Competition and Mobile Penetration in Sub-Saharan Africa

By
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Abstract:

This paper examines the impact of competition on mobile penetration in 35 Sub-Saharan African (SSA) countries between 2000 and 2006. We examine both the impact of introducing competition and the role of intensity of competition on mobile penetration in these countries. Different specifications with different measures of competition that reflect either the introduction or intensity of competition on the sector have been used in the analysis. Controlling for various sector characteristics and macro-economic indicators, we apply panel data regression analysis with fixed effects. For the most part, the results in this study are consistent with the existing literature, and confirm that the introduction of competition in the mobile market is strongly and positively associated with mobile penetration. Furthermore, the results of this study indicate that promoting effective competition plays a significant role in increasing mobile penetration.

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Introduction

Until the early 1980s, academics as well as policy analysts classified most communications and transportation industries, including telecommunications, as natural monopolies based on the apparent economies of scale under which they operate (Shy, 2001). The policy implication of these arguments easily led to circumstances that favoured strong government interference. Interferences in the sector varied from direct government ownership of such enterprises to strong state regulation. Visible and easily tractable inefficiencies in public enterprises, technological progress, and globalization stimulated fresh and entirely different views about the merits of such interventions. Consequently, many nations started to reform these industries.

An important technological development in the telecommunications industry during the 1980s was the introduction of mobile / cellular telecommunications.

The introduction of cellular technology has significantly affected peoples' lives. In fact, it is considered as one of the tremendous success stories in the industry's history. According to very recent estimates of the International Telecommunication Union (ITU), cellular connection worldwide is about to reach 4 billion, by growing at an average rate of 24 per cent between 2000and2008.http://www.itu.int/newsroom/press_releases/2008/29.html..
Currently, mobile subscribership surpasses fixed telephone lines in many parts of the world.

Since its introduction coincided with the privatization and introduction of competition in the telecommunications sector, unlike the fixed line, the mobile market has been subject to competition as of its infancy. Currently, although, there are a few countries that prohibit competition in the mobile sector, most have opened it up to competition.

The African mobile market, which has been recording an impressive growth rate, is not an exception to these phenomena. Except for a few African countries that still maintain monopoly power in mobile service provision, many of them have been permitting competition in the past decade. Though the extent of competition varies from country to country, a 2007 data set from ITU indicates that 89.4 per cent of the countries have introduced some form of competition.

Though mobile penetration (*MP*) is still very low in Africa, which was 28.3 subscribers per 100 inhabitants in 2007[2], its mobile market recorded an impressive growth rate in the past few years. For instance the number of mobile subscribers grew by 49.1per cent between 2002 and 2007[3]. Moreover, the MPs of a number of African countries have begun exceeding those of fixed lines networks, making mobile subscription more attractive, in the eyes of both policy makers and regulators, for improving access to telecommunications. There is some evidence suggesting that competition in the mobile sector may have played a significant role in the African mobile boom (Portio Research, 2006). Of course, cheaper network deployment costs and the introduction of prepaid services in this network are also contributors to this phenomenon.

In light of this, we aim to investigate the effect of competition in the mobile sector on the increases of *MP* in Sub-Saharan Africa(SSA). We also aim at identifying the impact of other sector characteristics and socio-economic variables on Africa's *MP*.

There are a number of studies on the impact of competition on the telecommunications sector performance (in terms of employment, investment, output, service pricing, network expansion, labor productivity and total factor productivity both in the developed and developing countries) such as Ros (1999),

[2] The figures were 37.5 for Asia, 72.4 for the Americas, 79.2 for Oceania and 109.6 for Europe.
[3] Summarized form ITU ICT Indicators Database (2007)

Wallsten (2001), McNary (2001), Fink et al. (2002), Li and Xu (2004), Li (2008). We contribute two issues into the debate in this literature: first, we extend the applications in the literature to Sub-Saharan Africa (SSA), where significant mobile telephone growth has been observed in the past decade; and, second, we study not only the impact of the existence of competition but also its intensity. For the second contribution, in addition to using number of mobile operators as a proxy to measure intensity of competition, the use of a more informative as well as continuous measure--- Herfindahl-Hirschman Index (HHI)--- can be considered as a significant departure of this paper from the existing literatures.

Review of Literature

While competition is a global trend in the whole telecommunications sector, the leading elements in this are the mobile and internet services' providers. For instance, 88per cent and 92per cent of countries in the world have either partial or full competition in the mobile and the internet services, respectively. On the other hand, the provision of fixed services is still a monopoly in many countries. Yet, between 62 and 65 per cent of the countries have allowed competition in the provision of international, domestic long distance and local call services (ITU, 2007b).

Following this trend, there are several cross-country studies examining the effect of competition and other reforms on the telecommunications sector. Except few, most of these studies analyze the effect of competition and privatization on telecommunications performance. The findings of these studies largely indicate that competition has led to significant improvements in performance and efficiency. For instance, Wallsten (2001) examines the effects of privatization, competition and regulation on fixed line telecommunication performance using a panel dataset for 30 African and Latin American countries from 1984-1997. The study found that competition has a positive effect on the telecommunications sector by increasing level of fixed line penetration and

decreasing the price of local calls. The results of the impact of privatization, however, are mixed.

Li and Xu (2004), using a cross country panel data set covering the period from 1990 to 2001, studied the impact of privatization and competition in the telecommunications sector around the world. The paper found that countries that allowed competition and full privatization, in both fixed-line and mobile sectors, showed improved performance gains than countries that did not allow such reforms.

Their results show that 'an increase in competition index by one (for example, a move from a monopoly market structure to competition in either fixed line or mobile market) would raise telecom investment per capita by about 30 per cent. Their econometric results indicate that there is complementarity between privatization and competition. Particularly, they find that in countries where the services are privatized, competition significantly decreases the cost of local phone calls.

Other cross-country studies like McNairy (2001), and Fink et al. (2002) also show that competition increases fixed line penetration and boosts labor productivity significantly. McNairy (2001) estimated that 'every sixteen months of mobile competition increases penetration by approximately one line per hundred people'.

A study by Boylaud and Nicoletti (2000), which investigates the effect of entry liberalisation and privatization on productivity, prices and quality of service, in both long distance and mobile telephone markets in 23 OECD countries for 1991-1997, came up with a similar conclusion. Controlling for technological developments and differences in economic structure, the study found that prospective competition (using the number of years after liberalization as a proxy) and effective competition (using the number of competitors as a proxy) bring about increased productivity, quality improvements and reductions in the prices of all telecommunications services.

On the other hand, there are a few studies that resulted in different conclusions. For instance, Ros (1999), which examines the effects of privatization and competition on network expansion and efficiency on the basis of data from 110 countries from 1986-1995, found that competition in at least one fixed line market segment (local, long distance, or international) did not significantly affect fixed line penetration but has a positive effect on efficiency. This was strengthened by the argument suggested by Bortolotti et al. (2002). For them, a more competitive environment may crowd out investment by the incumbents as they will have to share some of the benefits from these investments with their competitors.

Except for the Boylaud and Nicoletti (2000) study, most of the earlier empirical work focus primarily on the impact of competition on the performance of fixed line telecommunications service. To our knowledge, the only study that analyzes the impact of telecommunications reforms on the mobile sector performance is the one by Li (2008). This study examines the impacts of reforms, privatization, new entry and existence of an independent regulatory authority on mobile network penetration in 29 OECD countries and China for the period 1991-2006. The result of the study shows that allowing new entry is positively correlated with *MP* and expansion. It also highlighted that independent regulation is positively correlated with penetration and its role is particularly crucial in privatized mobile markets.

Moreover, there are also empirical studies whose primary objective is to find the determinants of demand for mobile networks, including competition as an explanatory variable.
For instance, Gruber (2000) identifies determinants of the mobile telecommunications diffusion in 10 Central and Eastern Europe countries for the period 1990-1997. The results of his study show that competition, as measured by both simultaneous entry of firms and number of firms, considerably affects mobile diffusion in that region.

It also shows that the number of customers in waiting list for a fixed line connection (as a proxy for measure of efficiency of fixed line operator) and the number of fixed telecommunications lines per head (as a measure of the size of fixed network) has a positive significant effect on mobile diffusion. Similarly, Chakraarty (2005), in investigating the diffusion of mobile and the role of competition and regulation in 29 Asian countries, concluded that competition and independent regulation played a major role in increasing the diffusion of mobile service. In addition, the paper found that income per capita and the size of fixed network affected diffusion positively.

Econometric Model

In this study, we employ panel data model to measure the impact of competition on *MP* for 35 SSA countries between 2000 and 2006. There are two approaches used in estimating panel data models: the fixed and random effects approach. The fixed effects approach allows intercepts (of each country) to vary at a point of time. The random effects approach, on the other hand, assumes country variation to be randomly distributed and uncorrelated with the explanatory variables in the model. In the latter case, countries are assumed to be included in the sample randomly from a larger universe of such countries. Hence, all have a common mean value and individual difference of the intercept values of each country are reflected in the error term (Baltagi 2005). Accordingly, the selection between these two approaches depends on their assumptions explained above and the characteristics of the data at hand.

In this study, we intend to measure the impact of competition on *MP* in 35 countries out of 48 SSA countries (the rest 13 countries are excluded because of insufficient data). Given this nature of the data, therefore, from the outset we can not describe the observations as being a random sample from a much larger population. As a result, we are compelled to follow fixed effects model which controls for unobserved (country-specific) effects

by using country level dummies in addition to a common regression constant in the model. We formally tested whether this specification is justifiable using the Hausman specification test to statistically confirm whether the fixed effect is a justifiable specification[4]. The tests in all our different specifications of the measures of competition are in favor of using the fixed effects panel estimation[5].
Hence the panel data model is specified as follows;

$$\ln MP_{it} = \alpha_i + \beta_0 + \beta_1 \ln P_{it}^{M} + \beta_2 Y_{it} + B_3 \ln UR_{it} + \beta_4 \ln FPR_{it} + \beta_5 IR_{it} + B_6 comp_{it} + \varepsilon_{it} \quad (1)$$

Where i = 1, 2,…, M is the subscript for the cross-sectional dimension (country) and t (1, 2,…,T) is the subscript for the time- dimension (year). The variables used in this model are: *MP* represents mobile penetration–(number of mobile subscribers per hundred inhabitants); *Y* and *UR* represent GDP per capita and percentage of urban population respectively; P^M represents the price for a local, three-minute-peak-hour mobile call price, and *FPR* represents fixed line penetration (number of fixed telephone lines per hundred inhabitants). Competition (*Comp*) is represented by four different measures: a dummy for existence of two or more operators, the number of years since the existence of two or more operators, the total number of mobile network operators, and the *HHI*. Finally, *IR* represents a dummy that indicates whether a country has an independent telecommunications regulatory authority or not, and ε is an error term.

Moreover, in order to see the detailed impact of each consecutive entrant into the market, we constructed two

[4] The Hausman test checks a more efficient model (random effects) against a less efficient but consistent model (fixed effects) to make sure that the more efficient model also gives consistent results. In other words, the Hausman test is used to test whether the coefficients estimated by the efficient random effects estimator are the same as those estimated by the consistent fixed effects estimator. If they are (insignificant P-value, Prob>chi2 larger than .05) then it is safe to use random effects. If we get a significant P-value, however, we should use fixed effects

[5] Hausman Specification Test Result, are $\chi^2(6)= 161.94$, $\chi^2(6)= 44.05$, $\chi^2(6)= 111.82$, $\chi^2(6)= 124.41$, when $Comp_{it}$ represents dummy for existence of two or more mobile operators, number of years passed with two or more mobile operators, total number of mobile network operators, and HHI respectively (with p-value .0000)

equations based on equation 1.[6] First, we include all control variables and a set of entry dummies; with monopoly as base; *dumentry2* equals one if there are two mobile network operators, and equals zero, otherwise; *dumentry3* equals one if there are three mobile network operators, and equals zero, otherwise; and so on. Second, we replace the set of dummies with a quadratic form for the number of mobile operators (*NO*) to see the impact of competition (measured by number of mobile operators). The equations used are presented as follows;

$$\ln MP_{it} = \alpha_i + \beta_0 + \beta_1 \ln P_{it}^{M} + \beta_2 Y_{it} + B_3 \ln UR_{it} + \beta_4 \ln FPR_{it} + \beta_5 IR_{it} + B_6 DEntry2_{it} + B_7 DEntry3_{it} + B_8 DEntry4_{it} + B_9 DEntry5_{it} + \varepsilon_{it} \quad (2)$$

And

$$\ln MP_{it} = \alpha_i + \beta_0 + \beta_1 \ln P_{it}^{M} + \beta_2 Y_{it} + B_3 \ln UR_{it} + \beta_4 \ln FPR_{it} + \beta_5 IR_{it} + B_6 NO_{it} + B_7 NO_{it}^{2} + \varepsilon_{it} \quad (3)$$

Hypothesis

Building on the theoretical and empirical literature, we put forward the maintained hypotheses regarding the plausible relationship between the effect of the explanatory variables included in the model and the dependent variable (i.e. *MP*).

Economic theory proposes that competition increases rivalry among firms in a market that induces firms to be efficient and offer greater quantity and a variety of choices in terms of products or services at a relatively lower price. Though some empirical studies could not find results that support this hypothesis (for instance, Ros (1999) and Bortolotti et al. (2002)), most of the others support the idea that competition is positively and significantly related with telecommunications penetration (Boylaud and Nicoletti (2000), Gruber (2000), Wallsten (2001), McNary (2001), Fink et al (2002) Li and Xu (2004), Chakraarty (2005), and Li (2008)). Accordingly, our

[6] Using a similar approach adopted by Li (2008)

major hypothesis, which is subjected to test in our sampled countries during the time period under investigation, is:

Both the introduction and the intensity of competition in the mobile sector will increase *MP*. Therefore, the coefficient of $Comp_{it}$, is expected to have a positive sign when it represents dummy for the existence of mobile competition, or year with mobile competition, or total number of mobile operators, but will be negative on the *HHI*.

Since higher levels of GDP per capita indicate affordability and prosperity, we expect it to lead to higher demand for mobile services. Therefore, we expect GDP per capita to positively affect *MP*. On the other hand, two hypotheses are possible for percentage of urban population. Urbanization results in increased business transactions and demand for communication, that easily leads to higher levels of demand for mobiles by urban dwellers; hence, a positive correlation with *MP* is expected. Yet, a mobile telephone network is a good alternative for increasing access to telecommunication to rural areas; hence, the percentage of urban population might be negatively associated with *MP*. Therefore, the relationship is ambiguous a priori.

It seems obvious that, from law of demand, the relationship between price and quantity demanded is negative. Accordingly, most of the studies came up with results consistent with the widely accepted theory. However, some studies on the sector, particularly on fixed line penetration in developing countries, have obtained the opposite result. Their explanation is that in many developing countries low penetration is not due to insufficient demand at current prices, but rather due to insufficient supply (Ros 1999).

In the case of regulatory intervention in the mobile market, some argue for minimal level of regulation compared to fixed line service sector. According to them, mobile service is a value-added service and hence should fall outside the regulatory scope of basic voice telephony in regulatory agencies. In addition, they

argue that the existence of 'intense' competition in the mobile sector is strong enough to make mobile operators efficient. However, these views are highly criticized, not only because of the prevalent imperfect competition in the mobile sector, and intensive use of mobile telephony for universal service, but also because of the necessity of interconnection, fixed mobile termination, and mobile number portability issues. Therefore we expect existence of independent regulatory agency to be positively correlated with a MP.

The relationship between *FP* and *MP* is also a matter of debate. Some cross-country studies indicate that the mobile service is a substitute for fixed line services (Gruber and Verboon (2001), Madden Coble-Neal (2004), Waverman et al (2005)), while others indicate that the two services are complementary (Ahna and Leeb (1999), Garbacz and Tompson (2005), Chakravarty (2005)).
A study by Garbacz and Thompson (2007)) shows that there is lack of symmetric relationship between the demand for the two services. Accordingly, although fixed line service is a substitute for the mobile market, mobile phones are complementary in the fixed line market. Given the variability of the empirical outcomes (depending on countries, periods and the methodology used), the expected impact of *FP* on *MP* is also ambiguous. Complementarily between these two services implies positive network externalities, i.e. an increased incentive to acquire a mobile phone when there is additional fixed line user. But for anyone consumer, the substitutability implies a reduced incentive to acquire a mobile telephone when he/she has a fixed line. The net effect, therefore, depends on the relative strength of these two effects.

Data and Variables

This study relies on a recently published data by the International Telecommunication Union (IT World Telecommunications/ICT Indicators (2008)). Besides, we

compiled all measures of competition from Wireless Intelligence (A global database of mobile market information)[7].

The socio-economic statistics are drawn from the World Development Indicators Database (2008) published by the World Bank[8]. We also consulted ITU Regulatory. Database(http://www.itu.int/ITUD/ICFTEYE/Regulators/Regulators.aspx).InformationWorld Bank Privatization Database (http://rru.worldbank.org/privatization), and ITU publications (Trends in Telecommunications reform (2000-2006)) to get data on regulatory and privatization.

The variable of interest in this study is the measure of competition. Earlier studies defined the index of competition in different ways. Ros (1999) defined fixed line competition as 'a government approval of competition in fixed line services' while Li and Xu (2004) defined it as 'the existence of more than one fixed/wireless telecom operator' but both of them measure competition as a dummy variable in their econometric model. Wallsten (2001) defined and measured fixed-line competition by 'the number of wireless operators in the country not owned by the incumbent', while McNary (2001) defines mobile competition as 'the existence of more than one interconnected carrier with greater than one per cent market share' and measures it by the years of competition in the mobile services market.

In this paper, we examine the effect of competition on *MP* from two distinct perspectives. Firstly, we examine the effect of the

[7] https://www.wirelessintelligence.com/

[8] We also used WDI database for data on labour force, which is used as instrumental variables for income (GDP per capita). But capital stock data requires estimation for the specified period and countries, as it is unavailable from different sources including WDI database. Therefore we construct capital stock series based on annual investment from WDI database and initial capital stocks from Miketa (2004), and is calculated using the perpetual inventory method.

introduction (mere existence) of competition on *MP*. In this setting, we use two alternative variables: a dummy variable indicating the existence of two or more mobile network operators in the market; and a variable defining the number of years with two or more mobile operators. Secondly, we examine the effect of intensity of competition, measuring it by number of mobile subscribers and the *HHI*, alternatively.

McNary (2001) indicates the shortcomings of defining competition in a dichotomous fashion as it has been widely observed in a number of countries that introduce competition, where the previously state-owned monopoly remains a virtual monopoly with a huge market share while other operators remain with insignificant market share. This is one of the main reasons for this paper to directly use the market share of each individual firm and calculate the *HHI* values for each country and period under investigation. *HHI* takes into account the relative size and distribution of the firms in a market and approaches zero when a market consists of a large number of firms of relatively equal size. This measure decreases both as the number of firms in the market increases and as the disparity in size between those firms decreases, which, in both cases, shows increase in the intensity of competition.

Even if *HHI* is by far a better measure of intensity of competition than dichotomous measures, caution has to be taken as it cannot be considered as a full fledged measure of intensity for the existence of competition. This is mainly because it does not give signals on the contestability of a market. In this case, existence of barriers to entry (structural, strategic and policy/regulatory barriers) and other anti-competitive conduct of firms (vertical and horizontal restraints) need to be assessed to understand the degree to which the behavior of incumbent(s) is affected by the threat of potential entrant(s).

In addition to the variable of interest – measures of competition- other control variables used in this study can be grouped into two categories. The first group includes socio-economic

indicators, such as GDP per capita and degree of urbanization while the second comprises telecommunications performance indicators, such as yearly measurements of *MP*, *FP*, P^M and existence of independent telecommunications regulator.

Descriptive Analysis

Figure 1 shows the trend of mobile and fixed line penetration in our sampled countries over the period 2000-2006. By the year 2000, penetration in the mobile sub-sector has surpassed that of fixed line. As of 2000, *MP* has been increasing at a fast rate (the annual average growth rate is 35.3 per cent) and reached around 21 subscribers per hundred inhabitants by 2006. *FP*, on the other hand, is increasing at a mere 1.9 per cent per annum. Despite this remarkable growth, *MP* is still very low, as compared to the rest of the world's average, which was 66.16 per cent in the year 2006. That is one of the reasons for many mobile industry observers to come into consensus that there is still a wide room for mobile expansion in the SSA in the coming decade.

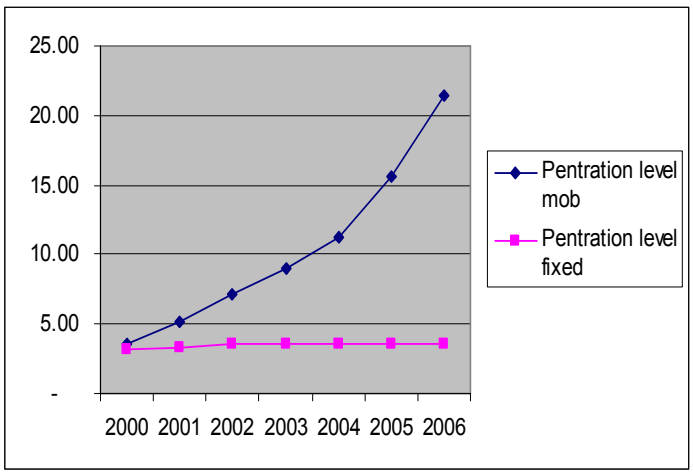
Behind this fast growth trend, however, there is a considerable variation across countries, which tends to increase over the years under investigation. For instance, the variance of *MP* increases form 49.31 in 2000 to 356.29 in 2006. Table 1 shows that for both 2000 and 2006 the highest *MP* was recorded for Seychelles, South Africa, Gabon, Mauritius and Botswana. On the other hand, Ethiopia, Central Africa Republic and Niger are among countries that recorded the lowest level of *MP* in both years.

Similarly, Figure 2 shows the trend in the price of mobile service in SSA. It is interesting to note that the average prices were increasing for the period during which penetration was increasing at a very fast rate. Even though not strong, we observe that there is a positive correlation between *MP* and P^M especially in the latter years of the investigation. For instance, the correlation coefficient of average P^M and *MP* for the period

2000-2006 was 0.58. We can also see from Figure 2 that the price of mobile service was increasing and reached its peak in the year 2005 and started to fall thereafter. On the average, the annual growth rate of P^M was 5.2 per cent for the period 2000-2006. There is a huge difference in prices among countries throughout the study period. We can see that the highest P^M in 2006 were observed for Cote d'Ivoire (USD 2.26), Seychelles (USD 1.63) and South Africa (USD 1.42), respectively while the lowest were observed for Mauritius (USD 0.11) Botswana (USD 0.20) and Ethiopia (USD 0.29).

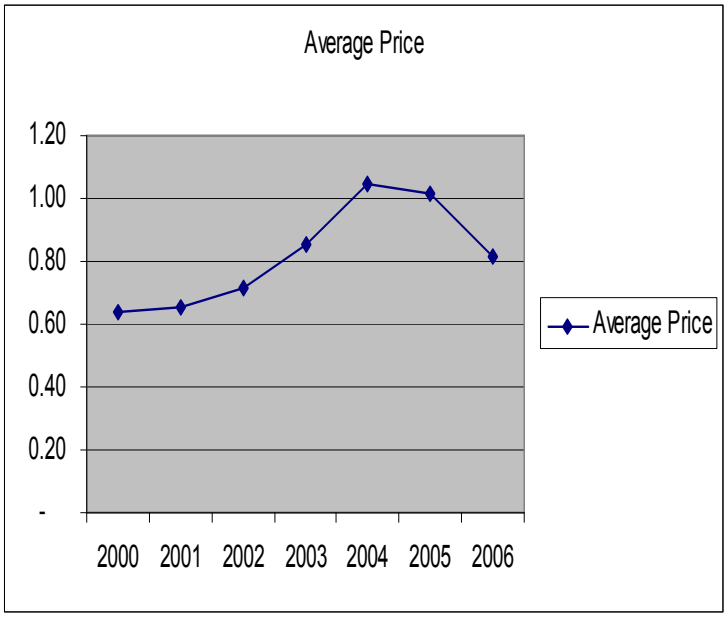
On the other hand, as shown in Figures 3 (a) and (b), the market structure has been significantly changing in the period under investigation. Competition among mobile operators appears to have increased. Countries with a monopoly mobile operator have been decreasing from 10 in 2000 to only five (Eritrea, Ethiopia, Namibia, Rwanda and Swaziland) in 2006. Even though oligopoly market structure largely dominates the region's mobile industry, it can be observed that the number of countries that have 3 and 4 or more operators have also increased in the years under investigation.

Figure 1: Trend of *MPEN* and *FPEN* in SSA over the period 2000-2006 (calculated mean across 35 countries by year)



Data Source: ITU Telecommunication/ ICT Indicators (2008)

Figure 2: Trend of *MPR* in SSA over the period 2000-2006 (mean across 35countries by year)



Data Source:- ITU Telecommunication/ICT Indicators (2008)

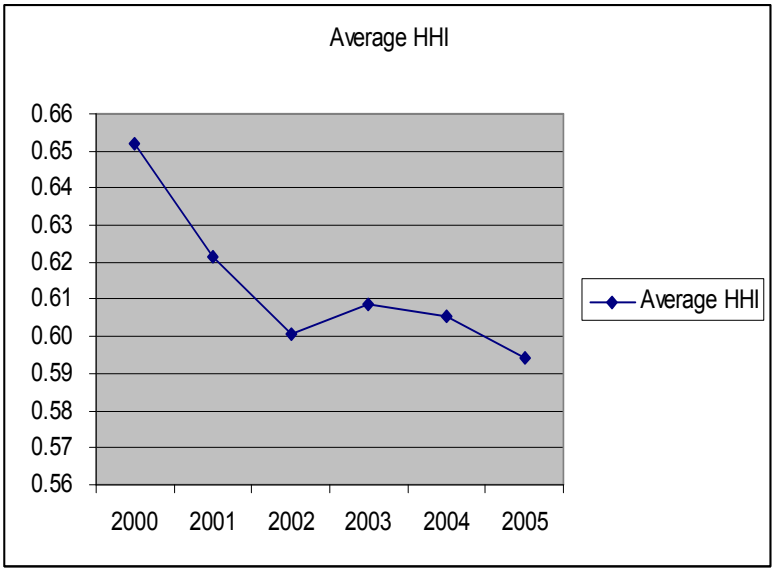
Table 1: The ten lowest and highest level of *MP* recording countries (2000 and 2006)

2000				2006			
Lowest		Highest		Lowest		Highest	
Country	MP	Country	MP	Country	MP	Country	MP
Niger	0.02	Seychelles	33.63	Ethiopia	1.09	Seychelles	86.52
Nigeria	0.03	South Africa	18.28	Eritrea	1.36	South Africa	83.33
Ethiopia	0.03	Mauritius	15.08	Burundi	2.55	Gabon	63.86
Sudan	0.07	Botswana	13.52	Central Afr. Rep.	2.69	Mauritius	61.50
Mali	0.10	Gabon	9.79	Niger	3.35	Botswana	46.78
Cent.African. Rep.	0.14	Namibia	4.61	Rwanda	3.40	Mauritania	33.57
Angola	0.20	Cape Verde	4.54	Malawi	4.71	Namibia	29.67
Burkina Faso	0.22	Swaziland	3.27	Madagascar	5.47	Senegal	24.99
Burundi	0.24	Cote d'Ivoire	3.20	Zimbabwe	6.49	Swaziland	24.29
Mozambique	0.30	Senegal	2.63	Uganda	6.73	Nigeria	24.05

Data Source: ITU Telecommunications/ICT Indicators (2008)

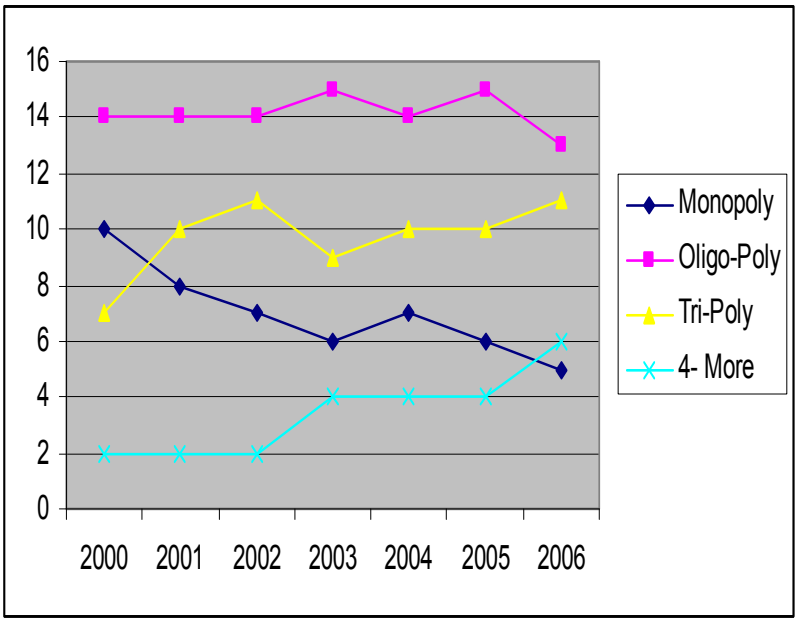
Figure 3: Mobile Market Structure: the HHI and number of operators ((i.e. calculated means across 35 countries by year)

(a)



Data Source: ITU Telecommunications/ICT Indicators (2008)

(b)



Data Source: ITU Telecommunications/ICT Indicators (2008)

Table 2: Summary statistics (mean, standard deviation and correlation) of variables used in this study by year (2000-2006)

0	2000	2001	2002	2003	2004	2005	2006	C.C*
Mobile Penetration (MP)	3.54 (7.02)	5.21 (9.68)	7.15 (12.03)	9.00 (13.53)	11.30 (15.23)	15.56 (18.88)	21.48 (22.27)	
Per capita GDP (USD)	1,004.71 (1,594.02)	981.82 (1,560.72)	1,036.18 (1,638.58)	1,199.78 (1,835.11)	1,361.86 (2,008.75)	1,488.98 (2,150.71)	1,652.57 (2,277.09)	0.98
Urban Population (per cent)	34.13 (15.71)	34.57 (15.82)	35.01 (15.93)	35.46 (16.05)	35.90 (16.17)	36.35 (16.29)	36.82 (16.38)	0.97
Measures of Competition								
HHI	0.63 (0.28)	0.60 (0.25)	0.58 (0.24)	0.59 (0.24)	0.61 (0.22)	0.59 (0.21)	0.57 (0.21)	-0.71
Mobil Operator Number	1.91 (0.98)	2.14 (1.00)	2.20 (0.99)	2.29 (1.05)	2.34 (1.00)	2.37 (0.97)	2.54 (1.01)	0.92
NO. of Years with Mobile Competition	1.43 (1.65)	2.11 (1.97)	2.83 (2.31)	3.60 (2.61)	4.40 (2.91)	5.23 (3.19)	6.11 (3.39)	0.98
Dummy Competition	0.66 (0.48)	0.74 (0.44)	0.77 (0.43)	0.80 (0.41)	0.80 (0.41)	0.83 (0.38)	0.86 (0.36)	0.88
MPR (3 minute peak hour price)	0.64 (0.30)	0.65 (0.31)	0.72 (0.37)	0.83 (0.55)	1.05 (1.57)	1.02 (1.24)	0.82 (0.47)	0.58
Fixed Line Penetration	3.10 (5.95)	3.26 (6.23)	3.45 (6.58)	3.51 (6.71)	3.61 (6.83)	3.62 (6.81)	3.56 (6.79)	0.76
Dummy: an independent regulator exists	0.46 (0.51)	0.51 (0.51)	0.60 (0.50)	0.60 (0.50)	0.60 (0.50)	0.60 (0.50)	0.66 (0.48)	0.82

* Correlation Coefficient (C.C) with MPEN

Data Source:- World Development Indicators Database (2008), Telecommunications/ICT indicators (2008), ITU Regulatory Data base and Wireless Intelligence

Econometric Analysis and Results

A central assumption imposed in estimating consistent estimators is the conditional independence of the error term. This requires, among others, that our independent variables are exogenous. There are compelling reasons to suspect existence of endogeneity of the following variables: mobile price, fixed-line-penetration and GDP per capita.

First, the prices of the mobile services may depend on the level of its penetration. That is, though people may/may not afford telecommunications services because of low/high prices, existing high or low prices may, on the other hand, be attributable to the current smaller or larger levels of penetration. Second, fixed-line penetration and mobile penetration may also have a reverse causality endogeneity problem. That is, fixed line penetration could in turn depend on mobile penetration. Third, the relationship between income (GDP per capita) and mobile penetration could also be bidirectional. On the one hand, income, which indicates ability of users to use the service, is one of the most important determinants of demand for mobile phones. While, on the other hand, expansion of telecommunications infrastructure generates and speeds up economic development as the spread of telecommunications services reduces costs of interaction, expands market boundaries, and facilitates information flows both in urban and rural areas (Waverman et al 2005).

Consequently, in the presence of the above endogeneity problems, one of the most important OLS assumptions--- error term is independent of the explanatory variables--- would be violated and OLS can produce biased and inconsistent parameter estimates.

Accordingly, the following instrumental variables are considered for testing potential endogeneity of the three variables.

For income (GDP per capita), we used capital stock and labour force as instrumental variables. This is based on Aggregate Production Function (APF), which is one of the basic ways used to determine the impact of some socio-economic factors, such as telecommunications, on economic growth (see Waverman et.al 2005). For mobile service price, we used population density as instrumental variable since it can be considered as a proxy for a per subscriber cost of setting up a network. In addition, one year lagged mobile 3 minutes peak hour price (MPL_{it}) is also used as instrumental variable. Finally, for *FPEN*, we used a dummy variable for fixed competition (*DUMFC*) and a dummy variable for privatization ($DUMPRV_{it}$) are added on in the *FPEN* equation to be used as instrumental variables. We use these instrumental variables since they are among major variables that affect fixed line penetration (see Ros (1999), Wallsten (2001), McNary (2001), Fink et al. (2002), Li and Xu (2004), Li (2008)).

Subsequently, using the above instrumental variables we examined whether there is evidence that correlation between the potentially endogenous variables and the error term is strong enough to result in substantively biased estimates. For this purpose, we use Durbin-Wu-Hausman Test[9]. The test results show that neither MPR's nor FPEN's correlation with the error term is strong enough to warrant substantially biased estimates for all measures of competition. However, we find that GDP per capita may pose endogeneity problem in the case where year of mobile competition is used as a measure of competition. Therefore, it is only in this case that we use the two-stage least squares (2SLS) method of estimation.

Further to the endoginity problem we discussed above in estimating a model containing Time-Series Cross-Section (TSCS) data, it is very important to look at the error structure and test

[9] Where; H0: the regressor is exogenous; H1: it is endogenous. In which case, a higher value of the test statistic indicates a more serious endogeneity problem.

whether there is heteroscedasticity and/ or autocorrelation or not. Accordingly, we use Likelihood-Ratio Test to test the presence of heteroscedasticity. This test, however, cannot be used for testing autocorrelation, as Iterated Generalized Least Square (GLS) with autocorrelation does not produce the maximum likelihood estimates. Instead, we use a simple test derived by Wooldridge (2002) for autocorrelation in panel-data models with a null hypothesis of no autocorrelation.

Accordingly, the Likelihood Ratio Test for heteroscedasticity and Woldrige (2002) test for autocorrelation indicate that our data suffer from both autocorrelation and hetr scedasticity[10]. Though, the reason behind the presence of hetroscedasticy is not quite clear, we believe that the following possible causes discussed in Fink et al (2002) for the case of fixed lines can be adapted for mobile services as well. That is, it could be because of different government initiatives on mobile expansion under different regimes, so that countries with a more volatile political environment (or unstable and frequently changing governments) have a higher variance in the level of mobile penetration than others arising from differing government initiatives on mobile expansion. Another hypothesis is that the relatively richer developing countries can more easily overcome natural and geographical obstacles (for example terrain) than relatively poorer countries.

Consequently, OLS cannot be used for models with these features. Instead, the Feasible Generalized Least Squares or FGLS (Parks, 1967) and Panel Corrected Standard Errors or PCSE

[10] When $Comp_{it}$ represents dummy for existence of two or more mobile operators, number of years passed with two or more mobile operators, total number of mobile network operators, and HHI respectively;

A likelihood ratio test for hetroscedasticity are $\chi^2(34)= 99.32$, $\chi^2(34)= 146.96$, $\chi^2(34)= 115.13$, $\chi^2(34)= 109.14$, (with p-value .0000.). These therefore strongly rejects the null hypothesis of no group-wise heteroscedasticity

Wooldridge (2002) test for autocorrelation with significant test statistics are 82.94, 115.63, 37.02, and 101.11 (with p-value .0000), indicating the presence of serial correlation.

(Beck and Katz, 1995) are used to produce consistent and efficient estimators. Nevertheless, Beck and Katz (1995) criticize the FGLS, as it only works if time period (T) is greater than cross-sectional units (N).

Even then, however, this method leads to extreme overconfidence of the standard errors, leading to inaccurate confidence intervals. Moreover, PCSE outperforms FGLS, and is at least as good as OLS and more efficient even when T is less than N (ibid). Therefore, for the same reason given above and the nature of the data we have (T<N), we prefer to estimate our econometric model using PCSE approach assuming heteroscedasticity and AR(1) autocorrelation of errors within panels. Accordingly, estimation results will be discussed based on these models.

Table 3 presents the estimation results of our investigation on both the impact of introduction and intensity of competition. Our hypothesis that *MP* is affected by both the introduction and intensity of competition is strongly confirmed in all our specifications. Competition in the mobile sub-sector positively and significantly affects penetration. The coefficients of the different measures of competition are all positive and significant at 1 per cent level. This result is consistent with most of the findings of existing empirical literature.

Table 3: Fixed effect estimation results using different measures of mobile competition
Dependent variable: Natural logarithm of mobile penetration

	Measuring the impact of introduction (existence) competition		Measuring the intensity of competition	
	Specification 1 (Dummy variable for existence of two or more mobile operators)	Specification 2 (Number of years with two or more mobile operators)	Specification 3 (Number of operators)	Specification 4 (HHI)
Natural logarithm of per capita GDP(USD)	1.105*** (0.196)	2.078*** (0.379)	1.284*** (0.189)	1.203*** (0.210)
Natural logarithm of percentage of urban population	-0.362 (0.312)	6.189*** (1.762)	-0.563** (0.267)	-0.494** (0.236)
Measure of completion in the mobile market	1.195*** (0.141)	0.189*** (0.039)	0.566*** (0.095)	-1.483*** (0.168)
Natural logarithm of prices of mobile call	0.299*** (0.068)	0.043 (0.098)	0.194** (0.091)	0.237*** (0.077)
Natural logarithm of fixed line penetration	0.290*** (0.091)	0.884*** (0.269)	0.316*** (0.109)	0.248* (0.130)
Dummy: an independent regulator exists	0.314** (0.142)	-0.324 (0.229)	0.134 (0.112)	0.283** (0.112)
R^2	.74	.76 (within)	.66	.65
Countries	35	33	35	35
Observations	222	209	222	221

***significant at 1per cent; **significant at 5per cent; *significant at 10per cent. -All the above specifications are similar except that they include different measures of mobile competition; dummy variable for existence of two or more mobile operators, Number of Years with two or more mobile operators, number of operators and HHI, for specification 1 to 4 respectively. - Except Specification 2, which is estimated using the two-stage least square IV method, all the above specifications are estimated using Panel Corrected Standard Error (PCSE) Approach. -Though the total data set has 35 countries, the data analyzed in Specification 2 include only 33 countries as we are forced to drop Guinea and Seychelles because of lack of data when we apply instrumental variables in the estimation of the model; number of observations has also decreased for the same reason.

Looking at the impact of the existence of competition in the mobile sector, it is observed that a move from a single to two or more mobile operators results in 1.20 additional lines per 100 inhabitants. Similarly, one year of mobile competition results in approximately 0.19 additional lines per hundred inhabitants. On the other hand, looking at the impact of intensity of competition, we observe that each mobile competitor is associated with an increase of almost 0.57 additional lines per hundred inhabitants. Similarly a 1 per cent decrease in HHI is associated with 1.48 per cent increase in the *MP* level.

Table 4: Estimation Results of Equations Measuring the Impact of Different Number of Mobile Operators in the Mobile Market Dependent Variable: Natural logarithm of mobile penetration

	Equation 1	Equation 2
Natural logarithm of per capita GDP (USD	1.217*** (0.179)	1.239*** (0.216)
Natural logarithm of percentage of urban population	-0.676** (0.289)	-0.543** (0.253)
Number of operators	- 	1.181*** (0.303)
Number of operators squared	- 	-0.120** (0.060)
Entry2Dummy	1.028*** (0.153)	-
Entry3Dummy	1.268*** (0.169)	-
Entry4Dummy	2.119*** (0.274)	-
Entry5Dummy	2.039*** (0.463)	-
Natural logarithm of price of mobile services	0.256*** (0.070)	0.190*** (0.066)
Natural logarithm of fixed line penetration	0.297*** (0.091)	0.279** (0.112)
Dummy Independent Regulator	0.173 (0.127)	0.249** (0.124)
R^2(Adjusted) Countries Observations	.75 35 222	.71 35 222

***significant at 1per cent; **significant at 5per cent; *significant at 10per cent.
- Equations are estimated using Panel Corrected Standard Error (PCSE) Approach.

In Table 4, we present the regression result of two equations that are constructed to have a closer look on the impact of different number of mobile operators in the market. Accordingly, results in first column show that each entry of an operator in the mobile market is associated with a significant positive effect on MP. On the other hand, when we look at the results of estimation in column 2, we can see that the linear term of the number of operators is associated with a positive coefficient and its squared term is associated with a negative coefficient. This indicates

that, in general, early entries into the mobile market have considerable effect on MP, but the impact progressively decreases with further market entries. This result is consistent with Li (2008) who found that the entry effect of mobile competition follows an inverted U shape.

In all our estimated specifications we included three indicators of sectoral performance (P^M, *FP*, and a dummy for the existence of independent regulatory authority) that are expected to affect the rate of MP. Therefore, in this subsection we discuss the estimation results of each indicator.

We observe that P^M is positively and significantly associated with the level of MP[11]. Though it seems contrary to intuition and much of the empirical literature, there could be a couple of plausible explanations for this result. The first explanation is that the limited *MP* observed in many developing countries could be a result of supply side rather than demand side constraints[12]. That is *MP* is low for the period not due to insufficient demand at the current prices but rather due to insufficient supply. Therefore, even though prices are increasing with new operators entering the market, more subscribers may join the network as the incumbent operators might not have sufficient capacity to accommodate the available demand. The other possible explanation is the limitation of a price variable to incorporate quality of service differences in different countries and/or periods under consideration. This problem is critical in the telecommunications sector where quality of service plays a significant role in the expansion of a particular service. That is, higher price may be associated with higher quality of service and vice versa. In this case, therefore, even though *MP* seems to increase with an increase in the level of P^M, it might be

[11] In all specifications (1,2, and 3) we found similar result using MPR adjusted for PPP in place of MPR with current exchange rate.

[12] Similar explanation is given by Ross (1999) who found that higher residential price is positively associated with higher main lines per 100 inhabitants in case of countries with 100 inhabitants.

negatively associated with a real price level adjusted to quality of service.

Fixed-line penetration on the other hand is positively and significantly associated with MP. This implies a positive network externality whereby the fixed line network is a complement rather than a substitute for mobile service. This result is consistent with Ahn and Lee (1999), Garbacz and Tompson (2005), Chakravarty (2005), but contrary to studies by Gruber and Verboon (2001), Madden Coble-Neal (2004), Waverman et.al (2005).

Finally, we can observe that, the impact of independent regulator is significantly correlated with MP. As indicated in our hypothesis, this might be because of intensive use of mobile telephony for universal service, the necessity of interconnection, fixed mobile termination, and mobile number portability issues. This result is consistent with results by Maiorano & Stern (2007) and Li (2008).

Finally, our empirical estimates suggest that per capita income is significantly and positively associated with MP. This is consistent with the theoretical presumption that per capita income indicates greater affordability and hence results in enhanced demand for mobile telecommunications services. A number of empirical papers have also come up with results congruent with this presumption. Percentage of urban population is negatively associated with *MP* indicating that mobile is a good alternative for rural areas coverage.

Conclusion

The Sub-Saharan African mobile markets have recorded substantial growth in the past decade. Looking at countries and the period under investigation we observe that *MP* increased from 3.54 to 21.48 people per 100 inhabitants. However, not only the *MP* level is very low as compared to the world average, which is 66.16 in 2006, but also there is a considerable variation across countries, and this variability vividly increases in each year under investigation.

Using an econometric approach, this study therefore attempts to explore the impact of competition on *MP* in 35 Sub-Saharan African countries over the period 2000-2006. Likewise, we tried to identify the impact of other telecommunications performance indicators and socio economic variables on MP.

The paper analyses both the impact of existence and intensity of competition using different measures of competition. To measure the impact of a mere introduction (existence) of competition, we use two variables alternatively; a dummy variable (that shows whether the market is under a single mobile operator or not), and number of years with mobile competition. The intensity of competition was measured by the number of operators and the HHI of the mobile market. Furthermore, the paper has analyzed the impact of the existence of different number of mobile operators (two, three or more operators) in the market using a set dummy variable for each entry in the market.

For the most part, the econometric evidences presented in this study are consistent with the existing literature. It shows that both existence and intensity of competition have a positive and significant effect on *MP*. *MP* is higher in countries that allow competition; existence of completion in the mobile market results in 1.20 additional lines, while one year of mobile competition results in, approximately, 0.19 additional lines per hundred inhabitants. In addition to allowing competition in the sector, the results of this study indicate that fostering effective

competition also plays an important role in improving MP. We can observe that each mobile competitor is associated with an increase of almost 0.57 additional lines per hundred inhabitants. While a 1 per cent decrease in HHI is associated with 1.48 per cent increase in the *MP* level.

A closer investigation of the impact of the number of operators in the market shows that each mobile entry is significantly and positively associated with *MP*. However, it is also observed that initial entries have greater impact on *MP* than further market entries.
Similarly, the study also shows that MP is positively affected by FP, and per capita income. However, unlike the theoretical and empirical literature, the study shows that P^M is positively associated with *MP*. This is either an indication of supply rather than demand-side problems as a cause of limited *MP* in the SSA countries, or result of increase of P^M with increase in quality of service.

Finally, based on the findings of this study, we recommend countries in the region not only to allow competition but also foster effective competition in the mobile sector in order to expand mobile services and harness the economic benefits of information connectivity. In view of this, it is very important to identify and address any anti-competitive arrangements and practices in both the private and public spheres.

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