adeya [61] found that the initial cost of PCs was also a major constraint affecting the adoption of ICTs by academics in Kenya and Nigeria. They also identified the ease of use, technical skills, and perceived advantages as key factors of this first-level digital divide. Findings from a household survey in Cameroon found that lifestyle and perceived utility of the service are all individual characteristics that influence adoption [93]. Using household survey data in Gabon, Penard et al [9] found that a high level of education and computer skills were primary factors supporting Internet use across African countries. While age had a positive effect on mobile use, it was found to have a negative effect on Internet use. Replicating the study in Cameroon revealed evidence that the probability of using the Internet is higher for English speaking, computer-savvy individuals and those that have family abroad [52].

By March 2017, with 44 submarine cables connecting Africa and multiple methods of providing broadband connections to the last mile, Internet adoption had grown to 350 million; a 28% penetration rate. The majority of this growth is accounted for by five countries; Nigeria, Egypt, Kenya, South Africa and Morocco. The improved connectivity led to more affordable data rates and reliable connections. Despite this, the digital divide persists across the continent. Lack of locally appropriate content – due to language and legal barriers – have been identified as a key factor in the slowdown of Internet adoption [89]. However, social media and OTT applications such as Facebook and WhatsApp provide channels of communication that support user-generated content in any language, thus solving the challenges behind the language barrier. Affordability, lack of digital skills and a significant gender gap remain key factors limiting Internet adoption today [94].

There are conflicting findings in the literature on the effect of socioeconomic characteristics on the second-level digital divide using evidence from African countries. Earlier literature, using data from Cameroon, found that Internet usage patterns differed across age, gender, and education, with college educated individuals more likely to use the Internet for information search than for entertainment [52]. Using data from 6 countries, contrary to findings on the first-level digital divide and earlier literature on the second-level divide, Silver et al. found age and socioeconomic status to have no effect on Internet use patterns. However, similarly to the earlier study, more educated people were seen to be more likely to use the Internet to gather information and apply for a job. Furthermore, while gender had no effect on the frequency of Internet use, it affected the type of online activity [62].

3.2.3 State of the Mobile Market in Nigeria

With an estimated population of 190 million in 2017, Nigeria is the most populous country, second largest economy and largest mobile market in SSA. Fixed telecommunications has remained almost nonexistent across SSA. In Nigeria, fixed-line access is consistently less than 0.2% [35], [55]. As a result, mobile dominates the telecommunications industry. The penetration rate of mobile phone has grown rapidly in Nigeria. Since the inception of mobile in 2001, the Nigerian mobile market has grown significantly to over 154 million mobile cellular subscriptions in 2016; 82% of the population [56], [57]. However, given that each subscriber has an average of 1.8 SIMs, unique penetration is only at 45% [4]. Unaccounted for, however, is SIM sharing which the literature suggests to be common in some parts of SSA. A single SIM can be shared by many users, for instance, members of the same family or among neighbors. Although the rate of adoption of mobile phones in Nigeria is greater than the average in SSA, it continues to lag behind the average rates in developing and developed countries as shown in Fig. 9. In addition,

significant variation in penetration exists within the country. In 2016, mobile subscription rates across states ranged from 40% to 170% with an estimated 33% of users concentrated in 5 out of 36 states, and mostly in cities [58].

Despite being the largest mobile market in SSA, a significant subset of the Nigerian population remains unconnected compared to other leading markets in the region as shown in Table 6. This large unconnected subset of the population is expected to drive the future growth in the SSA mobile market. Comparing the demographic and mobile market distributions of Nigeria with that of two other leading mobile markets in SSA (South Africa, and Kenya), shows similar trends. Across countries in SSA, there is a high proportion of younger people within the population; over 50% are below 25 years in most countries.

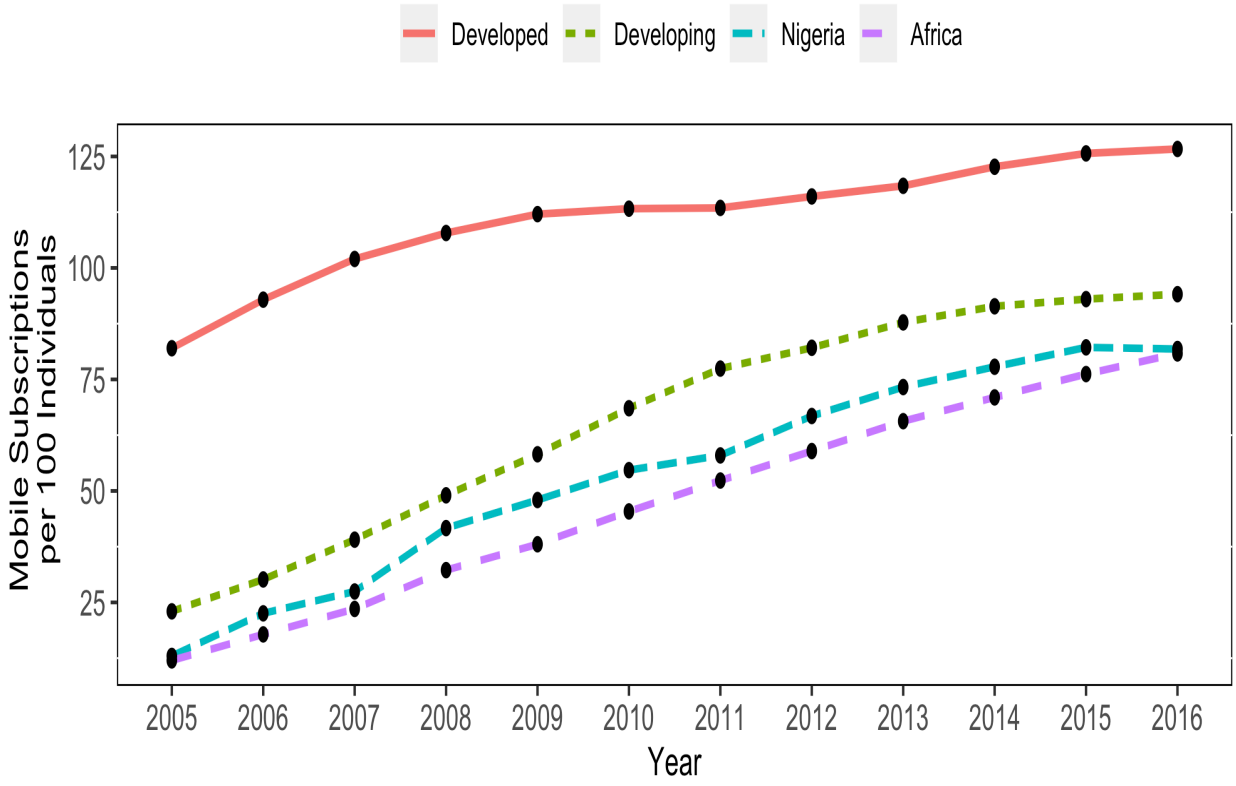


Figure 9. Mobile subscriptions per 100 people [Data source: ITU]

Table 6. General demographic and mobile market distribution of Nigeria in comparison to South Africa and Kenya [Data sources: MTN Group Limited, ITU, Nigerian Communications Commission, GSMA]

	Nigeria	South Africa	Kenya
General Demographic			
Population (Millions)	190	56	48
Median Age (Years)	18	26.4	19.7
Female	44%	52%	50%
GDP/Capita ($ nominal 2016)	2175	5262	1410
Mobile Market			
Unique Subscribers	45%	68%	59%
Individuals Using the Internet	25%	54%	26%
Market Leader (Market Share)	MTN (48%)	Vodacom (46%)	Safaricom (65%)
Number of Mobile Carriers	Over 4	4	Over 4
Fixed Telephone Subscription Rate	0.08%	6.62%	0.15%

In the first quarter of 2016, there were 92 million broadband connections in Nigeria, with 70% of the connections via mobile (42% via feature phones, and 28% via smartphones) [59]. Similar to mobile penetration, the adoption rates of the Internet in Nigeria lags behind the average rates in developed and developing countries as shown in Fig. 10. In addition, there is a wide variation in the adoption of mobile broadband across Nigerian states; subscription ranged from 20% to 110% across states in 2016 [58]. The introduction of 3G services in 2007, the presence of competition, and the regulatory reforms in the industry have been identified as a few key industry characteristics that drove the rapid growth in the past decade [64].

While users across the country have access to good GSM (2G) coverage, UTMS (3G) and LTE (4G) coverage are more limited. Big cities such as Lagos, Abuja, and Kano benefit from access to high quality signals while rural areas struggle with connectivity. The access to 3G and 4G LTE networks could be a significant determinant of the second-level digital divide in Nigeria. The access to networks with larger bandwidth would allow the use of data-intensive applications and services, thus affecting differences in Internet use.

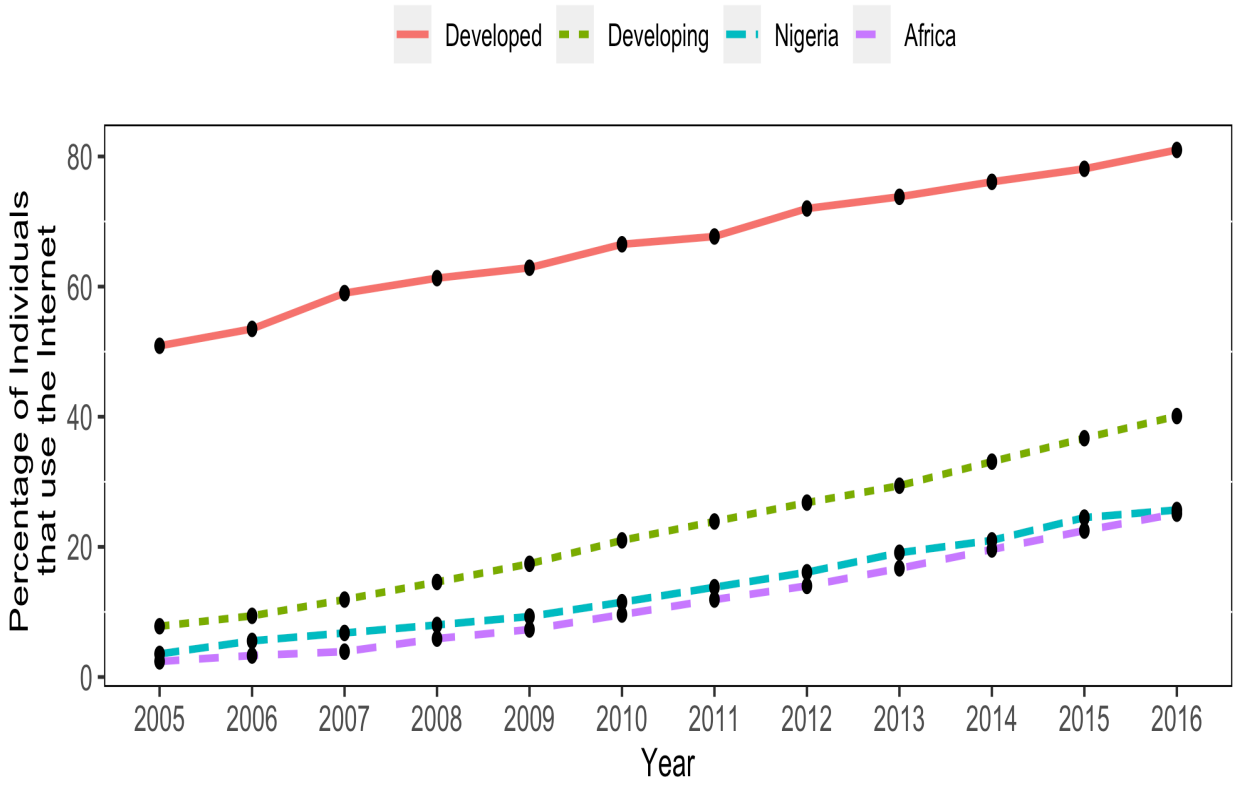


Figure 10. Percentage of individuals using the Internet. [Data source: ITU].

3.3 Methods

In this section, the sampling method is described, the sample and data are summarized, and the statistical methods used in this study are presented.

3.3.1 Sample Generation

The dataset used in this study was retrieved from the billing records of the Nigerian subsidiary of an international mobile carrier; one of the big 4 mobile carriers in Nigeria. From this population, we drew a representative random sample of 30,000 customers. The dataset includes a panel data of mobile usage records; the number of outgoing text messages, minutes of outgoing cellular calls and volume of mobile Internet data used in each month by each customer for seven months

starting in 2016[13]. Demographic characteristics such as age, gender and location are also included in the dataset.

Cleaning the initial sample resulted in removing 12,160 customers for a number of reasons. First, we removed customers that had missing demographic values. Second, we dropped customers that didn't use at least one mobile service in each month, i.e. customers that did not generate traffic for either cellular calls, texts, or mobile Internet in each month. Third, we also dropped customers that were below 16 years old. Although the sub-population below 16 years make up a third of the Nigerian population, they remain underrepresented on the mobile market. Finally, our initial dataset was for 16 months but we analyzed the use intensities for the 2 months before the price change, and the 5 months after the price change. Therefore, we removed customers that had been on the network for less than one year, as the SIM card would likely have been reassigned to a new customer and the demographic characteristics only describes the most recent user. At the end of the cleaning process, we had a final sample of 17,840 mobile customers.

To improve our understanding of the effect of the reduction in the prices on this network on the adoption and use of mobile services, we transformed the month variable to a dummy variable depicting before (the first two months in the study) and after (the subsequent five months in the study) the change in prices.

[13] To protect the anonymity of the mobile carrier, we do not disclose the months in the study. The NCC Policy to remove the price floor was passed in September 2015 and the mobile carrier reduced its prices a few months after this policy was implemented.

3.3.2 Measurement Variables

3.3.2.1 Use Intensity of Mobile Services

The dependent variables in this paper are the use intensities of the different mobile services. The differences in the volume of data used could be an indication of differences in the extent and pattern of use of the Internet. Table 7 summarizes the distribution of the monthly use intensities of the Internet, outgoing calls, and sent text messages averaged per customer in both rural and urban locations over the 7 months in the study.

Table 7. Distribution of monthly mobile Internet megabytes, outgoing call minutes, and sent text messages averaged per customer over seven months.

	Rural (n=5620)	**Urban (n=12221)**	**Overall (n=17841)**
Internet (Megabytes)			
Mean (SD)	713 (1100)	965 (1530)	905 (1450)
Median [Min, Max]	286 [100, 14100]	390 [100, 22400]	362 [100, 22400]
Missing	4488 (79.9%)	8619 (70.5%)	13107 (73.5%)
Calls (Outgoing Minutes)			
Mean (SD)	144 (172)	182 (221)	170 (207)
Median [Min, Max]	86.9 [1.50, 2090]	112 [1.27, 3280]	103 [1.27, 3280]
Missing	3 (0.1%)	13 (0.1%)	16 (0.1%)
SMS (Outgoing Count)			
Mean (SD)	10.4 (22.7)	14.1 (31.1)	12.9 (28.8)
Median [Min, Max]	5.00 [1.00, 836]	6.25 [1.00, 966]	5.83 [1.00, 966]
Missing	255 (4.5%)	369 (3.0%)	624 (3.5%)

Following the approach used in the literature [45], [46], the use intensities of the Internet, cellular calls, and text messages are measured by the total megabytes, minutes of outgoing calls, and count of text messages used by an individual on the network of the mobile carrier. Across all

mobile services, the urban customers had higher use intensities than the rural customers. As shown in Fig. 11, the total number of active users in each month for the Internet increased slightly and there was a notable increase in the average volume of data used in each month. On the other hand, as shown in Fig. 12, the total number of active users for calls stayed mostly flat, while for texting there was a sharp decline after the drop in the prices of the Internet plans. The volume of use of both calls and text remained the mostly the same over the time period.

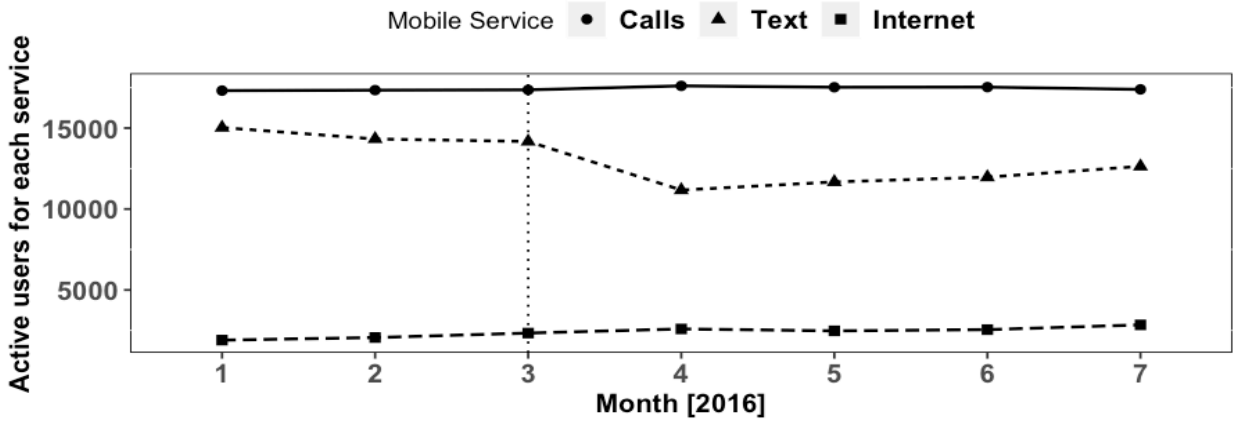


Figure 11. Total active users for cellular calls, text, and Internet mobile services in each month

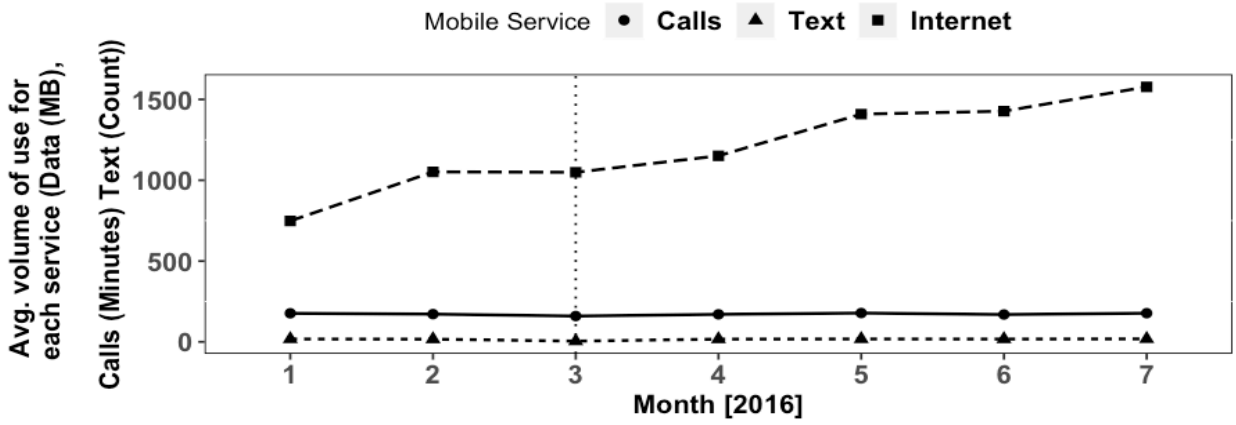


Figure 12. Average volume of use for cellular calls, text, and Internet mobile services in each month

3.3.2.2 User Demographic Characteristics

Table 8 summarizes the demographic characteristics of the sample. Comparing the rural and urban customers show wider first-level gender digital divides. A smaller subset of the rural users are female compared to the urban users. Furthermore, on average, urban users have a longer tenure on the network compared to the rural users. Comparing the demographic distribution of the sample to that of the Nigerian population shows some significant differences. While females make up approximately 50% of the Nigerian population, they make up only 30% of the sample.

This reflects findings in the literature on the first-level digital divide in SSA; females are less likely to own or use a mobile phone. There are also significant differences in the age distribution in the sample compared to the Nigerian population. In Nigeria, and most of Africa, the majority of the population is below 25 years. However, this is not reflected in the sample. This could be an indication of a generational digital divide, with the younger population being a disadvantaged group in first-level digital divide.

Furthermore, estimates by National Population Commission show that 51% of the Nigerian population reside in a rural area. There is no standard international definition of an urban area. Each country has its own definition based on a combination of characteristics not limited to; population size, population density, type of economic activity, physical characteristics and infrastructure [95]. Nigeria defines an urban area as a town with 20,000 people or more[14]. However, given that there is no available data on the population of towns in Nigeria, we defined a Local Government Area (LGA) with at least 1000 people per square mile as urban. With this

[14] United Nations website accessed on August 1st 2017 https://esa.un.org/unpd/wup/CD-ROM/WUP2014_DOCUMENTATION/WUP2014-DataSource-UrbanPopulation.xls

definition of urban, 32% of the sample resides in a rural area. While this does not reflect the distribution of the Nigerian population, it can be an indication of a first-level digital divide along the urban/rural lines. All 36 states and the Federal Capital Territory in Nigeria are fully represented in the sample. Out of 774 LGAs in Nigeria, 732 are represented in our sample. There are six. However, within the context of homogeneity in economic development, population distribution, and cultural norms, Nigeria can be divided into the Northern and Southern regions. The Northern region is more rural and economically underdeveloped compared to the Southern region. Therefore, to allow for meaningful insights into our results, we recoded the geographical zones as North and South. The distribution highlights that the northern population is underrepresented in the sample.

Table 8. Distribution of the individual demographic characteristics of the sample. Sources: National Population Commission, National Bureau of Statistics, World Bank

	Rural (n=5620)	**Urban (n=12221)**	**Overall (n=17841)**	**Nigerian population 2016 (n = 186 million)**
Gender				
Female	26%	34%	31%	51%
Male	74%	67%	68%	49%
Age				
Mean (SD)	35.2 (10.9)	36.1 (10.9)	35.8 (10.9)	-
Median [Min, Max]	33.0 [16.0, 67.0]	34.0 [16.0, 67.0]	34.0 [16.0, 67.0]	17.9
Zone				
South	43%	72%	62%	49%
North	58%	29%	38%	51%
Tenure on Network				
1 - 2 years	13%	10%	11%	-
2 - 4 years	23%	16%	18%	-
Over 4 years	64%	74%	71%	-

3.3.3 Statistical Modeling

3.3.3.1 Fixed Effects Model

To estimate the effect of the change in the prices of Internet plans on the second-level digital divide, we specify a log-log model using a fixed effects approach to capture the time-invariant differences across the individuals and the time period of the study. We compare the use intensities of the Internet, calls, and text before and after the change in prices. The use intensities for mobile Internet is specified as:

$$log\ (Data_{it}) = \beta_0 + \gamma_1 log\ (Calls_{it}) + \gamma_2\ log(Text_{it}) + \beta_1 After_t + \beta_2 factor(period_t) + \beta_3 factor(id_i) + \beta_4 Agegroup_i + After_t * \beta_4 Agegroup_i + \beta_5 Gender_i + \beta_5 Gender_i * After_t + \beta_6 Urban_i + \beta_6 Urban_i * After_t + \beta_7 Zone_i + \beta_7 Zone_i * After_t + \mu_{it} \quad (4)$$

where $Data_{it}$ is the megabytes of Internet data used in a month by each unique customer i, in a month in the period of study t. Calls_{it} is the total minutes of outgoing calls by each unique customer i, in a month in the period of study t, and Text_{it} is the total outgoing texts sent by each unique customer i, in a month in the period of study t. $After_t$ is a dummy variable for the months after the introduction of the change in price, and μ_{it} is the error term. We also control for the individuals' demographic characteristics; $\text{Agegroup}_{\text{i}}$ is a categorical variable indicating the age group of the individual, Gender_{i} is a dummy variable that captures the individual's gender, Urban_{i} is a dummy variable that indicates if the individual lives in an urban or rural area, and Zone_{i} is the geographic zone where the individual resides.

3.4 Results

To address the research question in this paper, Table 9 reports the results of the three regression models with the volume of use of the Internet, cellular calls, and text messages as the dependent variables. For all mobile services, no significant difference is found in the effect of the change in

the price of mobile Internet plans on the volume of use across geographical zone, gender, and urban/rural subgroups.

Model 1 depicts the effect of the changes in price on the volume of use of the Internet, measured in megabytes. The results show that after the reduction in the prices of the mobile Internet plans, the average megabytes of data used by an individual increased by 74%. The results also indicate that a 1% increase in the volume of use of cellular calls is associated with a 11% increase in the volume of use of the Internet, suggesting that they are compliments. Examining the main effects of demographic subgroups, no significant effect is seen.

Model 2 estimates the effect of the change in price on the volume of use of calls, measured as the average total outgoing minutes in a month by a customer. No significant effect is seen on the volume of calls after the change in the prices of the Internet plans. Examining the demographic main effects, the largest effect is seen across users in different geographic regions. Compared to users in the Southern region of Nigeria, Northern users have over 200% lower use intensity for cellular calls. The results also show that age is negatively correlated to the volume of use of cellular calls, with users between 31 and 45 years old generating the lowest volume of outgoing calls. Analyzing the effect of gender, the trend suggest that females have lower call volume compared to males, however, the result is not statistically significant. The results of the main effects of location (urban/rural) do not present significant differences. No significant effect of the price change on volume of use of cellular calls across the demographic subgroups is seen. Model 3 presents the effect of the change in the prices of Internet plans on the use intensity of texts, measured as the average total number of outgoing text messages by a customer in one month. The change in the prices of the Internet plans is associated with a 38% decrease in the volume of outgoing text by a customer, suggesting a substitution effect.

Table 9. Estimation results of the Fixed Effects models

	Dependent variable:		
	Data	Calls	Text
	1	*2*	*3*
(Intercept)	5.46*** (1.86)	7.38*** (0.97)	4.29* (2.21)
Calls	0.11*** (0.04)	-	0.06 (0.05)
Text	0.01 (0.03)	0.03 (0.02)	-
Data	-	0.07*** (0.03)	0.02 (0.03)
After	0.74*** (0.13)	0.01 (0.10)	-0.38*** (0.14)
Age group (*Ref. level: < 31 years*)			
31-45	-0.38 (0.83)	-1.64*** (0.40)	-1.51 (0.95)
> 45	0.57 (0.83)	-0.55 (0.40)	-0.28 (0.95)
Gender (*Ref. level: male)*			
Female	-1.36 (1.14)	-0.93 (0.67)	-2.91** (1.42)
Residence (*Ref. level: urban*)			
Rural	-1.13 (0.80)	-0.12 (0.55)	-1.68 (1.07)
Geographical region (*Ref. level: South*)			
North	-0.03 (0.84)	-2.18*** (0.41)	-0.10 (0.96)
After: Rural	0.05 (0.13)	0.0003 (0.11)	0.01 (0.14)
After: Female	0.002 (0.11)	-0.05 (0.09)	0.07 (0.12)
After: Age group 31-45	0.001 (0.11)	-0.07 (0.09)	0.14 (0.12)
After: Age group > 45	0.06 (0.14)	-0.14 (0.11)	0.28* (0.16)
After: North	-0.09 (0.11)	0.01 (0.09)	0.01 (0.12)
Period	Yes	Yes	Yes
User ID	Yes	Yes	Yes
Observations	15,005	15,005	15,005
R^2	0.76	0.85	0.74
Adjusted R^2	0.66	0.78	0.62
Note:			*p<0.1; **p<0.05; ***p<0.01
			Cluster robust standard errors in parentheses
			Errors clustered at the user level

Controlling for the effects of demographic characteristics on the use of text messaging shows that gender is a strong determinant of the volume of text used by an individual. On average, the volume of use of text messaging by females is approximately 300% lower than the usage volume than males. Examining the effect of the changes in the prices of the Internet plans across

demographic subgroups shows that after the change in the prices, older users increased their texting traffic. However, the result was only statistically significant for users over 45 years old.

3.5 Discussion

The results suggest that policies that address the affordability barrier to Internet use would affect the mix of the volume of use of different mobile services in developing countries. The implications of the findings, the limitations of this study, and the direction for future work are discussed in this section.

3.5.1 Implications of Main Findings

Internet access and adoption in SSA has grown rapidly in the last 5 years, supporting the need for increased research on the inequalities in usage in the region. The high cost of Internet access and use remains a key factor exacerbating the digital divide in Nigeria, where approximately 50% live in extreme poverty. To address this barrier to digital equality, in 2016, the NCC, Nigeria's telecommunications, removed the price floor for Internet services, leading to an increase in competitive pricing. Using a panel data of the use intensities of mobile Internet, cellular calling, and text messaging retrieved from the billing system of a national mobile carrier, this paper attempted to estimate the effect of the reduction in prices of Internet plans on the second-level digital divide.

First, the difference in the average use intensities of the Internet, measured as megabytes of data, before and after the change in prices was examined. Next, the impact of the reduction in the prices of Internet plans on the average total call minutes in a month by a customer was studied. Finally, the impact on the average total number of texts sent in a month was examined.

We do not see evidence that reducing the prices of mobile Internet plans would "close" the second-level digital divide across socioeconomic groups. There is a change in the volume of use of different mobile services. The reduction in the prices is associated with an increase in the volume of data used and a decrease in the volume of texts sent by an individual. The result showing the increase in the volume of use of the Internet could be an indication that people are increasingly using the Internet for new activities online, or using the Internet more for a particular activity. However, we do not see a convergence in the volume of use of any of the mobile services across any demographic subgroups. Furthermore, we do not see a statistically significant effect of the change in volume of use after the reduction in prices across any demographic subgroups except for users above 45 years old that increased their texting volume after the reduction in prices. Therefore, to close the second-level digital divide, more robust and targeted policies are needed, focused on specific subgroups in the population.

The results suggest that females and rural users have lower volume of use of all mobile services compared to the male and urban populations respectively. However, further research is needed to understand the factors driving the low volume of use in these populations. Results from an earlier paper showed that that users with high-speed Internet consume significantly higher volume of data, irrespective of their location [15]. However, rural areas typically have fewer and older generation infrastructures than urban areas. Therefore, the low volume of use could be due to limited access/connectivity and/or low bandwidth on the network. The rural population are also often disadvantaged with regards to access to education and learning resources. This could be an indication of a lack of technical skills on average and could also explain the trend showing that the rural users have lower volume of use than urban users. The same could be said for the female population. The lower volume of use could be as a result of lower technical skills than men.

However, it is also plausible, that the result is simply a reflection of differences in online activities. For example, an individual may use the Internet for five days in a month to stream videos and consume 5GB of data. On the other hand, another individual may use the Internet for an entire month and engage with a wide range of activities that consume lower bandwidth and so consume only 1GB of data.

The key insight for mobile carriers from the empirical analysis is that the increase in the volume of use of the Internet is associated with a decrease in the volume of use of text messaging. This could imply that mobile users are switching to using OTT services such as WhatsApp for communication and substituting text messaging with instant messaging. This supports the findings in Chapter 2 of this thesis and in the literature [96], [97], that on average, people have a significantly higher preference for OTT services compared to traditional texting in a pay-as-you-go business model mobile market, like Nigeria predominantly is. As the use of the Internet increases, mobile carriers are likely to see a cannibalization in the revenues generated through text messaging service. This suggest a need for a new business model. The results indicate that mobile Internet is elastic, reducing the price of mobile Internet plans is associated with higher demand. Given that we have shown mobile Internet and cellular calls have a complementary relationship, mobile carriers can protect themselves from the stagnating use of cellular calls and decreasing use of text messaging by offering bundled services. It is recommended that new business models prioritize the offering of mobile Internet and cellular calls given that they are complements.

The results also have important implications for the regulators in addressing the second-level digital divide. The results indicate that policies and/or business strategies that reduce the cost of Internet plans could drive the volume of Internet use. This result builds on earlier findings in the

literature that identified affordability as a key barrier to Internet adoption and use in SSA [3], [61]. The affordability barrier to digital equality is exacerbated in the low-economic rural areas. However, from the results, there is no indication that addressing the affordability barrier would have an effect in closing the urban/rural digital divide. Regulators should examine the impact of addressing other factors such as technical skills, network access, and the perceived advantage of Internet use among the rural population.

3.5.2 Limitations and Future Work

There were some unavoidable limitations encountered during the study. First, the sample was retrieved from the database of a single mobile carrier. Therefore, the results allow generalization only to the network of customers of the carrier. However, the carrier occupies a significant portion of the mobile market, therefore, the findings are significant to the Nigerian mobile market. Furthermore, given that on average each mobile user in Nigeria has 1.8 phone lines, they could be using different mobile services on other mobile networks. This limits the observable effects of the changes in price on use intensities that can be studied. The Internet users in our sample could have switched their usage from another mobile carrier to the mobile carrier in this study after they dropped their prices. This would appears to us as an increase in the volume of Internet use when the actual usage for this one user across different carriers may not have changed at all.

Thirdly, in this work, we are assume that the growth in Internet usage is not capacity limited, as demand increases, there is capacity in the network to carry all of that demand. However, as discussed earlier in the context of the difference in the volume of use between urban and rural users, this could affect the results and the implications of our findings. Future research can be built by using data from different mobile carriers and comparing the use intensities of the

customers on one mobile network (with the price changes – treatment group) against that of the customers on another mobile network (with no price changes – control group).

3.6 Conclusion

Affordability continues to remain a driver of the first-level and second-level digital divides in developing countries. In developing countries, the digital divides of different digital technologies are closely interrelated, and the policies on one digital technology could have an impact on the adoption and use of other technologies. To boost Internet use and improve competition in the mobile market, in September 2015, the national regulator of the telecommunications industry in Nigeria removed the price floor of mobile Internet plans. This led to a reduction in prices across the mobile industry.

In this paper, using a fixed effects method, the impacts of this price change on the differences in the use intensities of the Internet, cellular calling and text messages are investigated. A panel data of customer usage records, retrieved from the billing system of a major mobile carrier in Nigeria is used in this study. The results show that the reduction in the prices of Internet plans is associated with an increase in the average megabytes of data used and associated with a decrease in the average total text messages sent in a month. However, we do not see evidence that reducing the prices of mobile Internet plans would "close" the second-level digital divide across socioeconomic groups. We do not see a convergence in the volume of use of any of the mobile services across any demographic subgroups. This suggests that more robust policies that are targeted at specific subgroups are needed to reduce the existing second-level mobile technology digital divide that exists in developing countries.

What differentiates this paper from existing literature, to the best of the authors' knowledge, is first, a new approach to studying the second-level digital divide in developing countries is proposed and applied. A mobile device has been identified as the facilitating technology, with the use intensities of different supported digital technologies/services studied. Second, this paper is the first to investigate the impact of price changes on the second-level digital divide in SSA using historical customer panel data.

4. When Being Connected is not Enough. An Analysis of the Second and Third Levels of the Digital Divide in a Developing Country

Abstract

In Sub-Saharan Africa, the Internet has been identified as a tool to overcome poverty; by improving communication, facilitating innovation, and driving economic growth. However, studies on the benefits of Internet adoption and use in other regions show that the welfare effect of technology is not only based on its adoption, but also from the type of use. Using Nigeria as a case study, this paper draws on the Uses and Gratifications Theory and factor analysis to examine the differences in the extent and pattern of Internet use (second-level digital divide) and the differences in outcomes from Internet use (third-level digital divide). The results show that gender, age, and education are key predictors of the second-level digital divide at the individual level in a developing country. The results also suggest that the second-level digital divide in developing countries mirror other socioeconomic inequalities that preexist in the society. Technical skills, encouragement from family and friends, and performance expectancy from using the Internet predict behavioral intention to use the Internet. While behavioral intention to use the Internet significantly affects the frequency of engagement with social activities. The results also indicate that education level and the frequency of use of different types of Internet activities determine individual outcomes from Internet use.

4.1 Introduction

The Internet has been identified as a tool to overcome poverty; by improving communication, facilitating innovation, and driving economic growth. In recent years, Internet adoption and use in Africa has increased significantly. Between 2005 and 2016, the percentage of individuals using the Internet in the region increased from 2% to 25% [1]. This growth is expected to continue, with the rate increasing to 39% by 2025 [98]. Longitudinal data from a mobile carrier in Nigeria showed over 340% increase in the average volume of data used by a sample of

connected users between April 2016 and July 2017 [32]. The growth in adoption rates of the Internet is largely driven by the young population turning into adults and owning phones for the first time. Across SSA, a region that has struggled with connectivity and economic development for decades, the increase in Internet adoption and use is expected to contribute to economic and social development. Through the transformation of key sectors such as education, healthcare, and retail, the Internet is estimated to account for up to $300 billion of the annual GDP from SSA by 2025 [99]. This represents a 94% growth in the contribution of the Internet to the annual GDP in SSA compared to 2013.

However, studies have shown that the welfare effect of technology is not only based on its adoption, but also from the type of use [100]. This difference in the access to, use of, or impact of information and communication technologies is referred to as the digital divide. Initial literature that investigated the benefits of Internet use compared the differences between the connected and unconnected population (first-level digital divide) [7], [10], [12], [16], [24]. Even as Internet adoption and use increased, divides still remain among those that adopted the Internet, scholars identified a need for new approaches to understanding the digital divide; studying the difference in the extent and pattern of use of the Internet. Applying these new approaches showed differences could exist in digital skills and Internet use, referred to as the second-level digital divide [5], [10], [21], [101]. Differences could also exist in the outcomes from Internet use among users with comparable access, digital skills, and Internet use, this is referred to as the third-level digital divide [5]. These different levels of the digital divides could limit the expected benefits from Internet use.

Sociodemographic and socioeconomic factors have been identified as the significant determinants of the digital divide [5]. In SSA, there are significant socioeconomic challenges:

41% of people live in extreme poverty and the Human Development Index for African countries is 0.52 (low human development). Therefore, we might expect the digital divide to be a significant challenge. Lack of local content is another key barrier to Internet use in SSA [89]. To reap sustainable benefits from Internet use, there needs to be access to services and applications relevant to the local population. More broadly, mobile phones have been used differently as a "leapfrogging tool" in SSA compared to other regions. For example, through the implementation of mobile money, mobile phones have been used to facilitate banking and financial transactions in an unprecedented manner [83], [100]. The end-users of mobile money do not need to be connected to the Internet to use the service, however, they still have access to "online banking" via mobile money.

Mobile phone-based access to the Internet removes many barriers to Internet access compared to traditional desktop computers, obviating the need for reliable electricity, a secure location, and a significant financial investment in a PC. In fact, users can access the Internet with little or no investment through $10 phones that provide access to specific Internet services. Through SIM swapping and sharing, a single mobile phone can support multiple users who do not own an Internet-enabled mobile phone. Thus, low resource users who are more likely to lack literacy skills may be significant fraction of the overall mix of Internet users.

Due to the low adoption rates, existing literature on the digital divide in SSA have mostly examined the factors that drive the first-level digital divide [3], [52], [61], [91], [93]. With the increase in Internet connectivity in the region, the research on the digital divide in SSA has begun to shift to investigating the use and overall impact of Internet use. A recent report by the Pew Research Center shows that the increase in Internet connectivity has contributed to having a positive impact on life, with communicating with family and friends being the most widely used

Internet activity [62]. These socioeconomic challenges, novel access methods, and generally distinct mix of Internet use and users in SSA compared to earlier studies suggest a need for different approaches to understanding the digital divide in the region.

This paper aims to fill this gap with a case study that investigates the differences in the extent and pattern of Internet use as well as the differences in the outcomes from Internet use in Nigeria. To meet this objective, this paper attempts to answer three research questions, (1) What are the key factors that affect the type and frequency of use of different Internet activities? (2) What are the key factors that affect individual outcomes from Internet use? and (3) What is the relationship between patterns of Internet use (activities and frequency) and outcomes? To answer these questions, we surveyed 1500 mobile users in Nigeria and distinct classifications of Internet activities and Internet outcomes relevant to SSA were identified, based on the UGT. The differences in individual engagement with Internet activities and Internet outcomes were then examined across socioeconomic groups.

The paper is organized as follows. In Section 2, we summarize existing relevant literature. In Section 3, we outline our methodology and describe our sample. In Section 4, we discuss our results. In section 5, we present the discussions and policy implications.

4.2 Theoretical Background

4.2.1 The Concept of the Digital Divide

The digital divide has been studied extensively since the 1990s, as the use of PCs and the Internet increased [5]. The literature on the digital divide has examined the differences in the access, use and benefit from the use of digital technologies from different perspectives. These studies have explored the digital divide by comparing adoption and use patterns across nations

worldwide [12], [28], geographical locations within nations [13], [16], [24], select regions e.g. countries with high market penetration [18], and individuals within nations [21], [87].

The early research on the digital divide, coined the *first-level digital divide*, studied the difference between those connected to the Internet and those who were not. Understanding the first-level digital divide assisted in developing policies to drive Internet adoption. Studies of the first-level digital divide have shown that individual characteristics such as age, gender, socioeconomic status, and geographical location affect Internet adoption [5]. However, the first-level digital gap between men and women was found to be entirely as a result of existing socioeconomic differences between the genders [10], suggesting that closing gender inequalities need to be addressed in order to close gender digital divides. In addition, high-income and highly educated individuals were the early adopters of the Internet [7].

Over the past two decades, as adoption rates increased rapidly and the first-level digital divide has been closing [12], [28], [29], researchers on the digital divide have shifted to studying the difference in the extent and pattern of Internet use [5], [18], [29]. This is described as the *second-level digital divide*. The Internet service used by an individual is largely dependent on them having the required skills. For example, the skills to operate the required hardware and software, the information literacy to process the online content, as well as the social and creative skills to create content and connect with other individuals online. Up to half of the variance in having the required skills (and thus Internet use) are accounted for by sociodemographic factors [18]. Researchers have studied how the Internet services used by active users vary. Some of these studies examined the frequency of Internet use and how it varies across demographic groups [10], [32]. Others explored how the type of service or content accessed, such as information seeking or commercial transaction, varies across demographic groups [18], [21].

While a lot of research has explored the first-level digital divide, and increasingly explored the second-level digital divide, very little work has been done on studying the difference in the impact of Internet access and use. This difference in the impact of Internet use, where some individuals do not have beneficial outcomes, is described as the *third-level digital divide* [5]. Some researchers argue that studies on the digital divide need to focus on this third-level divide; examining the economic, social, cultural and human capital that could be attained through Internet use [18]. However, existing literature on the third-level digital divide have focused on developed markets, where penetration rates are high [5], [33].

4.2.2 Classifications of the Second and Third Levels of the Digital Divide

The literature on the second and third-level digital divides is comprised of several different approaches to identifying and classifying activities carried out online and the outcomes of these activities. The second-level digital divide is the difference in the extent and pattern of use of digital technologies by the connected population. Being connected to the Internet means having access to a wide variety of activities online such as email, online banking, downloading media, or searching for information. The set of the Internet activities an individual engages with, as well as the frequency of engagement with the selected activities constitute the second-level digital divide. Similarly, the third-level digital divide investigates the differences in the ability of individuals in utilizing digital resources to achieve specific offline objectives relating to their general well-being. These offline objectives that could be achieved through the utilization of digital resources include finding a job, quicker access to information, having more contact with people, and buying products at a discount online compared to buying in a physical store.

The different activities that individuals could engage with online and the potential outcomes from their online engagement are both nearly infinite. As a result, some studies on the second-

level digital divide have drawn on existing theoretical frameworks to create classifications of correlated activities. Some of these studies are based on a particular theory including the Social Cognitive Theory (SCT) [102], [103] and the UGT [21], [40]. The activities are selected to reflect the key classifications proposed in the theory. By investigating differences among general clusters of activities, these studies allow the findings to be generalized regardless of the specific type of activity within a cluster an individual engages in.

Numerous studies have applied the UGT to understand the differences in Internet use. This approach explains the way individuals adopt and use digital technology as a result of their motivation and gratification needs such as the need to improve their career or to search for information [21]. The difference in the usage within these clusters was found to be determined by age, gender, education and Internet experience. However, there have been arguments that the UGT offers a limited explanation of the variance in Internet usage. This lead to the application of the SCT in studies on the second-level digital divide [102], [104]. The SCT posits that the use pattern of the Internet is determined by the expected outcomes from the use of the Internet. Therefore, rather than classifications based on gratification needs, as seen in UGT, SCT posits clusters based on behavioral intentions.

Other approaches to studying the second-level digital divide rely on an inductive approach. A factor analysis of a growing current list of contemporary Internet activities is used to identify classifications of Internet activities [105]. Similarly, to conceptualize and operationalize the classifications of Internet outcomes, the existing list of Internet activities is used as a starting point [87]. For example, through applying for jobs online (Internet activity) an individual could find a job (Internet outcome).

4.2.3 The Unified Theory of Acceptance and Use of Technology

The adoption and use of technology have been studied extensively in multiple disciplines including Psychology, Sociology, and Information Systems. To explain the difference in attitudes and behavior towards technology adoption at the individual level, several theoretical models have been developed and applied in the literature on the digital divide. Some of these theories include the Technology Acceptance Model (TAM), the SCT, and the Theory of Reasoned Action (TRA) which explained over 40% of the variance in individual intention to use a technology [63], [106]. A limitation of these models is that they each had different, yet important, contributions to the study of technology acceptance and use. However, because they were distinct models, researchers had to often chose limited constructs from each model, or use constructs from only one model.

In the early 2000s, as a solution to the challenges faced from the availability of so many distinct and important models, the Unified Theory of the Acceptance and Use of Technology (UTAUT) was developed. The UTAUT presented a unified view towards user acceptance of technology. It is based on eight previously established theories of technology adoption and use; TRA, TAM, Motivational Model, Theory of Planned Behavior (TPB), PC Utilization Model , Innovation Diffusion Theory, SCT, and Combined TAM and TPB [106]. By adapting these earlier theories, the UTAUT proposes 4 main constructs of intention and usage; Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions which is joined with Behavioral Intention. While the models based on each of the eight initial theories explained between 17% and 53% of the variance in individual intentions to use a technology, the UTAUT explained up to 70% of the variance.

The UTAUT has been applied in a wide variety of studies that investigated technology adoption and use. It has been applied to study the use of e-learning websites in Taiwan [107], ICT adoption by students in higher institutions in Ghana [108], ICT use in Angola [63], and the adoption of mobile services in Finland [109]. While a lot of these studies have applied the UTAUT to examine adoption, its application in understanding use patterns is limited.

In this paper, one of the research goals is to examine the relationship between the second level and third level divides. In today's digital ecosystem, access to the Internet is a necessary condition to facilitate the use of applications to achieve any human development outcome. Therefore, I assume that if a person intends to get access to the Internet, they will soon intend to use various applications. The Internet is a general purpose technology (GPT). Whole eras of technical progress and growth appear to be driven by a few GPTs, such as the steam engine, the electric motor, and semiconductors. GPTs are characterized by pervasiveness, inherent potential for technical improvements, and 'innovational complementarities', giving rise to increasing returns-to-scale [110]–[112]. In developing countries, access to the Internet is a key strategy for public policies aimed at reducing the digital divide. These investments aim to increase returns on investment for applications for voice, data, and video that are co-dependent on the level of access to the Internet.

To model this, I use the UTAUT which specifically models the intention-behavior relationship. The model expects that behavioral intention (BI) will have a positive influence on usage. I examine the extent to which a person's BI to use the Internet and actual use and acceptance of specific types of Internet activities and the extent they engage with those activities has an outcome. This work does not attempt to test the UTAUT model. Instead, it draws on the model to frame the exploration of the second and third levels of the digital divides.

4.3 Methods

4.3.1 Sample

A sample of the Nigerian population was recruited into this study between April and June 2019 using a site-based sampling method (N= 1500). Participants were recruited from eight states across all the geographic zones in Nigeria. Within each state, recruitment took place at higher educational institutions, shopping malls, markets, and corporate/government organizations.

Several steps were taken to ensure a good response rate. The survey was administered using the CAPI tool of Sawtooth Software[15]. This allowed the data to be collected offline, automatically checked for missing responses, and prompted the respondents to answer questions that were skipped. Furthermore, the survey was designed to minimize the average time to complete the survey to approximately 10 minutes. Two rounds of pretesting were conducting before administering the survey to the target population. First, the survey was pretested with survey experts at Carnegie Mellon University, and then a second pretesting round was conducted with 10 individuals in Nigeria. After each pretesting round, amendments were made to the survey instrument.

The demographic distribution of the sample is summarized in Table 10. Although attempts were made to recruit a representative sample, there are some notable deviations from the national demographic distribution. Approximately 40% of the sample is female. This is lower than the national average, where approximately 50% of the population is female. Furthermore, the Nigerian population is predominantly young, over 50% of the population is below 20 years old.

[15] https://www.sawtoothsoftware.com

Table 10. Distribution of the individual demographic characteristics of the sample

	Rural (n=543)	Urban (n=973)	Overall (n=1517)
Gender			
Female	41%	40%	40%
Did not respond	5%	5%	5%
Age (years)			
18-30	37%	45%	42%
31-40	24%	25%	25%
41-50	20%	15%	17%
51-60	9%	7%	8%
> 60	3%	2%	2%
Did not respond	7%	5%	6%
Education			
High School	40%	33%	35%
OND/Bachelors	44%	48%	47%
Masters/PhD	3%	12%	9%
Did not respond	13%	8%	9%
Monthly Income[16]			
Low (Below $165)	47%	47%	47%
Middle ($166 - $1,380)	10%	22%	18%
Upper (Over $1,380)	1%	2%	2%
Did not respond	43%	30%	34%
Mobile phone ownership			
Smartphone	56%	80%	72%
Basic phone	48%	32%	38%
No phone	11%	3%	6%
Internet users	64%	82%	76%
Device used in connecting to the Internet			
Mobile phone (only)	41%	41%	41%
Mobile phone and laptop	10%	21%	17%
Mobile phone and tablet	8%	15%	13%

[16] At the rate of 0.0028 US Dollar to 1 Nigerian Naira

However, the young population is underrepresented in the mobile market as seen in an earlier study [32] and in this sample as well, in part since respondents younger than 18 were excluded. Approximately 40% of the sample have a bachelor's degree or higher. Examining the distribution of phone ownership in the sample, 6% do not own a phone and 72% own a smartphone. The data suggests that smartphone ownership among the urban population is significantly higher than among the rural population. Furthermore, 76% of the respondents used the Internet in the past one year, and approximately 40% of the sample connected to the Internet in the past year only on their phones.

4.3.2 Measures

4.3.2.1 Measurement of Internet Activities

Following the approach widely applied in the literature [18], [21], [105], in this paper, the second-level digital divide is measured by the frequency of use of different online activities. The Internet activities measured in this study were derived using the UGT and were validated through pretesting. The list of all Internet activities included in the survey instrument and the percentage of the sample of Internet users that engaged with each activity is included in Appendix C and shown in Table 19. The frequency of use of each activity was self-rated by the respondents using a 6-point scale ranging from "Never" to "Over 3 times a day".

4.3.2.2 Measurement of Internet Outcomes

The Internet activities included in the survey were used as a starting point for identifying the expected outcomes from Internet use. For example, using the Internet to apply to an academic program (Internet activity) could lead to the outcome of being admitted into the academic program (Internet outcome). For each outcome, the respondent reported on if they achieved the identified benefit in the past year through the use of the Internet. There were 3 response options;

True, False, and NA. Individuals who were not seeking a particular outcome, e.g. an individual who is currently employed and not seeking new employment, were asked to choose "NA". The list of all the measures of Internet outcome and the distribution of the self-reported outcomes is included in Appendix C shown in Table 20.

4.3.2.3 UTAUT Measures

The literature shows performance expectancy, effort expectancy, and social influence are significant determinants of intention to use a technology. On the other hand, in predicting usage behavior, behavioral intention and facilitating conditions were found to be significant. In this study, this two-part model of the acceptance and use of technology is explored. The literature shows that gender and age predict behavioral intent and use of technology. The effect of other demographic measures such as education, income, location, and type of device used to access the Internet are explored in this work, as shown in Fig. 14. The positive response rates of these measures are shown in Table 11. The data shows that approximately 20% of Internet users and over 90% of non-users do not have the technical skills required to use the Internet for a wide range of activities. Furthermore, non-users of the Internet have a low rate of expectation that the Internet is a tool for improving general well-being.

Table 11. UTAUT Measures

Variable	UTAUT Construct	Description	User	Non-User
			% Agree	
UTAUT: EE	Effort Expectancy	I feel comfortable using the Internet for a wide range of activities without asking for help	80	9
UTAUT: PE	Performance Expectancy	Internet users are better off in general than non-users	63	25
UTAUT: SI	Social Influence	My family and friends think I should use the Internet	76	37
UTAUT: ANX	Anxiety	I am worried about the rapid advancements in broadband technology	34	25
UTAUT: FC	Facilitating Condition	Internet access (data plan/supported device) is too expensive	64	45
UTAUT: BI	Behavioral Intention	In the next one year, I plan to increase my Internet use	71	26

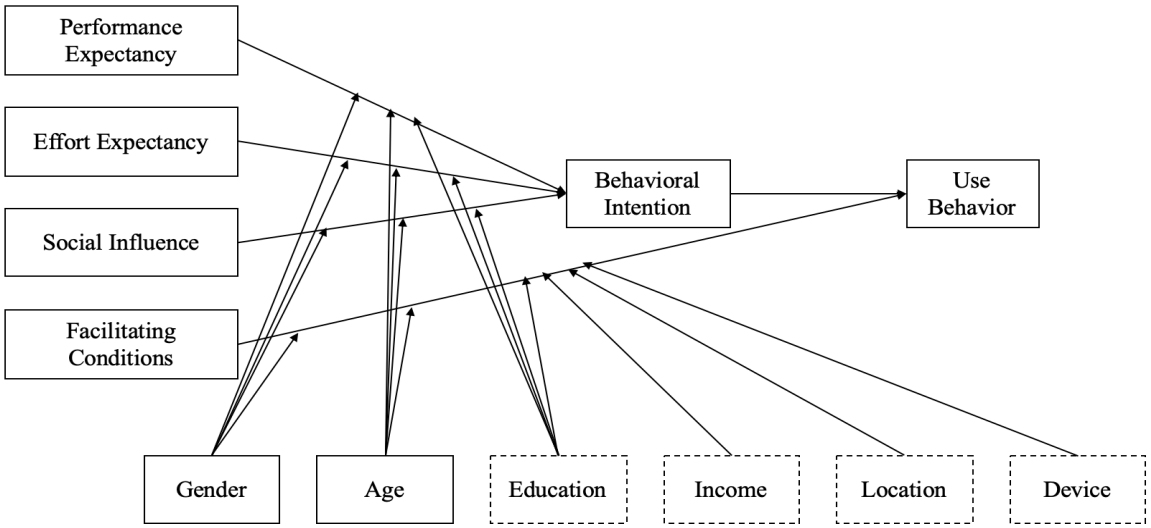


Figure 13. Theoretical framework of the study hypotheses. Adapted from the UTAUT model [106]

4.3.3 Data Analyses

4.3.3.1 Data Analyses of Internet Use

To investigate the differences in Internet use, we followed a four-step process. First, we performed exploratory factor analysis using the initial list of 21 Internet activities. Using a Scree test and parallel analysis in Principal Axis Factoring (PAF), we identified the recommended number of factors (n=5) to be extracted from the initial list of 21 Internet activities. Then using PAF with varimax rotation, 17 Internet activities were loaded on the five factors: personal development, social, business, and novel. There were no activities that loaded on two or more factors. The four Internet activities that did not load onto any factor are; forums, online_banking, health_info, and media_download. These four Internet activities were dropped from the dataset and the process was repeated. The Internet activity "gaming" was not loaded on any factor; therefore, it was removed from the dataset and the process repeated. Through this round of extracting the factors and the factor loadings, all the Internet activities were loaded onto a factor

and no activity was loaded on more than one factor. The final factors and the factor loadings of the Internet activities in each factor are presented in Table 12.

Next, a confirmatory factor analysis was performed on the dataset. The fit of a five-factor model and a model without factors were estimated and tested. The five-factor model performed better than the model with no factors indicating that running the regression models using the five factors is appropriate; the results are included in the Appendix C. A reliability analysis was also conducted on the dataset. The reliability and average variance extracted for each factor are shown in Table 12.

Finally, multiple linear regression models are run on the dataset. Using the PE, EE, and SI constructs of the UTAUT model, the behavioral intent to use the Internet is analyzed. Next, the difference in individual extent and pattern of Internet use is analyzed using the FC and BI constructs of the UTAUT model as predictors while controlling for the demographic characteristics of the individuals.

4.3.3.2 Data Analyses of Internet Outcomes

To identify the clusters of Internet outcomes, the same process for exploratory factor analysis as applied above is used. Running the Scree test generated a recommendation of four factors levels to be used in the analysis. The PAF with varimax rotation was run on the dataset, resulting in five Internet outcomes that were not loaded on any factor. These five Internet outcomes – admission, personal_communication, health_info, mental_health, and privacy – were dropped from the dataset and then the process was repeated. This resulted in the outcome, meet_so, to not be loaded on any factor, therefore it was also dropped. Repeating the process again did not result in any outcomes not loaded on a factor. The final Internet outcomes that were successfully

loaded onto a factor and are used in the analysis are presented in Table 13. The reliability and the average variance extracted for each factor are also included in the table.

Using the four factors as dependent variables, multiple logistic regression models are run on the data to estimate the likelihood of an individual getting an outcome from each cluster. Within each cluster of outcomes, if an individual responded true to at least one outcome in a cluster, then the value for that cluster is true and used as an input in the regression model.

4.4 Results

4.4.1 Second-Level Digital Divide

First, the behavioral intent to use the Internet is analyzed, drawing on the constructs of the UTAUT model, as shown in Table 14. EE, PE, and SI are all significantly positively correlated with an individual's intention to use the Internet for a wide variety of activities. Age is seen to be significantly negatively correlated with the intent to use the Internet for a wide variety of activities, while gender is seen to have no effect.

For the five clusters of Internet activities listed – development, news, leisure, social, and business, the estimation results of the linear regression models are reported in Table 15. The dependent variables are the factor scores of the clusters of Internet activities. Gender, age, income, and education are significant predictors of the differences in frequency of use. Individuals with a higher income use the Internet more frequently for all clusters of activities except for novel activities. The BI construct is significantly positively correlated with the use of the Internet for social activities.

Table 12. Rotated matrix of the factor loadings of the Internet activities (In the past year, how often did you use the Internet for…)

		% users	Factors					Reliability	AVE
Variable Name	**Description**	**(n=1123)**	**Devt.**	**Social**	**Business**	**News**	**Novel**		
activities_training_search	Searching for online training	53%	0.85						
activities_training	Enrolling in an online training	47%	0.77						
activities_school_search	Searching for or applying to academic programs	49%	0.60					0.85	50%
activities_work	Activities directly related to work or study	76%	0.56						
activities_inde_learning	Independent online learning	74%	0.54						
activities_job_search	Searching for or apply to jobs	55%	0.53						
activities_sm_view	Viewing content on social networks	96%		0.84					
activities_personal_comms	Communicating with family and friends using WhatsApp or similar applications	98%		0.65				0.77	56%
activities_sm_upload	Uploading content on social networks	94%		0.56					
activities_selling	Selling things online	33%			0.62				
activities_buying	Buying things online	58%			0.58			0.74	51%
activities_business_info_search	Looking up information about a business/product	80%			0.57				
activities_naija_news	Searching or read Nigerian news online	89%				0.83		0.89	80%
activities_intl_news	Searching or read international news online	85%				0.83			
activities_online_dating	Online dating	25%					0.63	0.52	39%
activities_lottery	Betting, gambling, or playing the lottery	21%					0.52		

Factor loadings greater than 0.50 are shown. The Internet activities are sorted in the descending order of their factor loadings for its respective factor.

Table 13. Rotated matrix of the factor loadings of the Internet outcomes (In the past year, through the use of the Internet...)

		% Yes [%NA]	Factors				Reliability	AVE
	Description	**(n=1123)**	**Devt.**	**Commercial**	**Political**	**Health**		
outcome_ income	I earned additional income	32% [32%]	0.69					
outcome_ job_offer	I got a job offer	25% [37%]	0.63				0.60	29%
outcome_ training	I completed an additional training outside work/school	36% [29%]	0.59					
outcome_ admission	I got admitted to an academic program	33% [37%]	0.48					
outcome_purchase_discount	I frequently bought products at a discount	39% [24%]		0.66			0.52	35%
outcome_safe_transactions	I felt safe completing large commercial transactions	45% [22%]		0.63				
outcome_ political_info2	I kept up-to-date with government policies	59% [14%]			0.71			
outcome_ policitcal_opinions	I expressed political opinions	45% [19%]			0.59		0.69	37%
outcome_ govt_interaction	I interacted with government agencies	28% [23%]			0.59			
outcome_ political_info	I gained information about the elections	81% [7%]			0.56			
outcome_hospital	I found hospital to go to for treatment	29% [27%]				0.76	0.60	59%
outcome_ health_diagnosis	I diagnosed a health problem for self, a friend or family	43% [22%]				0.68		

Factor loadings greater than 0.40 are shown. The Internet outcomes are sorted in the descending order of their factor loadings for its respective factor.

Table 14. Regression coefficients of adoption factors for behavioral intention to use the Internet

(Intercept)	1.57 (0.14) ***
UTAUT:EE	0.16 (0.04) ***
UTAUT:PE	0.14 (0.03) ***
UTAUT:SI	0.11 (0.04) **
Gender (Reference level: female)	
Male	0.01 (0.04)
Age (Reference level: 18-30)	
31-40	-0.13 (0.06) *
41-50	-0.19 (0.08) *
>50	-0.23 (0.10) *
Education (Reference level: High School)	
OND/Bachelors	-0.00 (0.05)
Masters/PhD	-0.02 (0.08)
Income (Reference level: Low)	
Middle	0.06 (0.06)
Upper	0.25 (0.16)
R^2 / R^2 adjusted	0.119 / 0.107

Note: EE = effort expectancy; PE = performance expectancy; SI = social influence; * *p<0.05* ** *p<0.01* *** *p<0.001*

First, in Model 1, the differences in the frequency of use of the Internet for personal development activities, such as online training, searching for job vacancies, or applying to an academic program, are examined. The results show that males have a significantly higher frequency of use of the Internet for personal development activities than females. Age is also seen to be a significant determinant of the second-level digital divide for personal development. The results indicate that younger individuals use the Internet for personal development activities more frequently than older individuals. In addition, an individual's educational level is positively correlated with the frequency of use of the Internet for personal development activities. Individuals that access the Internet only over a mobile phone have a significantly lower

frequency of use of the Internet for personal development activities, compared to individuals that access the Internet over a tablet or a laptop.

Model 2 presents the results of the determinants of the second-level digital divide in using the Internet to search for or read news content. The results show that males use the Internet accessing news content more frequently than females. Examining the effect of education indicates that individuals with a higher education use the Internet to access news content more than individuals with a lower education. Gender and age are the key determinants of the frequency of use of the Internet for novel activities such as playing games online. Males and younger individuals have a significantly higher frequency of use of the Internet for novel activities.

Models 4 and 5 present the key determinants of the second-level digital divide in social and business activities respectively. For both clusters of Internet activities, age and income are significant drivers of use patterns. Younger people use the Internet more for social and business activities compared to older people. The result show that income has a positive correlation to the frequency of use for both clusters of activities, and males have a lower frequency of use of the Internet for social activities compared to females. The results also show that the frequency of use of the Internet for activities within the social cluster is also impacted by the type of device used to connect to the Internet in the previous year. The frequency of use of business activities, on the other hand, are driven by the educational qualification of the individual. Individuals with a higher educational qualification use the Internet more frequently for business activities.

Table 15. Estimations results of the linear regression models showing the determinants of the second-level digital divide

	Dependent Variables:				
	Development	**News**	**Novel**	**Social**	**Business**
	1	*2*	*3*	*4*	*5*
(Intercept)	7.91 (1.13) ***	3.80 (0.61) ***	2.39 (0.32) ***	8.16 (0.53) ***	3.87 (0.50) ***
UTAUT: FC	0.27 (0.20)	0.15 (0.11)	-0.04 (0.06)	0.17 (0.09)	0.05 (0.09)
UTAUT: BI	0.38 (0.24)	0.21 (0.13)	-0.02 (0.07)	0.35 (0.11) **	0.03 (0.11)
Gender (Reference level: female)					
Male	0.81 (0.31) **	0.83 (0.17) ***	0.56 (0.09) ***	-0.28 (0.14) *	-0.20 (0.14)
Age (Reference level: 18 -30)					
31-40	-2.58 (0.40) ***	0.16 (0.21)	-0.31 (0.11) **	-0.78 (0.19) ***	-0.75 (0.18) ***
41-50	-4.83 (0.54) ***	-0.53 (0.29)	-0.55 (0.15) ***	-2.08 (0.25) ***	-1.13 (0.24) ***
> 50	-4.33 (0.70) ***	-0.14 (0.38)	-0.85 (0.20) ***	-2.21 (0.33) ***	-1.36 (0.31) ***
Education (Refence level: High School)					
OND/Bachelors	1.17 (0.36) **	0.72 (0.20) ***	-0.05 (0.10)	0.11 (0.17)	0.45 (0.16) **
Masters/PhD	2.92 (0.60) ***	0.88 (0.32) **	-0.07 (0.17)	0.05 (0.28)	0.70 (0.26) **
Income (Reference level: Low)					
Middle	1.38 (0.42) **	0.82 (0.23) ***	-0.05 (0.12)	0.91 (0.20) ***	0.81 (0.19) ***
Upper	2.07 (1.13)	0.44 (0.61)	0.20 (0.32)	1.05 (0.53) *	1.23 (0.50) *
Device used (Reference level: tablet/laptop)					
Mobile phone	-1.66 (0.74) *	-0.12 (0.40)	-0.22 (0.21)	0.79 (0.35) *	-0.19 (0.33)
Mobile phone + laptop	0.53 (0.78)	0.68 (0.42)	-0.32 (0.22)	1.23 (0.37) ***	0.15 (0.35)
Mobile phone + tablet	1.08 (0.80)	0.97 (0.43) *	-0.31 (0.23)	1.35 (0.38) ***	0.60 (0.36)
Residence (Ref: rural)					
Urban	0.56 (0.35)	0.25 (0.19)	-0.18 (0.10)	0.13 (0.16)	0.04 (0.16)
Geographical region (Ref: South)					
North	0.87 (0.31) **	0.53 (0.17) **	-0.12 (0.09)	0.01 (0.15)	-0.07 (0.14)
Monthly Internet Subscription	0.00 (0.00) **	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00) ***
Observations	799	799	799	799	799
R^2 / R^2 adjusted	0.291 / 0.276	0.172 / 0.155	0.098 / 0.080	0.194 / 0.177	0.152 / 0.135
AIC	4591.583	3593.483	2581.085	3363.925	3288.114

Note: FC = facilitating condition; BI = behavioral intention;

** p<0.05 ** p<0.01 *** p<0.001*

4.4.2 Third-Level Digital Divide

The identified clusters of outcomes from Internet use; personal development, health information, political engagement, and commercial transaction are investigated using a logistic regression and the results are presented in Table 16. Across the four clusters of Internet outcomes, the results show that the key determinants are education and the frequency of use of different Internet activities. Individuals with a higher education are less likely to achieve positive outcomes relating to personal development compared to individuals with lower education. For other clusters of Internet outcomes, the results show that individuals with higher education are more likely to see benefits related to health. Positive outcomes related to political engagement and commercial transaction are also suggested for users with higher education. Analyzing the effect on gender on Internet outcomes indicate that males are less likely to get benefit relating to health than women. Gender is not significant for all other clusters of Internet outcomes.

The impact of the second-level digital divide on Internet outcomes is also examined. In general, the results suggest that the frequency of use of the Internet for all clusters of activities is positively correlated with positive Internet outcomes. This result is significant for the effect of personal development and social activities on development outcomes. An increase in the frequency of use of the Internet for social activities is associated with higher odds of achieving a positive outcome relating to personal development and health from the Internet. Also, a higher use of the Internet for personal development activities is correlated with an increase in the odds of achieving a positive outcome relating to personal development. Individuals that frequently read news online have a higher odds of achieving political outcomes through the Internet.

Table 16. Estimations results of the logistic regression models showing the determinants of the third-level digital divide

	Dependent Variables:			
	Development	**Health**	**Government**	**Commercial**
	Odds Ratio	*Odds Ratio*	*Odds Ratio*	*Odds Ratio*
(Intercept)	0.28 (0.93)	0.37 (0.66)	0.13 (1.05)	0.01 (0.83) ***
Gender (Reference level: female)				
Male	1.68 (0.29)	0.51 (0.20) ***	0.93 (0.37)	1.44 (0.23)
Age (Reference level: 18 -30)				
31-40	0.64 (0.34)	0.78 (0.24)	0.74 (0.43)	0.56 (0.28) *
41-50	0.29 (0.45) **	1.22 (0.35)	1.25 (0.58)	1.10 (0.42)
51-60	0.48 (0.72)	1.53 (0.50)	2.96 (0.94)	1.28 (0.66)
> 60	0.00 (916.18)	0.95 (0.84)	0.69 (1.35)	1.46 (1.45)
Education (Refence level: below Bachelors)				
Bachelors and higher	0.51 (0.31) *	1.82 (0.20) **	1.89 (0.40)	1.26 (0.24)
Income (Reference level: low)				
Middle	1.19 (0.38)	1.37 (0.26)	0.88 (0.47)	1.94 (0.31) *
Upper	0.87 (0.98)	0.53 (0.59)	-	1.11 (0.92)
Device used (Reference level: none)				
Mobile phone	0.43 (0.63)	0.60 (0.47)	1.16 (0.72)	1.47 (0.50)
Mobile phone + laptop	0.96 (0.70)	0.53 (0.49)	1.99 (0.85)	2.39 (0.53)
Mobile phone + tablet	0.73 (0.72)	0.49 (0.51)	1.13 (0.85)	2.63 (0.56)
Residence (Ref: rural)				
Urban	1.18 (0.30)	0.95 (0.21)	1.69 (0.37)	1.54 (0.25)
Geographical region (Ref: South)				
North	0.61 (0.28)	1.36 (0.19)	2.99 (0.36) **	1.57 (0.22) *
Activity: Development	1.22 (0.04) ***	1.00 (0.02)	1.08 (0.06)	1.05 (0.03)
Activity: News	1.02 (0.06)	1.08 (0.04)	1.40 (0.08) ***	1.09 (0.05)
Activity: Novel	1.16 (0.14)	0.97 (0.08)	1.16 (0.18)	1.29 (0.11) *
Activity: Social	1.17 (0.07) *	1.11 (0.05) *	1.04 (0.08)	1.07 (0.06)
Activity: Business	1.09 (0.09)	1.11 (0.06)	1.06 (0.13)	1.53 (0.08) ***
Observations	634	631	743	638
R^2 Nagelkerke	0.289	0.108	0.148	0.275
AIC	434.874	790.323	317.675	600.286

** p<0.05 ** p<0.01 *** p<0.001*

4.5 Discussion

4.5.1 Main Findings

Governments and development organizations such as the World Bank Group look to leverage mobile technologies to increase productivity and economic development in developing countries. Therefore, understanding the digital divide and developing policies to address the divide could have important economic impact.

This paper focused on characterizing the second and third levels of the digital divide in a developing country, using Nigeria as a case study. To do this, three research questions are answered: (1) *What are the key factors that affect type and frequency of use of different Internet activities?* (2) *What are the key factors that affect individual outcomes from Internet use? and* (3) *What is the relationship between patterns of Internet use (activities and frequency) and outcomes?*

As described below, gender, age, and education are the significant predictors of the second-level digital divide. In characterizing the second-level digital divide, this study identified five main clusters of Internet activities; personal development, searching for and reading news content, novel, social media and interaction, and commercial activities. These clusters and the activities within them are slightly different from the findings in existing literature. Applying the UGT as a framework to establish a list of Internet activities, seven clusters were identified for users in the Netherlands [21], [87]. An earlier study using the SCT framework derived two main clusters. The number of clusters on their own doesn't provide clear insight into differences in the second-level digital divide in developed and developing countries. Examining the activities within the clusters, we found a new cluster, which we named "novel", was identified in this work. This cluster included lottery and online dating, two activities that are relatively new and stigmatized

within the society. Furthermore, there are some activities, such as downloading a music/video, participating in an online hobby, or free surfing, that were identified as key activities in earlier studies but were not loaded on a factor using data from Nigeria [21]. These findings suggest that the types of Internet activities individuals engage with in a developing country is different from those in a developed country.

The technical skill of an individual, measured using the effort expectancy UTAUT construct, is seen as a key predictor of an individual's intention to increase the use of the Internet. However, the effect of an individual's intent to increase the use of the Internet on actual use behavior is only seen for social activities. Therefore, this supports arguments in an earlier work that improving access to over-the-top applications, such as WhatsApp, could increase Internet use. It also raises the question, do people develop high technical skills from the engagement with social activities and then "upgrade" to other activities? Other constructs such as support from family and friends, as well as the expected benefits from using the Internet are also associated with a positive intent to use the Internet.

The socioeconomic factors that are key predictors of individual differences in the extent and pattern of Internet use in a developing country are gender, age, and education. This supports earlier findings in the literature on the determinants of the second-level digital divide in a developed country. In this paper, the findings show that women have higher use of the Internet for social interaction activities such as using social networks or communicating with family and friends. On the other hand, males use the Internet more for traditionally economic activities like job search and application, online learning. For all clusters of Internet activities, age is negatively correlated with the frequency of use. Not surprisingly, the effect of age is largest for personal development activities such as searching for/applying to jobs or actively engaging in online

trainings. Older people are more likely to have a stable job and therefore less likely to engage in job search or professional training activities. The results also indicate that individuals with a higher educational qualification generally have a higher frequency of use for Internet activities in the development, news, and business clusters. The largest impact of the effect of education on differences in frequency of use is seen in the cluster of personal development activities, supporting findings in existing literature [21].

These results suggest that the second-level digital divide in developing countries is an indication of other socioeconomic inequalities that exist in the society. For example, the results suggest that lower educated people have a higher intent to increase their Internet use. However, they typically have lower technical skills and wouldn't be able to use a wide range of Internet services. Similarly, males have a digital advantage over females; they have a higher likelihood of ownership of a mobile device than females which could be a driver of differences in technical skills across genders. Furthermore, women in developing countries are typically economically disadvantaged i.e. they are more likely to be homemakers or a small business owner. This could be an explanation for the findings that females use the Internet for personal development less frequently than males.

The results show that education and the frequency of use of different types of Internet activities are significant predictors of the third-level digital divide. In this study, four main clusters of Internet outcomes are identified; personal development, health information, political engagement, and commercial transaction. Individuals with at least a bachelor's degree are more likely to get positive health outcomes from the Internet. However, they are less likely to get personal development outcomes such as getting a job or completing an online training. This could be because the more educated people may have steadier jobs compared to the less educated

people, therefore they did not use the Internet to search for a job. In addition, the limited economic opportunities in Nigeria could be an explanation for the results. Nigeria has a high unemployment rate of 23%. This high job scarcity, coupled with the method of job search/application (online or hardcopy) could mean using the Internet will not result in positive outcomes. The results suggest that individuals with a higher level of education benefit more from the Internet in political and commercial transaction outcomes. This differs slightly from existing literature which suggests that individuals with a higher level of education benefit more from the Internet than individuals without a higher level of education in development and government engagement [33]. Other demographic factors have less impact on the outcomes from Internet use. The results suggest that in general, older people are less likely to get personal development benefits from the Internet while the middle-aged users are most likely to get health and political outcomes from the Internet.

The results indicate that Internet use patterns have significant effect on outcomes from Internet use. Using the Internet for social activities such as using social networks and communicating with family and friends have the greatest impact on offline outcomes. Individuals that engage with these activities more frequently benefit more from the Internet in development and health outcomes. While development and political outcomes are seen in individuals that engage with development and news activities respectively.

4.5.2 Policy Implications

Reducing the digital divide remains a key policy objective in Nigeria and SSA. This policy is expected to drive inclusion and economic development in the region. However, the results show that improving access to the Internet alone will not lead to equitable use or economically beneficial outcomes.

To bridge these digital divides, policies that target the digitally vulnerable population – low educated and female populations – are recommended. It is plausible that the digital divide among socioeconomic groups is as a result of preexisting societal inequalities. Therefore, sustainable policies to close the second-level digital divide would also need to consider addressing these systematic inequalities. In particular, this work shows that the gender digital divide persists in the second-level digital divide and this could have implications on the expected benefits from Internet use, with females remaining disadvantaged. Therefore, policies that increase females' use of the Internet for economic opportunities are recommended. For example, policies to increase awareness on different personal development activities such as the accessibility of free online courses.

Drawing on the UTAUT constructs, effort expectancy, social influence, and performance expectancy are major predictors of intent to increase Internet use. However, behavioral intention is positively correlated only with a high use of the Internet for social activities. This suggest that social activities could be a tool used to increase Internet use. And, as with most technologies, frequent engagement with the Internet through social activities could lead to an increase in technical skills, and in turn an increased engagement with a wide range of activities. More specifically, creating opportunities for the digitally vulnerable population to develop their technical skills is recommended. These policies could utilize the effect of support from family and friends on Internet use by creating peer networks to drive the development of the required technical skills. For example, encouraging the development of applications that require limited technical skills to provide initial access to online services and as stepping stones to more advanced services.

4.5.3 Limitations and Future Research

This is an exploratory research that successfully highlighted differences in the conceptualization of the second and third levels of the digital divide in a developing country compared to a developed country. Other works have studied a population with uniform adoption rates and use. This work extended the literature by investigating the main effects of socioeconomic factors and use patterns on the third-level digital divide. However, given that socioeconomic factors have an effect on individual use patterns, future work could include the interaction effects between the socioeconomic factors and individual use patterns.

Second, in this work, we applied limited measures from the UTAUT model in investigating differences in Internet use patterns and found limited effects. Future work could include multiple measures in each construct in the UTAUT model and then perform a robust analysis on the effects of the UTAUT constructs on the second-level digital divide.

4.6 Conclusion

In Sub-Saharan Africa, the Internet has been identified as a tool to overcome poverty; by improving communication, facilitating innovation, and driving economic growth. In recent years, Internet adoption and use in SSA increased significantly. Through the transformation of key sectors such as education, healthcare, and retail, this increase in Internet use is estimated to account for a 94% growth in the contribution of the Internet to the annual GDP in SSA ($300 billion) by 2025. However, as seen in studies on the benefits of Internet adoption and use in other regions, the welfare effect of technology is not only based on its adoption, but also from the type of use.

In this paper, using Nigeria as a case study and drawing on both the Uses and Gratifications Theory and factor analysis, the key clusters of Internet activities and Internet outcomes were identified. The effect of socioeconomic factors and the previously established Unified Theory of Acceptance and Use of Technology (UTAUT) constructs on the differences in the extent of Internet use and types of Internet outcomes were then investigated. The results showed that gender, age, and education are key predictors of individual differences in the extent and pattern of Internet use in a developing country. The results also suggested that the second-level digital divide in developing countries mirrors other socioeconomic inequalities that exist in the society. Individual outcomes from Internet use are determined by the individual's education and the frequency of use of different types of Internet activities.

To bridge the second and third levels of the digital divides, policies that target the digitally vulnerable population – low educated and female populations – are recommended. For example, policies to increase awareness among females on different personal development activities such as the accessibility of free online courses. Technical skills are a major predictor of Internet use. The digitally vulnerable population are also more likely to have low technical skills. Creating opportunities, either through trainings or peer networks, for this population to develop their technical skills is recommended. In addition, encouraging the development of relevant applications that require limited technical skills would provide the digitally vulnerable population to have initial access to online services and use as stepping stones to more advanced services.

The main contributions of this paper are: this work applied the UGT and factor analysis in conceptualizing the second and third-levels of the digital divide in a developing country. Second, this paper extended the application of the UTAUT model in studying the differences in the extent

and pattern of Internet use. Third, in this work, the relationship between Internet use patterns and Internet outcomes in a developing country was investigated.

This research can be extended by testing the model with a larger sample from a different SSA country. This work showed that Internet use patterns are affected by socioeconomic factors. Using a larger sample size, future work could analyze the interaction effects between the socioeconomic factors and individual use patterns. In addition, this work can be extended by using more measures from the UTAUT model to perform a robust analysis on the effects of the UTAUT constructs on the second-level digital divide.

5. Conclusion

This thesis characterizes the digital divide in a developing country and provides a critical look at the factors that affect the three levels of the divide: access and adoption (the first-level digital divide), extent and pattern of use (the second-level digital divide), and benefit from use (the third-level digital divide). In this thesis, driven by changes in the mobile industry and drawing on the UTAUT, I proposed and applied new methods to understanding the digital divide in a developing country. I examined the effect of access to over-the-top services on the first-level digital divide to provide insight on regulatory policies that could be implemented on these, majorly, unregulated services. I also studied the impact of a reduction in prices of mobile Internet plans on the second-level digital divide. And finally, I investigated the factors that drive both the second and third levels of the digital divide.

In Chapters 2 and 3, I proposed that studies on the digital divide in SSA should examine the digital divide of the Internet in the context of the digital divide in the use of other mobile services such as cellular calling and text messaging.

By applying this approach in Chapter 2, I examined the impact of access to OTT services on users' preferences for traditional mobile services such as cellular calling and text messaging. I found that access to OTT reduces the probability of an individual not using any mobile service (bridges the first-level digital divide). I also find that access to OTT reduces the probability of using a traditional mobile service such as cellular calls and text (suggesting a shift in use of digital technologies). In explaining this impact of OTTs on preferences for mobile services, I found that affordability and the business model in place are the most important determinants. Mobile users in this market are price sensitive, and the first-level digital divide in a mobile

market operating the pay-as-you-go business model is more likely to be impacted by access to OTT services.

In Chapter 3, I examined the effect of a reduction in the prices of mobile Internet plans on the volume of use of the Internet, cellular calls, and text messaging (the second-level digital divide). Affordability has been identified as a key barrier exacerbating the first-level (differences in adoption) and second-level (differences in use patterns) of the digital divide in developing countries. In Nigeria, where approximately 50% of the population live in extreme poverty, addressing the affordability barrier could significantly address these levels of the digital divide. From this study, I found that a reduction in the prices of mobile Internet plans is associated with an increase in the volume of data consumed and a decrease in the volume of texts sent. The results also do not present any significant evidence that addressing the affordability barrier alone will "close" the second-level digital divide.

In Chapter 4, I investigated the differences in the extent and pattern of Internet use as well as the differences in the outcomes from Internet use in Nigeria. Studies have shown that the welfare effect of technology is not only based on its adoption, but also from the type of use. Mobile phones have been used differently as a "leapfrogging tool" in SSA compared to other regions. I found that evidence that the use of the Internet in a developing country remains different from the use in developed countries. I also found that, similar to the drivers in a developed country, the key determinants of the second-level digital divide are gender, age, and level of education. Technical skills, encouragement from family and friends, and behavioral intention to use the Internet also affects pattern of use. I also found evidence that the welfare effect of a technology is not only dependent on the type of use, but also from the users' level of education.

Based on these findings, several policy recommendations are presented in this thesis. Based on the findings in Chapter 2, I recommend that both the national regulator and mobile carriers should support the adoption and use of OTT services by mobile users. Given that OTT access is a tool that could aid in bridging the first-level digital divide, I recommend that regulators in developing countries should dismiss calls to ban OTT services. Rather, regulators should explore policies that will improve the facilitating conditions required for OTT adoption and use (access to a compatible mobile phone and Internet access) such as driving investment in broadband technologies in underserved areas.

The findings from Chapters 2 and 3 indicate that customers' preferences in the mobile market are changing. Given that in Nigeria, and the wider SSA, the Internet is predominantly accessed via mobile phones, I recommend that mobile carriers adapt their business model in response to the changing customer preferences. Mobile carriers should consider prioritizing the provision of Internet services to their customers and using special OTT Internet plans as a tool to increase market share.

The results show that users are price sensitive, and a reduction in prices is associated with higher probability of using at least one mobile service, and associated with an increase in the volume of use of Internet services. Therefore, policies that address the affordability barrier are recommended. However, this will likely result in closing the first-level digital divide and driving the substitution effect between OTT and texting. The results from Chapter 3 do not present evidence that addressing the affordability barrier would reduce digital inequalities across any socioeconomic subgroups. This suggest that more robust policies are needed to address the second-level digital divide.

Based on the findings from Chapter 4, in order to bridge the second and third levels of the digital divide in SSA, I recommend that policymakers should develop policies that target the digitally vulnerable population: low educated and female populations. In developing these policies, the policymakers should carefully consider preexisting inequalities in society that may be driving the digital inequalities, such as gender and urban/rural inequalities with respect to economic opportunities, technical skills, and mobile phone ownership. Chapter 4 also indicates that there is a positive relationship between intent to increase use of the Internet and a high frequency of use for social activities. Therefore, policies that encourage the engagement in social activities such as using social networks or OTT applications could drive the transition from intent to use to actual usage behavior. Furthermore, engagement with these social activities could be an opportunity for individuals with low technical skills to improve their ability to use the Internet for a wide range of activities, and eventually engage with other activities.

However, in developing and implementing these policies, the policymakers need to be cognizant of individual preferences and the unmeasured effect of preferences versus disadvantaged in the use, and/or outcomes from the use of the Internet in Chapters 3 and 4 of this dissertation.

Bibliography

[1] International Telecommunication Union, "ITU_Key_2005-2016_ICT_data," *ITU-D Dataset*, 2017.

[2] K. Salemink, D. Strijker, and G. Bosworth, "Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas," *J. Rural Stud.*, vol. 54, pp. 360–371, 2017.

[3] O. Tayo, R. Thompson, and E. Thompson, "Impact of the Digital Divide on Computer Use and Internet Access on the Poor in Nigeria," *J. Educ. Learn.*, vol. 5, no. 1, p. 1, 2015.

[4] GSM Association, "The Mobile Economy: Sub-Saharan Africa 2017." GSMA Intelligence, pp. 1–52, 2017.

[5] A. Scheerder, A. Van Deursen, and J. Van Dijk, "Determinants of Internet skills, uses and outcomes. A systematic review of the second- and third-level digital divide," *Telemat. Informatics*, vol. 34, pp. 1607–1624, 2017.

[6] J. R. Schneir and Y. Xiong, "A cost study of fixed broadband access networks for rural areas," *Telecomm. Policy*, vol. 40, pp. 755–773, 2016.

[7] A. Chaudhuri, K. S. Flamm, and J. Horrigan, "An analysis of the determinants of internet access," *Telecomm. Policy*, vol. 29, pp. 731–755, 2005.

[8] A. J. A. M. Van Deursen, J. A. G. M. Van Dijk, and O. Peters, "Rethinking Internet skills: The contribution of gender, age, education, Internet experience, and hours online to medium- and content-related Internet skills," *Poetics*, vol. 39, pp. 125–144, 2011.

[9] T. Penard, N. Poussing, and G. Z. Yebe, "Comparing the Determinants of Internet and Cell Phone Use in Africa: Evidence from Gabon," *Digiworld Econ. J.*, vol. 2, no. 86, 2012.

[10] B. Bimber, "Measuring the Gender Gap on the Internet.," *Soc. Sci. Q.*, vol. 81, no. 3,

2000.

[11] J. Mariscal, “Digital divide in a developing country,” *Telecomm. Policy*, vol. 29, pp. 409–428, 2005.

[12] X. Zhang, “Exploring the patterns and determinants of the global mobile divide,” *Telemat. Informatics*, vol. 34, no. 1, pp. 438–449, 2017.

[13] D. Riddlesden and A. D. Singleton, “Broadband speed equity: A new digital divide?,” *Appl. Geogr.*, vol. 52, pp. 25–33, 2014.

[14] F. Williams, L. Philip, J. Farrington, and G. Fairhurst, “‘Digital by Default’ and the ‘hard to reach’: Exploring solutions to digital exclusion in remote rural areas,” *Local Econ.*, vol. 31, no. 7, pp. 757–777, 2016.

[15] E. Ogbo, T. Brown, and D. Sicker, “Is Broadband Speed a Barrier to Internet Use in Rural Communities? An Assessment of Mobile Infrastructure and Internet Use Habits in Urban and Rural Nigeria.”

[16] S. Park, “Digital inequalities in rural Australia: A double jeopardy of remoteness and social exclusion,” *J. Rural Stud.*, vol. 54, pp. 399–407, 2017.

[17] L. A. Dickes, R. D. Lamie, and B. E. Whitacre, “The Struggle for Broadband in Rural America,” *Choices*, vol. 25, no. 4, 2010.

[18] M. Büchi, N. Just, and M. Latzer, “Modeling the second-level digital divide: A five-country study of social differences in Internet use,” *New Media Soc.*, vol. 18, no. 11, pp. 2703–2722, 2016.

[19] B. Oyelaran-Oyeyinka and K. Lal, “Internet diffusion in sub-Saharan Africa: A cross-country analysis,” *Telecomm. Policy*, vol. 29, pp. 507–527, 2005.

[20] N. P. Howard, L. Busch, and P. Sheets, “Comparing Digital Divides: Internet Access and Social Inequality in Canada and the United States,” *Can. J. Commun.*, vol. 35, no. 1, pp. 109–128, Feb. 2010.

[21] A. Jam Van Deursen and J. Agm Van Dijk, “The digital divide shifts to differences in usage,” *New Media Soc.*, vol. 16, no. 3, pp. 507–526, 2014.

[22] M. Hasbi and A. Dubus, “Determinants of Mobile Broadband Use in Developing Economies: Evidence from Sub-Saharan Africa,” 2019.

[23] B. Bimber, “Measuring the Gender Gap on the Internet.: EBSCOhost,” *Soc. Sci. Q.*, vol. 81, no. 3, 2000.

[24] H. Akca, M. Sayili, and K. Esengun, “Challenge of rural people to reduce digital divide in the globalized world: Theory and practice,” *Gov. Inf. Q.*, vol. 24, pp. 404–413, 2007.

[25] R. E. Rice and J. E. Katz, “Comparing internet and mobile phone usage: digital divides of usage, adoption, and dropouts,” *Telecomm. Policy*, vol. 27, pp. 597–623, 2003.

[26] M. Hilbert, “Digital gender divide or technologically empowered women in developing countries? A typical case of lies, damned lies, and statistics ☆,” *Womens. Stud. Int. Forum*, vol. 34, pp. 479–489, 2011.

[27] R. Larose, J. L. Gregg, S. Strover, J. Straubhaar, and S. Carpenter, “Closing the rural broadband gap: Promoting adoption of the Internet in rural America,” *Telecomm. Policy*, vol. 31, pp. 359–373, 2007.

[28] M. Hilbert, “The bad news is that the digital access divide is here to stay: Domestically installed bandwidths among 172 countries for 1986–2014,” *Telecomm. Policy*, vol. 40, pp. 567–581, 2016.

[29] P. Dimaggio and E. Hargittai, “Working Paper Series, 15 From the ‘Digital Divide’ to ‘Digital Inequality’: Studying Internet Use as Penetration Increases,” *Princet. Cent. Arts Cult. Policy Stud. Work. Pap. 15*, 2001.

[30] M. R. Vicente and F. Gil-de-Bernabé, “Assessing the broadband gap: From the penetration divide to the quality divide,” *Technol. Forecast. Soc. Change*, vol. 77, no. 5, pp. 816–822, 2010.

[31] C. Jeffcoat, A. F. Davis, and W. Hu, “Willingness to Pay for Broadband Access by Kentucky Farmers,” *J. Agric. Appl. Econ.*, vol. 44, no. 3, pp. 323–334, 2012.

[32] E. Ogbo, T. Brown, and D. Sicker, “Understanding Mobile Service Substitution and the Urban-Rural Digital Divide in Nigeria,” in *TPRC45*, 2017.

[33] A. J. A. M. Van Deursen and E. J. Helsper, “The Third-Level Digital Divide: Who Benefits Most from being Online?,” in *Communication and Information Technologies Annual (Studies in Media and Communications)*, vol. 10, 2015, pp. 29–52.

[34] A. Jam, V. Deursen, and E. J. Helsper, “Collateral benefits of Internet use: Explaining the diverse outcomes of engaging with the Internet,” *New J. Phys.*, vol. 20, no. 7, pp. 2333–2351, 2018.

[35] International Telecommunication Union, “Fixed Telephone Statistics 2000-2016,” *ITU-D Dataset*, 2017.

[36] Nigerian Communications Commission, “Industry Statistics,” *NCC Website*, 2018.

[37] GSMA, “The Mobile Economy,” *GSMA Intell.*, 2018.

[38] International Telecommunication Union, “Nigeria Profile,” *ITU Ctry. Profile Rep.*, 2017.

[39] National Bureau of Statistics, “Telecoms Data : Active Voice and Internet per State, Porting and Tariff Information (Q4 2017),” *Niger. NBS*, no. February, 2018.

[40] A. Whiting and D. Williams, “Qualitative Market Research: An International Journal Why people use social media: a uses and gratifications approach Article information,” *Qual. Mark. Res. An Int. J.*, vol. 16, no. 4, pp. 362–369, 2013.

[41] F. Castellacci and V. Tveito, “Internet use and well-being: A survey and a theoretical framework,” *Res. Policy*, vol. 47, no. 1, pp. 308–325, Feb. 2018.

[42] International Telecommunication Union, “Individuals_Internet_2000-2016,” *ITU-D Dataset*, 2017.

[43] GSMA Intelligence, “The Mobile Economy,” 2016. [Online]. Available: https://www.gsmaintelligence.com/research/?file=97928efe09cdba2864cdcf1ad1a2f58c&download. [Accessed: 23-Aug-2016].

[44] T. J. Gerpott, S. Thomas, and M. Weichert, “Usage of established and novel mobile communication services: Substitutional, independent or complementary? An empirical study of residential mobile network operator customers in Germany,” *Inf. Syst. Front.*, vol. 16, no. 3, pp. 491–507, 2014.

[45] T. J. Gerpott and P. Meinert, “The impact of mobile Internet usage on mobile voice calling behavior: A two-level analysis of residential mobile communications customers in Germany,” *Telecomm. Policy*, vol. 40, pp. 62–76, 2016.

[46] T. J. Gerpott, “Impacts of mobile Internet use intensity on the demand for SMS and voice services of mobile network operators: An empirical multi-method study of German mobile Internet customers,” *Telecomm. Policy*, vol. 34, no. 8, pp. 430–443, 2010.

[47] T. J. Gerpott, “"SMS use intensity changes in the age of ubiquitous mobile Internet access“ A two-level investigation of residential mobile communications customers in Germany,” *Telemat. Informatics*, vol. 32, pp. 809–822, 2015.

[48] T. J. Gerpott, S. May, and G. Nas, “The impact of mobile Internet on mobile voice usage: A two-level analysis of mobile communications customers in a GCC country,” *Inf. Manag.*, 2017.

[49] S. T. Abu and M. Tsuji, “The Determinants of the Global Mobile Telephone Deployment: An Empirical Analysis.,” *Inform. Econ.*, vol. 14, no. 3, pp. 21–33, 2010.

[50] M. R. J. Lange and A. Saric, “Substitution between fixed, mobile, and voice over IP telephony – Evidence from the European Union,” *Telecomm. Policy*, vol. 40, pp. 1007–1019, 2016.

[51] G. Cecere and N. Corrocher, “The usage of VoIP services and other communication services: An empirical analysis of Italian consumers,” *Technol. Forecast. Soc. Chang.*, vol. 79, pp. 570–578, 2012.

[52] T. Penard, N. Poussing, B. Mukoko, G. Bertrand, and T. Piaptie, “Internet adoption and usage patterns in Africa: Evidence from Cameroon,” *Technol. Soc.*, vol. 42, pp. 71–80, 2015.

[53] D. H. Shin, “What makes consumers use VoIP over mobile phones? Free riding or consumerization of new service,” *Telecomm. Policy*, vol. 36, no. 4, pp. 311–323, 2012.

[54] S. Nikou, H. Bouwman, and M. De Reuver, “The potential of converged mobile telecommunication services: a conjoint analysis,” *Info*, vol. 14, no. 5, pp. 21–35, 2012.

[55] International Telecommunication Union, “Fixed_broadband_2000-2016,” *ITU-D Dataset*, 2017.

[56] Nigerian Communications Commission, “Industry Statistics,” *NCC Website*, 2017.

[57] International Telecommunication Union, “Mobile_cellular_2000-2016-2,” *ITU-D Dataset*, 2017.

[58] National Bureau of Statistics, “Nigerian Telecommunications Sector Q1 2016 (Summary Report): State Disaggregated Data,” 2016. [Online]. Available: http://www.nigerianstat.gov.ng/report/402. [Accessed: 08-Dec-2016].

[59] B. Guitton, “African Mobile Trends 2016.” JUMIA, 2016.

[60] O. E. Ani, U. Chika, and U. Atseye, Emmanuel, “Bridging the digital divide in Nigeria: a study of internet use in Calabar Metropolis, Nigeria,” *Libr. Manag.*, vol. 28, no. 6/7, pp. 355–365, 2007.

[61] B. Oyelaran-Oyeyinka and C. N. Adeya, “Internet access in Africa: empirical evidence from Kenya and Nigeria,” *Telemat. Informatics*, vol. 21, pp. 67–81, 2004.

[62] L. Silver and C. Johnson, “Internet Connectivity Seen as Having Positive Impact on Life in Sub-Saharan Africa,” Pew Research Center, 2018.

[63] G. Goncalves, T. Oliveira, and F. Cruz-Jesus, “Understanding individual-level digital divide: Evidence of an African country,” *Comput. Human Behav.*, vol. 87, pp. 276–291,

Oct. 2018.

[64] GSMA, “Digital inclusion and the role of mobile in Nigeria,” *GSMA Annual Report*. 2015.

[65] J. Louviere, “Conjoint Analysis Modeling of Stated Preferences: A Review of Theory, Methods, Recent Developments and External Validity,” *J. Transp. Econ. Policy*, vol. 10, pp. 93–119, 1988.

[66] D. L. McFadden, “Economic Choices,” *Am. Econ. Rev.*, vol. 91, no. 3, pp. 351–378, 2001.

[67] D. Hensher, J. Louviere, and J. Swait, *Stated Choice Methods: Analysis and Applications*. Cambridge University Press, 2000.

[68] O. Toubia, J. R. Hauser, and D. I. Simester, “Polyhedral Methods for Adaptive Choice-Based Conjoint Analysis,” *J. Mark. Res.*, vol. 41, no. 1, pp. 116–131, 2004.

[69] J. J. Louviere, T. N. Flynn, and R. T. Carson, “Discrete Choice Experiments Are Not Conjoint Analysis,” *J. Choice Model.*, vol. 3, no. 33, pp. 57–72, 2010.

[70] Y. Pu and J. Grossklags, “Using Conjoint Analysis to Investigate the Value of Interdependent Privacy in Social App Adoption Scenarios,” in *ICIS*, 2015.

[71] M. Ueda, “An Analysis on Smartphone Adoption for University Students by using Choice-Based Conjoint Analysis,” in *MISNC*, 2016.

[72] Y. Kim, “Estimation of consumer preferences on new telecommunications services: IMT-2000 service in Korea,” *Inf. Econ. Policy*, vol. 17, no. 1, pp. 73–84, 2005.

[73] National Population Commission, “Censuses,” 2006. [Online]. Available: http://www.population.gov.ng/index.php/censuses. [Accessed: 02-Jan-2017].

[74] R. Haaijer, W. Kamakura, and M. Wedel, “The ‘no-choice’ alternative in conjoint choice experiments,” *Int. J. Mark. Res.*, vol. 43, no. 1, pp. 93–106, 2001.

[75] D. Mcfadden, “Modeling the Choice of Residential Location,” *Transp. Res. Rec.*, vol. 673,

1978.

[76] Y. Croissant, “Estimation of multinomial logit models in R : The mlogit Packages,” *R package version 0.2-2*, 2012. [Online]. Available: https://cran.r-project.org/web/packages/mlogit/vignettes/mlogit.pdf. [Accessed: 01-Jan-2017].

[77] A. Daly, S. Hess, and K. Train, “Assuring finite moments for willingness to pay in random coefficient models,” *Transportation (Amst).*, vol. 39, no. 1, pp. 19–31, 2012.

[78] P. Armstrong, R. Garrido, and J. de D. Ortuzar, “Confidence intervals to bound the value of time,” *Transp. Res. Part E*, vol. 37, pp. 143–161, 2001.

[79] C. Srinuan, P. Srinuan, and E. Bohlin, “An analysis of mobile Internet access in Thailand: Implications for bridging the digital divide,” *Telemat. Informatics*, vol. 29, pp. 254–262, 2012.

[80] B. Orme and J. Howell, “Application of Covariates Within Sawtooth Software’s CBC/HB Program: Theory and Practical Example,” 2009.

[81] Internet World Stats, “Internet Users Statistics for Africa.” [Online]. Available: http://www.internetworldstats.com/stats1.htm. [Accessed: 29-Jun-2017].

[82] GSMA, “The Mobile Economy: Africa 2016,” GSMA Intelligence, 2016.

[83] J. Aker and I. Mbiti, “Mobile phones and economic development in Africa,” *Cent. Glob. Dev. Work. Pap.*, 2010.

[84] P. M. Napoli and J. A. Obar, “Mobile Leapfrogging and Digital Divide Policy: Assessing the limitations of mobile Internet access,” New America Foundation: Open Technology Institute (pp. 1–20), Washington, 2013.

[85] L. Bachan, C. Cobb, A. Fiore, M. Lieskovsky, and L. Paris, “Internet Access , Usage , and Aspirations : A Case Study from Nigeria,” 2015.

[86] Ericsson, “Ericsson Mobility Report:On the pulse of the networked society,” 2014. [Online]. Available: https://www.ericsson.com/assets/local/mobility-

report/documents/2014/ericsson-mobility-report-november-2014.pdf. [Accessed: 23-Aug-2016].

[87] A. J. A. M. Van Deursen, J. A. G. M. Van Dijk, and P. M. Ten Klooster, "Increasing inequalities in what we do online: A longitudinal cross sectional analysis of Internet activities among the Dutch population (2010 to 2013) over gender, age, education, and income," *Telemat. Informatics*, vol. 32, no. 2, pp. 259–272, 2015.

[88] C. Harris, L. Straker, and C. Pollock, "A socioeconomic related 'digital divide' exists in how, not if, young people use computers," *PLoS One*, vol. 12, no. 3, 2017.

[89] M. Kende, "Promoting Content In Africa," Internet Society, 2016.

[90] T. R. Roycroft and S. Anantho, "Internet subscription in Africa: policy for a dual digital divide," *Telecomm. Policy*, vol. 27, pp. 61–74, 2003.

[91] O. Birba and A. Diagne, "Determinants of adoption of Internet in Africa: Case of 17 sub-Saharan countries," *Struct. Chang. Econ. Dyn.*, vol. 23, pp. 463–472, 2012.

[92] P. Buys, S. Dasgupta, T. S. Thomas, and D. Wheeler, "Determinants of a Digital Divide in Sub-Saharan Africa: A Spatial Econometric Analysis of Cell Phone Coverage," *World Dev.*, vol. 37, no. 9, pp. 1494–1505, 2009.

[93] B. Mukoko, "Determinants of Computer and Internet Adoption and Use in Cameroon," *African Rev. Econ. Financ.*, vol. 3, no. 2, pp. 96–128, 2012.

[94] B. A. Lucini, "Consumer barriers to mobile internet adoption in Africa," GSMA Intelligence, 2016.

[95] C. Deuskar, "What does 'urban' mean?," *WorldBank Sustainable Cities Blog*, 2015. [Online]. Available: http://blogs.worldbank.org/sustainablecities/what-does-urban-mean. [Accessed: 10-Aug-2017].

[96] R. C. . Arnold, A. Schneider, and C. Hildebrandt, "All communications services are not created equal – Substitution of OTT communications services for ECS from a consumer

perspective," in *TPRC44*, 2016, vol. 49, no. 0.

[97] C. Stork, S. Esselaar, and C. Chair, "OTT - Threat or opportunity for African Telcos?," 2017.

[98] GSMA, "The Mobile Economy. Sub-Saharan Africa," GSMA Intelligence, 2019.

[99] McKinsey Global Institute, "Lions go digital: The Internet's transformative potential in Africa," McKinsey & Company, 2013.

[100] J. James, "Patterns of Mobile Phone Use in Developing Countries: Evidence from Africa," *Soc. Indic. Res.*, pp. 1–18, 2013.

[101] F. H. Ashmore, J. H. Farrington, and S. Skerratt, "Superfast Broadband and Rural Community Resilience: Examining the Rural Need for Speed," *Scottish Geogr. J.*, vol. 131, no. 3–4, pp. 265–278, 2015.

[102] R. Larose and M. S. Eastin, "A Social Cognitive Theory of Internet Use and Gratifications: Toward a New Model of Media Attendance," *J. Broadcast. Electron. Media*, vol. 48, no. 3, pp. 358–377, 2004.

[103] R. Larose, D. Mastro, and M. S. Eastin, "Understanding Internet Usage A Social-Cognitive Approach to Uses and Gratifications," *Soc. Sci. Comput. Rev.*, vol. 19, no. 4, pp. 395–413, 2001.

[104] K.-K. Wei, H.-H. Teo, C. Chan, and B. C. Y. Tan, "Conceptualizing and Testing a Social Cognitive Model of the Digital Divide," *Inf. Syst. Res.*, vol. 22, no. 1, pp. 170–187, 2011.

[105] V. Kalmus, A. Realo, and A. Siibak, "Motives for Internet use and their relationships with personality traits and socio-demographic factors," *TRAMES*, vol. 15, no. 4, pp. 385–403, 2011.

[106] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User Acceptance of Information Technology: Toward a Unified View," 2003.

[107] P. J. B. Tan, "Applying the UTAUT to understand factors affecting the use of english e-

learning websites in Taiwan," *SAGE Open*, vol. 3, no. 4, 2013.

[108] S. N. Attuquayefio and H. Addo, "Using the UTAUT model to analyze students ' ICT adoption," *Intenational J. Eucation Dev. Using Inf. Commun. Technol.*, vol. 10, no. 3, pp. 75–86, 2014.

[109] H. Bouwman, C. Carlsson, F. J. Molina-Castillo, and P. Walden, "Barriers and drivers in the adoption of current and future mobile services in Finland," *Telemat. Informatics*, vol. 24, no. 2, pp. 145–160, 2007.

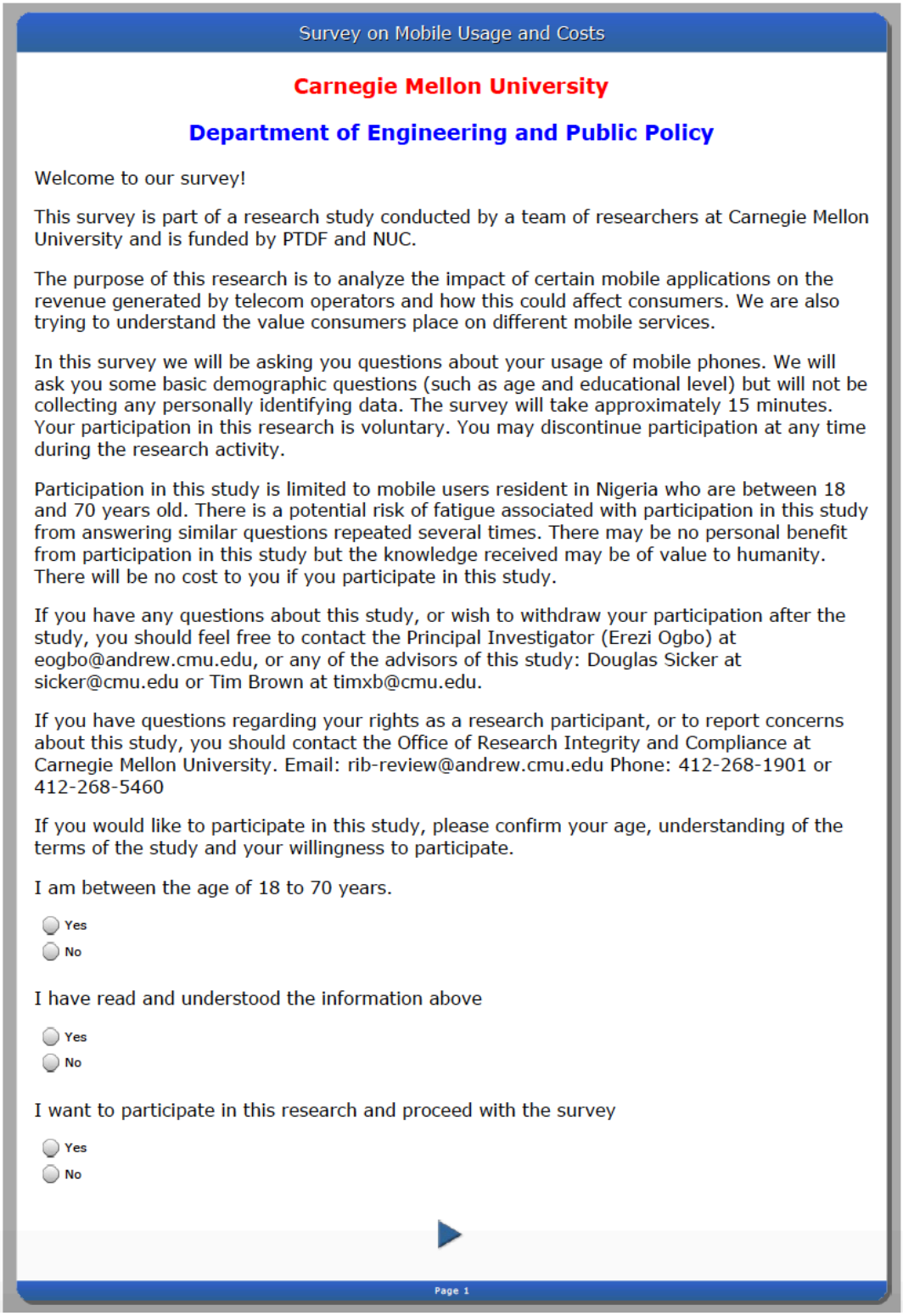
[110] Federal Communications Commission, "Connecting America: The national broadband plan," *Fed. Commun. Comm. Rep.*, 2011.

[111] T. Bresnahan, F. and M. Trajtenberg, "General Purpose Technologies: Engines of Growth?," National Bureau of Economic Research, 1992.

[112] S. Greenstein and R. McDevitt, C., "The Broadband Bonus: Accounting for Broadband Internet's Impact on U.S. GDP," National Bureau of Economic Research, 2009.

Appendix A: Supplementary Information for Chapter 2

Sample Survey Instrument



Survey on Mobile Usage and Costs

Carnegie Mellon University

Department of Engineering and Public Policy

Welcome to our survey!

This survey is part of a research study conducted by a team of researchers at Carnegie Mellon University and is funded by PTDF and NUC.

The purpose of this research is to analyze the impact of certain mobile applications on the revenue generated by telecom operators and how this could affect consumers. We are also trying to understand the value consumers place on different mobile services.

In this survey we will be asking you questions about your usage of mobile phones. We will ask you some basic demographic questions (such as age and educational level) but will not be collecting any personally identifying data. The survey will take approximately 15 minutes. Your participation in this research is voluntary. You may discontinue participation at any time during the research activity.

Participation in this study is limited to mobile users resident in Nigeria who are between 18 and 70 years old. There is a potential risk of fatigue associated with participation in this study from answering similar questions repeated several times. There may be no personal benefit from participation in this study but the knowledge received may be of value to humanity. There will be no cost to you if you participate in this study.

If you have any questions about this study, or wish to withdraw your participation after the study, you should feel free to contact the Principal Investigator (Erezi Ogbo) at eogbo@andrew.cmu.edu, or any of the advisors of this study: Douglas Sicker at sicker@cmu.edu or Tim Brown at timxb@cmu.edu.

If you have questions regarding your rights as a research participant, or to report concerns about this study, you should contact the Office of Research Integrity and Compliance at Carnegie Mellon University. Email: rib-review@andrew.cmu.edu Phone: 412-268-1901 or 412-268-5460

If you would like to participate in this study, please confirm your age, understanding of the terms of the study and your willingness to participate.

I am between the age of 18 to 70 years.

- Yes
- No

I have read and understood the information above

- Yes
- No

I want to participate in this research and proceed with the survey

- Yes
- No

Page 1

Survey on Mobile Usage and Costs

Part 1: Background Information

Recently, telecom operators in a number of developing countries have submitted proposals to ban the use of over-the-top (OTT) mobile applications ("apps"), such as WhatsApp, Skype and Viber on their networks. There are concerns that these apps have resulted in a decrease in the revenue generated by the operators. Each operator and country has the flexibility to implement restrictions or pricing on the provision of mobile Internet in different ways.

We are going to show you a series of choices between different **assumed mobile plans.** In each case, we will ask you to choose the plan that you would prefer for **yourself.** The goal is to learn what mobile services you value the most.

Before continuing with the survey, please tell us what mobile network you use primarily:

- AIRTEL
- ETISALAT
- GLO
- MTN

Based on the information previously provided, what are the answers to the following questions?

	True	False
WhatsApp, Skype, Viber, Facebook Messenger are all examples of OTT apps.		
OTT services can substitute for cellular services.		

Comparison of Cellular and OTT Services

OTT apps such as WhatsApp, Viber and 2go can subsitute for cellular services at a much cheaper rate.

For example, if you buy N100 credit on your phone, you can make either 11 minutes of cellular calls, send 25 SMS or buy data of 100MB. Using WhatsApp, 100MB would enable you make 310 minutes of call or send 25,000 messages.

Disclaimer: *This is a back-of-the-envelope calculation and the actual estimates could depend on the number of characters in the message and the settings on the application which could result in less or more data usage during a WhatsApp call.*

Part 2: Mobile Plan Choices

Now that you have gotten some background, you are ready for the choice part of the survey. You will see **14 sets of options of assumed mobile plans.** In each option, do not use information from a prior option in making your selection. **Choose the plan you prefer.**

Imagine your current mobile plan ends tomorrow and these are the new options available.

Each plan showed on the next 14 pages is made up of different services. For more information on any of the services, click on its name at the bottom of the page.

If you choose "None: I wouldn't choose any of these", this means that you would rather be without mobile service.

0% 100%

Page 2

Survey on Mobile Usage and Costs

If these were your only options for mobile services for one month, which would you choose?
Indicate with a tick in the bottom row:

(3 of 14)

Monthly price	N2,000	N8,000	
Mobile Internet	**Data bundle:** 5 GB **Speed:** slow (2G/GPRS/EDGE) **Internet access:** everything	**Data bundle:** unlimited GB **Speed:** moderate (3G) **Internet access:** everything	NONE: I wouldn't choose any of these.
Cellular calls	Unlimited minutes	300 minutes	
SMS	Unlimited SMS	Unlimited SMS	
	○	○	○

Survey on Mobile Usage and Costs

Follow up questions

Without checking your answers, for the mobile plan you chose **on the previous page...**

	More	Less	Both of them are equal	I don't know
...did the plan cost more or less than the alternatives?	○	○	○	○
...did the plan have a faster a slower speed than the alternatives?	○	○	○	○
...did the plan have more or less data bundle than the alternatives?	○	○	○	○
...did the plan have more or less minutes of cellular calls than the alternatives?	○	○	○	○
...did the plan have more or less number of SMS than the alternatives?	○	○	○	○

Is there any additional information about the plans that would have helped you make a choice? If so, please describe that information in a sentence or two.

- ○ No, the information covered what I think is important in a mobile plan
- ○ Yes, I would have like information about (specify below)

If you selected "None" for any of the choices, which most closely explains your reason?

- ○ The available options are too expensive.
- ○ I am not interested in the services offered.

Part 3: A few questions on your mobile usage

Please rate how important these functionalities on a mobile phone are to you in carrying out your daily activities.

	Very important	Important	Moderately important	Somewhat important	Not at all important
Calling (over cellular network)	○	○	○	○	○
Text messaging (SMS)	○	○	○	○	○
Browsing websites	○	○	○	○	○
Internet voice calling	○	○	○	○	○
Internet video calling	○	○	○	○	○
Checking emails	○	○	○	○	○
Instant messaging	○	○	○	○	○

0% 100%

Page 3

Survey on Mobile Usage and Costs

How important is your mobile phone to you in your daily activities?

- ○ Extremely important
- ○ Very important
- ○ Moderately important
- ○ Slightly important
- ○ Not important

On average, how much do you spend in a month (in Naira) on each of the following mobile services? (Please give your best estimate if you are not sure). How many phones does your estimate account for?

	Monthly cost	Number of phones
Mobile data		
Voice calls		
Text messaging (SMS)		
Total for all services		

How would you best characterize your mobile phone service?

- ○ A monthly bundle of data, voice and SMS
- ○ Separate monthly plans for data and for voice and SMS
- ○ A monthly plan for data and pay as you go for voice and SMS
- ○ A pay as you go or weekly plan for all services

On average, how many Gigabyte of data do you buy on your mobile phone in a month?

Please select the average Internet speed on your mobile phone (from the past 3 months)

- ○ Fast (4G)
- ○ Moderate (3G)
- ○ Slow (2G/EDGE/GPRS)

If your mobile network provider would give you free data but you could only have one application on your mobile phone, which application would you download?

Are there any details about your mobile phone service that have not been covered in this survey so far? If so, please briefly summarize them here.

0% 100%

Page 4

Part 4: A few questions about you

We are almost done with the survey. Please answer a few anonymous questions about you.

What is your gender?

- ○ Female
- ○ Male

What is your age group?

- ○ 18-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ 55-64
- ○ Over 65

What is the highest level of education you attained?

- ○ Finished primary school
- ○ Some secondary school
- ○ Finished secondary school
- ○ Some university
- ○ Finished university
- ○ Some graduate school
- ○ Finished graduate school

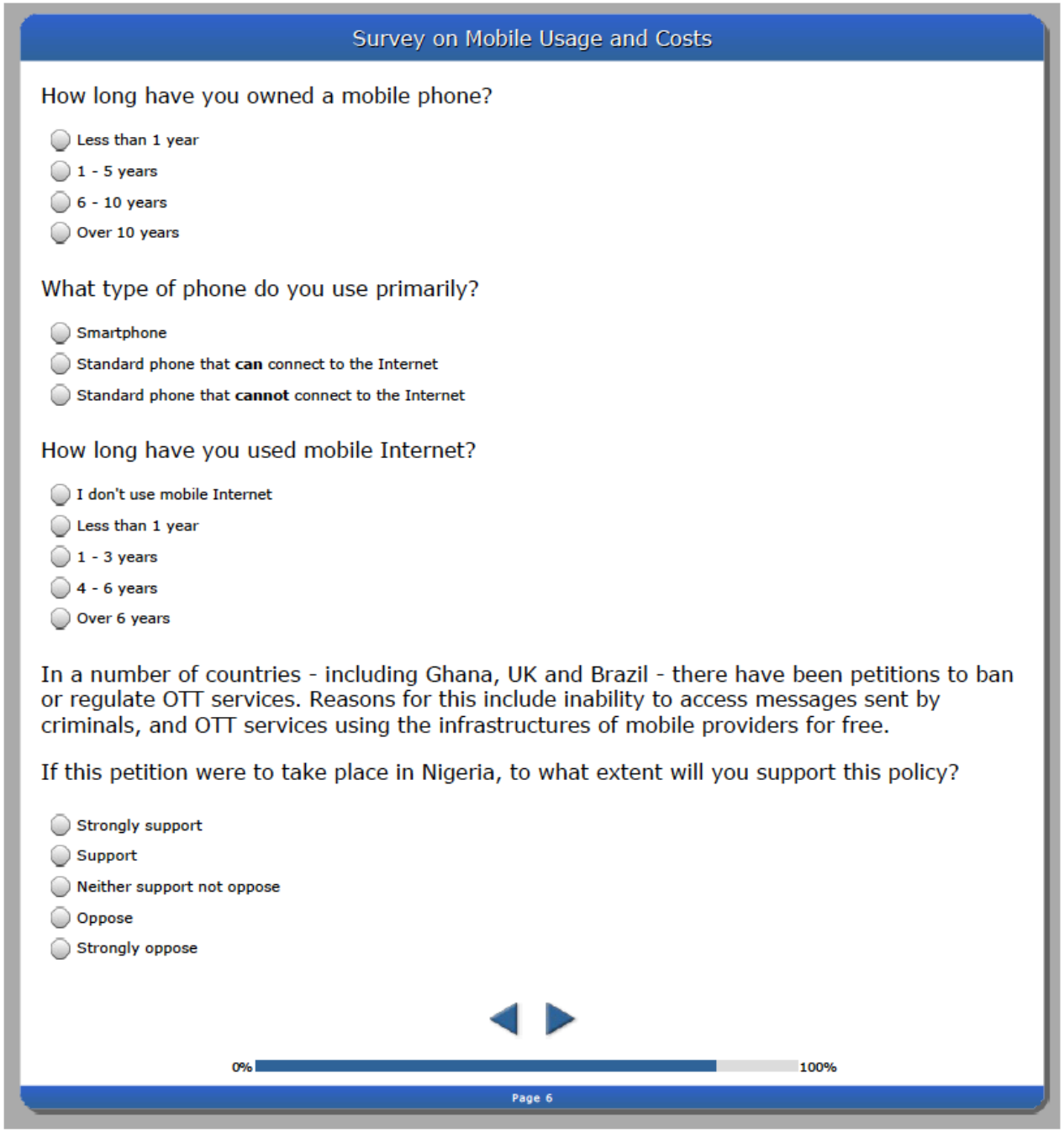
What range most closely captures your monthly income?

- ○ Less than N50,000
- ○ N50,000 - N100,000
- ○ N100,000 - N200,000
- ○ Over N200,000

What is your employment status?

- ○ Self employed
- ○ Small business employee
- ○ Large corporate employee
- ○ Non-profit employee
- ○ Government employee
- ○ Homemaker
- ○ Student
- ○ Retired
- ○ Unemployed

0% 100%


Survey on Mobile Usage and Costs
How long have you owned a mobile phone?
Less than 1 year
1 - 5 years
6 - 10 years
Over 10 years
What type of phone do you use primarily?
Smartphone
Standard phone that **can** connect to the Internet
Standard phone that **cannot** connect to the Internet
How long have you used mobile Internet?
I don't use mobile Internet
Less than 1 year
1 - 3 years
4 - 6 years
Over 6 years
In a number of countries - including Ghana, UK and Brazil - there have been petitions to ban or regulate OTT services. Reasons for this include inability to access messages sent by criminals, and OTT services using the infrastructures of mobile providers for free.
If this petition were to take place in Nigeria, to what extent will you support this policy?
Strongly support
Support
Neither support not oppose
Oppose
Strongly oppose
0%
100%
Page 6

Survey on Mobile Usage and Costs

Debrief & feedback

The survey is completed! Thank you for participating, your responses will provide valuable information to our research on the cost and usage of mobile services in developing countries.

The purpose of this study is to assess the willingness-to-pay for mobile services of a cross-section of mobile phone users.

The goal of this research is to analyze the impact of certain mobile applications on the revenue generated by mobile network operators and how this could affect consumers, mobile penetration and potential changes in the regulation of the telecommunications industry.

If you would like to withdraw your participation in this study, have further questions about the study or wish to obtain a copy of the rsults of the study, you should contact the lead researcher (Erezi Ogbo) at eogbo@andrew.cmu.edu or any of the Faculty advisors of the study; Douglas Sicker at sicker@cmu.edu or Tim Brown at timxb@cmu.edu

As stated previously, if you have questions regarding your rights as a research participant, or to report concerns about this study, you should contact the Office of Research Integrity and Compliance at Carnegie Mellon University. Email: rib-review@andrew.cmu.edu Phone: +1(412)-268-1901 or +1(412)-268-5460

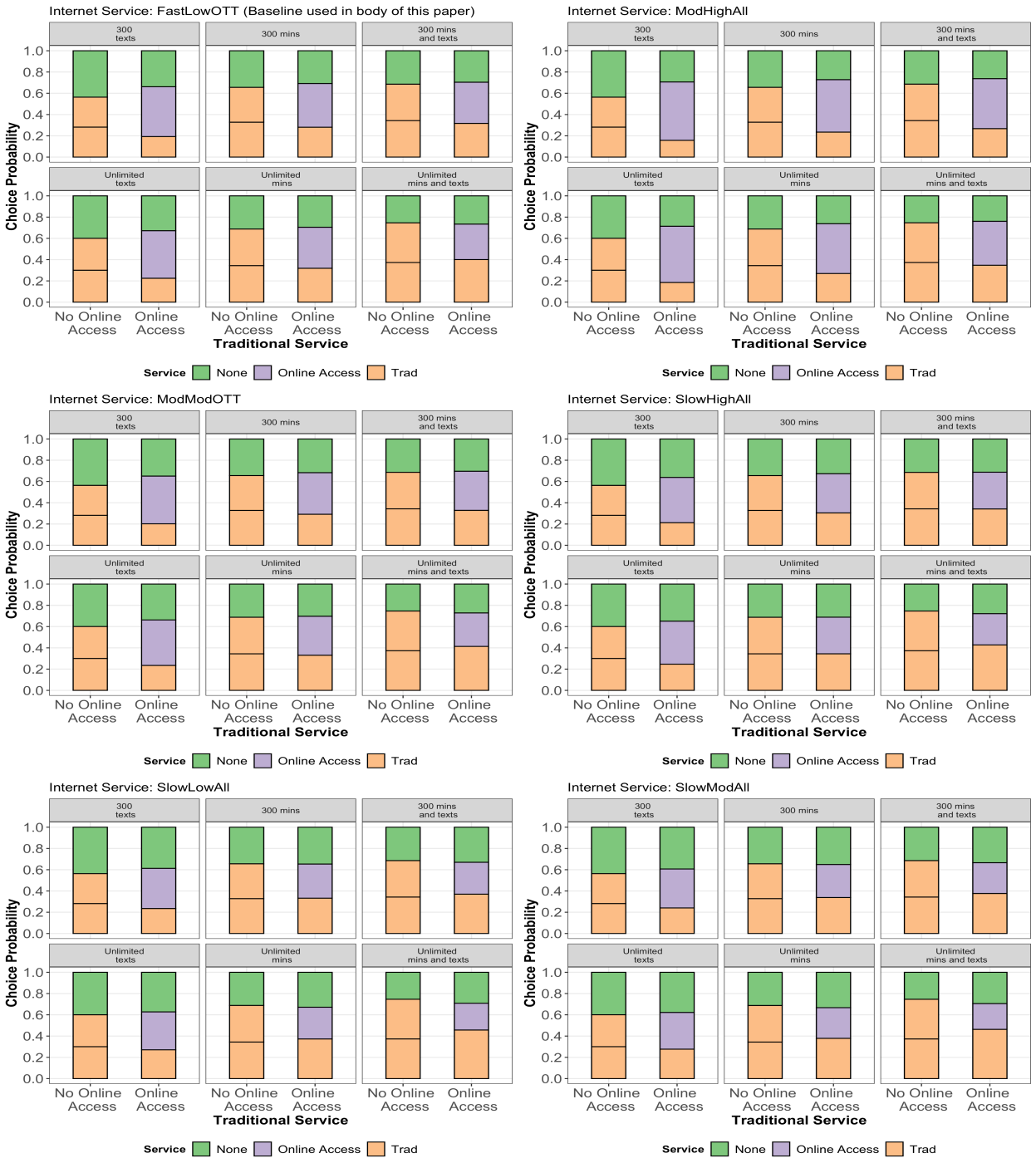


Figure 14. Comparing the impact of access to different Internet plans on preferences for traditional mobile services

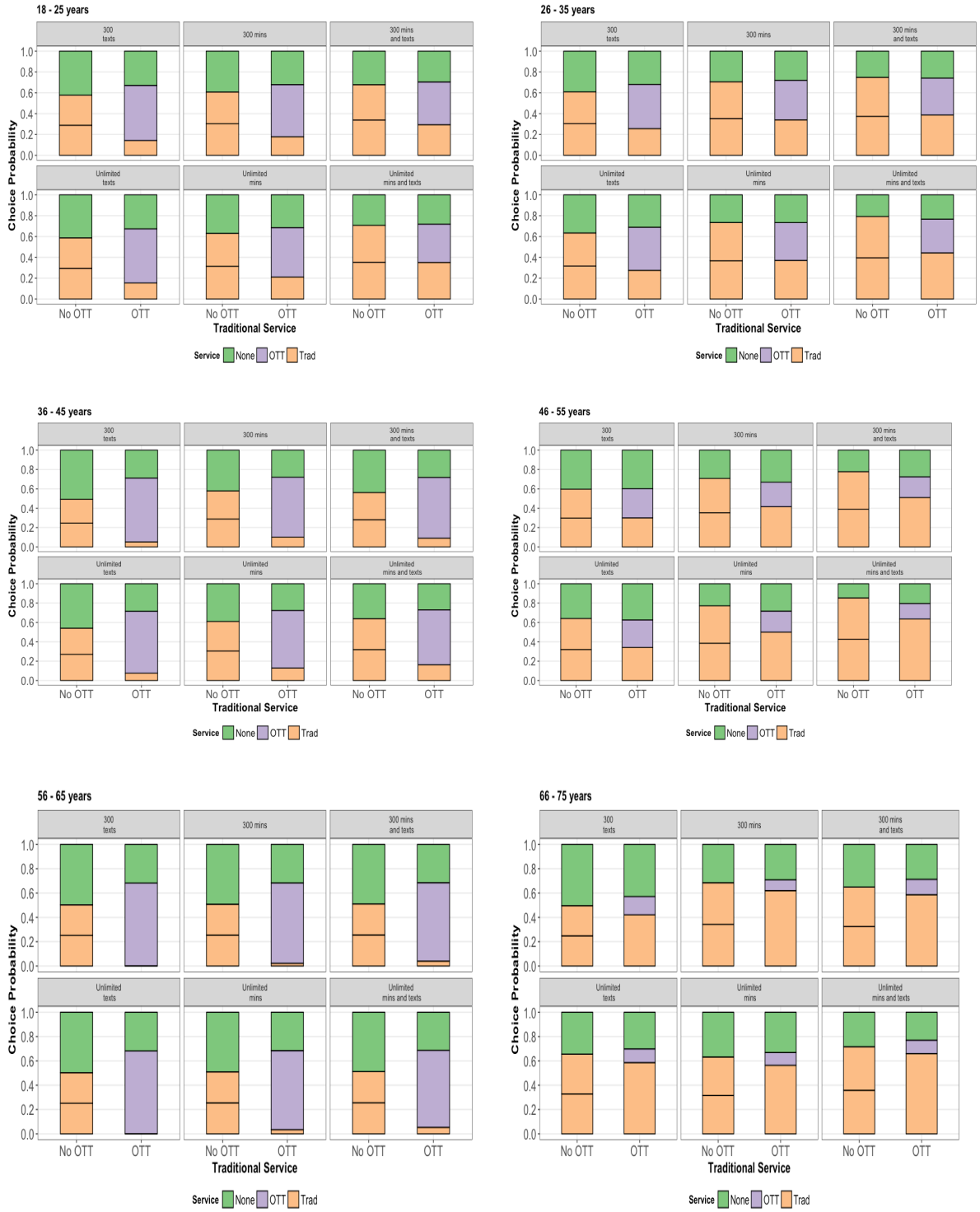


Figure 15. Comparing across different age groups, the impact of OTT on the choice probabilities of different traditional services and going with mobile service

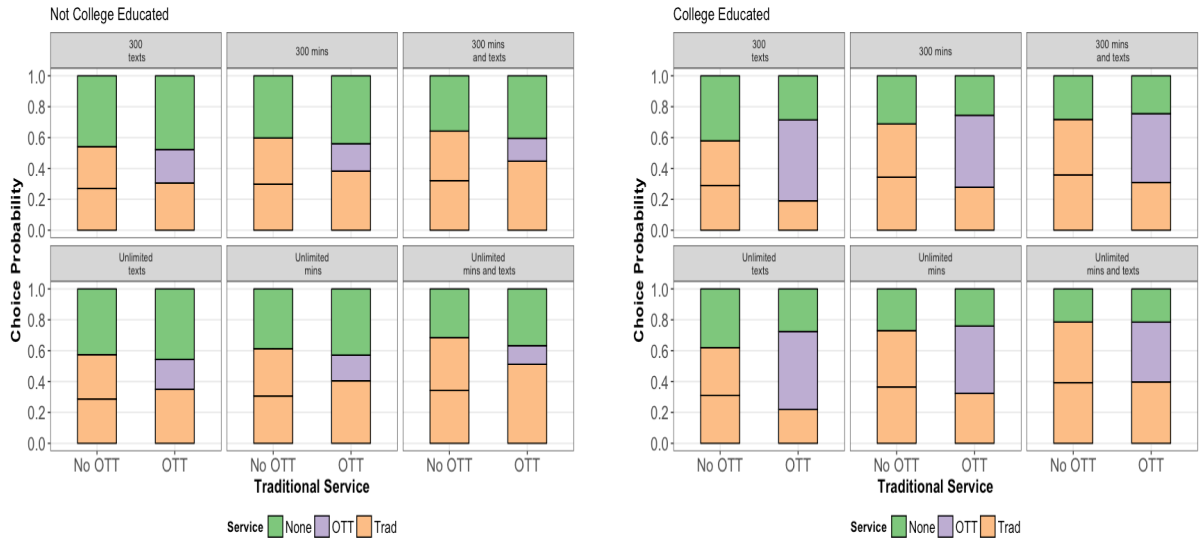


Figure 16. Comparing across college educated and non-college educated mobile users, the impact of OTT on the choice probabilities of different traditional services and going with mobile service

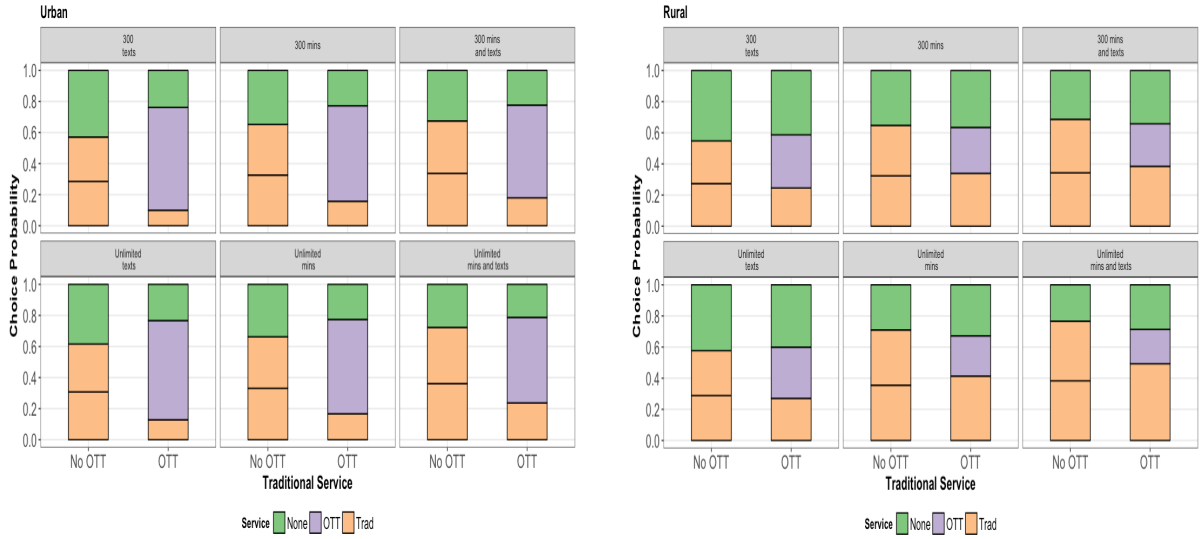


Figure 17. Comparing the choice probability of OTT and no service across urban and rural areas at a price of $10. The upper x-axis shows the different traditional mobile services

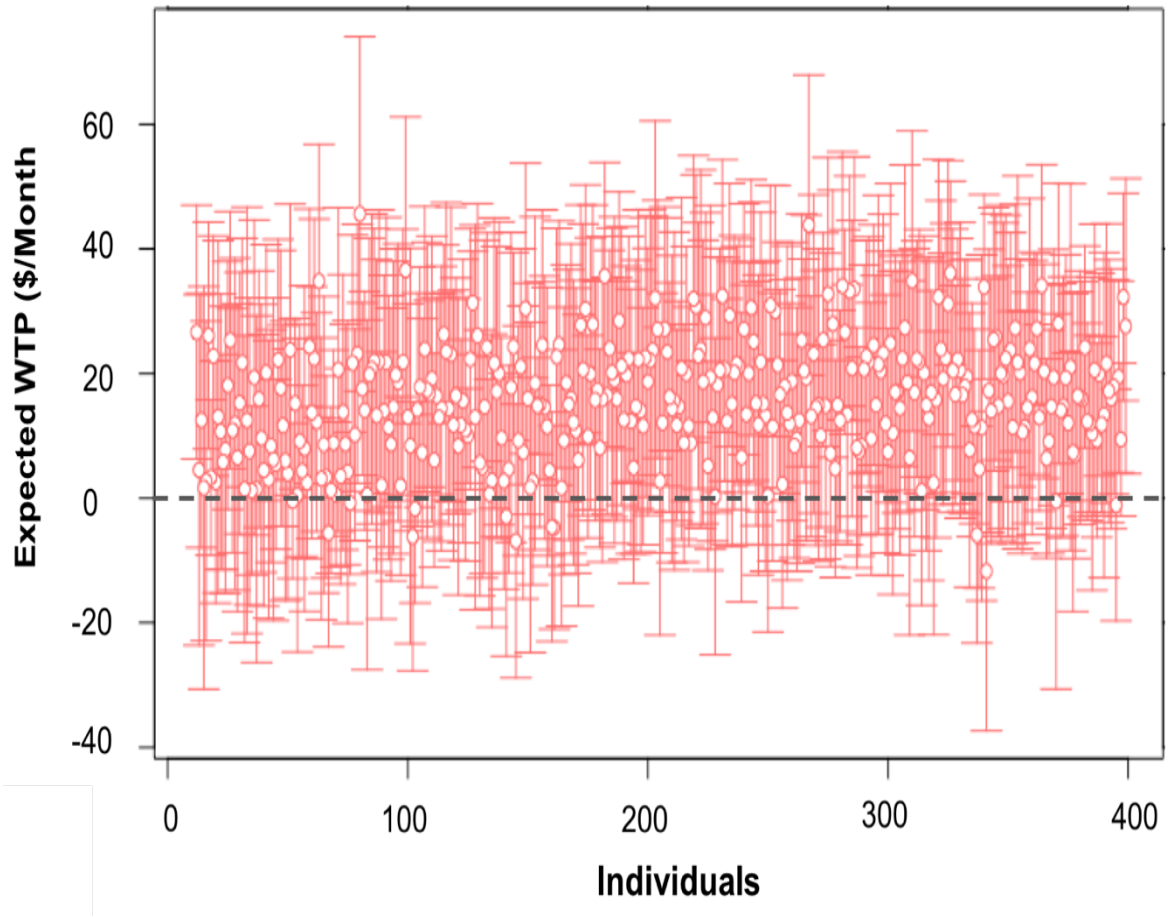


Figure 18. 95% confidence intervals of the individual willingness to pay for OTT.

Appendix B: Supplementary Information for Chapter 3

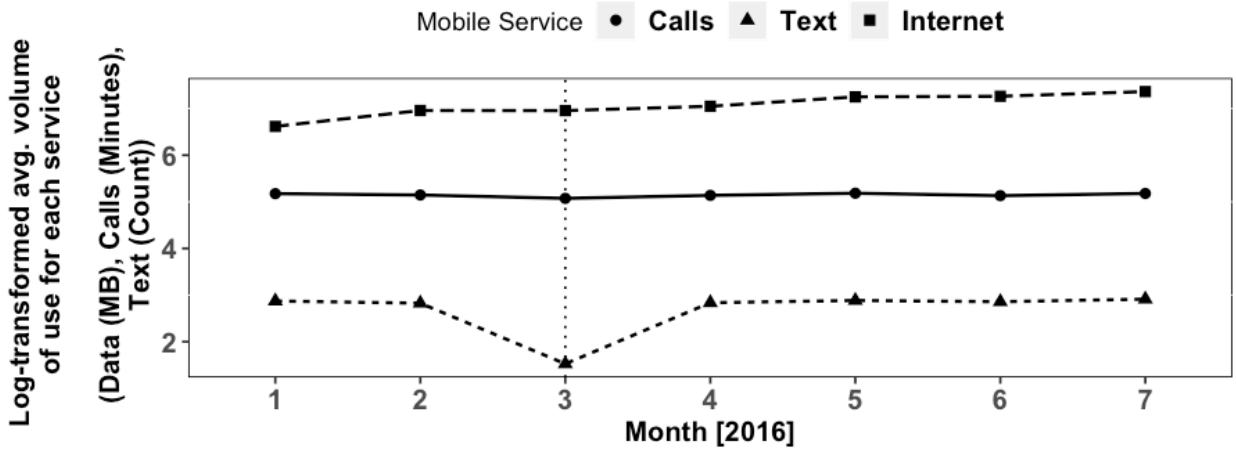


Figure 19. Log transformed scale of the volume of use of data, calls, and text over the 7 months observed in the study

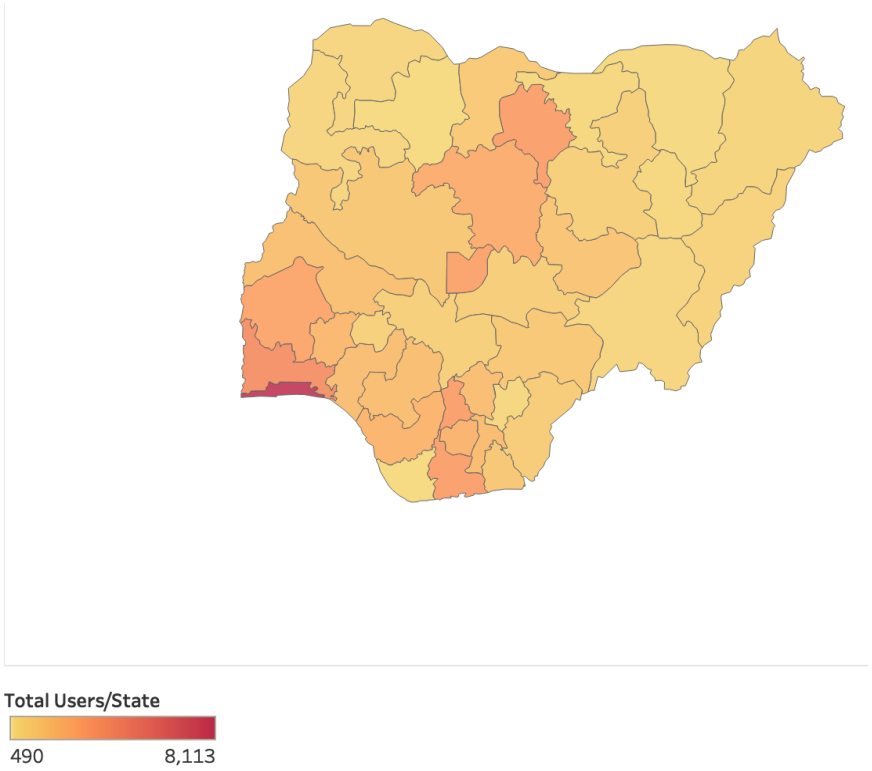


Figure 20. Distribution of active users in the dataset across the states in Nigeria

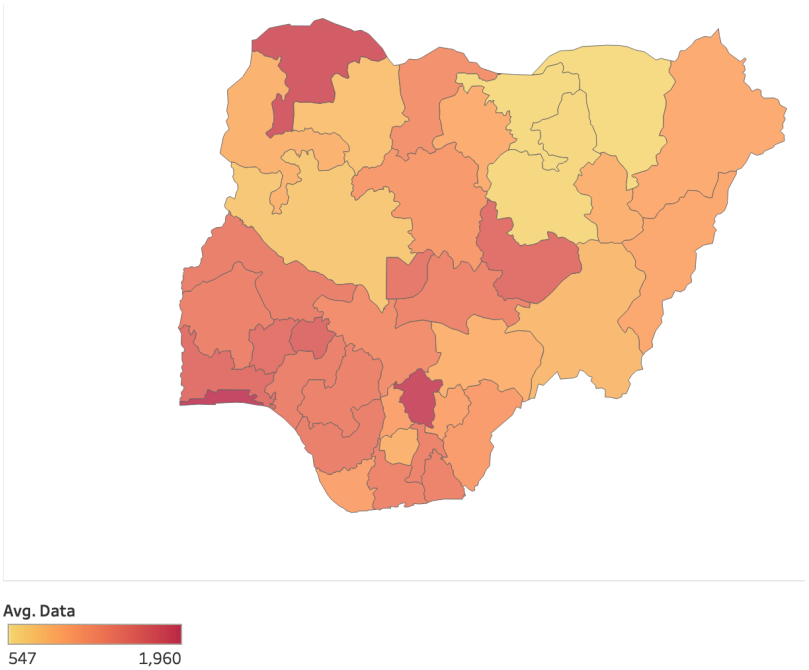


Figure 21. Distribution of the average volume of use of the Internet (measured in megabtyes) across the states in Nigeria

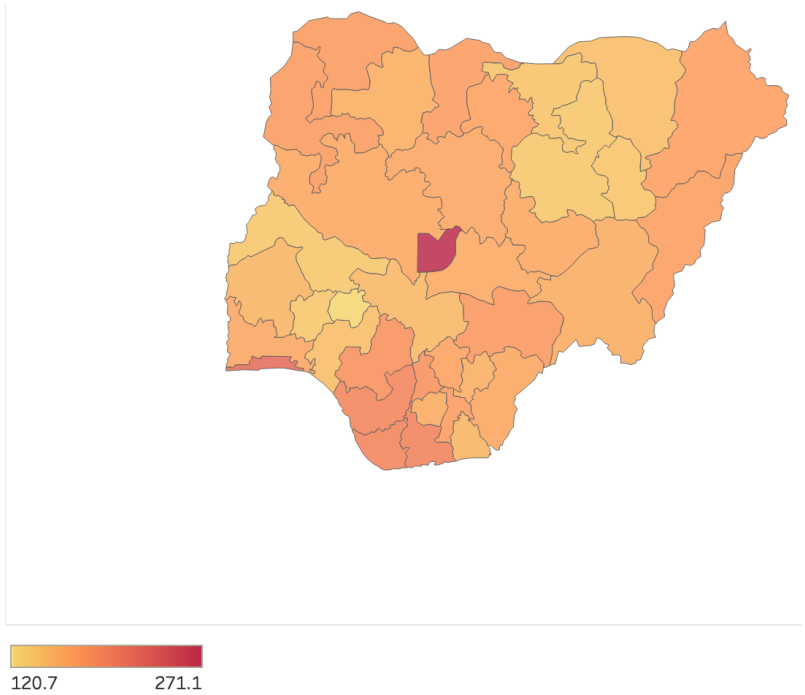


Figure 22. Distribution of the volume of use of cellular calls (measured in outgoing minutes) across the states in Nigeria

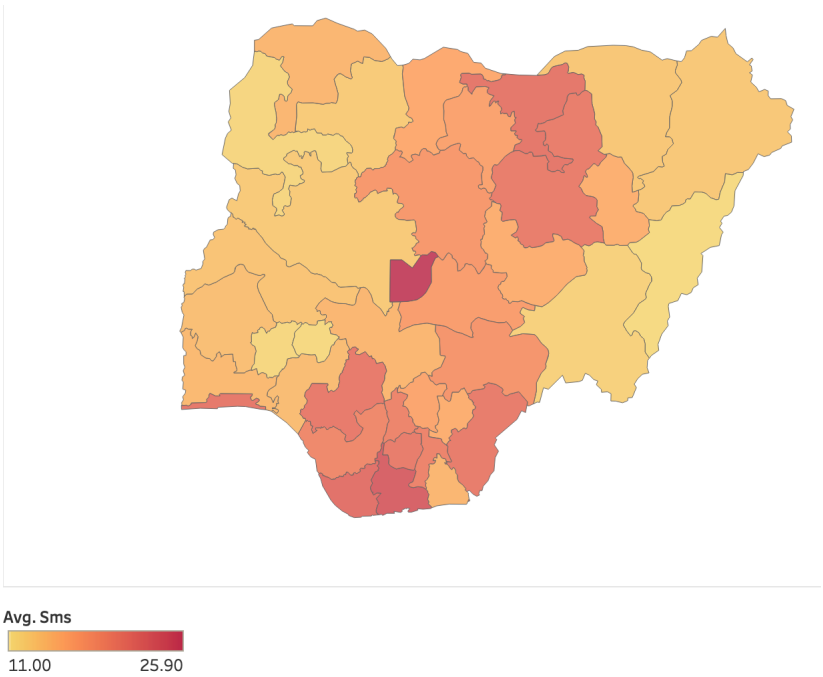


Figure 23. Distribution of the volume of use of text (measured in outgoing count) across the states in Nigeria

Appendix C: Supplementary Information for Chapter 4

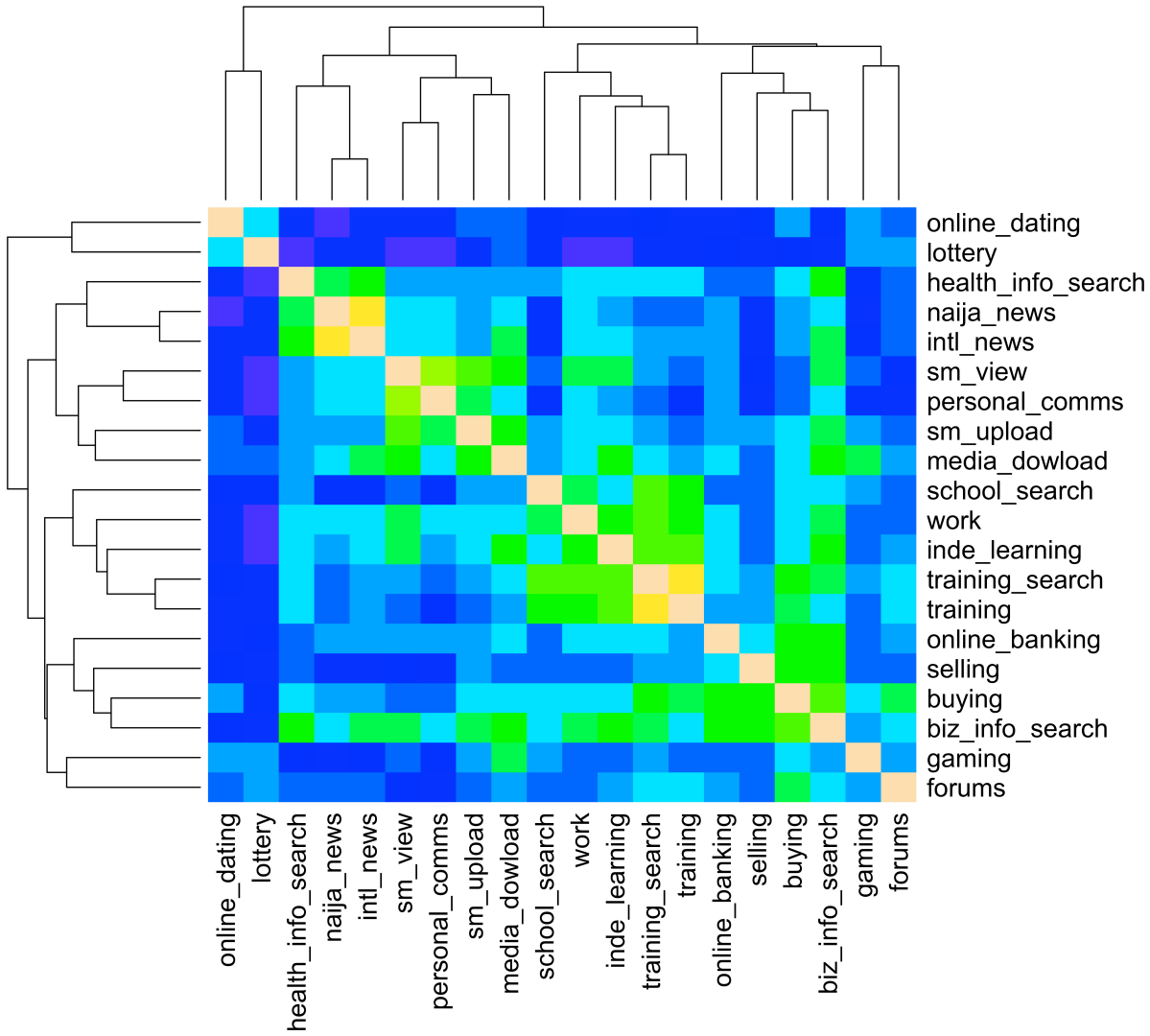


Figure 24. Heatmap showing the correlation between the raw Internet activities

The heatmaps in Fig. 24 and Fig.25 show that there are distinct clusters of activities and outcomes in the raw dataset prior to creating clusters. Examining these initial clusters of activities and outcomes indicate that after conducting the factor analysis, using varimax rotation,

the clusters are mostly preserved. A few items with intermediate scores are not loaded onto any factor and eventually dropped.

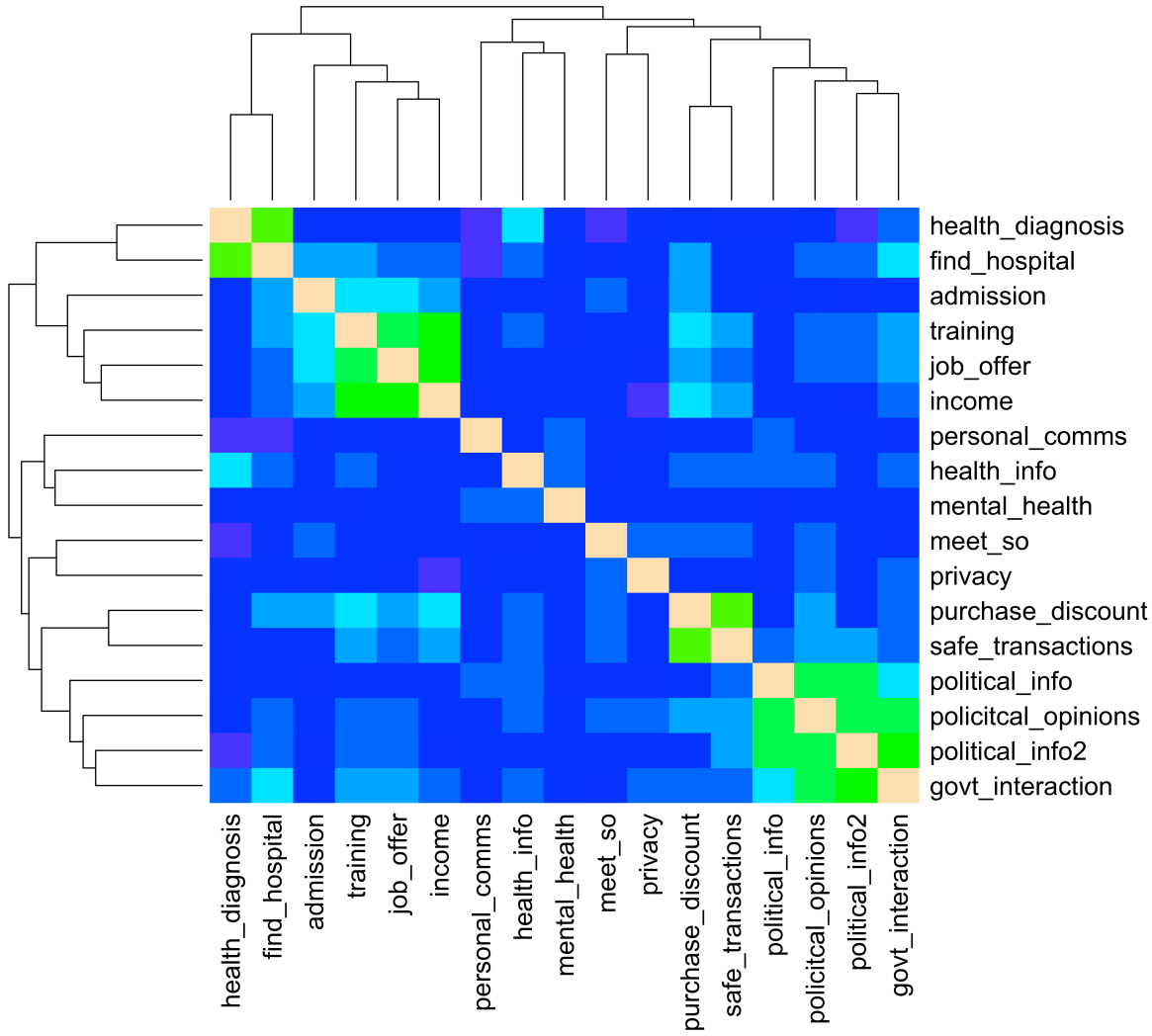


Figure 25. Heatmap showing the correlation between the raw Internet outcomes

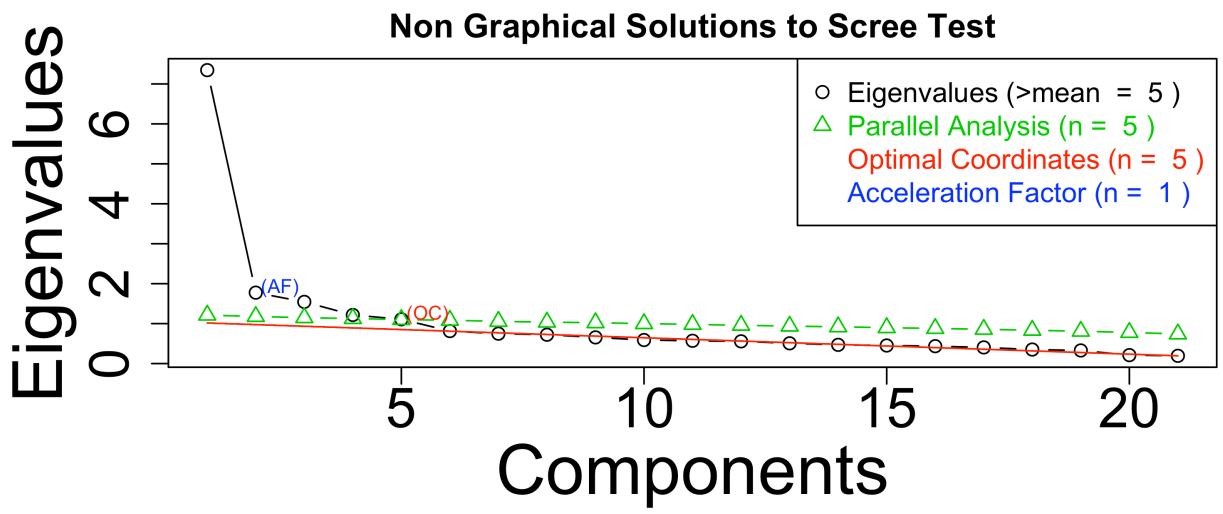


Figure 26. Scree plot showing the recommended number of factors for Internet activities

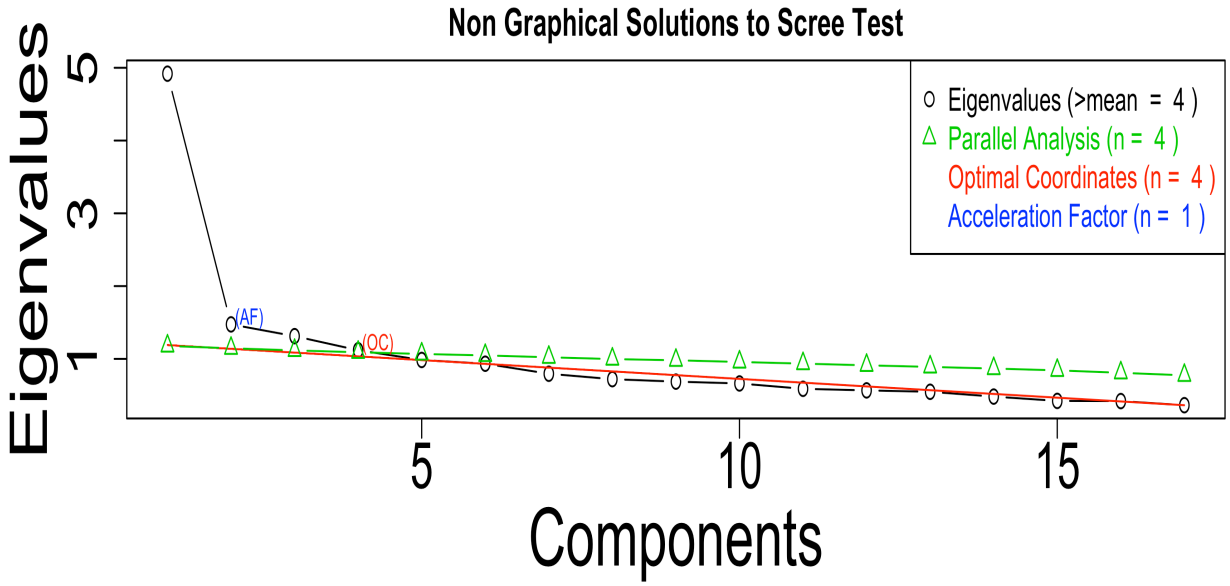


Figure 27. Scree plot showing the recommended number of factors for Internet outcomes

Table 17. Comparing the fit of a 1-factor model and a 5-factor model for Internet activities

	1 factor model	5 factors model
Number of free parameters	32	42
Chi Square	2669.456	677.146
Degrees of freedom	104	94
P-value	0	0
Confidence Interval (CI)	0.657	0.922
RMSEA	0.148	0.074
RMSEA.CI.lower	0.143	0.069
RMSEA.CI.upper	0.153	0.08
Standardized Root Mean Square Residual	0.093	0.056

Table 18. Scale intercorrelations corrected for attenuation raw correlations below the diagonal, alpha (bolded) on the diagonal, and corrected correlations above the diagonal

	all	Development	News	Leisure	Social	Business
all	**0.88**	1.02	0.71	0.58	0.85	0.94
Development	0.89	**0.85**	0.47	0.31	0.58	0.72
News	0.63	0.4	**0.89**	0.20	0.52	0.45
Leisure	0.39	0.21	0.14	**0.52**	0.28	0.45
Social	0.7	0.47	0.43	0.18	**0.77**	0.59
Business	0.76	0.57	0.36	0.28	0.45	**0.74**

Table 19. List of all measures of Internet activities included in the survey instrument (In the past year, how often did you use the Internet for…)

Variable name	Description	Percentage that used activity (n=1123)
job_search	Searching for or apply to jobs	55%
school_search	Searching for or applying to academic programs	49%
work	Activities directly related to work or study	76%
training_search	Searching for online training	53%
training	Enrolling in an online training	47%
inde_learning	Independent online learning	74%
sm_view	Viewing content on social networks	96%
sm_upload	Uploading content on social networks	94%
personal_comms	Communicating with family and friends using WhatsApp or similar applications	98%
online_dating	Online dating	25%
buying	Buying things online	58%
selling	Selling things online	33%
business_info_search	Looking up information about a business/product	80%
online_banking	Sending or receive money	81%
naija_news	Searching or read Nigerian news online	89%
intl_news	Searching or read international news online	85%
health_info_search	Searching for information on healthcare and medicine	82%
media_dowload	Downloading or stream music/videos	84%
gaming	Playing games	45%
lottery	Bet, gamble, or play the lottery	21%
forums	Respond to questions on online forums	41%

Table 19 presents a description of all the Internet activities presented to respondents in the survey and a summarized distribution of the responses. Activities that were engaged with by less than 30% of the respondents are named “novel activities”.

Table 20. List of all measures of Internet outcomes included in the survey instrument (In the past year, through the use of the Internet...)

Variable name	Description	% Yes [% NAs] (n=1123)
job_offer	I got a job offer	25% [37%]
admission	I got admitted to an academic program	33% [37%]
income	I earned additional income	32% [32%]
training	I completed an additional training outside work/school	36% [29%]
personal_comms	I frequently communicated with friends and family	92% [3%]
meet_so	I met a significant other	30% [32%]
purchase_discount	I frequently bought products at a discount	39% [24%]
safe_transactions	I felt safe completing large commercial transactions	45% [22%]
policitcal_opinions	I expressed political opinions	45% [19%]
political_info	I gained information about the elections	81% [7%]
political_info2	I kept up-to-date with government policies	59% [14%]
govt_interaction	I interacted with government agencies	28% [23%]
health_diagnosis	I diagnosed a health problem for self, a friend or family	43% [22%]
hospital	I found hospital to go to for treatment	29% [27%]
health_info	I found information on healthy habits	81% [8%]
mental_health	I fften viewed content that resulted in sad, depressed, or anxious feelings	63% [12%]
privacy	My personal information was compromised	21% [19%]

There are three outcome variables for the Internet outcomes measurements: yes, no, or NA, where NA means the respondent was not trying to achieve the particular outcome in the past one year. Examining the distribution of the outcomes, we see that the most commonly achieved outcome is frequent communication with family and friends. This supports findings in Chapters 2 and 3, that mobile users are increasingly depending on OTT services for communication.

Table 21. Regression results of the Internet outcomes with only user demographics as the predictor variables

	Dependent Variables:			
	Development	**Health**	**Government**	**Commercial**
	Odds Ratio	*Odds Ratio*	*Odds Ratio*	*Odds Ratio*
(Intercept)	14.18 (0.67) ***	1.78 (0.50)	2.78 (0.74)	0.59 (0.51)
Gender (Reference level: female)				
Male	**1.67 (0.25)** *	**0.54 (0.18)** ***	1.31 (0.31)	**1.49 (0.20)** *
Age (Reference level: 18 -30)				
31-40	**0.40 (0.31)** **	0.66 (0.23)	0.65 (0.39)	**0.42 (0.25)** ***
41-50	**0.11 (0.40)** ***	0.77 (0.32)	0.62 (0.53)	**0.44 (0.36)** *
> 50	**0.14 (0.57)** ***	0.83 (0.42)	0.81 (0.71)	0.40 (0.52)
Education (Refence level: below Bachelors)				
OND/Bachelors	0.76 (0.31)	**1.63 (0.21)** *	1.51 (0.34)	**1.67 (0.23)** *
Masters/PhD	1.28 (0.53)	**2.33 (0.36)** *	2.62 (0.81)	2.26 (0.43)
Income (Reference level: low)				
Middle	1.56 (0.34)	**1.80 (0.25)** *	1.64 (0.44)	**2.48 (0.28)** **
Upper	0.90 (0.84)	0.70 (0.59)	-	2.14 (0.85)
Device used (Reference level: none)				
Mobile phone	0.46 (0.58)	0.80 (0.44)	1.02 (0.65)	1.30 (0.44)
Mobile phone + laptop	1.55 (0.64)	0.86 (0.45)	2.84 (0.78)	**2.66 (0.47)** *
Mobile phone + tablet	1.13 (0.66)	0.85 (0.47)	2.03 (0.78)	**3.67 (0.50)** **
Residence (Ref: rural)				
Urban	1.16 (0.27)	0.97 (0.21)	1.83 (0.34)	1.42 (0.22)
Geographical region (Ref: South)				
North	0.63 (0.26)	1.35 (0.18)	2.92 (0.33) **	1.46 (0.20)
R^2 Nagelkerke	0.148	0.058	0.052	0.117
AIC	489.074	812.967	355.658	691.731

** p<0.05 ** p<0.01 *** p<0.001*

Table 22. Regression results of the Internet outcomes with only Internet activities as the predictor variables

	Dependent Variables:			
	Development	**Health**	**Government**	**Commercial**
	Odds Ratio	*Odds Ratio*	*Odds Ratio*	*Odds Ratio*
(Intercept)	0.03 (0.54) ***	0.40 (0.34) **	0.88 (0.49)	0.04 (0.46) ***
Activity: Development	**1.26 (0.04)** ***	1.02 (0.02)	**1.14 (0.04)** **	**1.09 (0.02)** ***
Activity: News	1.01 (0.04)	**1.10 (0.03)** **	**1.45 (0.06)** ***	**1.17 (0.04)** ***
Activity: Novel	1.24 (0.11)	**0.84 (0.06)** **	0.99 (0.12)	**1.20 (0.09)** *
Activity: Social	1.22 (0.05) ***	1.06 (0.04)	1.00 (0.06)	1.04 (0.05)
Activity: Business	1.13 (0.07)	**1.12 (0.05)** *	0.90 (0.09)	**1.47 (0.06)** ***
R^2 Nagelkerke	0.239	0.056	0.105	0.239
AIC	588.449	1095.056	456.460	825.537

** p<0.05 ** p<0.01 *** p<0.001*

Sample Survey Instrument

Survey on Internet Use Patterns and Outcomes

Welcome to our survey! This is a study by researchers at Carnegie Mellon University (CMU) Pittsburgh, PA USA. It is funded by the Department of Engineering and Public Policy at CMU. We want to understand Internet use in Nigeria. You will be asked questions about your Internet use. Your responses will be kept confidential and only summary data will be reported. The survey should take you around 10 minutes to complete. There is no cost, compensation, or known risk to you in participating in this study, but the knowledge received may be of value to humanity. Your participation is voluntary and you can leave the study for any reason. If you would like to discuss this research, please send an email to Erezi Ogbo (eogbo@andrew.cmu.edu). If you have questions regarding your rights as a research participant, or to report concerns about this study, you should contact the Office of Research Integrity and Compliance at Carnegie Mellon. Email: irb-review@andrew.cmu.edu Phone: 412-268-1901 or 412-268-5460.

If you are at least 18 years and you consent to being in this study, mark 'X' by the consent bullet below and begin.

- o I give consent
- o I do not give consent

Section 1

Please answer a few questions on your mobile use and perceptions about the Internet

1) In the past year, what type of phone(s) did you use? *Select all that apply*.

□ Smartphone (Android, iOS, Blackberry, or Windows phone)	□ Basic or feature phone (all other phones)	□ I had no phone

2) Think about your experiences with the Internet then rate how well you agree with each of these statements

	Disagree	Neutral	Agree
I feel comfortable using the Internet for a wide range of activities without asking for help			
People who use the Internet are better off in general than those who do not			
My family and friends think I should use the Internet			
I frequently use the Internet to complete work (or school)-related activities			
I am worried about the rapid advancements in broadband technology			
Internet access (data plan/supported device) is too			
I plan to increase my Internet use in the future			

3) Did you use the Internet in the past year? *Examples include WhatsApp, Facebook, emailing, web browsing, and YouTube. (If "no" skip to section 3)*

- ☐ Yes
- ☐ No

Section 2

Please answer specific questions about your Internet use.

4) How much (in Naira) would you need to be paid to not use the Internet for a week?

5) Which of the following devices did you use to access the Internet in the past year? *Select all that apply*

- ☐ Mobile phone
- ☐ Tablet
- ☐ Laptop/desktop computer
- ☐ Smart TV
- ☐ Other

_____

6) Which of the following describes how you accessed the Internet in the past year? *Select all that apply*

- ☐ Subscription on my phone
- ☐ Internet at work
- ☐ Internet at home
- ☐ Personal Mifi (portable modem)
- ☐ Free Wifi in a public place
- ☐ Internet cafe
- ☐ Other

_____

In the next question, answer N/A if you weren't trying to achieve the given outcome. For example, in the first row, if you did not search for a job in the past year, select N/A.

7) In the past year, through the use of the Internet

	TRUE	FALSE	N/A
I got a job offer			
I got offered admission to an academic program of my choice			
I earned additional income from a side job			
I completed additional training outside work/school			
I frequently communicated with my friends and family			
I met my significant other			
I frequently bought products at a discount without haggling (pricing)			
I felt safe completing a large commercial transaction			
I expressed my political opinions in forums			
I gained information about the election (e.g. the candidates, where/how to vote)			
I kept up-to-date with government policies			
I interacted with a government agency (e.g. to provide feedback, complaint, or use a service)			
I diagnosed a health problem suffered by myself, a family member, or friend			
I identified a hospital to get treatment for a health problem suffered by myself/a family member/friend			
I found information on healthy habits			
I often viewed content that made me			
My personal information was compromised			

8) On average, in the past year, how much (in Naira) did you spend on Internet (data) subscription in a month?

9) In the past year, how often did you use the Internet for…?

	3+ times/ day	1-3 times/ day	1-3 times/ week	1-3 times/ month	Less than once/ month	Never
Searching for vacancies/applying for a job						
Looking up schools/applying for admission						
Work/school related activities						
Searching for online courses/training						
Following an online course/training						
Independent learning (e.g. a YouTube tutorial)						
Viewing content on social networks (such as Facebook, Instagram)						
Uploading content on social networks						
Communicating with friends and family using WhatsApp or similar apps						
Online dating						
Buying a product						
Selling a product						
Looking up information about a product or business						
Sending or receiving money						

Searching for/reading Nigerian news						
Searching for/reading international news						
Searching for information about healthcare and medicine						
Downloading or streaming						
Playing games						
Casual browsing						
Betting, gambling, or playing the						
Responding to questions on online forums (such as Nairaland, Reddit, or Quora)						

Section 3

***Only answer questions in this section if you do not use the Internet

10) Which of the following closely describes why you did not use the Internet in the past year? *Select all that apply*

- ☐ The plans are too expensive
- ☐ I do not have a phone or computer to browse with
- ☐ Bad/no Internet service where I live
- ☐ I don't know how to use the Internet
- ☐ Not enough relevant content (e.g. in preferred language/about topics of interest)
- ☐ Other

_____

_____

In the next question, answer N/A if you weren't trying to achieve the given outcome. For example, in the first row, if you did not search for a job in the past year, select N/A.

11) In the past year,

	TRUE	FALSE	N/A
I got a job offer			
I got offered admission to an academic program of my choice			
I earned additional income from a side job			
I completed additional training outside work/school			
I frequently communicated with my friends and family			
I met my significant other			
I frequently bought products at a discount without haggling (pricing)			
I felt safe completing a large commercial transaction			
I expressed my political opinions in forums			
I gained information about the election (e.g. the candidates, where/how to vote)			
I kept up-to-date with government policies			
I interacted with a government agency (e.g. to provide feedback, complaint, or use a service)			
I diagnosed a health problem suffered by myself, a family member, or friend			
I identified a hospital to get treatment for a health problem suffered by myself/a family member/friend			
I found information on healthy habits			
I often viewed content that made me sad/depressed/anxious			
My personal information was compromised			

Section 4
A few basic demographic questions and we are done

12) Please select your age range
- o 18 - 30 years
- o 31 - 40 years
- o 41 - 50 years
- o 51 - 60 years
- o Over 60 years
- o Prefer not to respond

13) Gender
- o Male
- o Female
- o Prefer not to respond

14) What is your highest educational level completed?
- o Less than secondary school
- o Secondary school
- o OND or equivalent
- o Bachelors or equivalent
- o Masters or postgraduate
- o Doctorate
- o Prefer not to respond

15) Which language(s) are you very comfortable in reading and writing? *Select all that apply*
- □ English
- □ French
- □ Hausa
- □ Igbo
- □ Pidgin English
- □ Yoruba
- □ Other _____

16) What is your current employment status?
- o Full-time employment
- o Part-time employment
- o Self-employed
- o Home-maker
- o Student
- o Retired
- o Unemployed
- o Prefer not to respond

17) Monthly income (if a student, select your monthly allowance)
- o Below N20,000
- o N20,000 to N34,999
- o N35,000 to N59,999
- o N60,000 to N199,999
- o N200,000 to N499,999
- o Over N499,999
- o Prefer not to respond

18) Which ethnic group do you identify with?
- o Hausa
- o Igbo
- o Yoruba
- o Other
- o Not Nigerian
- o Prefer not to respond

**********_To be completed by the field officer_**********

19) Location

City/town/village

_____

LGA _____

State _____

20) Recruitment location

- University
- Business/workplace
- Public market
- Shopping mall

21) Location type

Urban/Rural