



Essays on Telecommunications Demand and Regulatory Policies

Thesis Presented to
SCHOOL OF ECONOMICS
UNIVERSITY OF CAPE TOWN

In partial fulfillment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

Under the supervision of
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MTHONK003

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Declaration

I declare that, this thesis has been composed by myself and that the work has not been submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where work which has formed part of jointly-authored publications has been included. My contribution and those of the other authors to this work have been explicitly indicated below. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

The work presented in Chapter 2 was previously published in Information Economics and Policy as Infrastructure deficiencies and adoption of mobile money in Sub-Saharan Africa by Onkokame Mothobi (student), co-authored with Lukasz Grzybowski, Supervisor. This study was conceived by all of the authors. About 75% of this chapter is my own work. This includes data collection and merging of the survey data with the location nighttime light intensity, data cleaning and analysis with my supervisor refining the idea and providing guidance on how to write a research for publications.

Onkokame Mothobi

Signature

October 11, 2017.

Abstract

This thesis employs models of homogenous and differentiated products to empirically investigate the demand for mobile phone services in Sub-Saharan African countries. The thesis consists of a short introductory chapter, three self-contained empirical chapters, and a summary chapter.

In Chapter 2, we use survey data conducted in 2011 in eleven countries in Sub-Saharan African to analyze how the availability of physical infrastructure influences the adoption of mobile phones and usage of mobile services. The availability of physical service infrastructure is approximated by data on nighttime light intensity in the areas in which survey respondents reside. After controlling for a number of individual and household characteristics including disposable income, we find that adoption of mobile phones is higher in areas with better physical infrastructure. However, in the group of mobile phone adopters, the use of mobile phones for mobile financial transactions is negatively influenced by the level of infrastructure. Mobile phone users who live in areas with poor infrastructure are more likely to rely on mobile phones to make financial transactions than individuals living in areas with better infrastructure. On the other hand, the use of mobile phones to access services such as email, skype, social media networks and Internet browsing is not dependent on the availability of physical infrastructure. Our results support the notion that mobile phones improve the livelihoods of individuals residing in remote areas by providing them with access to financial services which are otherwise not available physically.

Chapter 3 examines the effect of mobile number portability (MNP) on own- and cross-price elasticities. Using quarterly data for 28 mobile operators in seven Sub-Saharan Africa countries between 2010Q4 to 2014Q4 to estimate a differentiated products demand

model, we find that MNP increased own-price elasticities of demand in countries that have implemented the facility. This increase in price elasticities may be a result of a reduction in switching costs between operators. On average, the introduction of MNP increases own-price elasticities by 0.47 in absolute value. We compare the level of price elasticities before and after the implementation of MNP in Ghana and Kenya, which implemented this policy in the time period of our study. Our results suggest that in Ghana, MNP increased own-price elasticities by an average of 0.35 in absolute terms from an average value across firms and over time of -0.74. In Kenya, the introduction of MNP increased own-price elasticities by an average of 0.21 in absolute terms from a lower average value across firms and over time of -0.39. However, we find that in Kenya and Ghana the average own-price elasticities remained small even after the implementation of MNP relative to other countries without MNP in place. Thus, our results suggest that MNP is not the ultimate solution for increasing competitiveness within the mobile industry.

While in Chapter 3 we use a product differentiated model of demand, in Chapter 4 we make assumptions that allow us to use a homogenous model of demand to examine the effect of regulatory policies on mobile retail prices. Using aggregated quarterly data for eight African countries for the period 2010:Q4 to 2014:Q4, we estimate structural demand and supply equations. We find that mobile termination rates (MTR) have a significant positive impact on mobile retail prices. A decline in average MTR of 10% decreases average mobile retail prices by 2.5%. On the other hand, MNP has an insignificant effect on price and subscriptions in selected African countries. This may be due to inadequate implementation of MNP, which subsequently lead to low demand for porting numbers. The average market conduct in the mobile telecommunications industry for selected African countries can be approximated by Cournot Nash equilibrium.

In Chapter 3 we find price elasticities that are closer to 1 in absolute terms. The price elasticity, however, is estimated at an average of -0.27 for Sub-Saharan Africa countries in Chapter 4. We attribute this inconsistency to the different assumptions made in each chapter.

Acknowledgements

This project was made possible by the scholarship from the AERC and the commitment of my supervisors. I am grateful to my supervisors, Lukasz Grzybowski and Anthony Black for many useful discussions and comments. This thesis benefited from technical expertise of Lukasz Grzybowski who treated it like his own baby. I also thank participants in the following seminal series for their valuable comments: African Economic Research Consortium (AERC) in Arusha (2014) and Addis Ababa (2015); University of Botswana, Department of Economics (2014, 2015, 2016); University of Cape Town (UCT) brown bag (2014, 2015, 2016), University of Lesotho (2016) and Research ICT Africa, Cape Town (2016). Many thanks to Lebogang Mateane, G. Charles-Cadogan for reading and commenting on this piece.

The students in the PhD programme in the UCT School of Economics have been the most important part of my PhD life. I specifically thank David Khaoya, Fredrick Wamalwa, Pinkie Kebakile, Peter Wamalwa, Ramaele Moshoeshe, and Refilwe Lepelle for all the support, which made my stay in Cape Town pleasant and memorable.

I am highly indebted to my mother (Sebelegi Mothobi) and younger sister (Tlhomamo Mothobi), who had to bear with my selfish interest of persuing school dreams. I thank Keoagile Thaga and Masego Makepe (Professors at the University of Botswana) for their support and motivation. Lastly I thank Boadhi family and Pinkie Kebakile for all the support and guidance.

Onkokame Mothobi

October 11, 2017.

Dedication

To my mother, Sebelegi Mthobi and my sister, Thomamo Mthobi.

Contents

1	Introduction	1
2	Infrastructure Deficiencies and Adoption of Mobile Money in Sub-Saharan Africa	7
2.1	Introduction	7
2.2	Mobile Telecommunications in Sub-Saharan Africa	10
2.2.1	Mobile Money	12
2.3	Data	13
2.4	The Econometric Model	19
2.5	Estimation Results	19
2.6	Conclusions	24
3	The Impact of Mobile Number Portability on Demand Price Elasticities in Sub-Saharan Africa	26
3.1	Introduction	26
3.2	Literature Review	28
3.3	Mobile Number Portability in Sub-Saharan Africa	30
3.4	Data	33
3.5	The Model	38
3.6	Identification	39
3.7	The Results	41
3.8	Conclusion	47
4	The Impact of Telecommunication Regulatory Policy on Mobile Retail Price in Sub-Saharan Africa	50
4.1	Introduction	50
4.2	Literature Review	53

4.3	Telecommunications Policy in Africa	56
4.3.1	Mobile Number Portability	56
4.3.2	Mobile Termination Rates	57
4.4	Data	58
4.4.1	Mobile Pricing	63
4.5	Econometric Model	65
4.6	Identification	67
4.7	Results	69
4.8	Conclusions	72
5	Conclusion	75
A	Appendix	86

List of Tables

2.1	Usage of mobile phones	14
2.2	Night light intensity by country and type of area	16
2.3	Usage of mobile services (by mobile phone users)	17
2.4	Descriptive statistics	18
2.5	Estimation results	21
2.6	Usage of mobile services (by income group)	23
3.1	African Countries with MNP	30
3.2	Termination Rates Data Sources	34
3.3	Distribution of minutes and SMS depending on time and destination network	36
3.4	Summary Statistics	38
3.5	Exogeneity check: Cox proportional hazard regression	41
3.6	Estimation results for ordinary least squares (OLS) and instrumental variables (IV)	42
3.7	Mean country-level own-price elasticities between 2010:Q4-2014:Q4	43
3.8	Mean operator own- and cross-price elasticities between 2010:Q4-2014Q:4	45
3.9	Mean operator own- and cross-price elasticities between 2010:Q4-2014Q:4	46
3.10	Mean operator own- and cross-price elasticities between 2010:Q4-2014Q:4	47
4.1	Simple Statistics	60
4.2	The Supply Side	71
4.3	The Demand Side	72

List of Figures

2.1	Aggregated and Country Level Mobile Phone Subscriptions For The Sub-Saharan Countries	11
2.2	Nighttime light intensity	15
4.1	Pre-paid Mobile Subscriptions for Selected African Countries (millions) . .	61
4.2	Mobile Termination Rates for Selected Countries, 2010-2014.	63
4.3	Mobile Prices for Selected Countries, 2010:Q4-2014:Q4	64
A.1	Mobile-Cellular Subscriptions by Regions	86
A.2	Evolution of market shares in countries with MNP between 2010-2014 . . .	87
A.3	Evolution of market shares in countries without MNP between 2010-2014 .	87
A.4	Mobile Prices for Selected Countries with MNP.	88
A.5	Mobile Prices for Selected Countries without MNP.	88

Chapter 1

Introduction

The roll-out and increasing usage of telecommunications services are important contributors to economic growth by improving factor productivity of some sectors of the economy and by creating employment (Bresnahan et al., 1999; Brynjolfsson & Hitt, 2000). For instance, in 2014, the mobile industry generated 3.8% of global gross domestic product (GDP), a contribution that amounts to over US\$3 trillion of economic value across 236 countries.¹ As for developing countries, the sector has also attracted a lot of investments and facilitated competition within the sector and other sectors of the economy (Atsu et al., 2014). However, various competition and regulatory authorities express concern about the lack of effective competition in the mobile telecommunication industry. Limitations in the amount of spectrum and high network investments tend to make the industry oligopolistic in nature and susceptible to collusion and the exercise of market power (see Gruber (2001); Valletti (2003)). In addition, consumers of mobile phone services tend to have high switching costs, which may weaken competition among existing firms and make successful entry of new firms difficult. Moreover, the increasing demand of mobile broadband services and scarcity of spectrum has already led to rapid consolidation in some markets. Hence antitrust regulators are faced with tough choices as they balance their mandate of attaining healthy competition with the financial imperatives facing the industry.

To improve access and usage of mobile phone services and to ensure that customers are not exploited, regulatory authorities worldwide introduced mobile number portability

¹see, www.gsmamobileeconomy.com

(MNP), a facility that allows consumers to retain their mobile phone numbers when changing mobile operator. At the same time, regulatory authorities, such as the Botswana Communication Regulatory Authority (BOCRA) and Kenya Competition Commission (KCC), have adopted a glide path for reducing mobile termination rates (MTRs). This policy requires operators to reduce the charges they set for terminating calls on each other's network over time. ²

We are not aware of any economic literature that provides an assessment of the impact of the mentioned regulatory policies on price and own-price elasticities in African countries. Moreover, in spite of the importance of mobile phone usage in daily life, there is limited literature on the impact of mobile phone services such as mobile banking, mobile health and mobile agriculture on the wellbeing of population in developing countries. This thesis breaks new ground by analyzing the determinants of mobile phone adoption and investigating the effects of regulatory policies on market outcomes for selected Sub-Saharan African countries. Specifically, the thesis contributes to economic literature by addressing the following objectives. Firstly, the thesis analyzes how the availability of physical infrastructure influences the adoption of mobile phones and usage of mobile services. Secondly, it assesses the effect of MNP on own- and cross-price elasticities. Finally, it examines the effect of MNP and MTRs on mobile retail prices. These objectives are common themes in the three empirical chapters of the thesis.

Chapter 2 uses unique survey data conducted in 11 countries in Sub-Saharan Africa in 2011 by Research ICT Africa to analyze how the availability of physical infrastructure influences adoption of mobile phone services, such as M-Pesa, mobile banking and mobile agriculture. The availability of physical service infrastructure such as banks, hospitals and agricultural markets, is approximated by data on nighttime light intensity in the areas in which survey respondents reside. Chapter 3 assesses the effect of MNP on own- and cross-price elasticities using a unique quarterly dataset for 27 firms in seven African countries running from 2010:Q4 to 2014:Q4. Chapter 4 uses aggregated price and quantity data for eight African countries for the period 2010:Q4 to 2014:Q4 to examine the effect of regulatory policies on mobile retail prices. The main sources of data for Chapter 3 and

²MTRs refer to the charges which are set by operators for terminating on each other's networks. Each network is a de facto monopoly for termination of calls, which can be a source of collusion.

4 are Research ICT Africa (RIA) and the World Cellular Information Services (WCIS).

The thesis draws from several strands of literature. Chapter 2 draws on the literature that analyzes the diffusion process of telecommunication services, such as M-Pesa and mobile banking (see Mbiti & Weil (2011); Gutierrez & Singh (2013); Economides & Jeziorski (2014)). However, due to the scarcity of individual-level data on the usage of mobile banking and mobile money, these studies tend to use aggregated data. The use of aggregated data cannot answer the question posed in this chapter, since this type of data is generally silent about the geographical circumstances of mobile phone users. Hence, we add to this literature by constructing a unique data set that consists of individual characteristics and information on the level of infrastructure for each respondent. After controlling for a number of individual and household characteristics including disposable income, we find that adoption of mobile phones is higher in areas with better physical infrastructure. However, in the group of mobile phone adopters, the use of mobile phones for mobile financial transactions is negatively influenced by the level of infrastructure. Mobile phone users who live in areas with poor infrastructure are more likely to rely on mobile phones to make financial transactions than individuals living in areas with better infrastructure. On the other hand, the use of mobile phones to access services, such as email, Skype, social media networks and Internet browsing, is not dependent on the availability of physical infrastructure. Our results support the notion that mobile phones improve the well-being of individuals residing in remote areas by providing them with access to financial services which are otherwise not available physically.

Chapter 3 is concerned with literature that estimate own- and cross-price elasticities. Even though the mobile telecommunication industry is characterized by switching costs, we are not aware of any research that control for factors influencing switching costs when estimating price elasticities of demand. In this thesis, we consider MNP as a policy that reduces switching costs and we assess its impact on own- and cross-price elasticities. We use quarterly data for 28 mobile operators in 7 Sub-Saharan Africa countries between 2010:Q4 to 2014:Q4 to estimate a differentiated products demand model. Our results suggest that MNP increased own-price elasticities of demand in countries that have implemented the facility. This increase in price elasticities may be the result of a reduction

in switching costs between operators. On average, the introduction of MNP increases own-price elasticities by 0.47 in absolute value. We compare the level of price elasticities before and after the implementation of MNP in Ghana and Kenya, which implemented this policy in the time period of our study. Our results suggest that in Ghana, MNP increased own-price elasticities by an average of 0.35 in absolute terms from an average of -0.74. In Kenya, the introduction of MNP increased own-price elasticities by an average of 0.21 in absolute terms from a lower average of -0.39. However, we find that in Kenya and Ghana, relative to other countries without MNP in place, the average own-price elasticities remained small even after the implementation of MNP. Thus, our results suggest that MNP is not an ultimate solution for increasing competition within the mobile industry. Generally, operator own-price elasticities are high in all the sampled countries except for Ghana and Kenya.

Lastly, Chapter 4 deals with literature that analyzes the impact of regulatory policies on market outcomes. There is a growing debate on the impact of MTRs and MNP on mobile retail price. The debates on MTRs were largely sparked by Genakos & Valletti (2011) who conclude that a reduction in mobile-to-fixed termination rates is likely to lead to an increase in mobile retail prices, a phenomenon commonly known as waterbed effect. The waterbed effect theory suggests that, in two-sided market, when prices in one market are pushed down by regulatory controls, the prices in the unregulated market will increase towards monopoly prices. This holds when demand or marginal costs are interdependent; firms use non-linear pricing or there is a zero-profit constraint (see Schiff (2008)). However, in a later study the same authors found no waterbed in the mobile telecommunication industry. Moreover, this chapter relates to the literature that assesses the impact of MNP on mobile retail prices. There is a consensus in the literature that MNP lowers mobile retail prices (see Cho et al. (2013)). However, the existing literature on the impact of MNP on mobile retail price does not provide evidence on how this regulatory policy affects mobile retail price. Furthermore, studies that evaluate the impact of MNP on price only consider demand factors and do not control for supply side effects. We add to this literature by considering both supply and demand factors effects on price. We assume that MNP affects the demand side while MTRs affect the supply side.

We estimate a structural model of demand and supply using quarterly time series data between 2010:Q4 and 2014:Q4 for eight African countries. On the supply side, we find that MTRs have a significant and positive impact on mobile retail prices. On average, a 10% increase (decrease) in MTRs will result in 2.5% increase (fall) in prices. This result opposes the waterbed effect theory, which was tested for telecommunications markets by Genakos & Valletti (2011). Thus, pushing down the price in the regulated market, that is, the termination rate, does not increase unregulated mobile retail prices in the group of countries used in this analysis. This result supports the glide path termination rate policy.³ Moreover, we do not find that MNP has a significant negative impact on retail prices for selected African countries, which contrast with the results found by Grzybowski (2005), Park (2011) and Cho et al. (2013) for European countries. This may be due to less effective implementation of MNP in African countries and consequently lower attractiveness and take up of this option by consumers. For instance, even though it has been found that the effectiveness of MNP depends on porting time and charges, the porting process in Africa is characterized by long porting time. Furthermore, in some countries such as Nigeria, subscribers are not allowed to port again for the next three months.

On the demand side, we find that MNP does not change the responsiveness of consumers to price, a result which coincides with our findings on the supply side. This may be due to the fact that in many African countries, it is common to use multiple subscriber identity module (SIM) cards.⁴ A household survey conducted by ResearchICTAfrica in different African countries in 2008, reports that 36.3% of adult mobile phone subscribers hold more than one SIM card in Benin, 25.8% in Kenya and only 2.9% in Mozambique (see ResearchICTAfrica (2008)). Hence, many consumers are connected to two or more operators with low demand for porting numbers. We estimate the price elasticity of demand to be on average -0.27. We use the estimate of price elasticity to approximate

³Glide path termination rates policy is a policy that requires network operators to reduce charges that they charge each other for completing or terminating calls on each network, commonly known as termination rates.

⁴Although in Botswana the population is estimated to be around 2 million, the number of active SIM cards is about 3.5 million. For statistics on active SIM cards see www.itu.int. Popular use of multiple SIM cards from different operators has delayed implementation of MNP, with the authority not convinced of the facility's economic benefits (see www.budde.com.au)

the average market conduct parameter in selected African countries, which takes value of 1.29. Thus, the average market conduct in the mobile telecommunication industry for the selected Sub-Saharan African countries can be approximated by static Cournot Nash equilibrium.

Future research should examine the impact of the discussed regulatory policies on prices and quantities using firm-level data. An analysis which is expected to guide competition and regulatory policies for markets that have operators that are asymmetric in size. Moreover, investigation of the existence of switching costs in the presence of multiple subscriber identity module (SIM) card is vital.

The remainder of this thesis is as follows. Chapter 2 analyzes how the availability of physical infrastructure influences the adoption of mobile phones and mobile financial services in developing countries. Chapter 3 examines the effect of mobile number portability (MNP) on own- and cross-price elasticities. Chapter 4 assesses the effect of regulatory policies on mobile retail prices and Chapter 5 concludes by giving a brief summary and outlining the implications for future research.

Chapter 2

Infrastructure Deficiencies and Adoption of Mobile Money in Sub-Saharan Africa

2.1 Introduction

The deployment of mobile telecommunications allows developing countries to overcome poor or non-existent fixed-line infrastructure and lack of Internet access. These are key burdens to economic growth in these countries. Access to mobile telecommunications can dramatically improve standard of living in these countries by saving wasted trips, providing information about prices or serving as a conduit to banking, health care and other services. Aker & Mbiti (2010) identify a few potential mechanisms through which mobile phones can provide economic benefits to consumers and producers in developing countries. First, mobile phones can increase market efficiency by improving access to information and reducing search costs. Second, better communication can improve management of supplies and increase productive efficiency of firms. Third, mobile phones facilitate services which are in general not available to low income households, such as mobile phone-based financial, agricultural, health, and educational services. In this chapter, we focus on the third point and analyze how the availability of physical infrastructure influences the adoption of mobile phones and the use of mobile phone services such as mobile money.

As of 2014, mobile-cellular penetration in low income countries reached 90%.¹ This

¹see <http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2014-e.pdf>

contrasts with high income countries which have a penetration rate of 121%. At the same time, in low income countries, only about 54% of the population have a bank account, compared to 94% in high income countries (see www.worldbank.org). The main reasons for lack of access to financial services are deficient infrastructure, inaccessibility and financial illiteracy. Mobile phones can change this situation by enabling people to make use of financial services overcoming the problem of poor physical infrastructure. Mobile banking or m-money provides access to account balances and money transfers using mobile networks, which does not require the proximity of other physical infrastructure.² In this way, the expansion of mobile banking may have a significant impact on economic growth and poverty reduction in low income countries.

To date, there is a limited body of literature on the adoption of mobile financial services in low income countries.³ This is largely due to the shortage of individual-level data on the use of mobile banking in low income countries. Aggregate country-level data is unfit for this purpose because of short time span since the availability of mobile banking and low level of adoption in the majority of countries world-wide. Among few available studies, Mbiti & Weil (2011) use two waves of individual-level data in Kenya to analyze the use of M-Pesa. They find that the use of M-Pesa lowers the propensity of people to use informal savings mechanisms, but raises their probability of being banked. Gutierrez & Singh (2013) use data on 37,000 individuals from 35 countries to analyze factors which determine mobile banking usage. They construct a regulatory index and find that a supporting regulatory framework is associated with a higher use of mobile banking for the general population as well as for the unbanked. They conclude that regulators can foster the development of mobile banking services through the enactment of supporting regulation. In another paper, Economides & Jeziorski (2014) use mobile financial transactions among subscribers of a major mobile phone service provider in Tanzania to estimate price elasticities for different types of transactions. They find that demand

²For instance, one of the main South African banks, Standard Bank, as of 2012 operated about 10,000 so-called bank shops in townships with predominantly black residents. These bank shops have a mobile phone banking capability allowing clients to effect money transfers. They enable hawkers, who usually close shops in the evening when banks are already closed, to use the bank shops to deposit their money.

³The empirical literature focused on the adoption of mobile phones is already mature. For instance, Grzybowski (2015) analyzes adoption of mobile phones using panel data of South African households.

for long-distance transfers is less elastic than for short-distance transfers, which suggests that mobile networks actively compete with traditional cash transportation systems in addition to competing with each other.

There is also emerging literature on the impact of mobile phones on the wellbeing of people. For instance, Jensen (2007) uses data on fishermen in the Indian state of Kerala to show that usage of mobile phones may improve market performance and increase welfare. In another paper, Aker (2008) analyzes how the phasing-in of mobile phone coverage between 2001 and 2006 affected grain prices in Niger. Klöpper et al. (2010) analyse the effect of mobile phone coverage on rural labor market outcomes in South Africa.

Our study contributes to this growing literature by analyzing how the availability of physical infrastructure influences the adoption of mobile phones and mobile financial services. We estimate a number of logit models using a households and individuals survey of telecommunications use and access from eleven Sub-Saharan African countries, which was conducted in 2011 by ICT Research Africa.⁴ The survey data is complemented with the Defense Meteorological Satellite Program Open Linear Scanner (DMSP/OLS) nighttime light intensity data, which we use to approximate the availability of service infrastructure at the location of survey respondents. The use of nighttime light intensity data enables us to analyze how spatial differences in infrastructure development across Sub-Saharan Africa influence the adoption of mobile phones and use of mobile services by individuals.

After controlling for a number of individual and household characteristics including disposable income, we find that adoption of mobile phones is higher in areas with better physical infrastructure. However, the estimation results suggest that, in the group of mobile phone adopters, the use of mobile phones for financial transactions is negatively influenced by the level of infrastructure development. Individuals who live in areas with poor infrastructure are more likely to use mobile phones to make financial transactions than individuals living in areas with better infrastructure. On the other hand, in the

⁴Research ICT Africa conducts research on ICT policy and regulation that facilitates evidence-based and informed policy making for improved access, use and application of ICT for social development and economic growth. The organization collects survey data on ICT access and use across African countries. see <http://www.researchictafrica.net>

group of mobile phone adopters, the use of mobile phones to access services, such as email, skype, social media networks and Internet browsing, does not depend on the availability of physical infrastructure. Our results support the notion that mobile phones improve the livelihood of individuals who reside in remote areas by providing them with access to services which are otherwise not available physically. Moreover, we find that all income groups equally benefit from mobile financial services.

The remainder of the chapter is organized as follows. In Section 2.2 we discuss the evolution of the mobile phone industry in Sub-Saharan Africa. Section 2.3 discusses the data sets used in the chapter. Section 2.4 introduces the econometric model and Section 2.5 presents the estimation results. Finally, Section 2.6 concludes.

2.2 Mobile Telecommunications in Sub-Saharan Africa

Mobile services have become affordable to a broader group of consumers in low income countries with the introduction of prepaid services. Before that, most individuals, and especially those living in remote areas, did not have access to any telecommunications services at all.

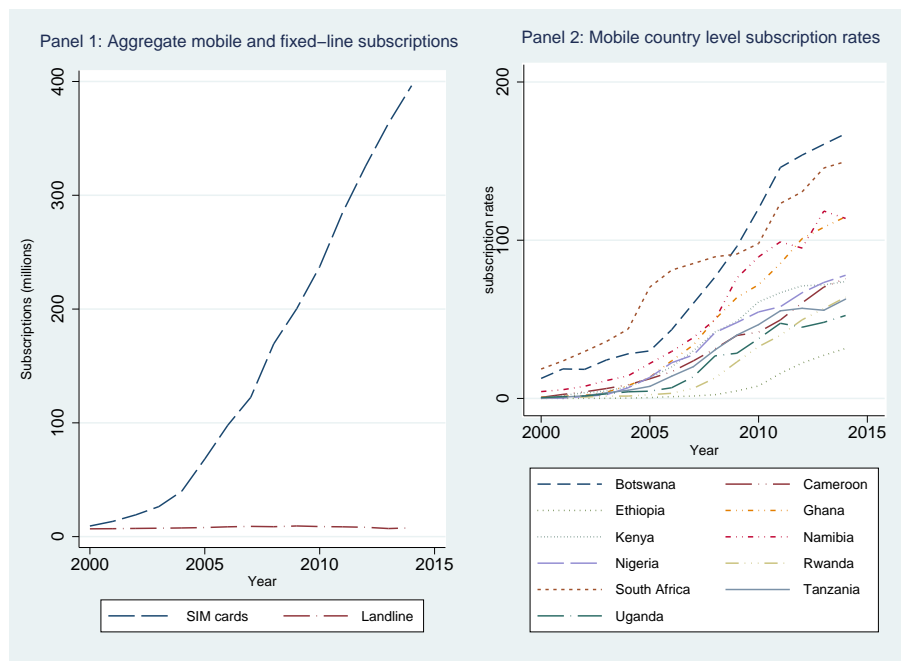
Due to a poor fixed-line infrastructure, Sub-Saharan Africa almost completely skipped the era of fixed-line telecommunications and embraced mobile telecommunications for the use of both voice and Internet services. By the end of 2014, there were 600 million mobile phone subscribers in Africa. This represents a penetration rate of about 68%.⁵

Figure 1, Panel 1 shows the total number of mobile phone and fixed-line subscribers in the 11 surveyed countries in years 2000-2014 and Panel 2 shows the subscription rates per country. The number of mobile phone subscriptions has grown exponentially, from 9.3 million in 2000 to 396.3 million in 2014. This represents a growth rate of 41.5% over the period of 14 years. As of the end of 2014, there were in total about 396 million active SIM cards in the countries of interest. In 2014, Botswana had the highest subscription rate with about 167 SIM cards per 100 inhabitants. Other countries with high subscription rates are South Africa (150), Ghana (115) and Namibia (114). On the opposite end, the subscription rate in Ethiopia stood at 32 SIM cards per 100 inhabitants. At the same

⁵www.gsma.com

time, the number of fixed-line connections in Africa stagnated, growing from about 6.8 million in 2000 to 7.8 million in 2014, which represents a growth rate of only 12% in the period of 14 years.⁶

Figure 2.1: Aggregated and Country Level Mobile Phone Subscriptions For The Sub-Saharan Countries



Many mobile phone users in Africa live in remote areas where there is inadequate access to financial services, health services and educational programs.⁷ The evolution of mobile networks coupled with advances in mobile technologies has led to the emergence of various initiatives which rely on mobile phones to provide financial, health care, agricultural and other services. However, increased demand for mobile phone services and broadband Internet puts pressure on the current network capacity. To ease pressure on their, networks most operators in Africa are now connected to fiber optics cables and are migrating from the 3G to the 4G/LTE networks.

⁶Own calculation from ITU mobile phone subscriptions data.

⁷To achieve universal access to mobile services, some countries such as Botswana introduced infrastructure sharing policy. This initiative of sharing towers reduced the cost of network development and made it possible for mobile network operators to connect to areas which were initially deemed unprofitable.

In 2008, a number of mobile phone operators in Africa started to deploy the 3G networks based on the UMTS/HSDPA and W-CDMA technologies. The introduction of the 3G networks increased Africa's Internet connectivity which was very low in most of the countries. A number of mobile operators on the continent are already deploying fourth generation mobile networks (4G) which enable high speed Internet access. These networks allow users to browse the Internet, engage in mobile commerce, receive and send emails and connect with friends on various social media networks.

2.2.1 Mobile Money

Mobile phone services are defined as the use of mobile phones to remotely access services which are typically provided over the counter. In particular, we analyze the determinants of usage of: (i) mobile money and (ii) mobile social and Internet activities.

The provision of financial services on the mobile phone, generally called mobile banking, enables consumers to use mobile phones to access bank accounts, transfer money, make payments and perform other financial operations. A mobile phone can serve as a virtual bank card, a point of sale terminal, an automated teller machine (ATM) and an Internet banking terminal which provides immediate access to accounts and enables transfers remotely. The services may be provided by a particular financial institution as an extension of its existing electronic banking services, or independently by a telecommunications provider. Alternatively, financial institutions and telecommunications providers may establish a partnership to provide mobile banking services (see Brown et al. (2003); Kim et al. (2009)).

The most common form of mobile banking in Sub-Saharan Africa is the M-Pesa, which is a mobile money transfer and micro financing service launched in 2007 by Vodafone in Kenya for the operators Safaricom and Vodacom. It enables users to transfer or cash-in money using a mobile account (referred to as wallet) that is linked to a unique mobile phone number of a subscriber. It also allows accessing a wide range of services such as domestic and international money transactions, payments for bills, flights, hotels, and airtime top-up (see Morawczynski & Miscione (2008)).

M-Pesa is most common in Eastern African countries, such as Kenya, Uganda and

Tanzania, Rwanda and Burundi, but it has also expanded to other African countries such as Cote d'Ivoire, Senegal, Madagascar, Mali, Niger, Botswana, Cameroon and South Africa. Outside of Africa, M-Pesa operates in Afghanistan, Jordan and other countries. In Botswana, it is rolled out by two operators Orange Botswana (Orange Money) and Mascom Wireless (MyZaka) and it enables VISA card payments and automated teller machine (ATM) cash withdrawals. A number of banks in Africa have also rolled out a similar service called e-wallet. E-wallet differs from M-Pesa in that it requires the sender to have a bank account even though the receiver can only withdraw cash at an ATM using their mobile phone number and a personal identification number (PIN), which is sent to their mobile phone.⁸ The introduction of smartphones in recent years has allowed banks to launch mobile services that complement over the counter and Internet services.

2.3 Data

We combine two data sets to analyze the impact of infrastructure deficiencies on the use of mobile services. The first database includes a set of representative individual and household surveys which were conducted by Research ICT Africa in 2011 in the following 11 countries: Botswana, Cameroon, Ethiopia, Ghana, Kenya, Namibia, Nigeria, Rwanda, South Africa, Tanzania and Uganda. The survey data includes individual and household-level information on fixed, mobile and Internet access and use.⁹ Table 2.1 shows the number of individuals surveyed in each country and the share of mobile phone users. Out of the total number of 13,814 survey respondents there are 8,829 respondents who declared having a mobile phone.¹⁰

⁸see www.bocra.org.bw

⁹The survey was also conducted in Mozambique. The data for Mozambique was not made available to us. For details on the representativeness, sampling and data collection procedures see <http://www.researchictafrica.net>.

¹⁰The initial sample size is 13,877, but 63 observations were dropped during data cleaning.

Table 2.1: Usage of mobile phones

Country	Full sample		Restricted sample		
	% mobile	obs.	% mobile	obs.	% of full
Botswana	84%	893	85%	824	92%
Cameroon	53%	1199	66%	839	70%
Ethiopia	36%	1608	45%	600	37%
Ghana	61%	1203	69%	809	67%
Kenya	70%	1239	72%	1162	94%
Namibia	66%	955	69%	746	78%
Nigeria	68%	1552	70%	1271	82%
Rwanda	32%	1200	54%	336	28%
South Africa	85%	1588	86%	1326	84%
Tanzania	47%	1177	56%	841	71%
Uganda	61%	1200	64%	912	76%
Total	60%	13814	69%	9666	70%

Notes: Restricted sample includes observations on individuals for which night light data was available.

The second database is Defense Meteorological Satellite Program Operational Line Scanner (DMSP/OLS) nighttime lights time series from the National Oceanic and Atmospheric Administration/National Geophysical Data Center (NOAA/NGDC).¹¹ We use information on nighttime light intensity for the year 2011 in which the survey data was collected. Nighttime light intensity is measured on a continuous scale from 1-63 pixel at a resolution of approximately 1 square kilometre.¹²

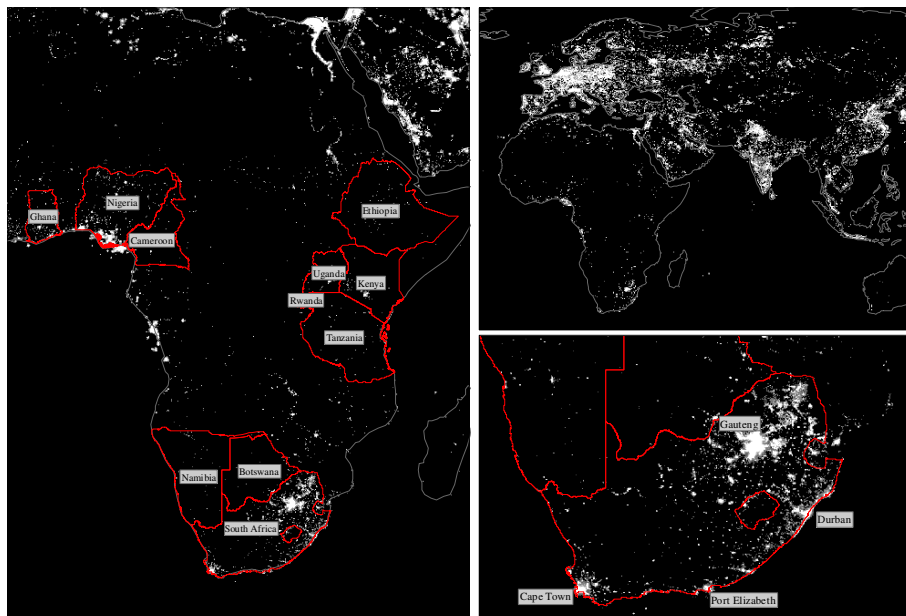
Google Maps was used to generate coordinates for the 405 districts in 11 countries in which the survey respondents reside. Nighttime lights data was then extracted using these coordinates and merged with the survey database. Figure 2 shows the 2011 nighttime light intensity on the African continent. The lines on the map divide Africa into different countries using border line coordinates. The line shows countries where night light intensity data was extracted for the purpose of this analysis. Unfortunately, we

¹¹The Defense Meteorological Satellite Program Operational Line Scanner (DMSP/OLS) was originally used to detect the global distribution of clouds and cloud top temperatures in the early 1970s. Since the establishment of a digital archive in 1992 by the NOAA/NGDC, these nighttime data have been widely exploited by the scientific community, for instance, in economic applications to approximate economic growth and development (see Ghosh et al. (2010); Henderson et al. (2011); Ma et al. (2012))

¹²The extracted data ranges between 0 and 63 but zero measures imply the background, which is thus replaced by missing values. For details on the data see <http://www.ngdc.noaa.gov>

information on nighttime light intensity is only available for 275 areas out of 405.

Figure 2.2: Nighttime light intensity



The survey respondents are associated with 91 rural and 174 urban areas for which nighttime light intensity data is available. Table 2.2 shows the mean and standard deviation of light intensity across different countries in rural and urban areas. As anticipated, the urban areas are more lit in the night than rural areas. There are significant differences in night light intensity across countries.

Table 2.2: Night light intensity by country and type of area

Country	Rural		Urban	
	Mean(std)	No. of areas	Mean(std)	No. of areas
Botswana	21.0 (20.8)	8	45.1 (13.2)	8
Cameroon	11.8 (10.4)	4	38.7 (25.6)	19
Ethiopia	14.0 (12.7)	2	34.9 (22.1)	17
Ghana	15.1 (19.5)	9	32.1 (24.2)	19
Kenya	12.6 (7.9)	9	19.9 (19.7)	15
Namibia	15.0 (14.0)	14	36.0 (22.5)	23
Nigeria	20.0 (23.0)	20	34.9 (23.2)	29
Rwanda	7.0 (0.0)	1	7.3 (1.3)	4
South Africa	33.3 (26.2)	11	41.6 (22.5)	19
Tanzania	11.3 (4.3)	4	20.7 (16.8)	15
Uganda	11.8 (5.1)	9	23.3 (18.8)	6

We analyze individuals' decision to adopt mobile phone and to use mobile services in the following areas: (i) mobile money, (ii) mobile transfers and (iii) mobile social and Internet activities. Table 2.3 shows the percentage of mobile phone owners which use each of these services. The variable 'Mobile money' is defined as 0-1 variable based on the answers to the following question: "Do you ever use your mobile phone to send or receive money (Mpesa, mobipay)?", while 'mobile transfer' is constructed from answers to the following question: "Do you use mobile phone for sending or receiving money?" Overall, 18% of mobile phone adopters use mobile money with large differences across countries. Kenya has the highest share of mobile money users (81%) followed by Tanzania (46%) and Uganda (39%). The high level of adoption of mobile banking in these countries can be attributed to the widespread use of M-Pesa. The adoption of mobile money in the remaining countries is below 10% with the exception of 14% in Botswana. The use of

mobile transfers is a bit higher (on average 21%) with a similar pattern across countries.

Table 2.3: Usage of mobile services (by mobile phone users)

Country	Full sample				Restricted sample			
	Social	Money	Transfer	Obs.	Social	Money	Transfer	Obs.
Botswana	28%	14%	17%	751	29%	14%	18%	701
Cameroon	14%	1%	5%	640	14%	1%	5%	552
Ethiopia	12%	0%	0%	580	17%	0%	1%	270
Ghana	17%	2%	2%	735	18%	2%	2%	562
Kenya	31%	81%	80%	871	32%	81%	80%	832
Namibia	34%	7%	9%	632	36%	7%	9%	513
Nigeria	26%	1%	6%	1058	26%	1%	6%	891
Rwanda	21%	9%	17%	386	29%	10%	22%	181
South Africa	32%	5%	8%	1349	34%	5%	9%	1141
Tanzania	19%	46%	48%	555	21%	50%	52%	471
Uganda	18%	39%	42%	735	18%	41%	44%	588
Total	24%	18%	21%	8292	26%	21%	23%	6702

Notes: Statistics is provided for users of mobile phones only. Restricted sample includes observations on individuals for which night light data was available. Social is defined as usage of mobile social and communications services. Money is defined as usage of mobile money and transfer as use of mobile phones for money transfer.

‘Mobile social’ variable in our study is defined as 0-1 variables when survey respondents confirmed using mobile phones for the following activities: (i) Browsing the Internet; (ii) Reading and writing emails; (iii) Facebook, Twitter, Mixit or other social networking; (iv) Skype / Voice over IP. On average 24% of survey respondents having a mobile phone use ‘mobile social’ services. The distribution is more even across countries with the highest share of users in Namibia (34%) followed by South Africa (31%) and Kenya (31%) and the lowest in Cameroon (14%) and Ethiopia (12%).

Table 2.4: Descriptive statistics

	N	Mean	Std	Min	Max
mobile_phone	13814	060	049	0	1
mobile_money	13814	012	032	0	1
mobile_transfer	13814	013	033	0	1
mobile_social	13814	015	035	0	1
mobile_friends	13814	313	201	0	5
female	13814	053	050	0	1
married	13814	046	050	0	1
age below 25	13814	033	047	0	1
age > 25 and ≤ 35	13814	033	047	0	1
age > 35 and ≤ 45	13814	016	036	0	1
age > 45 and ≤ 55	13814	008	027	0	1
age > 55 and ≤ 65	13814	006	023	0	1
primary	13814	032	047	0	1
secondary	13814	033	047	0	1
tertiary	13814	013	033	0	1
employed	13814	023	042	0	1
self_employed	13814	034	047	0	1
income > 20 and ≤ 100	13814	034	048	0	1
income > 100 and ≤ 300	13814	036	048	0	1
income > 300 and ≤ 500	13814	013	034	0	1
income > 500	13814	005	022	0	1
electricity	13814	062	049	0	1
radio	13814	066	047	0	1
tv	13814	049	050	0	1
satellite	13814	017	037	0	1
computer	13814	011	031	0	1
bank_account	13814	048	050	0	1
fixed_line	13814	007	025	0	1

Table 2.4 presents descriptive statistics for dependent and explanatory variables used in the estimation. The explanatory variables can be divided into: (i) individual characteristics such as gender, marital status, age group, level of education and employment; household characteristics such as disposable income in US\$ PPP, access to electricity, radio, TV, satellite TV, computer, bank account and fixed-line telephone. In addition, we also use information on how many friends of the survey respondent have mobile phones. This controls for network externalities in the adoption of mobile phones and mobile services.

2.4 The Econometric Model

We estimate a standard model in which an individual decides whether to adopt a mobile phone or not. In addition, for the group of mobile phone adopters, we estimate three models in which they decide whether to use, ‘mobile money’, ‘mobile transfers’ and ‘mobile social’ services, which we defined in the previous section. Each of these decisions are 0-1 variables which are estimated using a logit model.

We assume that consumer i in geographic area m derives a linear utility from having a mobile phone or using a mobile service given by:

$$U_i = X_i\beta + I_{im}\gamma + \epsilon_{im} = V_i + \epsilon_i \quad (2.1)$$

where X_i denotes a vector of individual and household characteristics specified in the previous section, I_{im} is the availability of service infrastructure approximated by nighttime light intensity in the geographic area where the individual resides and ϵ_i is the error term which is assumed to be extreme value distributed. The probability that individual i decides to have a mobile phone, $y_{im} = 1$, is given by:

$$P_i(y_i = 1) = \frac{\exp(V_i)}{1 + \exp(V_i)} \quad (2.2)$$

and the probability of not having a mobile phone is denoted by $P_i(y_i = 0) = 1 - P_i(y_i = 1)$. The probability of using a particular mobile phone service can be written analogously.

Assuming that the decisions of all individuals in the sample $i = 1, 2, \dots, N$ are independent, the cumulated log-likelihood function can be written as:

$$\mathcal{L}(\theta) = \sum_{i=1}^N y_i \log(P_i) \quad (2.3)$$

The vector of all parameters, which is estimated using maximum likelihood estimators, is denoted by $\theta = (\beta, \gamma)$.

2.5 Estimation Results

Table 2.5 shows the estimation results for eight logit regressions. First, we estimate two regressions for an individual’s decision to adopt a mobile phone. The first estimation is

conducted using full survey data and the second for a sample restricted to individuals for whom nighttime light intensity data is available. Next, for the group of mobile phone users, we estimate the decision to use the following mobile phone services: ‘mobile money’, ‘mobile transfers’ and ‘mobile social’. Again, we estimate these models using data of all mobile phone adopters and a sample restricted to mobile phone users for whom nighttime light intensity data is available. We use the same set of explanatory variables in all regressions.¹³

¹³As shown in Table 2.1, there are large differences in the use of mobile services between countries in the sample. We do not use country fixed effects in the estimation which explain large part of the variation, but make many of the individual and household variables insignificant and do not have clear economic interpretation.

Table 2.5: Estimation results

	Mobile phone		Mobile money		Mobile transfer		Mobile social	
	Est. I	Est. II	Est. I	Est. II	Est. I	Est. II	Est. I	Est. II
night light		0.01*** (0.001)		-0.01*** (0.001)		-0.01*** (0.001)		-0.00 (0.001)
mobile friends	0.47*** (0.014)	0.46*** (0.017)	0.10*** (0.024)	0.08*** (0.026)	0.06*** (0.022)	0.04 (0.024)	0.09*** (0.024)	0.08*** (0.027)
female	-0.12** (0.053)	-0.09 (0.065)	0.24*** (0.062)	0.22*** (0.066)	0.18*** (0.058)	0.19*** (0.063)	-0.42*** (0.062)	-0.41*** (0.067)
married	0.19*** (0.056)	0.21*** (0.068)	0.37*** (0.066)	0.38*** (0.071)	0.37*** (0.063)	0.38*** (0.068)	-0.15** (0.068)	-0.18** (0.074)
age below 25	0.21 (0.134)	0.05 (0.160)	0.75*** (0.270)	0.89*** (0.289)	0.57** (0.230)	0.63** (0.244)	1.35*** (0.234)	1.51*** (0.262)
age > 25 and ≤ 35	0.59*** (0.135)	0.50*** (0.161)	0.64** (0.268)	0.77*** (0.287)	0.43* (0.229)	0.49** (0.243)	0.77*** (0.234)	0.93*** (0.262)
age > 35 and ≤ 45	0.73*** (0.142)	0.62*** (0.172)	0.31 (0.274)	0.37 (0.294)	0.05 (0.235)	0.06 (0.249)	0.60** (0.240)	0.72*** (0.269)
age > 45 and ≤ 55	0.57*** (0.154)	0.50*** (0.185)	0.14 (0.288)	0.13 (0.310)	-0.18 (0.250)	-0.27 (0.267)	0.05 (0.257)	0.20 (0.285)
age > 55 and ≤ 65	0.61*** (0.160)	0.57*** (0.191)	0.24 (0.303)	0.40 (0.321)	0.02 (0.263)	0.05 (0.278)	-0.45 (0.286)	-0.31 (0.315)
primary	0.45*** (0.068)	0.45*** (0.088)	0.72*** (0.172)	0.62*** (0.186)	0.65*** (0.155)	0.69*** (0.177)	0.04 (0.175)	0.36 (0.222)
secondary	1.15*** (0.079)	1.10*** (0.097)	0.93*** (0.171)	0.71*** (0.184)	0.84*** (0.154)	0.80*** (0.176)	0.53*** (0.168)	0.74*** (0.214)
tertiary	1.67*** (0.142)	1.61*** (0.160)	1.54*** (0.179)	1.44*** (0.193)	1.38*** (0.163)	1.45*** (0.184)	1.28*** (0.175)	1.54*** (0.220)
employed	0.40*** (0.082)	0.50*** (0.095)	0.46*** (0.083)	0.46*** (0.088)	0.43*** (0.079)	0.45*** (0.084)	-0.19** (0.081)	-0.19** (0.088)
self-employed	0.03 (0.064)	0.22*** (0.079)	0.30*** (0.087)	0.32*** (0.094)	0.31*** (0.082)	0.36*** (0.089)	-0.43*** (0.090)	-0.39*** (0.099)
income > 20 and ≤ 100	3.49*** (0.172)	3.22*** (0.186)	-0.32 (0.461)	-0.04 (0.503)	0.34 (0.540)	0.39 (0.546)	0.37 (0.464)	0.32 (0.473)
income > 100 and ≤ 300	3.92*** (0.173)	3.61*** (0.187)	0.14 (0.459)	0.40 (0.499)	0.87 (0.538)	0.92* (0.544)	0.78* (0.461)	0.73 (0.469)
income > 300 and ≤ 500	3.89*** (0.186)	3.75*** (0.204)	0.08 (0.461)	0.33 (0.502)	0.78 (0.540)	0.82 (0.546)	1.10** (0.463)	1.05** (0.472)
income > 500	4.41*** (0.251)	4.15*** (0.280)	-0.27 (0.470)	0.02 (0.511)	0.58 (0.546)	0.66 (0.552)	1.34*** (0.467)	1.28*** (0.477)
electricity	0.44*** (0.067)	0.32*** (0.083)	-0.77*** (0.104)	-0.76*** (0.114)	-0.65*** (0.099)	-0.66*** (0.110)	-0.17 (0.121)	-0.12 (0.140)
radio	0.43*** (0.054)	0.42*** (0.067)	0.83*** (0.088)	0.78*** (0.093)	0.65*** (0.079)	0.57*** (0.084)	0.19** (0.078)	0.20** (0.086)
TV	0.61*** (0.073)	0.58*** (0.086)	0.16 (0.097)	0.13 (0.104)	0.16* (0.092)	0.18* (0.099)	0.56*** (0.104)	0.58*** (0.117)
satellite	0.22** (0.099)	0.34*** (0.110)	-0.82*** (0.088)	-0.82*** (0.093)	-0.69*** (0.082)	-0.68*** (0.086)	0.10 (0.074)	0.11 (0.080)
computer	0.31** (0.134)	0.39*** (0.145)	0.44*** (0.089)	0.38*** (0.094)	0.45*** (0.084)	0.40*** (0.089)	1.25*** (0.078)	1.27*** (0.084)
bank account	0.39*** (0.061)	0.27*** (0.072)	0.70*** (0.081)	0.72*** (0.087)	0.67*** (0.076)	0.70*** (0.083)	0.65*** (0.083)	0.73*** (0.093)
fixed-line	-0.51*** (0.127)	-0.70*** (0.142)	-0.43*** (0.127)	-0.37*** (0.134)	-0.28** (0.114)	-0.18 (0.121)	0.13 (0.102)	0.16 (0.111)
constant	-6.67*** (0.221)	-6.42*** (0.253)	-4.52*** (0.559)	-4.29*** (0.608)	-4.50*** (0.604)	-4.08*** (0.622)	-4.54*** (0.547)	-4.97*** (0.586)
Observations	13,814	9,666	8,292	6,702	8,292	6,702	8,292	6,702

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

Our main variable of interest is the availability of physical infrastructure approximated by nighttime light intensity at the geographic location of survey respondents based on a one kilometer radius. We find that, after controlling for individual and household characteristics, the availability of infrastructure has a significant and positive impact on

adoption of mobile phones. Thus, people residing in more developed areas tend to benefit more from having a mobile phones. At the same time, the availability of infrastructure has a significant and negative impact on the usage of mobile money and mobile transfers in the mobile phone adopters group. For comparison, it has no impact on the use of mobile phones for social and Internet activities. We test the robustness of this result by re-estimating the model using two kilometers instead of a one kilometer radius. The estimation results are broadly the same with a significant and positive impact of this variable on mobile phone adoption and a significant and negative impact on the use of mobile money and mobile transfers. Thus, mobile money can be considered as an alternative to physical infrastructure which benefits people who live in remote areas and may be excluded from access to financial services. This result confirms the role which mobile phones have for social inclusion and economic development in developing countries with poor physical infrastructure.

We find that the decision to adopt mobile phones and use mobile services is determined by a number of consumer characteristics. In particular, the declared number of friends and family members, who have mobile phones, has a significant and positive impact on the probability of using a mobile phone. This effect can be attributed to network externalities. When the number of mobile phone users in the communications circle of an individual increases, the value of having a mobile phone also increases. Previous literature also reports on the role of network externalities in the diffusion of mobile phones, see for example, Birke & Swann (2010) and Grzybowski (2015). We also find that the number of friends and family using mobile phones have a positive impact on the probability of adopting mobile services considered.

Furthermore, we find that females are less likely to adopt mobile phones possibly due to social and cultural factors. However, once they have a mobile phone, they are more likely to use it for mobile money and mobile transfers but less likely for social and Internet activities. This result suggests that women manage finances in the household. Married individuals are more likely to adopt mobile phones and use it for mobile money and transfers, but less likely for social and Internet activities. Individuals in the age between 25 and 65 are more likely to adopt mobile phones than individuals who are

less than 25 years. Interestingly, individuals aged between 15 and 35 are more likely to use mobile phones for finances and for social and Internet activities than the other age groups. Adoption of mobile phones and use of mobile services is higher for individuals with education and increases with the level of education. Moreover, adoption of mobile phones is higher among employed individuals. Usage of mobile phones for finances is also higher for employed individuals, but at the same time, employment reduces the use of mobile phones for social and Internet activities.

Individuals with higher disposable income are more likely to adopt mobile phones but, interestingly, the level of income does not determine the use of mobile money and transfers. At the same time, higher income groups are more likely to use mobile phones for social and Internet activities. This result suggests that once consumers adopt a mobile phone, all income groups benefit equally from mobile money and transfer services. This emphasizes the role of mobile phones for social inclusion and economic development. Table 2.6 illustrates shares of users of mobile services by disposable income categories. It confirms that the adoption of mobile phones is determined by the level of income. In the group of mobile phone adopters, however, the use of mobile money and transfer services is comparable for all income categories, while mobile social and Internet services are used more by wealthier individuals.

Table 2.6: Usage of mobile services (by income group)

Country	Full sample				Mobile phone users			
	Social	Money	Transfer	Obs.	Social	Money	Transfer	Obs.
no income	0%	1%	0%	1566	16%	14%	9%	44
income > 0 and <= 20	6%	6%	7%	4753	13%	12%	13%	2335
income > 20 and <= 100	17%	17%	18%	4926	23%	21%	24%	3704
income > 100 and <= 300	28%	19%	21%	1863	34%	22%	25%	1546
income > 300	46%	16%	20%	706	49%	17%	22%	663
Total	15%	12%	13%	13814	24%	18%	21%	8292

Statistics for all survey respondents vs. mobile phone users.

Another result which indicates households with limited access to infrastructure benefit from mobile financial services is that not having electricity at home negatively influences

adoption of mobile phones, but has a positive impact on the use of mobile money and transfers. Thus, people living in remote areas without basic infrastructure must rely on mobile phones for financial transactions. Moreover, the ownership of radio, TV and computer has overall a positive impact on adoption of mobile phones and mobile services. This implies that better equipped and wealthier households are more likely to adopt mobile phones and mobile services. Also, individuals with bank accounts are more likely to adopt mobile phones and mobile services. Finally, individuals from households with fixed-line connection are less likely to adopt mobile phones and use mobile money and mobile transfers. This suggests that mobile and fixed-line connections are substitutes and that fixed-line can be used as an alternative to financial transactions made on mobile phones.

2.6 Conclusions

The deployment of mobile telecommunications overcomes the main burdens to economic growth in developing countries, which are poor or non-existent physical infrastructure including fixed-line and Internet access. In particular, mobile phones provide access to services which are in general not available to low income households, such as mobile phone-based financial, agricultural, health and educational services. However, the empirical literature which documents the benefits brought by mobile phones to consumers in low income countries is limited due to lack of detailed data. In this thesis, we contribute to this literature by analyzing the determinants of adoption of mobile phones and mobile financial services. We use a unique database which we combine using two data sources. We use data from a survey of 13,814 individuals in 11 Sub-Saharan African countries in 2011, which includes answers to questions on access to mobile phones and use of mobile services including mobile money, transfers and social and Internet activities. The survey data is complemented with nighttime light intensity data, which we use to approximate the availability of service infrastructure at the location of survey respondents. The use of nighttime light intensity data enables us to analyze how spatial differences in infrastructure development across Sub-Saharan Africa influence the adoption of mobile phones and use of mobile services by individuals.

We estimate a number of logit regressions. After controlling for a number of individual and household characteristics including disposable income, we find that adoption of mobile phones is higher in areas with better physical infrastructure. However, in the group of mobile phone adopters, the use of mobile phones for mobile money and transfers is negatively influenced by the level of infrastructure. On the other hand, the use of mobile phones to access services, such as email, skype, social media networks and Internet browsing, is not dependent on the availability of physical infrastructure. In this way, mobile money can be considered as an alternative to physical infrastructure which benefits people who live in remote areas and may be excluded from access to financial services. This result confirms the role which mobile phones have for social inclusion and economic development in low income countries with poor physical infrastructure. Our results support the notion that mobile phones improve the livelihood of individuals residing in remote areas by providing them with access to financial services which are otherwise not available physically. Moreover, we find that while individuals with higher disposable income are more likely to adopt mobile phones, the level of income does not determine use of mobile money and transfers. At the same time, higher income groups are more likely to use mobile phones for social and Internet activities. This result suggests that once consumers adopt a mobile phone, all income groups benefit equally from mobile money and transfer services. This emphasizes the role of mobile phones for social inclusion and economic development.

Chapter 3

The Impact of Mobile Number Portability on Demand Price Elasticities in Sub-Saharan Africa

3.1 Introduction

Provision of mobile telecommunication services requires large investments in infrastructure designed to access spectrum and coverage expansion.¹ The industry is therefore considered to be a natural oligopoly and licences to operate mobile networks are granted only to a few competitors (see Valletti (2003)). Because of this constraint in the viable number of competitors, the mobile telecommunications industry is often subject to competition concerns raised by the regulators and competition authorities. The characteristics of the mobile industry make it susceptible to collusion and the exercise of market power. In addition, consumers of mobile services tend to have high switching costs, which may weaken competition among existing firms and make successful entry of new firms difficult. Moreover, the increasing usage of mobile Internet services and scarcity of spectrum has already led to a reduction in the number of competitors in a few countries, in which mergers between mobile operators were cleared by the regulators.²

Critical market information in the assessment of market power and price effects of mergers are price elasticities of demand. Price elasticities of demand are also an input

¹The radio spectrum includes both licensed and unlicensed frequencies up to 300GHz used to transmit voice, video and data.

²For instance, in 2014 the European Commission cleared Telefonica's 8.6 billion Euros takeover of German mobile rival E-Plus.

into regulation of telecommunications incumbents. For instance, in the case of Ramsey pricing regulation, prices for individual services are set above marginal cost according to each service's price elasticity of demand. Since the price elasticities of demand are an important input into policy debates in telecommunications markets, there is a growing number of studies which provides such estimates. In particular, due to the differentiated products character of mobile industry, the appropriate estimation of price elasticities requires use of firm-level data.

Most of the empirical studies estimating price elasticities focus on developed economies. We are not aware of any studies estimating price elasticities of demand for mobile markets in African countries. This is mainly due to the scarcity of firm-level data. Furthermore, even though a number of regulatory authorities in Africa have introduced mobile number portability (MNP), which allows consumers to keep their phone numbers when changing operator, we are not aware of any study that evaluates the impact of this policy on price elasticities of demand and competition between operators. This chapter contributes to the literature by estimating price elasticities of demand for a number of African countries using operator-level time series data. In addition, in the estimation we allow the price elasticities of demand to depend on whether MNP is in place in a particular country. For this purpose, we use quarterly data for 27 operators in seven African countries between 2010:Q4 and 2014:Q4 to estimate multinomial logit of demand.

We find that MNP increased own-price elasticities of demand in countries that have implemented a policy that mandates MNP. The increase in price elasticities due to MNP may be a result of the reduction in switching costs between operators. On average, the introduction of MNP increases own-price elasticities by 0.47 in absolute terms. We compare the level of price elasticities before and after the implementation of MNP in Ghana and Kenya, which implemented this policy in the time period of our study. Our results suggest that in Ghana, MNP increased own-price elasticities by an average of 0.35 in absolute value from an average across firms and over time of -0.74. In Kenya, the introduction of MNP increased own-price elasticities by an average of 0.21 in absolute term from a lower average value across firms and over time of -0.39. However, we find that in Kenya and Ghana, the average own-price elasticities remained small even after

the implementation of MNP relative to other countries without MNP in place. Thus, our results suggest that MNP is not a complete solution for increasing competitiveness in the mobile industry. Generally, operator own-price elasticities are high in all the sampled countries except for Ghana and Kenya.

The remainder of this chapter is organized as follows. Section 3.2 discusses theoretical and empirical literature on switching costs and demand price elasticities in the mobile telecommunication markets. Section 3.3 provides an overview of implementation of mobile number portability in Sub-Saharan African countries. Section 4.4 presents the data. Section 4.5 introduces the empirical model. Section 3.7 discusses the estimation results and Section 3.8 concludes.

3.2 Literature Review

This chapter draws on two strands of literature on price elasticities and switching costs. There is a consensus in the theoretical literature that switching costs reduce consumer responsiveness to price changes, and make each firms' individual demand less elastic (see, for example, Von Weizsäcker (1984), Klemperer (1987a), Klemperer (1987b) and Shy (2002)). However, there is little evidence of the impact of switching costs on price elasticities.

Among studies which estimate price elasticities of demand in mobile telecommunications markets, Doganoglu & Grzybowski (2007) use aggregate monthly firm-level data for Germany to estimate price elasticities of demand for subscriptions. They find large own-price elasticities ranging from -5.04 to -4.20. In another study, Grzybowski & Pereira (2007) use a model proposed by Doganoglu & Grzybowski (2007) to estimate own- and cross-price elasticities for mobile telecommunication subscriptions in Portugal. Using quarterly data, they find large own-price elasticities ranging from -6.41 to -2.59. In another study, Iimi (2005) estimates price elasticities using operator-level data for Japan, which contains information on subscriptions and prices between January 1996 to December 1999. He finds high own-price elasticities ranging from -1.30 to -2.43.

There is consensus with regard to the existence of switching costs in the mobile telephone industry, (see for instance Lee et al. (2006), Grzybowski (2008b)), which may be

due to compatibility, transaction or search costs. However, we are not aware of any empirical literature that provides evidence on how switching costs affect price elasticities in the mobile telephone services. Literature that evaluates the impact of switching costs on price elasticities in other industries includes a paper by Strombom et al. (2002) who use a data set containing information on choice of health plans and premiums for 103,835 University of California employees. They estimate a conditional logit model and find that price sensitivity declines with consumer's age which is the determinant of switching costs. Hartmann & Viard (2008) analyze switching costs in the context of a dynamic structural model of demand in a reward program. They consider a program in which golfers are given a green fee certificate after purchasing ten rounds of golf. The green card entitles subscribers to a discount of 25, 50 or 100% off the price of a round of golf depending on the course. They find that when customers face significant switching costs, their demand become less elastic. The study concludes that when customers are not locked-in, in other words, when customers have no incentive from the program, elasticities mimic those realized when the program did not exist.

Another stream of literature that is close to the present study is the literature on MNP and switching costs. For instance, Gans et al. (2001) and Bühler et al. (2006) conclude that MNP reduces switching costs by allowing subscribers to retain their number when changing operators. However, these studies draw their conclusions from a qualitative analysis. Lyons et al. (2006) use international time-series cross-sectional data for 22 quarters between 1999 and 2004 to examine the impact of MNP on market outcomes. They find that MNP reduces switching costs. Using quarterly panel data of 218 major operators in 52 countries for the period 2003-2009, Wei & Zhu (2010) find that the introduction of MNP reduces switching costs and balances market shares between large and small firms. Specifically, they find that MNP reduces large firms' market share by an average of 0.8%, while small firms gain on average 1.5%. They also find that large firms become more profitable after the introduction of MNP.

In another study, Viard (2007) studies the effect of number portability on switching costs and price competition when new and old consumers are charged the same price. Using a dataset that contains information on the nature of subscriber contracts and the

timing of portability decisions, he employs a difference-in-difference estimation strategy and concludes that portability reduces switching costs and increases price competition.

Studies which conclude that MNP reduces switching costs do not provide empirical evidence on the size of the impact of MNP on price elasticities. We fill this gap in the literature by providing empirical evidence on the impact of MNP on price elasticities of demand in selected African countries using firm-level data. To the best of our knowledge, this is the first study that uses detailed firm-level data for mobile telecommunications markets in African countries for this purpose. It therefore provides useful information for competition and regulatory proceedings.

3.3 Mobile Number Portability in Sub-Saharan Africa

Mobile number portability is recognized as an important tool to intensify competition between mobile operators and, as of 2012, was implemented in 73 countries worldwide.³ In Africa, the facility has been implemented by eight countries: Democratic Republic of Congo, Egypt, Ghana, Kenya, Morocco, Nigeria, South Africa and Sudan (see Table 3.1).⁴ Among these countries, due to the availability of data, this present study considers Ghana, Kenya, Nigeria and South Africa.

Table 3.1: African Countries with MNP

Country	Time	Country	Time
Egypt	07/04/2008	Nigeria	01/01/2007
Ghana	07/07/2011	South Africa	10/11/2006
Kenya	01/07/2011	DRC	30/09/2009
Morocco	01/01/2007	Sudan	01/11/2012

Source: mcclist.com

Notes: Table 3.1 presents African countries with mobile number portability and the date at which number portability was implemented in each country.

³see mcclist.com

⁴As pointed out by Bühler & Haucap (2004), the first country to adopt MNP is Singapore in 1997. However, MNP in Singapore was only call forwarding. In order to use this facility, one had to have two mobile phone numbers at the same time. A more structural MNP based on a centralized database was introduced in the UK, Hong Kong, and the Netherlands as early as 1999.

A number of factors differentiate MNP implementation in African countries. These includes the speed of processing requests and the time allowed to effect another port after completing the previous one. By 2014, on average, it took four minutes and 16 seconds to complete the porting process in Ghana. For comparison, in Nigeria, the process took 48 working hours.⁵

The MNP in Ghana was launched in 2011 and by the end of 2014. The policy was implemented to facilitate competition among operators. The number of successfully completed ports amounted to 1,655,404 among which 832,202 were completed in 2014. As of 2014, after only three years, the total number of completed ports stood at 6% of the total active mobile numbers.⁶ The evolution of market share shows that prior to the introduction of MNP in 2011 in Ghana, MTN controlled around 52% of the market.⁷ Its share declined over time after the implementation of MNP, from 51% to 46% in 2014. Tigo, the second largest mobile operator in Ghana also lost some market share due to MNP. Its market share declined from 21%, prior MNP, to 14% in 2014. The largest gainer was Vodafone, which increased its market shares to 23% in 2014 from 16% in 2010. These dynamics shows that the implementation of MNP in Ghana increased consumer mobility across competitors.

In Kenya, MNP policy was implemented in 2011 with the objective of reducing the market power of Safaricom, which owned 68% of market at that time. However, this policy did not achieve its intended objective due to low demand for porting. Only 163 ports were successfully completed in 2016 with about 1,388, less than 0.01% of subscriber base, completed in 2014.⁸ To revive this failed policy, in 2016, the regulator stipulated new guidelines aimed at shortening and simplifying the switching process. These included zero charges for porting requests and a time cap of four hours for completing the porting process. The observed market share dynamics suggest that indeed MNP did not achieve its objective of reducing Safaricom's dominance. In 2010, prior to the implementation of

⁵Source:www.balancingact-africa

⁶Source:www.balancingact-africa

⁷For all the discussions on market shares refer to Figure A.2 for Ghana, Kenya, Nigeria and South Africa, which are countries that have implemented MNP. Refer to Figure A.3 for countries that have not implemented MNP: Botswana, Mozambique and Zambia

⁸www.balancingact-africa.com

MNP, Safaricom owned 69% of the market. Its market share declined to 68% in 2011, which is the year of MNP implementation. A further decline was observed in 2012 with Safaricom losing 4% of its market share, its lost share was mostly gained by Essar Telecom (3%). However, between 2013 and 2014, Safaricom gained more market share which stood at 68% in 2014. Thus, in the first years of implementation, mobile subscribers switched from the large operator to smaller operators. Nevertheless, over time, subscribers switched from smaller operators to the market leader, Safaricom.

South Africa launched MNP in 2006. In 2012, around 1.2 million ports were successfully completed out of a subscriber base of about 60 million. As of 2012, the net gainer from this process is Vodacom with an overall increase of 150,000 in its subscriber base.⁹ Although, in totality, the market observed switching between 2006 and 2012, the market share of dominant operators stagnated at 37% for MTN and 47% for Vodacom in the period 2010 to 2012. This implies that the demand for porting declined over time. Between 2010 and 2012, consumer mobility was observed in 2011, with Cell C losing 1% of its market share to the smallest operator, Telkom. However, between 2012 and 2014, the two dominant operators lost some of their market share. The market share for MTN declined to 33% while that one of Vodacom fell to 43%. The biggest gainer from these movements was the third largest operator, Cell C, which increased its market share from 15% to 22% between 2012 and 2014.

In Nigeria, MNP was introduced in 2007. However, little data has emerged about the usage of this facility in Nigeria. During the time of implementation, there were 115,000 ports which were successfully completed.¹⁰ Although the market is dominated by two operators, MTN and Globacom, since 2010 the market shares of these dominant operators have been declining. As of 2010, MTN controlled 48% of the total mobile subscriptions. However, this was reduced to 45% in 2014. The second largest mobile operator, Glabacom, also saw a decline in market share from 24% in 2010 to 20% in 2014, over the same period. While the market share of Airtel have mostly remained constant, Etisalat gained some market share growing from 8% to 15% between 2010 and 2014.

A similar trend in market shares are also be observed in countries that have not im-

⁹businessstech.co.za

¹⁰www.balancingact-africa.com

plemented MNP. Early entrants are losing market share to small operators. In Botswana, Mascom Wireless saw a decline in its market share from 58% in 2010 to 55% in 2014, while Orange Botswana saw its market share decline from 32% to 28% in the same period. This was largely gained by the third entrant, beMOBILE, which increased its market share from 10% in 2010 to 16% in 2014.

In Mozambique, the first entrant, Mozambique Cellular, lost market share from 2010 to 2014. Between 2010 and 2011, its market share declined by 3% from 69% which was largely gained by the second competitor, Vodacom, which increased its market shares from 31% to 34%. The successful entry of the third operator, Movitel in 2012, further reduced the market share of Mozambique Cellular from 66% in 2011 to 44% in 2012 and 34% in 2014. The lost market share were largely gained by the new entrant, which increased its market share from 11% in 2011 to 30% in 2014.

Similarly, in Zambia, the largest operator, Airtel, saw a decline in its market share over the period of the study. By 2010, Airtel controlled 56% of the total subscriptions. This declined to 43% in 2014. The largest gainer was MTN, which increased its market share from 35% in 2010 to 48% in 2014. Zamtel gained some market share in the period between 2010 to 2013, increasing its share from 10% to 13%, but in 2014 its share declined to 10%.

3.4 Data

The data used in this chapter consists of a unique quarterly panel between 2010:Q4 and 2014:Q4 for 28 mobile operators in seven African countries: Botswana, Ghana, Kenya, Mozambique, Nigeria, South Africa and Zambia. The sampled countries were chosen based on market characteristics and wholesale regulatory policies. For instance, all countries in the sample have adopted a glide path policy in termination rates. We did not include North African countries in our sample due to different market characteristics. North African countries adopt the Arab telecommunication standards and, in some instance, their calls are terminated in other countries such as France.

Countries with monopoly and those that have licensed only two operators were also not considered in the sample on the basis that they are less likely to adopt MNP. To be

precise, countries with one operator, such as Ethiopia and Swaziland, cannot adopt MNP, while those with two operators are likely not to implement this facility due to high costs of implementation. Furthermore, our sample is also determined by the availability and consistency of data. For instance, MTRs data is very scarce and we were able to collect MTRs for nine countries. However, we could not include Tanzania and Uganda in the sample due to price data inconsistencies.

The constructed dataset contains information about operator prepaid prices, number of prepaid subscribers, population, mobile termination rates (MTRs) and time of implementation of MNP. The price information was obtained from Research ICT Africa (RIA). The number of subscribers to particular operators and population were gathered from World Cellular Information Service (WCIS).¹¹ MTRs data was obtained from different data sources, as presented in Table 3.2.

Table 3.2: Termination Rates Data Sources

Country	Data source
Botswana	www.bocra.co.bw ; www.emeraldinsight.com
Ghana	www.itu.int
Kenya	www.standardmedia.co.ke
Mozambique	www.researchictafrica.net ; http://researchictafrica.net
Nigeria	www.itu.int; www.techcentral.co.za
South Africa	www.helgilibrary.com
Zambia	news.idg.no; www.mediastudies.co.za

Note: Due to lack of a single data set, data for termination rates in Africa was collected from a number of data sources.

Mobile prepaid prices and termination rates are expressed in local currencies and, for the purposes of this analysis are transformed to US\$ purchasing power parity (US\$ PPP) using the World Bank conversion factor. Pricing of telecommunication services needs careful consideration due to its complexity. Mobile phone consumers face different tariff plans and they are billed based on destination and timing of their calls. The phone

¹¹Research ICT Africa (RIA) is a regional information and communication telecommunications policy and regulation think tank active across Africa and the Global South. RIA tracks prepaid mobile prices for voice, short messages and broadband services and conduct telecommunication surveys. World Cellular Information Surveys (WCIS) is the cellular world's benchmark source of global mobile subscriptions, KPIs, financial and operational indicators.

calls can be made on- or off-net and during peak or off-peak hours. In addition to voice communication, consumers can use a wide range of other services including SMS, data, and others.

Empirical studies on mobile telecommunications typically use different measures for prices of mobile phone services. For instance, Shy (2002) uses average revenue per user (ARPU), while Grajek (2010) uses the lowest average customer bill. On the other hand, Fuentelsaz et al. (2012) and Cho et al. (2013) use price per minute, which is computed by dividing ARPU by the average monthly minutes of usage (MOU). The problem with the approach used by Shy (2002), Grajek (2010), Fuentelsaz et al. (2012) and Cho et al. (2013), is that it does not take into consideration the timing and destination of phone calls, which determines the price. Other studies construct a price for mobile phone services using information on usage profiles (see, for instance, Doganoglu & Grzybowski (2013)). These studies assume that a representative prepaid user makes a certain number of phone calls per month, which are distributed across time and networks according to certain assumptions. The cost of the usage basket represents the prepaid price of mobile services. We take a similar approach to these studies and use as prepaid price, the cost of usage basket, which was constructed by RIA using the Teligen Ltd approach.¹² Table 3.3 presents the assumed distribution of minutes and messages according to destination network and time of the day.

¹²For more details on the basket see www.oecd.org

Table 3.3: Distribution of minutes and SMS depending on time and destination network

Timing	Minutes (1)	Proportion minutes (2)
On-net-peak	12.55	0.60
On-net-off-peak	7.91	0.50
Off-net-peak	6.82	0.40
Off-net-peak	6.26	0.50
Off-net-off-peak	3.94	0.40
Off-net-offoff-peak	3.40	0.60
Fixed peak	4.42	0.50
Fixed off-peak	2.78	0.40
Fixed offoff-peak	2.40	
On-net peak SMS	18.02	
Off-net-peak SMS	31.02	
Off-net-off-peak SMS	15.98	
Total basket minutes	50.48	
Total SMS	100	

Source: ResearchICTAfrica

Notes: The number of minutes depending on time and destination network, which were assumed to create price for voice call services. Column (1) shows the number of minutes/SMS and column (2) presents the the share of minutes that are charged at subsidized prices.

Figure A.4 shows changes in operators' prices over time for four countries which implemented MNP, while Figure A.5 shows price for countries without MNP. For both groups of countries, prices for mobile phone services are decreasing over time. Figure A.4 shows that immediately after the implementation of MNP in Ghana, prices declined sharply, while in Kenya prices first increased but then followed a downward trend. South Africa was the first country which adopted MNP in the third quarter of 2006, followed by Nigeria in the first quarter of 2007. Ghana and Kenya introduced the facility in the second and third quarter of 2011 respectively. For the latter two countries, the implementation of MNP falls within the period of the study, as shown in Figure A.4.

In the time period covered by our study, there were also new licences given to mobile operators in Ghana, Mozambique and Nigeria. In 2012, two mobile operators, Etisalat and Glo Mobile, were granted licenses to operate mobile technology in Nigeria and Ghana,

respectively. Our period of study covers the time when Espresso, one of the companies in Ghana, experienced significant liquidity challenges after the takeover by Sudanese based Sudatel Telecom Group (STG). This has led to the regulator banning the company from registering new subscribers in 2014.¹³ We present these entry periods in Figure A.4 and A.5

Another variable which requires careful consideration when modelling demand of mobile phone services is subscription. This is because pre- and post-paid subscribers are offered differentiated services.¹⁴ The services are differentiated by price. Existing literature typically uses the aggregated network subscriber base (see, for instance, Karacuka et al. (2011)). We find this to be a critical shortcoming in the literature since there is differentiation in services provided to different subscribers. Literature that uses firm-specific tariff in the estimation of demand is very rare. Dewenter & Haucap (n.d.) use data on pre- and post-paid to calculate price elasticities.

Our rich data contains firm-level information disaggregated into pre- and post-paid subscribers. This allows us to take a similar approach to Dewenter & Haucap (n.d.). Though we have information on pre- and post-paid subscriptions, we focus on estimating demand for mobile pre-paid services. This is because we were unable to find information on post-paid prices. Furthermore, the share of post-paid subscriptions in Africa is very small (4%).¹⁵ Moreover, this study only concerned with the total number of registered subscriptions which are in regular use rather than the total subscriptions, which might include inactive subscribers. The information on the number of prepaid subscribers is used to construct market shares. To do this, we need to define market size which is assumed to be twice the population size because, in some countries, the penetration rate is higher than 100%. Table 3.4 presents the summary statistics of variables used in this study. We were unable to get prices for all the quarters of 2014 for MTN Zambia.

¹³www.modernghana.com

¹⁴Pre-paid subscriptions require pre-payment and does not require a contract. The post-paid allows post-payment for services which requires a contract for a minimum of one month.

¹⁵see www.globalrewardsolutions.com

Table 3.4: Summary Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Price (US\$ PPP)	420	15.60	7.622	2.970	37.31
Subscription (mln)	424	9.827	12.00	0.1	59.90
MTR	459	0.0918	0.0350	0.0387	0.195
MNP	459	0.580	0.494	0	1
Share	424	0.117	0.0954	0.00223	0.429
Operator's age	449	12.44	5.555	1	23

Notes: Operator's age represents the number of years a firm has been operating in a country.

3.5 The Model

Modeling the demand side of product differentiation dates back to Lancaster (1971) and McFadden et al. (1973). In this study, we consider mobile telecommunication services as differentiated products since we observe that firms charge different prices, provide product of different quality and invest in branding and advertising. Our empirical model follows Berry (1994) for case of the multinomial logit model, where operator market shares are derived as the aggregate outcome of individual consumer decisions. We assume that each consumer selects one among all mobile operators available in a country. The consumer may also eventually choose an 'outside' option, which is not to use mobile services at all. Hence, the choice set consists of $J + 1$ alternatives. The utility which consumer i derives from subscribing to mobile operator j in country m at time t is given by:

$$U_{ijmt} = x'_{jmt}\beta - \alpha p_{jmt} + \xi_{jmt} + \varepsilon_{ijmt} = \delta_{jmt} + \varepsilon_{ijmt} \quad (3.1)$$

where the price of subscription is denoted by p_{jmt} , the vector x'_{jmt} includes operator dummy variables and a dummy for MNP implementation in a country, ξ_{jmt} is the unobserved product quality and ε_{jt} , is the logit error term, which is assumed to be double exponential distributed. The utility of the outside good is normalized to zero and becomes $U_{i0mt} = \varepsilon_{i0mt}$. In addition, the coefficient on price is interacted with the dummy variable for the implementation of MNP in a country, which should capture the effect of MNP on price elasticities of demand.

An individual i chooses operator j in country m and quarter t if this choice maximizes the utility among all available alternatives, in other words, if $U_{ijmt} = \max_{n \in A_{imt}} U_{inmt}$ where A_{imt} is individual i 's available choice set in country m and quarter t . Following Berry (1994), there is a one-to-one representation between the mean utility values and the market shares, which yields the following equation which we take to the data:

$$\ln(s_{jmt}/s_{0mt}) = \delta_{jmt} = x'_{jmt}\beta - \alpha p_{jmt} + \xi_{jmt} \quad (3.2)$$

For multinomial logit model, the price elasticity of demand is written as follows:

$$\frac{\partial s_{ijt}}{\partial p_{ikt}} \frac{p_{ikt}}{s_{ijt}} = \begin{cases} -\alpha p_{ijt}(1 - s_{jt}), & \text{if } k = j. \\ \alpha p_{ijt}s_{ikt}, & \text{otherwise;} \end{cases} \quad (3.3)$$

3.6 Identification

A practical endogenous concern with all empirical analysis that assesses the effect of a legislative initiative (such as MNP) on an outcome (in our case utility) is understanding the motivation behind the introduction of such a policy. Specifically, we need to assess whether or not the adoption of MNP was driven by low levels of utility of mobile telecommunication consumers. If the adoption of MNP was endogenous to utility of consumers, the unbiased impact of the initiative on price elasticities will be hard to estimate.

Consistent with existing empirical studies, we consider the introduction of MNP as an exogenous policy to reduce switching costs. In practice, the authorities set stringent implementation dates, and mobile telecommunication agents (consumers and operators) consider it as a given external shifter of market condition (see, for instance, Bühler et al. (2006); Park (2011); Cho et al. (2013)). As long as pricing strategies developed by mobile carriers and the utility of consumers do not influence the implementation date or the government's policy schemes, we can treat the policy as an exogenous factor with respect to operators' pricing decisions and consumer choices. However, it is still necessary to check whether or not market characteristics, including price and consumer utility, drove the adoption of MNP. For instance, if the adoption period of MNP is endogenous to the price and utility of consumers or highly correlated to market attributes, it is hard

to estimate the unbiased impact of the law. We therefore present this in greater detail here by discussing the background of MNP adoption in Sub-Saharan African countries and present empirical evidence.

In most countries, the regulator's decision to implement MNP is based on the motive to facilitate market competition by decreasing market power of the incumbent. For instance, in South Korea, the authority adopted MNP because the regulator assessed that the incumbent was exploiting excessive profits by introducing a 3-digit identification prefix. In terms of MNP adoption in African countries, however, the major difference from other countries is that the regulator's decision on whether to adopt MNP or not cannot be attributed to market characteristics. For instance, most African authorities have not implemented MNP even though the telecommunications market is dominated by incumbent operators. The decision not to implement MNP in Botswana and Uganda was based on costs of implementing the facility, while other countries have shown no interest in the facility.¹⁶ This suggests that, the adoption of MNP in Africa is likely to be based on external pressures rather than on internal market conditions.

For robustness checks, it is necessary to check whether or not the time adoption of MNP across countries is correlated with the dependent variable to market factors, such as utility, price and the time since entry of mobile operator. Following Romanosky et al. (2011) and Cho et al. (2013), we test whether the implementation of MNP is affected by utility of consumers and other market characteristics by running Cox proportional hazard regression. We present the results in Table 3.5.

¹⁶(see www.budde.com.au, www.cellular-news.com)

Table 3.5: Exogeneity check: Cox proportional hazard regression

VARIABLES	(1)	(2)
Utility	-0.066 (0.054)	0.011 (0.063)
Price		-0.037*** (0.009)
Operators' age		-0.034 (0.123) (0.130)
Observations	424	420

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

Column (1) presents a regression with utility as the only explanatory variable and Column (2) shows the results of estimating the model with all market variables such as price and operators' age. We find no particular correlation between MNP and utility in columns (1) and (2). The estimated hazard ratio values for utility are not statistically significant. This finding which does not support the endogeneity of MNP.

3.7 The Results

We estimate the demand specification given by equation 3.2 with a set of explanatory variables including the operator-level price of mobile subscription, a dummy variable for the implementation of MNP in a country, operator-specific fixed effects, the time passed since the operator entered the market, as well as the interaction term of MNP dummy variable with price. The use of panel data techniques require testing whether the error term are correlated with the regressor. We perform a Hausman test, which allow us to reject the null hypothesis of random effects in favour of panel data fixed effects technique. Since price of mobile services is correlated with the error term, which represents unobserved quality of mobile services, the ordinary least square (OLS) estimation yields biased results (see Berry (1994)). We account for endogeneity of price and its interaction term with MNP dummy by means of instrumental variables (IV) estimation. As instruments, we use country-level termination rates and termination rates interacted with the MNP

dummy variable. Termination rates are the key component of marginal costs for mobile operators. Since they are usually set during a regulatory process, they should not be correlated with the error term. We also perform Durbin-Wu-Hausman test of endogeneity, which does not allow rejecting the null hypothesis of endogeneity of price and its interaction term with MNP. The estimation results are shown in Table 3.6, where column (1) presents OLS estimation and column (2) presents IV estimation.

Table 3.6: Estimation results for ordinary least squares (OLS) and instrumental variables (IV)

Variables	OLS	IV
Price	-0.031*** (0.006)	-0.066*** (0.025)
MNP*Price	0.002 (0.006)	-0.041** (0.020)
MNP	0.081 (0.078)	0.605*** (0.184)
Operator's age	0.986*** (0.123)	-0.216 (0.338)
Constant	-5.301*** (0.413)	-1.254 (1.342)
Observations	410	410
Number of operators	27	27
Operator fixed effects	Yes	Yes

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. In the IV estimation we use MTRs and MTRs interacted with MNP as instruments.

In both the OLS and IV regression, the coefficient on price is significant and negative. It increases in magnitude in the IV estimation, which suggests that the instrumental variables that we used, correct for the bias in the estimate of price coefficient by means of OLS. The interaction term of price and MNP dummy is insignificant in the OLS estimation, but becomes significant with a negative sign in the IV regression. This implies that MNP increased price elasticity of demand in countries which implemented this policy. The increase in price elasticity due to MNP may be a result of a reduction in switching costs between operators. At the same time, MNP has a significant and positive impact on

the utility which consumers derive from mobile services. This is suggested by a positive and significant coefficient on MNP dummy variable in the IV estimation. The time since entry of the mobile operator, which may approximate the recognition of brand by consumers, is not significant in the IV estimation, even though it was significant and positive in the OLS estimation. We do not report the estimates of operator-specific fixed effects due to space constraints.

We use IV estimates to compute average operator-specific price elasticities. Table 3.7 presents country-specific average own-price elasticities for the time period of this study. We find that, on average, MNP increases own-price elasticities by 0.47 in absolute terms. The data set used in this study contains information for before and after the implementation of MNP in Kenya and Ghana. Thus, we are able to compare the impact of MNP on own-price elasticities before and after implementation. Our results suggest that the introduction of MNP in Ghana increased own-price elasticities by an average of 0.35 in absolute terms, from an average of -0.74. On the other hand, in Kenya, own-price elasticities increased by an average of 0.21 in absolute term from a lower average of -0.39.

Table 3.7: Mean country-level own-price elasticities between 2010:Q4-2014:Q4

Country	Mean	Sd	Min	Max
Botswana	-1.225	0.311	-1.770	-0.798
Ghana	-0.878	0.174	-1.266	-0.505
Kenya	-0.514	0.108	-0.694	-0.291
Mozambique	-1.520	0.294	-2.352	-1.196
Nigeria	-1.570	0.680	-2.980	-0.664
South Africa	-1.752	0.472	-2.714	-0.945
Zambia	-0.965	0.255	-1.364	-0.449

Calculations based on IV estimation.

We also compare average price elasticities for countries and periods in which MNP was in place with those where it was not. We find that average own-price elasticities are -1.23 for periods in the presence of MNP and -1.11 for periods in the absence of MNP. However, a country level comparison shows that, in Kenya and Ghana, the average own-price elasticities remained small, even after the implementation of MNP, relative

to other countries without MNP in place (see Table 3.7). This may be attributed to the market structure and other factors in these two countries. For instance, in Kenya, Safaricom continues to dominate the voice traffic and the mobile money markets.¹⁷ Thus, our results suggest that MNP is not the ultimate solution for increasing competitiveness in the mobile industry.

Excluding Kenya and Ghana from the analysis, we find average own-price elasticities of -1.66 for countries that implemented MNP prior to the period of our study. As for countries that never implemented MNP, we find average own-price elasticities of -1.21. These numbers are higher than the average own-price price elasticities for the whole sample. This result shows that demand for telecommunication services is generally elastic. The demand, however, is more elastic in countries with MNP than those that have not implemented MNP, except for Kenya and Ghana.

Finally we discuss own- and cross-price elasticities for operators in our sample. We categorize countries in groups according to the timing of MNP implementation. In the first group, we include countries with no MNP (Botswana, Mozambique and Zambia). The second group includes countries that introduced MNP prior to the period of study (Nigeria and South Africa), the third group consists of countries that adopted MNP in a time that falls within the period of the study (Ghana and Kenya). Table 3.8 presents own- and cross-price elasticities for countries in group 1. Table 3.9 presents the own- and cross-price elasticities for countries in group 2, while Table 3.10 presents own- and cross-price elasticities for countries belonging to group 3. We find large operator own-price elasticities in group 2 countries relative to group 1 and group 3 countries. Surprisingly, we find smaller and inelastic own price elasticities in group 2 relative to operator own-price elasticities in group 1 countries, which are generally elastic. This result suggests that even after the introduction of MNP in Kenya and Ghana, firms' own-price elasticities remained small compared to countries that have not implemented MNP.

In Botswana, the own-price elasticities of beMOBILE and Orange are high. However, we find low values for own-price elasticity for Mascom Wireless. A percentage increase in the price of beMOBILE decreased its sales by 1.56% and increased the sales of Orange and

¹⁷see www.ca.go.ke and www.businessdailyafrica.com

Table 3.8: Mean operator own- and cross-price elasticities between 2010:Q4-2014Q:4

Botswana	beMobile	Orange	Mascom
beMobile	-1.556	0.176	0.176
Orange	0.315	-1.179	0.315
Mascom	0.621	0.621	-0.939
Mozambique	Vodacom	Movitel	MCellular
Vodacom	-1.651	0.101	0.101
Movitel	0.106	-1.223	0.106
MCellular	0.140	0.140	-1.458
Zambia	Airtel	MTN	Zamtel
Airtel	-1.061	0.172	0.172
MTN	0.08	-0.665	0.08
Zamtel	0.042	0.042	-1.135

Notes: Countries which have not implemented MNP.

Mascom by 0.18% each. Moreover, a 1% increase in price of Orange decreased its sales by 1.18% and increased sales of beMOBILE and Orange by 0.32% each. In Mozambique, all operator own-price elasticities are high. A 1% increase in the price of MCellular decreased its sales by 1.46% and increased the sales of Vodacom and Movitel by 0.14% each. However, the same incremental price increase of Movitel decreased its sales by 1.22% and increased the sales of Mcellular and Vodacom by 0.11% each. Moreover, a similar increase in the price of Vodacom decreased its sales by 1.65% and increased the sales of both Mcellular and Movitel by 0.10%. In Zambia, we find low own-price elasticities for MTN, while own-price elasticities for Airtel and Zamtel are high. A percentage increase in the price of Airtel decreased its sales by 1.06% and increased the subscriptions of MTN and Zamtel by 0.17% each (see Table 3.8).

Table 3.9: Mean operator own- and cross-price elasticities between 2010:Q4-2014Q:4

Nigeria	Globacom	Airtel	Etisalat	MTN
Globacom	-1.083	0.076	0.076	0.076
Airtel	0.123	-1.968	0.123	0.123
Etisalat	0.082	0.082	-1.698	0.082
MTN	0.249	0.249	0.249	-1.576
South Africa	Cell C	Vodacom	Telkom	MTN
Cell C	-1.773	0.211	0.211	0.211
Vodacom	0.627	-1.592	0.627	0.627
Telkom	0.023	0.023	-1.833	0.023
MTN	0.515	0.515	0.515	-1.807

Notes: Countries which implemented MNP before 2010.

In Nigeria and South Africa, operator own-price elasticity are high. In Nigeria, we find that a 1% increase in the price of Airtel decreased its sales by 1.97% and increased the sales of Globacom, Etisalat and MTN by 0.12% each. A similar increase in the price of MTN reduces its sales by 1.58% and increased the sales of Globacom, Airtel and Etisalat by 0.25% each. In South Africa, a percentage increase in the price of MTN decreased its sales by 1.81% and increased sales of Cell C, Telkom and Vodacom by 0.52% each. A similar incremental price increase of Cell C decreased its sales by 1.77% and increased the sales of MTN, Telkom and Vodacom by 0.21% each (see Table 3.9). In Kenya, all operator own-price elasticities are low, while in Ghana only one operator, Expresso, among the six, have high own-price elasticity. A 1% increase in the price of Expresso decreased its sales by 1.12% and increased sales of Airtel, Glo, MTN, Tigo and Vodafone by an insignificant percent.

Assuming that observed prices are the result of a pure strategy Nash equilibrium, we make use of the first-order equation to get information about marginal marginal costs. This strategy ignores the effects of current prices on future profits. Thus it overestimates markup hence these measures are an upperbound. Following Berry (1994), the marginal cost may be written as

$$c_{jmt} = p_{jmt} - \frac{1}{\alpha(1 - s_{jmt})} \quad (3.4)$$

Table 3.10: Mean operator own- and cross-price elasticities between 2010:Q4-2014Q:4

Kenya	Safaricom	Orange	Essar	Airtel		
Safaricom	-0.527	0.153	0.153	0.153		
Orange	0.016	-0.505	0.016	0.016		
Essar	0.016	0.016	-0.568	0.016		
Airtel	0.027	0.027	0.027	-0.453		
Ghana	Glo	Tigo	Vodafone	MTN	Airtel	Expresso
Glo	-0.887	0.026	0.026	0.026	0.026	0.026
Tigo	0.074	-0.929	0.074	0.074	0.074	0.074
Vodafone	0.108	0.108	-0.967	0.108	0.108	0.108
MTN	0.193	0.193	0.193	-0.668	0.193	0.193
Airtel	0.047	0.047	0.047	0.047	-0.788	0.047
Expresso	0.003	0.003	0.003	0.003	0.003	-1.123

Notes: Countries which implemented MNP after 2010.

The markups are calculated as $(p_{jmt} - c_{jmt}/p_{jmt})$. Given that average price elasticities are -1.23 for Botswana, -1.52 for Mozambique, -1.57 for Nigeria and -1.75 for South Africa, the markups for these countries are on average are 53%, 42%, 62% and 58%, respectively. The implied marginal costs are negative for Ghana, Kenya and Zambia, since price elasticities are less than 1 in absolute terms. Thus, the elasticities of demand may be under estimated on these countries, or Nash Bertrand equilibrium may not be the correct assumption.

3.8 Conclusion

We constructed a unique quarterly panel data series for 28 mobile operators in seven African countries for the period 2010:Q4 to 2014:Q4, which we use to estimate a differentiated products demand model based on the instrumental variables technique. We find that the coefficient on price is significant and negative. Moreover, the interaction term of price and a dummy variable for the implementation of MNP is also significant with a negative sign. This implies that MNP increased price elasticity of demand in countries which implemented this policy. At the same time, MNP has a significant and positive impact on the utility which consumers derive from mobile services. This increases demand

for mobile subscriptions.

We use the estimated parameters to compute average operator-specific price elasticities. Our findings, suggest that the introduction of MNP increases own-price elasticities. We find that they are on average higher in periods in which MNP was implemented. However, in Ghana and Kenya, relative to other countries without a MNP policy in place, the average own-price elasticities remained small, even after the implementation of MNP. This may be attributed to the market structure and other factors in these two countries. For instance, in Kenya, Safaricom dominates both the voice and mobile money markets. Our results are thus an indication that MNP is not an ultimate solution for increasing competition within the of mobile phone industry. Hence, it is important to understand the sources of switching costs in order to apply the appropriate policy. For instance, in markets where there is dominance with consumer valuation of network effects greater than costs of switching, consumers are likely to be locked into a dominant operator. The implementation of MNP will not be effective in this case.

An analysis of own-price elasticities at operator-level shows that in countries that have implemented MNP prior to the period of our study, operator own price elasticity is higher relative to those in countries without MNP. However, as for countries that have implemented MNP within the period of our study, we find small operator own-price elasticities, except for Expresso in Ghana. A comparison of own-price elasticities between countries that implemented MNP in 2011 with countries that have never implemented MNP in the period of our study shows that operators in countries that have never implemented MNP have higher own-price elasticities relative to operators in Ghana and Kenya. These findings have a number of implications. First, our results support the decision taken by regulators in countries that never implemented MNP, given that the mobile telephone services in those countries are elastic. Our results also show that MNP has differential effects across countries and the impact of MNP is likely to be determined by market structure. Hence, before implementing MNP, understanding of price elasticities and the sources of switching costs is crucial.

Our study has admitted limitations which must be emphasized in the interest of future research directions. The problem with the model used in this chapter, multinomial logit,

is that own-price elasticities are proportional to own price. That is the lower the price, the lower the estimated own-price elasticities. This characteristic implies higher markups for the lower priced products. Cross-price elasticities are entirely driven by one parameter, market share and price of the service. With this characteristic, consumers are assumed to substitute towards other mobile operators in proportion to market shares, regardless of characteristics. We did not consider consumer welfare and therefore, we cannot comment on the implications of decisions taken by the regulator on whether to implement or not. Second, our study does not measure switching costs in the African telecommunication market.

Chapter 4

The Impact of Telecommunication Regulatory Policy on Mobile Retail Price in Sub-Saharan Africa

4.1 Introduction

Switching costs and mobile termination rates (MTRs) are the focal point of many telecommunication regulatory policies and antitrust cases.¹ Switching costs bias consumers' choices towards previously selected products and services. This, in turn, reduces their responsiveness to price and allows firms to charge higher prices. In an effort to reduce switching costs in mobile telecommunications markets, many regulatory authorities worldwide introduced mobile number portability (MNP), which allows consumers to take their mobile phone numbers with them when changing to a different mobile operator.

On the other hand, MTRs refer to charges which are set by mobile operators for terminating calls on each others' networks. Although the MTRs have a direct impact on mobile retail prices, they are not observed by the consumers who make subscription decisions without taking them into consideration. Therefore, each network is a de facto monopoly for termination of calls, which can be a source of collusion.² The regulatory

¹Klemperer (1987a), Klemperer (1987b) and Klemperer (1987c) extensively discusses the theory of switching costs. Switching costs refer to costs which inhibit consumers from changing products and services, which in general allows firms to set prices above marginal costs. Grzybowski (2008b) states that switching costs in the mobile telecommunication market arise from incompatibility, transaction and search costs.

²For example, a number of African regulatory authorities have adopted a glide path in MTR regulation. This is a policy which requires operators to reduce the charges they set for terminating calls on each other's networks over time.

authorities generally recognize this fact and intervene by regulating MTRs.

In spite of the importance of MNP and MTRs, we are not aware of any economic literature which provides an assessment of the effect which these policies have on prices and competition in low income countries. This gap in the literature is largely due to the scarcity of data on the telecommunication market in these countries. Our study contributes to the literature by examining the effect of MNP and MTRs on pre-paid mobile phone service prices in Sub-Saharan African countries. Our approach is similar to Parker & Röller (1997) and Grzybowski (2005) who, assuming that mobile services are homogenous products, applied a static Cournot model to study competition in mobile telecommunication market. In particular, Grzybowski (2005) analyzes the impact of MNP on mobile retail prices for a number of European countries. However, in the estimation, he does not control for country-specific MTRs as a determinant of marginal costs, but instead uses country-specific cost dummies to take into account differences in marginal costs between countries. In this study, we control for differences in marginal costs in terms of country-specific MTRs.

We estimate a structural model of demand and supply using quarterly time series data between 2010:Q4 and 2014:Q4 for eight African countries. The data was constructed by aggregation of firm level information for 35 mobile operators which are active in these countries.

On the supply side, we find that MTRs have a significant and positive impact on mobile retail prices. On average a 10% increase (decrease) in MTRs will result in a 2.5% increase (fall) in prices. Thus, pushing down the price in the regulated market, in other words, the termination rate, does not increase unregulated mobile retail prices in the group of countries used in this analysis. Our result supports the glide path termination rate policy. A glide path in termination rate refers to regulated price control where regulators mandate operators to reduce termination rate charges over time rather than an immediate move to the cost-oriented level. This allows operators time to plan for the decreased revenue from mobile termination charges. This policy is expected to offer stability as compared to a one-off shock if the difference between the existing MTRs and the cost-orientated

MTRs is great.³ Moreover, we do not find that MNP has a significant negative impact on retail prices for the selected African countries, which contrast with the results found by Grzybowski (2005), Park (2011) and Cho et al. (2013) for European countries. This may be due to less effective implementation of MNP in African countries and consequently lower attractiveness and take up of this option by consumers. For instance, even though it has been found that the effectiveness of MNP depends on porting time and charges, the porting process in Africa is characterized by long porting time. Furthermore, in some countries such as Nigeria, subscribers are not allowed to port again for the next three months.

On the demand side, we find that MNP does not change the responsiveness of consumers to price, a result which coincides with our findings on the supply side. This may be due to the fact that in many African countries, it is common to use multiple subscriber identity module (SIM) cards.⁴ Popular use of multiple SIM cards from different operators has delayed the implementation of MNP, with the authority not convinced of the facility's economic benefits (see www.budde.com.au). A household survey, conducted by ResearchICTAfrica in different African countries in 2008, reports that 36.3% of adult mobile phone subscribers hold more than one SIM card in Benin, 25.8% in Kenya and only 2.9% in Mozambique (see ResearchICTAfrica (2008)). Hence, many consumers are connected to two or more operators with low demand for porting numbers. However, these results contradict our finding in the previous chapter. This could be due to the use of different assumptions made when estimating the models. We estimate the price elasticity of demand to be on average -0.27. We use the estimate of price elasticity to approximate the average market conduct parameter in the selected African countries, which takes value of 1.29.

The remainder of this Chapter is as follows. Section 4.2 discusses theoretical and empirical literature on MNP and MTRs. Section 4.3 provides an overview of MNP, regulation and termination rates. Section 4.4 presents our data. Section 4.5 introduces the

³This policy has been implemented by a number of countries worldwide, including the United Kingdom, Botswana, Ghana, Kenya, South Africa, Tanzania and Zambia

⁴Although in Botswana the population is estimated to be around 2 million, the number of active SIM cards is about 3.5 million. For statistics on active SIM cards see <http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>

empirical model. Section 4.7 presents estimation results and finally Section 4.8 concludes.

4.2 Literature Review

There is a large theoretical literature on switching costs.⁵ Among the few empirical studies that estimate the existence of switching costs in the telecommunication industry, Grzybowski (2008b) uses a multinomial logit and a mixed logit approach based on stated preferences to estimate switching cost in the UK mobile telephony market. His findings suggest that the UK telecommunications market is characterized by significant switching costs. In a later study, Grzybowski & Pereira (2011) use a series of multinomial and mixed logit techniques on a panel data of Portuguese subscribers to test the existence of switching costs in the mobile phone market. Similar to Grzybowski (2008b), they find that switching costs are an important element of mobile telecommunications market structure. However, these studies do not consider the impact of MNP on switching costs.

Another strand of literature studies switching costs in the context of number portability. Some of these studies use individual level data to examine the effectiveness of MNP. These studies find that the implementation of MNP significantly lowers switching costs ((Shy, 2002; Lee et al., 2006)). However, these studies do not provide evidence on how MNP affects market outcomes. To fill this gap in the literature, Lyons et al. (2006) use international time-series and cross-section data to test the impact of MNP on switching costs. They find that MNP reduces switching costs when the switching process is rapid. In countries where the switching process is slow, MNP does not reduce switching costs. However, this study does not control for country specific porting charges and uses a five day cutoff for MNP to be considered effective, which is arbitrary. Sánchez & Asimakopoulou (2012) investigate the effectiveness of MNP in thirteen European countries using yearly country level data for years 2000-2009. Similar to Lyons et al. (2006), they show that MNP effectiveness is determined by both porting time and charges.

The aforementioned studies do not provide evidence on how prices and consumer welfare changes in the presence of MNP. Shi et al. (2006) presents a theoretical model for testing the impact of MNP on price and market concentration, and provide empirical

⁵See, for instance, Klemperer (1987a,b), Beggs & Klemperer (1992) and Chen & Rosenthal (1996).

evidence. In support of other empirical studies, they find MNP has a negative impact on prices. On the contrary, Shi et al. (2006) find that rather than helping small firms grow, as intended, the introduction of MNP accelerates the process of market concentration. This finding can be attributed to price discrimination across on-net and off-net charges. A paper by Viard (2007) analyzes the impact of reducing switching costs when there is a large proportion of new consumers. Using data on the toll-free service market, he finds that a reduction of switching costs leads to less competition in the market. The study concludes that the reduction of prices after the implementation of MNP implies less competition.

Focusing on European mobile telecommunications, Cho et al. (2013) examine the impact of MNP on price and market concentration. Using quarterly data for 47 mobile operators in 15 countries between 1999-2006 they conclude that MNP reduces market concentration by tightening price range and reduces large firms' market share. Moreover, when MNP is introduced smaller firms reduce prices more than large firms.

Nevertheless, Cho et al. (2013) state that prices of mobile phone services have been declining over the past years. It is, therefore, hard to determine whether the introduction of MNP contributed to this. They do not control for any other factors which might have caused this decline. In this study we control for some factors that could have led to this decline. Among the factors that could have contributed to a decline in mobile prices is the reduction of MTRs, which are the main component of marginal costs. Over the past decades, a number of regulatory authorities intervened in the MTRs market as a way of reducing mobile retail prices. However, existing literature that examines the impact of MNP on prices fails to account for MTRs in the empirical analysis.

Another branch of literature which relates to our study is the literature that examines the impact of mobile termination rates on prices. Using panel data of mobile operators' prices and profit margins, Genakos & Valletti (2011) test the waterbed effect in the mobile telecommunication market. They find a negative relationship between fixed-to-mobile termination rates and mobile retail prices. In a later study, Genakos & Valletti (2015) re-evaluate the existence of the waterbed effect in the mobile phone market. Contrary to their initial finding, their results predict a positive relationship between mobile-to-fixed

termination rates and mobile retail prices. They attribute this result to changing telecommunication industry characteristics such as the reduction of fixed-line market share. The focus of these two studies is on fixed-to-mobile termination rates.

Other studies focused on mobile-to-mobile termination rates. Using data on mobile termination rates from 2001-2003, Dewenter & Haucap (2005) examine the effect of regulating termination rates when networks have asymmetric sizes. They find that in markets where consumers are ignorant about MTRs, smaller networks charge higher MTRs. They also find that asymmetric regulation of larger operators induces smaller operators to increase their termination rates. Their study, however, does not provide clear evidence on how regulation of MTRs might affect retail prices and consumer welfare.

Cricelli et al. (2012) examine the economic justification of regulating MTRs. They find that symmetric MTRs decreases lead to a reduction in retail prices and enhance consumer welfare. Andersson et al. (2016) show that the increase in one operator's MTR increases its profitability, but when firms offer bundles with fixed-line an identical change in all MTRs does not affect firms' retail prices or profits. The shortcoming of this paper is that, it does not provide evidence on whether reduction in MTRs will be an effective instrument to reduce prices.

Grzybowski (2005) study is similar to ours in that it studies the impact of regulatory policy including MNP on mobile retail prices in Europe. This study considers price as a function of market power and marginal costs, where MNP is considered to influence market power and other regulatory policies affect marginal costs. However, this analysis does not include MTRs as a determinant of marginal costs, but relies on a set of country specific dummy variables instead.

The contribution of this chapter is as follows. For our empirical analysis, we focus on selected African countries for years 2010-2014. The most distinguishing part of our study from prior work on MNP is that we estimate a demand and supply model which includes MTRs and MNP among explanatory variables. We model MNP as a policy that affects switching costs, while MTRs affect marginal costs.

4.3 Telecommunications Policy in Africa

4.3.1 Mobile Number Portability

As of 2012, 73 countries have implemented MNP.⁶ The first country in Africa to introduce MNP was South Africa in 2006. (Refer to Table 3.1 in Chapter 3).⁷

In contrast to industrialized countries, MNP has not reached its potential and its performance has not been effective in Africa, with Ghana as the only exception. Although Ghana launched its MNP scheme in 2011, until 2014 the number of successfully completed ports amounted to 1,655,404. Among these ports a total of 832,202 were completed in 2014. As of 2014, after only 3 years, the total number of completed ports stood at 6% of the total active mobile numbers. For comparison, it has taken 7 years for South Africa to reach 5% porting rate.

A number of factors differentiate the MNP implementation in Ghana from the rest of the African countries, which includes the speed of processing requests and the time allowed to do another port after completing the previous one. By 2014, on average it took 4 minutes and 16 seconds to complete the porting process. For comparison, in Nigeria, the process took 48 working hours. In Ghana, the implementation of MNP has brought changes in market shares. In particular, between 2011 and 2014, MTN, the largest operator, lost 402,244 subscribers (a net loss of 3%), while the smaller operators Tigo and Vodacom, gained 249,725 (6.2%) and 228,183 (3.4%) subscribers respectively.

In Sub-Saharan Africa, the MNP is only available in large markets, namely, South Africa, Kenya and Nigeria. In Kenya, MNP policy was implemented in 2011 with the objective of reducing Safaricom's market power, which controlled more than 75% market share at that time. Since the uptake of MNP has been low since inception, some market

⁶see mcclist.com

⁷The first country to adopt MNP is Singapore in 1997. However, this facility was only call forwarding (see, (Bühler & Haucap, 2004)). To use the facility, one had to have two mobile phone numbers at the same time. A more structural MNP based on a centralized data base was introduced in the UK, Hong Kong, and the Netherlands as early as 1999 (Cho et al., 2013). Singapore adopted a structured MNP in 2008 (Cho et al., 2013). The benefits of MNP has been widely seen in Turkey. Since the implementation of MNP in 2008, Turkcell has been consistently losing its subscribers to rivals Avea and Vodafone. Turkcell attributed this trend to the fact that its competitors continued to push for lower prices and offered high incentives through bundled packages which in combination with the ease of switching operators via MNP led to the operator's market share declining from 56% in 2008 to 51% in 2013 (see gsmintelligence.com)

specialists have labeled it a failed policy. The request for porting peaked in January 2012, but thereafter declined to reach its lowest level in November 2013. A gradual increase in demand for ports was later registered in January 2014. However, the policy had an impact on operators' market shares. By 2014, small companies gained substantial market share from the dominant operator, Safaricom. The market share of Safaricom subsequently reduced from 79% to 68%, with the other three companies owning the remaining 32%.

A number of factors contribute to unsuccessful performance of MNP in Africa. For instance, in South Africa the regulator awarded the licence of operating MNP to a company owned by one of the operators. As such, the results of porting is prone to being unduly influenced by that operator. The Nigerian MNP is also far from being a success. The poor performance of the policy in Nigeria could be due to long porting time and the fact that consumers are not allowed to port again for the next three months. Though Nigeria has a much larger subscription base, the number of ports amounted to 115,000, compared to 363,000 ports in Ghana.⁸

4.3.2 Mobile Termination Rates

Termination rates are prices that carriers charge for terminating or completing calls on each others' network. These charges form part of operators' cost of providing calls to its customers. These rates may be commercially negotiated or may be regulated. In some countries, the regulator only facilitates termination negotiations but cannot set termination charges. The regulator only set termination rates when operators fail to reach an agreement.

The approach to regulating MTRs adopted by most regulatory authorities allows for total cost recovery based on fully allocated cost models (Harbord & Pagnozzi, 2010). In Kenya, for instance, the authority regulates termination charges using a pure-long-run incremental cost (pure-LRIC). In Botswana, the authority uses long-run incremental charges plus (LRIC+). This approach has been adopted by Ofcom in the UK. In both schemes, the regulators set cost by comparing calculated costs to a hypothetical efficient new entrant. The difference between these two approaches is in the calculation costs with

⁸All the African number portability statistics come from this article : www.balancingact-africa

the pure-LRIC considering the marginal costs while under the LRIC+, the regulator sets termination rates based on detailed costs which include common costs.

The main reason for regulating termination rates is to avoid a welfare distortion in the structure of price. If left unregulated, operators might be incentivized to exploit their monopoly power in call termination to gain excessive profits. These profits may in turn be used to subsidize subscriber acquisition costs (Harbord & Pagnozzi, 2008). This is an issue that is frequently discussed in the waterbed effects theory, whereby an increase in termination rates leads to a decline in retail prices (Armstrong & Wright, 2009).

However, a number of regulatory authorities have been taken to court over termination rates. In South Africa, for instance, Cell C summoned the regulator to court claiming that the way that Independent Communications Authority of South Africa (ICASA) set termination rates is an acknowledgement that the duopoly that exists in South Africa is acceptable and should be allowed to continue.⁹ Cell C's proposition was that, the regulator must implement an asymmetric termination rates system in which the two largest operator (MTN and Vodacom) terminate Cell C calls at a price lower than that which Cell C charges.

In 2009, MTN Uganda through court proceeding, blocked the regulator from imposing new reduced termination rates. Their argument was that the regulator should only facilitate discussion, but not impose an outcome on the companies. MTN argued that the only time the regulator should intervene is when the operators themselves cannot come to an agreement. As of 2011, MTN Uganda threatened to stop accepting phone calls from its network to Uganda Telecom (UTL) over claims of unpaid bills for termination charges.¹⁰

4.4 Data

We estimate demand and supply specifications using a unique quarterly time series data between 2010:Q4 to 2014:Q4 for eight African countries: Botswana, Ghana, Kenya, Mozambique, Nigeria, South Africa, Tanzania and Zambia. The sampled countries were selected based on market characteristics, wholesale regulatory policies and availability of

⁹<http://www.moneyweb.co.za/uncategorized/icasa-finalises-new-call-termination-rates/>

¹⁰<http://www.cellular-news.com/story/Operators/48234.php>

data. For instance, all countries in the sample have adopted a glide path termination rates policy. We do not include North African countries in our sample due to their differences in the market industry characteristics. North African countries adopt the Arab telecommunication standards and in some instance their calls are terminated in other countries such as France.

Countries with monopoly and those that have licensed only two operators were also not considered in the sample on the basis that they are less likely to adopt MNP. To be precise, countries with one operators, such as Ethiopia and Swaziland, cannot adopt MNP, while those with two operators are likely not to implement this facility due to high costs. The cost of operating an MNP facility are likely to be higher than the benefits to subscribers in markets with a small number of operators. Furthermore, our sample is also determined by the availability and consistency of data. For instance, MTRs data is very scarce and were able to collect MTRs for nine countries. We could not include Uganda in the sample due to price data inconsistencies.

The data was constructed by aggregation of firm level information for 35 mobile operators which are active in the selected countries. Data on pre-paid retail prices was gathered from Research ICT Africa (RIA), while operators' pre-paid subscriber base and population were obtained from World Cellular Information Services (WICS). Fixed line subscriptions were obtained from the International Telecommunication Union (ITU). We used different data sources to gather termination rates data. The data sources are presented in Chapter 3, Table 3.2.

The variables used in the study can be grouped into regulatory and non-regulatory. The regulatory variables include: country-level mobile termination rates (MTRs) in US\$PPP and a dummy variable for the implementation of mobile number portability (MNP) in a country. The non-regulatory variables are pre-paid mobile subscriptions (Subs), population (Pop), GDP per capita (GDP) in US\$PPP, mobile retail prices for pre-paid services in US\$PPP and fixed penetration (Fixed). We transform the variables Subs, Pop, GDP and Fixed using logarithms. They are then used as explanatory variables in the demand equation. These variables were also used in previous studies, see for instance Gruber & Verboven (2001) and Grzybowski (2005). Table 4.1 presents summary statistics of the

above discussed variables.

Table 4.1: Simple Statistics

Variable	N	Mean	Std.Dev.	Min	Max
Price	136	5.272	3.224	1.299	16.86
Pop('000000)	136	48.100	49.700	1.978	181
rates	136	0.099	0.040	0.038	0.203
Subscr('000000)	136	34.300	34.300	2.456	137
GDP('000)	136	5.800	4.778	0.895	15.991
1/N	136	0.254	0.068	0.167	0.333
Fixed	136	2.451	3.346	0.100	9.450
Price*MNP	136	1.541	2.162	0	7.308
time	136	9	4.917	1	17
MNP	136	0.441	0.498	0	1

An important variable when estimating demand in the mobile industry is subscriptions. One of the main shortcoming of the existing empirical literature is on its inability to distinguish subscribers. For instance, Parker & Röller (1997) use the total number of cells in a given network to proxy for subscriptions. Recent studies use mobile penetration or total subscriptions to proxy subscriptions (see, for instance Grzybowski (2005); Cho et al. (2013)). The problem with these measures is that penetration rate does not distinguish between pre-paid and post-paid subscribers. Hence, the results of these studies might be biased given the fact that post-paid and pre-paid plans are priced differently. Furthermore, the use of penetration rate or number of cells per network tends to capture registered subscribers who might not be active.

Our data is interesting as it uses new and unique subscription data, which is generally not available for African countries. The data contains firm-level subscriber information, which is disaggregated into pre-paid and post-paid plans.¹¹ In contrast to developed economies, mobile subscriptions in Africa are largely pre-paid. For instance, while in North America and Northwestern Europe the share of post-paid subscriptions is 75%, in Africa, only 4% of subscribers are on post-paid.¹² Our study uses information on pre-paid

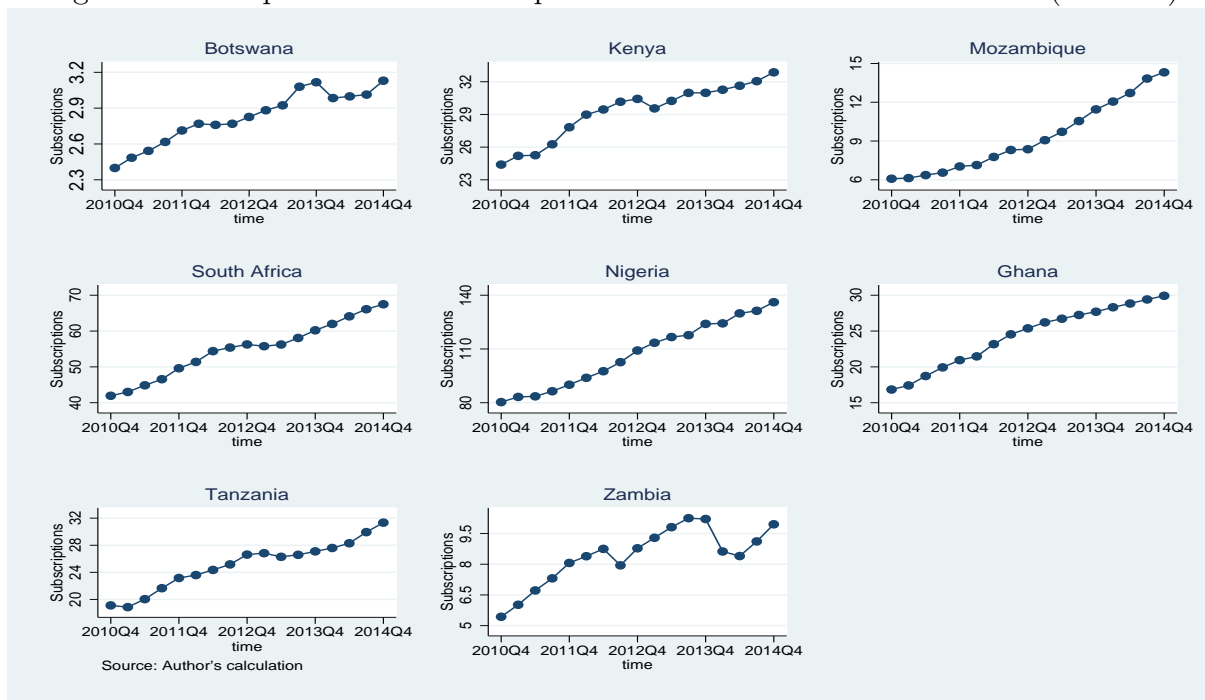
¹¹Generally, mobile operators offer two types of subscription plans, pre-paid and post-paid. Pre-paid subscriptions require pre-payment and does not require a contract. The post-paid allows post-payment for services which requires a contract for a minimum of one month.

¹²see www.globalrewardsolutions.com

mobile subscriptions in the demand estimation.

The frequency of mobile phone service usage is very critical when analysing subscriptions. For instance, the use of total registered subscriptions, which merely relate to the total number of connections that have been registered with an operator, might be misleading since some of the registered connections might be inactive. In contrast to the existing studies, we use the total number of active connections in regular use on a network as subscriptions. Figure 4.1 shows trends of total active pre-paid subscription for each country for the period of the study.

Figure 4.1: Pre-paid Mobile Subscriptions for Selected African Countries (millions)



Over the period of the study, the pre-paid subscriptions were growing rapidly. Innovations within the industry have led to development of new services, such as mobile banking, mobile Internet and the provision of over the top services, such as Voice over Internet Protocol (VoIP) and Skype. These changes were mainly supported by technological shifts, such as movements from second generation (2G) to third generation (3G) and recently to fourth generation (4G) or the long term evolution. To account for these technological advances, we use a common time trend variable (Time). This variable can be interpreted as a constant upgrade in the quality of service, the rising range of available

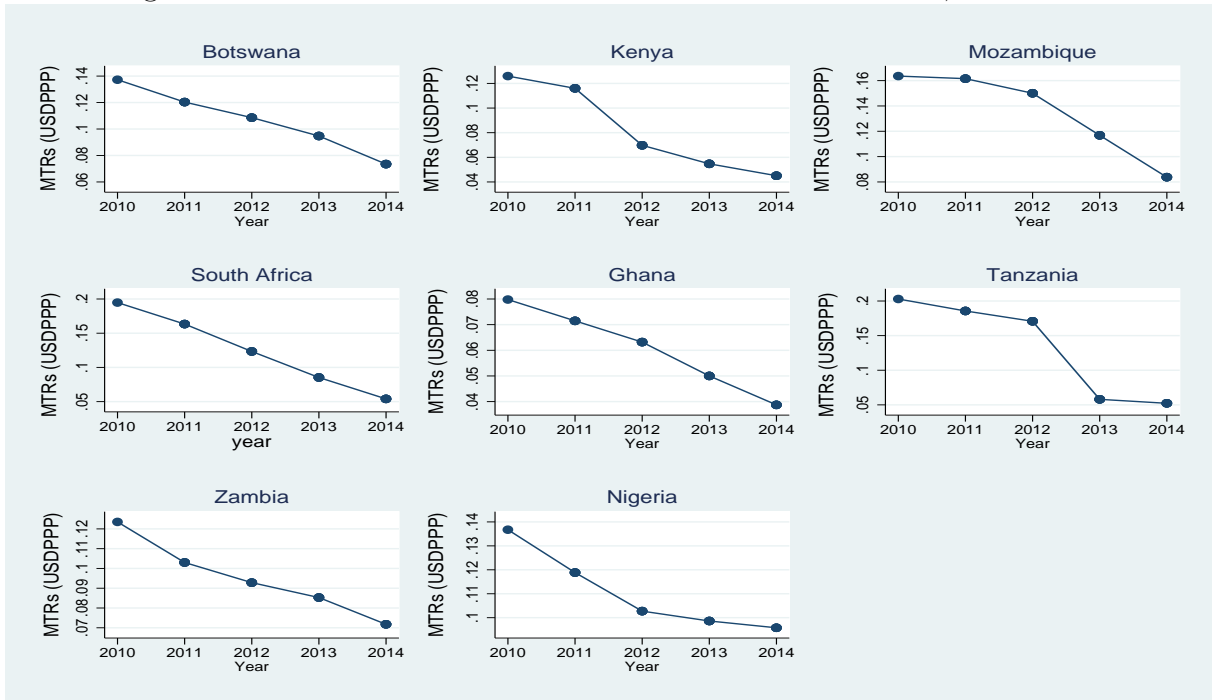
services, as well as enhanced performance of mobile telecommunication services.

On the supply side we use two types of explanatory variables to explain the prices of mobile pre-paid calls (Prices): (i) exogenous determinants of markup and (ii) determinants of marginal cost. As for the exogenous price shifters we use MNP, which is expected to have a negative effect on price. This is because MNP is expected to reduce switching costs and, thereby, increase consumer responsiveness to price. To capture the impact of MNP on markup, we interact it with the inverse of number of operators. The inverse of the number of firms variable comes into the supply function through our derivation of the supply equation, as shown in subsection 4.5. Grzybowski (2005) also uses the inverse of the number of firms and MNP as explanatory variables, but he does not attribute MNP to the market power component.

Another important determinant of price is the marginal cost. Data on marginal cost is in general not available to researchers. A number of studies turn to proxies for it using bond rate, labour costs and electricity costs (see, for instance, Grzybowski (2005)). However, some of these proxies are not specific to the telecommunication industry. In our study, we use the mobile termination rate, which is a better proxy for telecommunication marginal costs and is expected to have a positive effect on prices.

In order to obtain homogeneous comparisons of termination across the selected countries, we collected average rates per minute calls. We further transformed the rates from local currencies to US\$ PPP using the World Bank PPP conversion factor. Figure 4.2 shows evolution of termination rates in the selected countries. The figure reveals that in all the countries considered in this study, MTRs are falling. This is because the countries considered in this study have adopted glide path termination rate policy. This policy requires operators to reduce termination rates.

Figure 4.2: Mobile Termination Rates for Selected Countries, 2010-2014.



4.4.1 Mobile Pricing

Measuring the prices of pre-paid telecommunication services is complex. The price is determined using tariffs of a wide range of services including voice, SMS and data. Adding to the complexity is the fact that mobile customers are billed based on destination and timing of their calls. The phone calls can be made on- or off-net and during peak or off-peak hours.

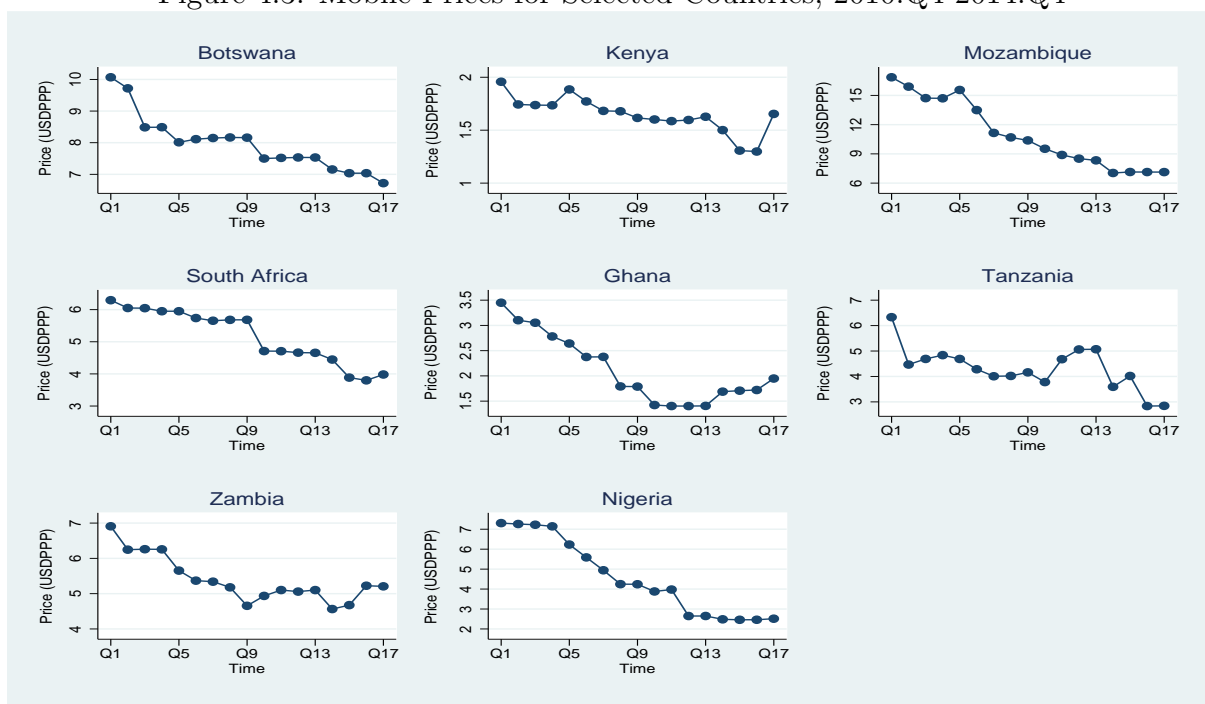
Due to this complexity, studies that analyze pricing of mobile telecommunication turn to use different measures for prices of mobile phone services. For instance, Shy (2002) uses average revenue per user (ARPU), while Grajek (2010) uses the lowest average customer bill. On the other hand, Fuentelsaz et al. (2012) and Cho et al. (2013) use price per minute. Price per minute measure is computed by dividing ARPU by the average monthly minutes of usage (MOU).

The problem with the measures used by Shy (2002), Grajek (2010), Fuentelsaz et al. (2012) and Cho et al. (2013) is that they do not take into consideration the different timing and destinations of phone calls. Other studies construct a price for mobile phone services using information on usage profiles (see, for instance, Grzybowski (2008a); Doganoglu &

Grzybowski (2013)). These studies assume that a representative user makes a certain number of phone calls per month, which are distributed across time and networks according to certain assumptions. The cost of the usage basket represents the price of mobile services. We take a similar approach to these studies and use as price the cost of pre-paid mobile phone service usage basket, which was constructed by RIA using the Teligen Ltd approach.¹³ Table 3.3 presents the assumed distribution of minutes and messages for pre-paid services according to destination and time of the day are presented in Chapter 3, Table 3.3.

We construct price by weighting the price of each firm by its market share. We use average weighted price per country to proxy the price of pre-paid mobile phone services. Prices are measured in US\$ PPP. We show price trends for each country for the period of the study in Figure 4.3. Similar to the MTRs, prices for mobile phone services have been falling over the period of the study.

Figure 4.3: Mobile Prices for Selected Countries, 2010:Q4-2014:Q4



¹³For more details on the basket see www.oecd.org

4.5 Econometric Model

We assess the impact of MNP and MTR on mobile retail price using the equilibrium model proposed by Green & Porter (1984) and later, used by Parker & Röller (1997) and Grzybowski (2005) in the application to telecommunications industry. We assume that firms produce homogenous products and compete in quantities. This assumption is supported by the fact that the telecommunication output is constrained by spectrum availability, and as such firms strategically set subscriptions to sell. Subject to certain conditions, the capacity constrained price game yields the same output as the Cournot quantity game as shown in (Kreps & Scheinkman, 1983).

Following Grzybowski (2005), we assume that mobile operators are faced with the following inverse demand function:

$$p_{ts} = f\left(\sum_{i=1}^N q_{its}, X_{ts}, \epsilon_{ts}\right), \quad (4.1)$$

where $i = 1, \dots, N$ is the mobile operator subscript, $s = 1, \dots, S$ is the country subscript, $t = 1, \dots, T$ is the time subscript, N_{ts} is the number of mobile operators in country s at time t , p_{ts} is the average price of pre-paid mobile phone service in country s at time t , q_{its} is total active subscriptions of mobile operator i in country s at time t , X_{ts} represents observable and ϵ_{ts} the unobservable demand shifters. Firms are assumed to have the following similar cost structure as follows:

$$TC_{its} = FC_{its} + VC(q_{its}, W_{ts}, \omega_{ts}), \quad (4.2)$$

with FC_{its} representing firm specific fix costs changing over time and across countries. Variable costs, $VC(q_{its})$, depend on the number of network subscriptions and some other country-specific cost drivers W_{ts} . Unobservable cost shifters are captured by ω_{ts} . Given such demand and cost specifications, a firm's profit function can be expressed as:

$$\pi_{its} = p_{ts}(\cdot)q_{its} - VC(q_{its}, W_{ts}, \omega_{ts}) - FC_{its}, \quad (4.3)$$

this provides the first order conditions in the form:

$$\lambda_{its} \frac{\partial p_{ts}(\cdot)}{\partial q_{its}} q_{its} + p_{ts}(\cdot) - MC_{its}(\cdot) = 0, \quad (4.4)$$

where $MC_{its}(\cdot) = \frac{\partial VC_{its}}{\partial q_{its}}$ is the marginal cost function for firm i in country s and $\lambda_{its} = 1 + \sum_{j \neq i}^N (\frac{\partial q_{jts}(\cdot)}{\partial q_{its}})$ represents conjectural variation (degree of collusion). The conjectural variation formulation might be interpreted as the firm's expectations about the reaction of the other firms to a change in quantity (see Bresnahan (1989); Grzybowski (2005)). Summing up FOCs (4.4) over all firms within the industry and dividing by the number of firms N_{ts} to get the average industry supply equation in the form:

$$\frac{\lambda_{its}}{N_{ts}} \frac{\partial p_{ts}(\cdot)}{\partial Q_{ts}} Q_{ts} + p_{ts}(\cdot) - \frac{1}{N_{ts}} \sum_{i=1}^N MC_{its}(\cdot) = 0. \quad (4.5)$$

Three basic cases can be considered: $\lambda_{ts} = 0$ in the perfect competition case, $\lambda_{ts} = 1$ corresponds to Nash equilibrium and $\lambda_{ts} = N_{ts}$ implies joint profit maximization.

In the estimation, we assume that MTRs affect prices through marginal costs and MNP is assumed to influence prices by affecting price elasticities and firms' market power. This is because MNP is expected to give consumers an opportunity to switch without losing their mobile numbers which reduced switching costs. Based on the above assumption, we estimate the following demand specifications:

$$Q_{ts} = \exp(-(\alpha_0 + \alpha_1 R_{ts})p_{ts} + X_{ts}\beta + \epsilon_{ts}), \quad (4.6)$$

where Q_{ts} is the sum of mobile subscriptions of all operators in country s at time t , p_{ts} represents the price of pre-paid services, $X_{ts} = [1, Fixed_{ts}, GDP_{ts}, Pop_{ts}, Time_t]$ is a set of exogenous explanatory variables and ϵ_{ts} represents the unobservable demand shifters. Given the above demand specification we get $\frac{\partial p_{ts}(\cdot)}{\partial Q_{ts}} = \frac{1}{-(\alpha_0 + \alpha_1 R_{ts})Q_{ts}}$. Hence, the supply side equation becomes:

$$p_{ts}(\cdot) = \frac{1}{N_{ts}} \frac{\lambda_{ts}}{(\alpha_0 + \alpha_1 R_{ts})} + MC_{ts}(\cdot)\gamma + \omega_{ts}. \quad (4.7)$$

where $R_{ts} = [MNP_{ts}]$ is an exogenous regulatory variables which affects market power. In this specification, $MC_{ts} = [MTR_{ts}, Time_t]$ and N_{ts} is the number of firms in country s at time t . We assume that the telecommunication market is similar across African states

with the same collusion parameter λ_{ts} and ω_{ts} are the unobservable cost shifters. This is a strong assumption which we make due to limitations in our data. We do not have enough data points to estimate country-specific parameters. However, this assumption is not far-fetched as there are similarities in the African telecommunication markets. For instance, first-movers tend to dominate the mobile telecommunication market. In terms of ownership, the government have ownership of incumbent operators. In terms of regulation of MTRs, regulatory authorities follow a glide path. Furthermore, the African mobile telecommunication markets have similar firms. For instance, MTN provides its networks in the following countries: Botswana, Ghana, Tanzania, Uganda and Zambia. Airtel operates in Ghana, Kenya, Zambia, while Orange operates in Botswana and Kenya. The pricing equation is nonlinear in parameters. The price elasticity of demand for the demand function in equation 4.6 is given by:

$$\eta_{ts} = \frac{\partial Q_{ts}}{\partial p_{ts}} \frac{p_{ts}}{Q_{ts}} = -(\alpha_0 + \alpha_1 R_{ts}) p_{ts}. \quad (4.8)$$

4.6 Identification

An important factor when examining the impact of a policy on an outcome is to understand the motivation behind the introduction of such a legislative initiative. As for our case, understanding the motivation behind the implementation of MNP and the glide path in termination rate policy are critical as we seek to tease out the impact of these policies on price. If the implementation of these policies were endogenous to market characteristics, the unbiased impact of these initiatives on prices will be hard to estimate.

Similar to other empirical studies that examine the impact of MNP on price, we consider the introduction of MNP as an exogenous policy to reduce switching costs. In practice, the authorities stipulate stringent implementation dates, and mobile telecommunication agents (consumers and operators) consider it as a given external shifter of market condition (see, for instance, Bühler et al. (2006); Park (2011); Cho et al. (2013)). As long as pricing strategies developed by mobile carriers do not influence the implementation of MNP, we can treat the policy as an exogenous factor with respect to operators' pricing decisions. We present this in greater detail here by discussing the background of MNP

adoption.

In most countries, the regulator's decision to implement MNP is based on the motive to facilitate market competition by decreasing market power of the incumbent. For instance, in South Korea, the authority adopted MNP because the regulator assessed that the incumbent was exploiting excessive profits by introducing a 3-digit identification prefix, an appealing point and a differentiated value ((Cho et al., 2013)). In terms of MNP adoption in African countries, however, the major difference from other countries is that the regulator's decision on whether to adopt MNP or not cannot be attributed to market characteristics. For instances, most African authorities did not implement MNP even though the telecommunications market is dominated by incumbent operators. The decision not to implement MNP in Botswana and Uganda, for example, was based on the costs of implementing the facility.¹⁴ Hence, the adoption of MNP in Africa is likely to be based on external conditions rather than on internal market conditions.¹⁵

We also consider the setting of termination rates to be influenced by external factors and not to be endogenous to retail prices. In practice, the mobile sector is made up of two markets: the wholesale or upstream and the retail or downstream market. In the upstream market network providers sell termination services. In setting termination rates, regulators generally assume that call termination on each individual mobile network is a separate market and each operator in that market is a monopoly. To prevent market distortions, regulators impose remedies by requiring operators to set cost-oriented prices for call termination. For instance, when implementing the glide path termination rate policy, the regulators used a cost-based model assuming, a hypothetical efficient entrant. In addition, the rate at which the termination reduces is determined by the regulators and the operators take it as given. Furthermore, what makes this policy exogenous is that after realizing that mobile operators are setting termination rates that are not cost-orientated, the regulators mandated the operators to reduce termination charges over time, rather than mandate a one-off shock which will reflect market conditions. Hence, the setting of termination rate in Africa is likely to be based on exogenous factors rather

¹⁴(see www.budde.com.au, www.cellular-news.com)

¹⁵For instance, in countries where MNP is implemented, market agents (operators and subscribers) do not have any influence in its adoption. Instead, this was at the discretion of the regulator.

than endogenous market conditions.

4.7 Results

We estimate the demand and supply sides separately using panel data random effects techniques. This estimation strategy relies on the assumption that the unobserved product-level errors are uncorrelated with explanatory variables. However, this assumption may not hold due to endogeneity of price and quantity variables. We perform a Durbin-Wu-Hausman test of endogeneity, which does not allow rejecting endogeneity of price in the demand estimation. A standard way of solving this problem is to use instrumental variables estimation. The literature suggests using cost variables as instruments for price (see, for instance, Berry (1994)). Hence, in this study we use termination rates, which are the main components of operators' marginal costs, to instrument for retail prices. The use of panel data techniques require testing whether the error term are correlated with the regressor. We perform a Hausman test, which allows us to reject the null hypothesis of random effects in favour of panel data fixed effects technique. However, our model estimation requires inclusion of a country-level inverse of number of firms variable in the supply side. Hence, using panel data fixed effects model omits this variable. The results of panel data fixed and random effects techniques are practically similar, for the demand estimation.¹⁶ This gives us a reason to discuss the results from a panel data random effects techniques.¹⁷

Tables 4.2 and 4.3 present the result of estimating the supply side and demand formulations respectively. On the supply side, N represents the number of firms in a country, MNP/N is the interaction of MNP with the inverse number of firms. *rates* represents mobile termination rates and *time* is the time trend measured in quarters. In column (1) of Table 4.3, we present the results of estimating a demand equation using standard panel

¹⁶The magnitude of coefficients in price and time are similar and significant in both fixed effects and random effects estimation strategies. However, the fixed effects model, population loose its significance

¹⁷One way of solving this problem is to use simultaneous equations techniques. Unfortunately our data cannot handle this type of estimation as we do not have enough exogenous variables to identify parameters. Though our estimation strategy might not be efficient, our results are consistent. Furthermore, our strategy have an advantage over system estimation in the sense that if one equation is misspecified, it would not spill over and contaminate the estimation results for the other equation.

random effects, while column (2) presents the result of estimating the same model with instrumental variable techniques. We interpret the results in column (2).

Overall, the demand estimation has a much better fit than the supply estimation. Significant exogenous variables in the demand estimations explain about 86% of the variation in subscriptions, while on the supply side they only explain 46% of price variation. These results show that there is much more unexplained noise in the pricing policies than in the consumers' decision to purchase mobile phone services. Much of these unexplained variations might be attributed to the fact that the model used assumes static interactions, while firms in this industry apply dynamic strategies. Moreover, some other variables such as regulatory issues are unobservable or difficult to approximate and implement in the model. Furthermore, each country seems to have a specific competitive environment.

In the supply side specification, MTRs have a positive and significant impact on mobile retail prices, which suggests that lowering the MTRs leads to a reduction in mobile retail prices. A decline in average MTR of 10%, decreases average mobile retail prices by 2.5%.¹⁸ Our results are in support of the glide path termination rate policy. Moreover, our study finds that there is no significant impact of MNP on retail price, which opposes the hypothesis that MNP reduces price by reducing switching costs. We attribute this result to African industry characteristics such as ownership of multiple SIM cards (see, Aker & Mbiti (2010); Jentzsch (2012)). Subscribers in developing countries adopt multiple SIM cards to overcome poor network coverage and to avoid network congestion. Subscribers also connect to multiple operators to save money by making on-net calls and also to benefit from discounted or bundled tariffs for voice calls or for data (see Sutherland (2009)). In markets with multiple SIM cards, there is no need for porting numbers since consumers subscribe to more than one operator. Moreover, as we discussed earlier, the speed of processing a request for porting is very low in the countries considered in this analysis. We also find MNP to be insignificant in the estimation of the demand equation. This coincides with the supply side estimation.

¹⁸We calculate the impact of MTRs on retail price as $\frac{\partial p_{ts}}{\partial rates_{ts}} \frac{rates_{ts}}{p_{ts}} = \gamma \frac{rates}{p_{ts}}$

Table 4.2: The Supply Side

VARIABLES	Price
$1/N$	24.397*** (4.221)
MNP/N	-0.962 (2.076)
Rates	10.677** (5.371)
Time	-0.155*** (0.038)
Constant	-0.532 (1.299)
Observations	136
R- square	0.45

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Results based on panel data random effects estimation.

Our model specification requires the inclusion of inverse number of firms ($1/N$) in the supply side formulation. The coefficient of this variable is interpreted as market conduct divided by the coefficient of price. The inverse number of firms variable has a significant and positive effect on price, which implies that as the number of firms in the market increases, market power is reduced and prices decline. The market conduct parameter is estimated around 1.27, which is calculated as 24.39 multiplied by 0.05. The value of this parameter in the proximity of one implies Cournot competition conduct. Thus, the average market conduct in sub-Saharan African countries during the period of the study is approximated by the Nash equilibrium.

Similar to Grzybowski (2005), we include a time trend in our analysis of demand and supply. The coefficient of this variable should be interpreted as the effect of technological progress. The coefficient of time trend in the supply equation is negative and significant. This result suggests that technological progress leads to a reduction in prices. We find a significant positive effect of time trend on subscriptions. This result shows that technological progress increases customer valuation of mobile phone services.

On the demand side, population has a significant positive effect on mobile subscriptions across the selected African countries, which implies that demand for mobile services is

greater in populated countries. We find insignificant impact of GDP per capita and fixed penetration on demand for mobile phone services. The demand for pre-paid mobile telephone service is inelastic with respect to price. The price elasticity of demand for pre-paid mobile telephone services is -0.27, which agrees with estimates from other countries. This result contradicts the results found in Chapter 3. In Chapter 3, we find elastic price elasticities. We attribute this to different assumptions made in each chapter.

Table 4.3: The Demand Side

VARIABLES	1	2
Price	-0.056*** (0.007)	-0.052*** (0.006)
Price*MNP	0.024 (0.015)	-0.006 (0.035)
ln(Pop)	0.800*** (0.029)	0.202*** (0.064)
ln(Fixed)	0.008 (0.013)	-0.021 (0.025)
Time	0.015*** (0.002)	0.015*** (0.003)
ln(GDP)	0.307*** (0.055)	0.210 (0.174)
MNP	0.070 (0.052)	0.087 (0.088)
Constant	0.632 (0.723)	11.870*** (1.900)
Observations	136	136
R-square	0.83	0.87

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Results based on panel data random effects estimation in column (1) and based on instrumental variables random effects estimation in column (2). We use mobile termination rate and mobile termination rate interacted with MNP as instruments. The dependent variable is logarithm of mobile subscriptions.

4.8 Conclusions

This chapter examined the impact of mobile number portability and mobile termination rate on mobile retail price in selected African countries. MNP reallocates property rights of mobile phone number from carriers to customers. By doing so, it allows consumers to

keep their numbers when changing operators. Theory relating to switching costs suggest that prices can increase or decrease when switching costs reduce. Termination rates, on the other hand are charges which operators set for terminating calls on each others' network. These charges are not observed by customers, but they directly affect retail prices. Existing theory suggests that a decrease in MTR is more likely to increase mobile retail prices and reduce fixed-line prices. This phenomenon is called the waterbed effect.

We use a Nash equilibrium model proposed by Green & Porter (1984) to examine the effect of regulatory policies on mobile retail prices. Firms are assumed to produce a homogenous good and use static interactions. Using a unique quarterly dataset for 35 mobile phone operators in eight African countries for the period 2010:Q4 to 2014:Q4, we estimate demand and supply structural formulation separately using random effects panel data techniques.

First, we find that mobile termination rates (MTR) have a statistically significant positive impact on mobile retail prices, a result that rejects the waterbed effect in support of the glide path termination rate policy. This result contradicts the study by Genakos & Valletti (2011), which was used by one of the largest firms in the UK, Vodafone, to argue against regulatory authority policy of reducing termination rates. Vodacom cited the paper and argued that reduction of termination rates will lead to an increase in mobile retail prices and reduction in subscriptions. Our results show that a decrease in termination rate will lower mobile retail prices. It thus supports the glide path termination rate policy.

Second, our results oppose the hypothesis that MNP reduces prices and firms' markups. Both on the demand and supply side we find that MNP is insignificant. Although this policy might have an effective impact in industrialized countries, the same might not be true for developing countries. For instance, the African mobile telecommunication market is characterized by multiple SIM card ownership and the existence of dual SIM card mobile phone devices. Hence consumers are connected to at least two operators meaning that there is little demand for porting numbers.

Our study come with some limitations. The constructed data set does not allow us to determine whether MNP reduces switching costs or not. We were unable to determine

how firms' market share evolve after the introduction of MNP. This is because we use aggregated data. Furthermore, we were unable to get firm level termination rates, which could have allowed us to evaluate the impact of regulating termination rates on small and large firms. Future research must evaluate the effect of MNP and on market concentration and price demand elasticities.

Chapter 5

Conclusion

The deployment of mobile telecommunications provides an avenue for developing countries to overcome one of the main constraints to economic growth, such as, poor or non-existent physical and service infrastructure. In particular, mobile phones provide low income households with access to services which are in general not available to them such as financial services.

In Chapter 2 we analyze the determinants of adoption of mobile phones and mobile financial services. For this purpose, we combine two unique datasets. The first one contains information about access to mobile phones and the use of mobile phone services by 13,814 individuals in eleven Sub-Saharan African countries in 2011. Information on mobile service includes the use of mobile money, transfers and social and Internet activities. To approximate the availability of service infrastructure we complement the survey data with nighttime light intensity data which enables us to analyze how spatial differences in infrastructure development across Sub-Saharan African countries influence the adoption and use of mobile phone services by individuals.

Our results suggest that the adoption of mobile phones is higher in areas with better physical infrastructure. However, in the group of mobile phone adopters, the use of mobile phones for mobile money and transfers is negatively influenced by the level of infrastructure. Thus, mobile money can be considered as a substitute to physical infrastructure and benefits people who live in remote areas and who may be excluded from access to financial services. This result confirms the benefits that mobile phones have for social inclusion and economic development in low income countries with poor physical

infrastructure. These results are consistent with the view that mobile phones improve the livelihoods of remote area residents by providing them with access to financial services, which are otherwise not available physically. Moreover, we find that while individuals with higher disposable income are more likely to adopt mobile phones, the level of income does not determine use of mobile money and transfers. At the same time, higher income groups are more likely to use mobile phones for social and Internet activities. This result suggests that all income groups benefit equally from mobile money and transfer services. Even though our analysis only involves a number of low income countries in Sub-Saharan Africa, our finding on the use of mobile phones to overcome infrastructure deficiencies is more general. In high income countries, mobile phone users are able to save time and money by having mobile access to financial and other services.

While Chapter 2 we analyze the determinants of mobile phone adoption and usage, Chapter 3 and 4 focuses on the effect of telecommunication regulatory policies on demand price elasticities and price. Concerns have been raised by various competition and regulatory authorities about the lack of effective competition in the mobile telecommunication industry. Limitations in the amount of spectrum and high network investments result in the industry being oligopolistic in nature and susceptible to collusion and the exercise of market power. In addition, consumers of mobile phone services tend to have high switching costs, which may weaken competition among existing firms and make successful entry of new firms difficult. Moreover, the increasing demand for mobile broadband services and scarcity of spectrum has already led to rapid consolidation in some markets. Hence, antitrust regulators are faced with tough choices as they balance their mandate of attaining healthy competition with the financial imperatives facing the industry. To improve access and usage of mobile phone services and to ensure that customers are not exploited, a number of regulatory authorities have adopted a number of policies that are meant to reduce mobile retail price and reduce switching costs as well as increase competition. To reduce switching costs, regulatory authorities worldwide introduced mobile MNP which allows subscribers to move with their numbers when changing mobile operator. However, they have repeatedly intervened in the mobile termination rates (MTRs) market and implemented a policy that requires operators to reduce the charges they set for terminating

calls on each other's network over time.

Chapter 3, uses a unique quarterly panel dataset for 28 mobile operators in seven African countries for the period 2010Q4 to 2014Q4 to estimate a differentiated products demand model based on instrumental variables technique. Consistent with theory we find a negative relationship between price and utility. Moreover, the interaction term of price and a dummy variable for the implementation of MNP is also significant with a negative sign. This implies that the introduction of MNP increased price elasticities in countries which implemented the policy. At the same time, MNP has a significant and positive impact on the utility that consumers derive from mobile services. This increases the demand for mobile subscriptions.

We use the estimated parameters to compute average operator-specific price elasticities. Our findings, suggest that the introduction of MNP increases own-price elasticities. We find that they are on average higher in periods in which MNP was implemented. However, in Ghana and Kenya, the average own-price elasticities remained small even after the implementation of MNP relative to other countries without MNP policy in place. This may be attributed to market structure and other factors in these two countries. For instance, in Kenya, Safaricom dominates both the voice and mobile money markets. Thus, our results are an indication that MNP is not the ultimate solution for increasing competitiveness of the mobile industry. For this reason, it is important to understand the sources of switching costs in order to apply the appropriate policy. For instance, in markets where there is dominance with consumer valuation of network effects greater than the costs of switching, consumers are likely to be locked within a dominant operator. The implementation of MNP will not be effective in this case.

An analysis of own-price elasticities at operator-level shows that in countries that have implemented MNP prior to the period of our study, operator own price elasticities are higher relative to those in countries without MNP. As for countries that have implemented MNP within the scope of our study, we find small operator own-price elasticities, except for Expresso in Ghana. A comparison of own-price elasticities between countries that implemented MNP in 2011, with countries that have never implemented MNP in the period of our study shows that operators in countries that have never implemented MNP have

higher own-price elasticities relative to operators in Ghana and Kenya. These findings have a number of implications. Our results show that MNP has differential effects across countries and the impact of MNP is likely to be determined by market structure. Hence, before implementing MNP, understanding of price elasticities and the sources of switching costs is crucial.

Chapter 4 examines the impact of mobile number portability and mobile termination rates on mobile retail prices in selected African countries. MNP is a facility that reallocates property rights of mobile phone number from carriers to customers. By doing so, it allows consumers to keep their numbers when changing operators. Theory relating to switching costs suggests that prices can increase or decrease when switching costs reduce. Termination rates, on the other hand, are charges which operators set for terminating calls on each others' network. These charges are not observed by customers, but they directly affect retail prices. Existing theory suggests that a decrease in MTR is more likely to lead to an increase in mobile retail prices and reduce fixed-line prices. This phenomenon is called the waterbed effect.

We use a Nash equilibrium model proposed by Green & Porter (1984) to examine the effect of regulatory policies on mobile retail prices. Firms are assumed to produce a homogeneous good and use static interactions. Using a unique quarterly dataset for 35 mobile phone operators in eight African countries for the period 2010:Q4 to 2014:Q4, we separately estimate demand and supply structural formulation using random effects panel data techniques.

First, we find that mobile termination rates (MTR) have a statistically significant positive impact on mobile retail prices, a result that rejects the waterbed effect in support of the glide path termination rate policy. This result contradicts the study by Genakos & Valletti (2011), which was used by one of the largest firms in the UK, Vodafone, to argue against regulatory policy of reducing termination rates. Vodacom cited the paper and argued that reduction of termination rates will lead to an increase in mobile retail prices and reduction in subscriptions. Our results show that a decrease in termination rates will lower mobile retail prices. It thus support the glide path termination rate policy.

Second, our results oppose the hypothesis that MNP reduces prices and firms' markups.

Both on the demand and supply side, we find that MNP is insignificant. Although this policy might have an effective impact in industrialized countries, the same might not be true for developing countries. For instance, the African mobile telecommunication market is inherently characterized by multiple SIM card ownership and the existence of dual SIM card mobile phone devices. Hence, consumers are connected to at least two operators with no demand for porting numbers.

In summary, our study contributes to the telecommunication demand literature. The study specifically contributes to the literature on mobile phone service demand, switching costs and the waterbed effect theory. Our results show that mobile phones play a significant role in achieving social inclusion and economic development in low income countries. We find that the introduction of mobile number portability decreases switching costs, and increases utility that consumers derive from mobile phone services. However, on the supply side, we find that MNP has no effect on mobile price in the selected African countries. In Chapter 3, we find elastic price elasticity of demand, while in Chapter 4, we find inelastic price elasticity of demand for the selected African countries. This could be due to the assumptions made in each chapter.

Our study does have limitations, which are important to emphasize to direct future research. First, we did not consider consumer welfare and therefore, we cannot comment on the implications of decisions taken by the regulator on whether to implement or not to on consumer welfare. Second, our study does not measure switching costs in the African telecommunication market. We were unable to get firm level termination rates. Hence, the aggregation of data in Chapter 4. Due to this aggregation, the study could not evaluate the impact of regulating termination rates on small and large mobile operators. Understanding the impact of glide path termination rates on price on individual operators is critical for policy. Further studies must investigate the sources of switching costs and provide policies for reducing countering those costs. Future research must also evaluate the effect of MNP on market concentration.

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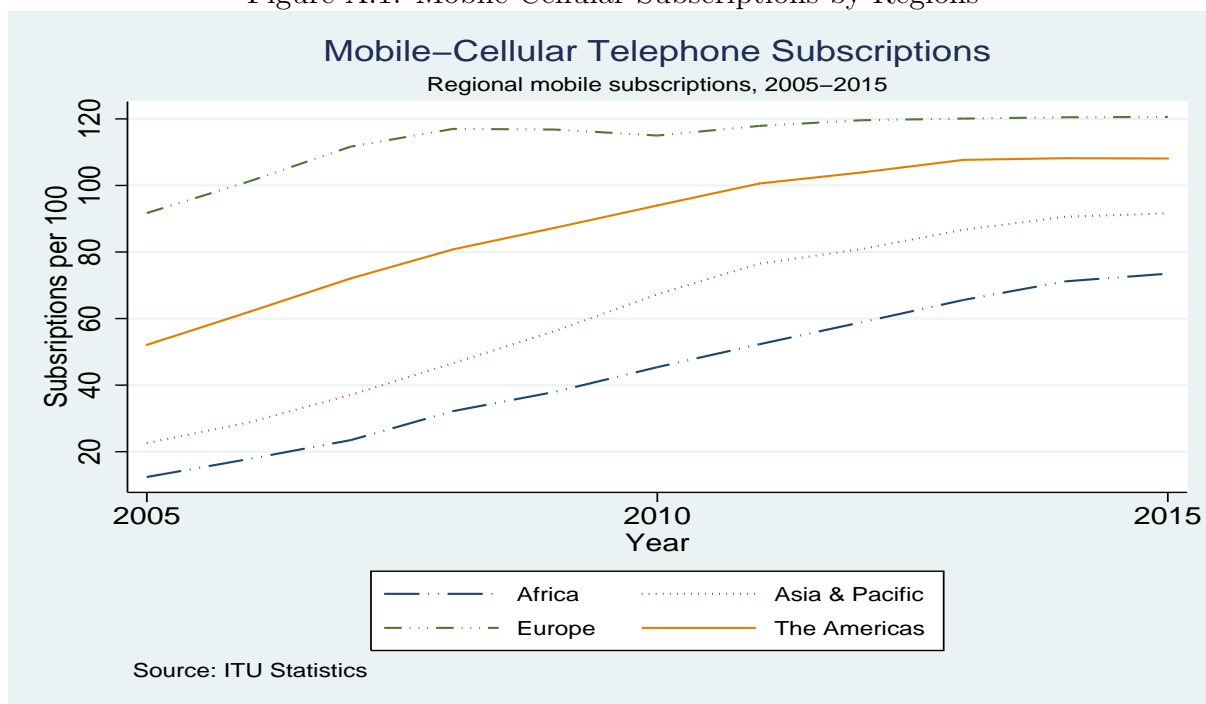
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Appendix A

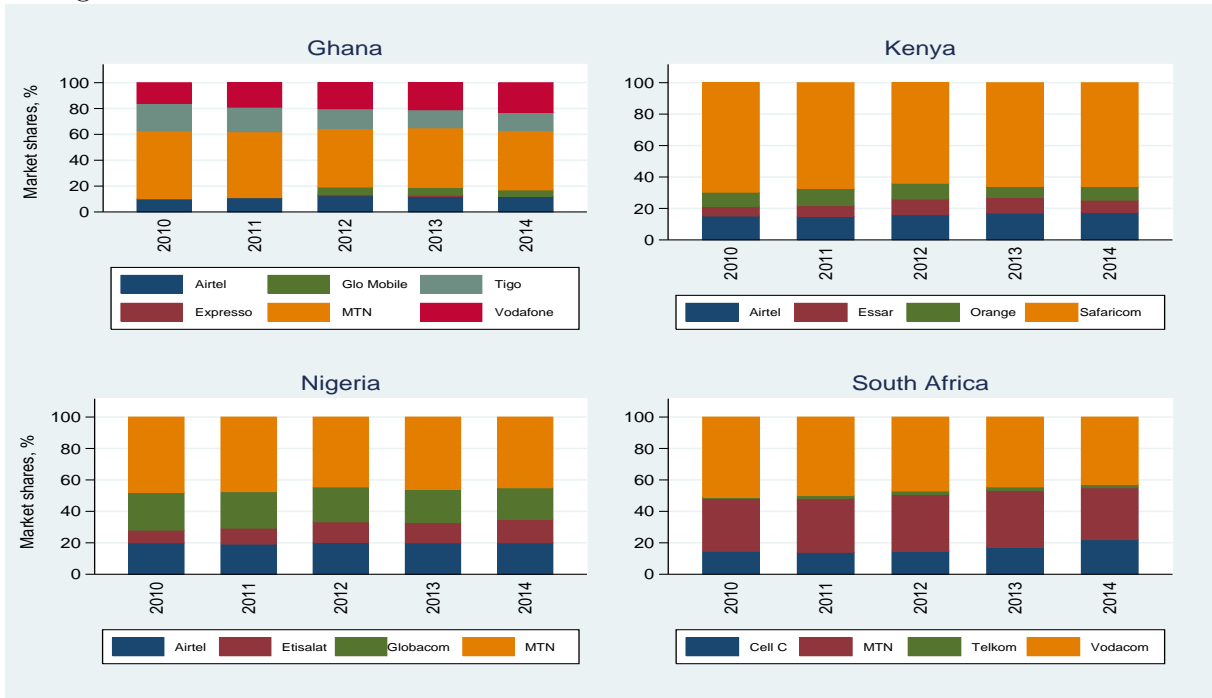
Appendix

Figure A.1: Mobile-Cellular Subscriptions by Regions



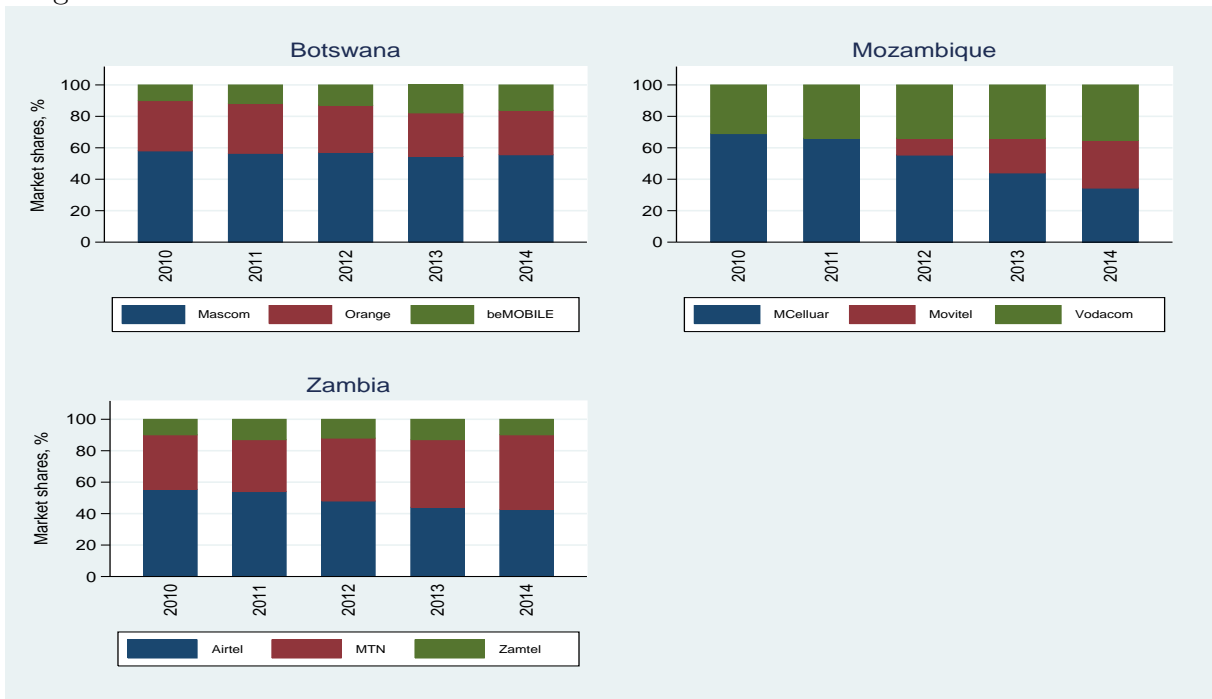
Source: ITU Statistics. The figure shows penetration of subscriptions to mobile services for Africa, Asia & Pacific, Europe and The Americas.

Figure A.2: Evolution of market shares in countries with MNP between 2010-2014



Source: Own calculations based on WCIS data. The figure shows evolution of market shares in countries that have implemented MNP.

Figure A.3: Evolution of market shares in countries without MNP between 2010-2014



Source: Own calculations based on WCIS data. The figure shows evolution of market shares in countries that have not implemented MNP.

Figure A.4: Mobile Prices for Selected Countries with MNP.

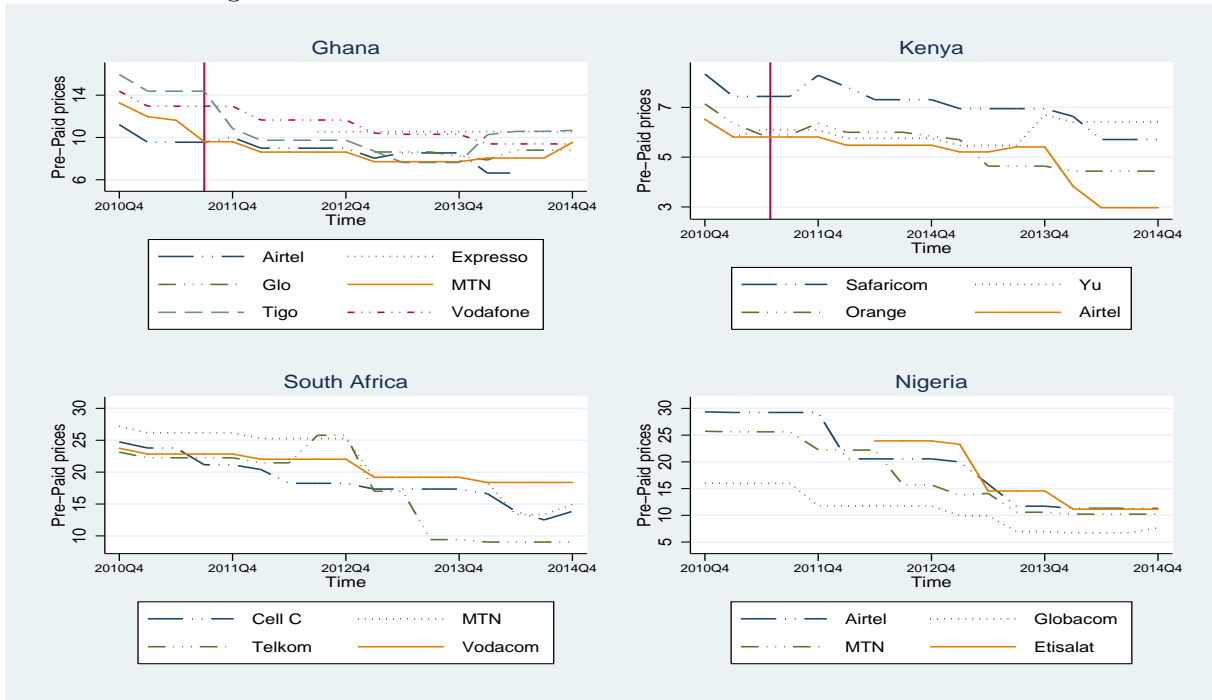


Figure A.5: Mobile Prices for Selected Countries without MNP.

