GETTING CONNECTED:
Competition and Diffusion in African Mobile Telecommunications Markets

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Competition is critical for rapid mobile expansion; participation in the mobile market by a State owned incumbent has a negative impact on expansion; however, privatization of the incumbent that is involved in cellular mitigates that negative effect. Finally, digitalization has a positive and significant impact on the diffusion of mobiles.

World Bank Policy Research Working Paper 2863, June 2002

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Abstract

This paper studies the determinants of the diffusion of mobile telecommunications in Africa in a fixed effects model. The study uses data over the period from 1987 to 2000 on 41 African countries that have adopted cellular telecommunications technologies. I find, among other results, that competition is the main driving force behind the mobile explosion that we have seen in Africa. Duopoly and triopoly markets grow significantly faster than monopoly markets, though growth does not appear to differ between the first two markets. In competitive sequential entries, evidence of pre-emptive behavior is found, but the major effect of competition on diffusion occurs after the actual year of entry. As far as technology is concerned, digitalization is found to have a positive and significant impact on the diffusion of mobiles. The presence of an incumbent-owned cellular in mobile markets has a negative impact on the diffusion of mobiles, suggesting again an abuse of a dominant position by the incumbent fixed-line operator. However, privatization of the incumbent fixed-line operator that is involved in cellular accelerates mobile growth, and mitigates the negative effect of the presence of an incumbent-owned cellular.

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I. Introduction

Technological changes have weakened the long-held argument of economies of scale and scope that favor a natural monopoly for the telecommunications industry. Therefore, competitive provision of telecommunications services has become a common phenomenon throughout the world, including Africa. Telecommunications competition in Africa has been seen primarily in the cellular segment of the industry, and rapid service expansions have been observed in many countries. For example, the average annual cellular expansion rate in Africa increased from 60 percent in the mid-90s to more than 100 percent in 2000 (ITU).[1] What determines the growth of mobile connections in Africa? It is important because mobile technology growth has outpaced fixed wire growth in many countries in Africa, and yet is not the main source of telecommunications service for many people. A number of factors can explain this growth, including the traditional ones, such as long waiting-time for fixed line connections and overall dismal performance of the fixed telecommunications network. However, we have not seen any systematic explanation of this phenomenon in a developing country context although various case studies and anecdotal evidence have recently appeared. This study, therefore, tries to fill this gap by econometrically identifying the determinants of mobile telecommunications diffusion/expansion using African data.

Despite the lack of empirical evidence in a developing country context, there is some evidence of mobile diffusion from emerging and developed economies. Gruber (2001) analyzed the diffusion of mobiles in Central and Eastern Europe using a logistic fixed-effects model, and found that the speed of mobile diffusion increases with the number of firms, the size of the fixed telecommunications network and the length of the waiting list. In the same study, he also found that simultaneous entry is more effective than sequential entry in accelerating the speed of diffusion of mobiles. Gruber & Verboven (2000) also analyzed the evolution of the global mobile communications industry using the same logistic fixed-effects model, and found that timing of the first entry, competition and mode of the second cellular entry are the major determinants of

[1] Growth calculated by the author using ITU data.

the speed of mobile diffusions. They also found that income (as measured by GDP per capita), main lines and the waiting list have significant positive impact on the diffusion of mobiles.

Furthermore, Gruber & Verboven (1999) studied the diffusion of mobile telecommunications in the EU using the same model, and reported that digitalization and competition had a significant impact on the diffusion of mobiles in the EU with the former having a lot more impact than the latter. They also reported that main line penetration has a negative impact on the speed of mobile diffusion, suggesting that mobiles are substitutes for fixed lines. While digitalization is an important explanatory factor in the EU study, it is not significant in either the CEE or the global mobile industry studies. The three studies also report divergent results on mode of entry and the size of the fixed network; however, they all agree on the fact that competition has a substantial impact on the growth of mobiles. This study aims, therefore, to shed some light on the issue and help resolve the observed anomalies.

This study is of interest to policy makers because of the important link between telecommunications penetration and economic growth. Growth in telecommunications penetration is positively associated with economic development. Norton (1992), using data from 47 countries for the period 1947 to 1977 and controlling for the initial stage of the level of telecom development and a number of macroeconomic variables, finds that telecommunications has positive and significant impact on economic growth, and concludes that the existence of a telecommunications infrastructure reduces transaction costs since output rises when the infrastructure is present. Moreover, Roller and Waverman (2001) found a causal relationship between telecommunications infrastructure and aggregate output using OECD data for the period 1970 to 1990 after accounting for simultaneity and country-specific fixed effects. Appreciating this important link, multinational institutions, including the World Bank, have been showing increasing interest in issues of finding better ways of providing telecommunications services and increasing penetration (World Bank, 1994).

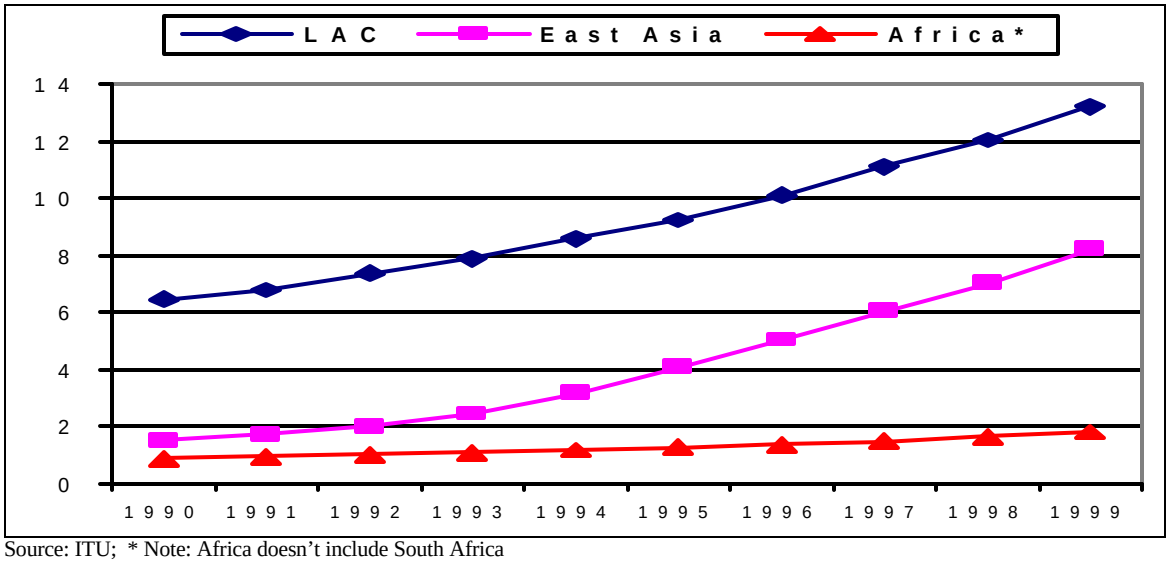
The paper is structured as follows: section 2 discusses telecommunications in Africa, and section 3 describes the data and their sources. Section 4 explains the model and section 5 presents the results. Finally, a concluding remark will follow.

II. Telecommunications in Africa

Telecommunications in Africa, mainly fixed line services, can be characterized by low penetration, poor quality, and unreliability. For example, Africa, excluding South Africa, had only 1.82 main lines per 100 population in 1999 while East Asia had 8.23 main lines per 100 population in the same year and Latin America and the Caribbean (LAC) had 13.21 main lines per 100 population that year (Fig. 1). The situation was even worse in sub-Saharan Africa where telecommunications penetration was about 0.64 main lines per 100 population in the same year. The International Telecommunications Union (ITU) identified the following as the main reasons for the underdevelopment of telecommunications in Africa: (1) lack of investment, (2) investment inefficiencies, (3) inadequate private sector involvement, (4) foreign exchange scarcity, (5) poor management incentives and (6) insufficient regional development (ITU 1994). Recognizing this reality and pressured by technological changes and donors, most African countries started reforming their government-dominated and monopoly-based telecommunications sector beginning the mid-90s.

Therefore, by 2001, about 17 African countries had already privatized their incumbent fixed-line operator and more were in the process of doing so, two countries had allowed competition in basic services, and more than 36 countries had created a separate regulatory body for the telecommunications sector. Moreover, about 45 countries have licensed private cellular operators and effective cellular competition has now emerged in many countries in the region. Almost all African countries have now introduced some kind of reforms in their telecommunications sector, and are at different stages of the reform process.

Figure 1: Main Lines Per 100 Population



Source: ITU; * Note: Africa doesn't include South Africa

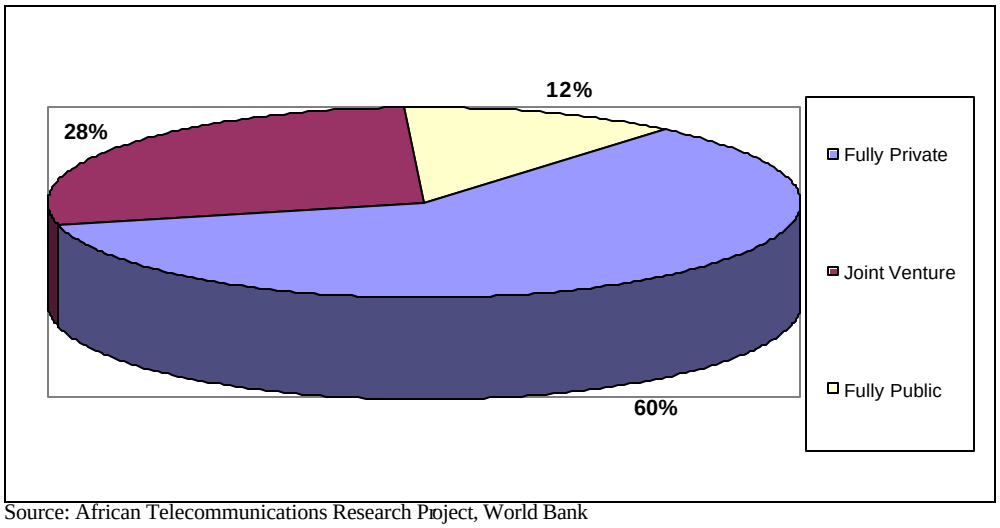
Cellular in Africa

Although the adoption of wireless telecommunications has been feasible since the late 1970s, it reached the African public mainly during the 1990s.[2] The introduction of cellular telecommunications in Africa disrupted the monopoly then enjoyed by African incumbent operators and for the first time opened access for private entrepreneurs to enter the telecommunications sector in Africa. By 2001, more than 90% of African countries had already adopted cellular telecommunications technologies compared to just 18% in 1993.

In Africa, private operators have pioneered the development of cellular networks, and the incumbent fixed-line operators seem to have a relatively modest role. For example, of the total of 110 cellular operators in the year 2001, 60 percent were fully owned by private investors and 28 percent were joint ventures between private investors and the incumbent, and only 12 percent were full subsidiaries of the incumbent fixed-line operator (Figure 2).

[2] This is except South Africa, Algeria, Egypt, Morocco, Tunisia, Congo (DR) and Mauritius which have had cellular since the second half of the 1980s.

Figure 2: Ownership Structure of African Cellular Operators (2001)



Source: African Telecommunications Research Project, World Bank

The leaders of the mobile miracle in Africa not only are private in their ownership, but also are pan-African and indigenous despite the presence of a number of foreign multinational carriers operating in different parts of the region. Mobile Systems International (MSI), MTN of South Africa and Orascom of Egypt are some of the indigenous pan-African operators. MSI was founded in 1998 by a Sudanese mobile communications expert, and it now holds mobile licenses in more than 14 African countries serving a population of over 250 million. Similarly, Orascom of Egypt, which was founded by an Egyptian entrepreneur, operates in more than 14 African countries and it is aggressively expanding in the region.[3] Likewise, Mobile Telecommunications Networks (MTN), which is based in South Africa and owned by South Africans, has already expanded its service coverage to other five African countries, including Uganda, Swaziland, Rwanda, Cameroon and Nigeria. Other indigenous operators are also becoming pan-African and are increasing their market presence and level of operations taking advantage of the changing telecom environment in the region.[4]

[3] See www.msi-cellular.com and www.orascomtelecom.com for further information.
[4] Econet Wireless of Zimbabwe, which is owned by a Zimbabwean businessman, can be a good example.

Cellular Market Structure & Competition

Most of the cellular markets in Africa are competitive although the level of competition differs from country to country. About 44% of the African cellular markets have two operators, 30% have three or more operators, and only 26% of the markets are monopoly.[5] Africa has seen cellular competition in markets as small as Seychelles, which has a population of only 76,000. Competition in these small markets has helped disprove the idea that market size is a serious constraint to competition.

The tendency in Africa is to issue nationwide licenses although some countries initially tried geographic-based licensing. Generally, cellular operators compete head-to-head against each other and the incumbent for local and long-distance traffic. As a result of the growing competition, the cellular market in Africa is being rapidly transformed. For example, cellular services which were limited to capital cities until recently can now be found in areas hundreds of miles away from the capital as operators compete for coverage. Almost all operators that started services using analog technologies have now migrated to digital technologies which allow for more customers to be served with the same amount of spectrum. The increasing shift from postpaid to prepaid services, which has led to rapid mobile use in the region, can also be attributed to the growing cellular competition.

Cellular competition in most parts of Africa came later than the cellular services. For instance, more than 80% of the competitive entries in the region were introduced sequentially over an average period of 5.44 years (Table 4). This is not a surprising phenomenon as most African governments and several investors doubted the feasibility of telecommunications competition until recently. However, simultaneous entry has made headway in the region as governments increasingly appreciate the value of cellular competition.

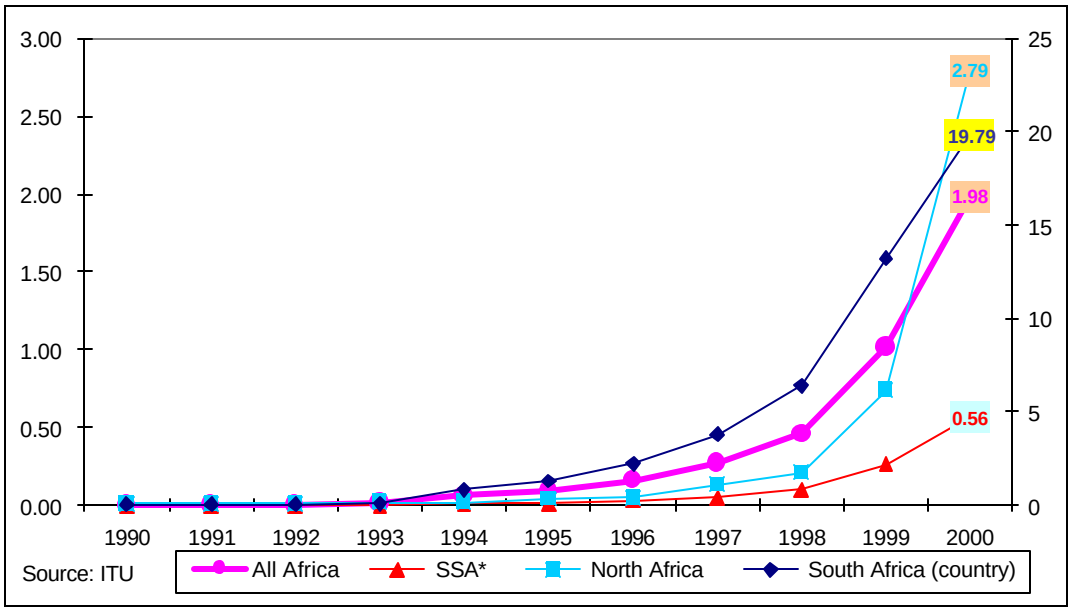
[5] Source: African Cellular Operators Database, African Telecommunications Research Project, World Bank

Cellular Penetration

The growth of mobile penetration in Africa has been impressive. Cellular penetration had already surpassed fixed line penetration over half the continent by the end of 2001. Some countries, such as Gabon and Uganda, have seen their cellular system grow to more than three times of the size of their fixed line network. Almost all countries with more cellular than fixed, except Swaziland, have competitive cellular markets. Cellular penetration in Africa varies not only by market structure, but also by region. In 2000, for example, South Africa had 19.79 cellular phones per 100 population while North Africa had 2.79 cellular phones per 100 population and sub-Saharan Africa had only 0.56 cellular phones per 100 population (Figure 3). Smaller countries, such as Reunion and Seychelles, have already achieved as much as 50% penetration.

Figure 3: Cellular Subscribers per 100 Population in Africa

(South Africa right scale)



Cellular Technologies in Africa

A number of analog and digital systems have been tried in Africa. The Global System of Mobile Communications (GSM) standard is the leading technology, and has seen wider application in the region, followed by AMPS and TACS. Almost all entrants during the last five or six years have been deploying the GSM standard, and earlier entrants which started with other technologies have also been migrating to this digital system. The penetration of the US digital systems, such as DAMPS and CDMA that have better spectral efficiency than GSM, is still very low. The GSM standard is emerging as a default digital standard in Africa. This standard is about 4 times more efficient in its spectrum usage than most efficient analog systems, and hence has that much higher connection capacity (see Gruber and Verboven 2000). [6] GSM networks currently account for more than 95% of the total mobile subscribers in the region, which is high compared to 70% in the world.[7] The region is likely to be fully digitalized in the very near future if the current trend of digitalization continues.

Table 1: Cellular Networks in Africa [2001]

Digital			Analog		
Type	***Developer***	***Number***	***Type***	***Developer***	***Number***
GSM900	Europe	85	AMPS	USA	11
DECT/WiLL	Various	7	TACS	UK	4
GSM1800	Europe	5	E-TACS800	UK	2
CDMA	USA	3	NMT-450	Scandinavian	2
D-AMPS	USA	1	NMT-900	Scandinavian	1
TDMA IS-136		1	RC2000	France/Italy	1
			C-NETZ		1
			E-TACS	UK	1
			MATS		1
			N-AMPS	USA	1
Total		102	Total		25

Source: www.cellular.co.za/african-standards.htm**, Access date 01/23/2002**

[6] Digital systems in general are 3 to 6 times more efficient than analog systems depending on the type of technologies (see Gruber and Verboven, 2000).

[7] See www.cellular.co.za , access date 01/23/2002

III. The Data

The sample contains information on 41 African countries for the period 1987 to 2000. Four of the sample countries are from North Africa and the rest are from sub-Saharan Africa, including South Africa. Cellular services are available in all of our sample countries although service was introduced at different times. The dataset includes information on entry, competition, technology, regulation, the number of cellular subscribers, main lines, GDP per capita, population and % of urbanization.

The data comes from different sources. The cellular and fixed line subscriber data comes from International Telecommunications Union (ITU) database, and the GDP, population and urbanization figures come from the World Bank SIMA database. The qualitative variables come from a combination of sources, such as EMC publications, Economist Intelligence Unit (EIU) publications, and http://www.cellular.co.za. Almost complete data, with very few exceptions, is available for all periods and countries.

IV. The Methodology

I estimate the determinants of cellular diffusion using a fixed-effects model controlling for different country characteristics. I also control for the effects of time using a non-linear time trend. First, I estimate equation (1) which simply defines the competition variable as the number of cellular operators to see the overall effects of competition, technological change, regulation and incumbent-owned cellular on mobile diffusion.

$$y_{it} = a_i + b_1(ncel_{it}) + b_2(reg_{it}) + b_3(ioc_{it}) + b_4(prv_{it}) + d(dig_{it}) + q(X_{it}) + e_{it} \qquad (1)$$

Equation (1) uses a very general definition of competition. This specification doesn't capture the growth rate differences among the different market structures, nor does it capture the effects of having a separate sector regulator across the different markets. Therefore, I further refine the competition variable in equation (2) by segregating the markets into different market structures, such as monopoly, duopoly, and triopoly markets. Also, I introduce interaction terms between regulation and the market-structure dummies to see how different markets perform when interacted with regulation. Therefore, I estimate equation (2) with this refinement which will enable us to test various hypotheses, including whether there are significant growth variations among different market structures, and whether the effectiveness of regulation (or having a separate telecom regulator) varies across different market structures. I will run equation (2) by dropping one of the market structure dummies alternatively to identify the relative significance of the included market structures as compared to the excluded one.

$$y_{it} = a_i + b_1(som_{it}) + b_2(dom_{it}) + b_3(tom_{it}) + b_4(som_{it} * reg_{it}) + b_5(dom_{it} * reg_{it}) + b_6(tom_{it} * reg_{it}) + b_7(reg_{it}) + b_8(ioc_{it}) + b_9(prv_{it}) + b_{10}(prv_{it} * ioc_{it}) + f(dig_{it}) + g(cme_{it}) + q(x_{it}) + e_{it} \qquad (2)$$

Y_{it} is the logarithm of total cellular subscribers in country i at time t. It includes both prepaid and postpaid subscribers. This variable is the main explainable variable for which we are trying to unravel the determinants of its diffusion.

$Ncel_{it}$ is the number of cellular operators in country i at time t. As the number of cellular operators increases, available capacity and the intensity of competition is expected to rise, resulting in different competitive behaviors, such as price cuts, quality improvements, expansion of coverage. This leads to an increase in the number of people adopting cellular, and hence the variable is expected to be positively correlated with mobile growth.

Reg_{it} is a dummy variable that captures the presence of a separate regulator in country i at time t. Therefore, this variable becomes one as soon as the country introduces a separate regulator for the telecommunications sector, and zero otherwise. A separate regulator is a specialized body that oversees the activities of all telecommunications sector players, and seems to be different, at least in form, from previous regulatory regimes, which were dominated by sector ministry and the incumbent. This variable could be positively or negatively correlated with mobile growth depending on whether the regulator is facilitating competition or is captured by players in the market.

Ioc_{it} is a dummy variable that becomes one if country i at time t has a fully or partially incumbent-owned cellular operator, and zero otherwise. This variable can be either positively or negatively correlated with mobile growth depending on whether the incumbent is able to stifle competition. The presence of an incumbent-owned cellular in a competitive market could slow down the growth of mobiles if the incumbent abuses its dominant position.

Prv_{it} is a dummy variable that becomes one when the incumbent operator in country i at time t is privatized, and zero otherwise. This variable is expected to be either positively or negatively correlated with mobile growth depending on whether the privatization of the incumbent creates a more competitive or stifling environment.

Som_{it} is a dummy variable that becomes one when the cellular market structure in country i at time t is a monopoly, and zero otherwise.

Dom_{it} is a dummy variable that becomes one when the cellular market structure in country i at time t is a duopoly, and zero otherwise. As market structures change from a monopoly to a duopoly, mobile growth rates are expected to rise because of competition. Therefore, this will lead us to the following testable hypothesis:

$$b_2 - b_1 > 0$$

If the above hypothesis holds true, it implies that the coefficient of the duopoly dummy is positive and significant when the excluded category is the monopoly dummy only.

Tom_{it} is a dummy variable that becomes one when the cellular market in country i at time t has three or more operators, and zero otherwise. Also, as the number of cellular operators rises to three or more, competition is expected to increase and hence mobile growth. Therefore, this will also lead us to the following testable hypothesis:

$$b_3 - b_2 > 0$$

If the data supports the above hypothesis, it implies that the coefficient of the triopoly market dummy is positive and significant when the excluded category is the duopoly dummy. Alternatively, it also implies that the coefficient of the triopoly dummy is significantly higher than that of the duopoly dummy when the excluded category is the monopoly dummy.

Cme_{it} is a vector of dummy variables for competitive modes of entries, such as sequential, simultaneous, and preemptive . (1) Sim_{it} is a dummy variable that becomes one as soon as country i at year t introduces a simultaneous competition, (2) Seq_{it} is a dummy variable that becomes one as soon as country i at year t introduces a sequential competition, (3) Pre_{it} is a dummy variable that becomes one only in the year prior to the introduction of the first sequential entry, and zero otherwise. This variable is expected to be positively correlated with mobile growth as incumbent mobile operators normally react to the potential threat of competition from a new entrant, (4) Seq_{it} *(0)* is a dummy variable that becomes one only in the year of the introduction of the first sequential entry,

and zero otherwise, (5) Seq_{it} *(-1)* is a one-year lagged sequential competitive entry mode variable, and (6) Sim_{it} *(-1)* is a one-year lagged simultaneous competitive entry mode variable

α_i and ε_{it} are country specific fixed-effects and error terms, respectively. X_{it} is a vector of control variables, including main lines, population, per capita income, and degree of urbanization. These control variables are defined as follows: (a) $Lnml_{it}$ is the logarithm of total main lines in country *i* at time *t*. A main line, as per the ITU's definition, is a telephone line connecting the subscriber's terminal equipment to the PSTN and has a dedicated port in the telephone exchange equipment. This variable can be positively or negatively correlated with the growth of cellular depending on whether cellular complements or substitutes fixed line telephony. (b) $Lnpo_{it}$ is the logarithm of total population in country *i* at time *t*, and this variable is expected to be positively correlated with mobile growth . (c)$Lngdp_{it}$ is the logarithm of per capita real gross domestic product in US dollars of country *i* at time *t*, and it is expected to be positively correlated with mobile growth. (d) Urb_{it} is the percentage of population living in urban areas in country *i* at time *t*, and it is expected to measure the level of urbanization of a country. People living in urban areas are usually considered to have a better income, standard of living, and awareness than those living in rural areas, and hence this variable is expected to be positively correlated with mobile growth. (e) Trd_{it} is the square of the time trend variable to control for time trend taking into account the non-linearity of the mobile diffusion over time.

V. The Results

I present the estimation results of the above fixed-effects mobile growth model in this section. Table 2 presents the results of equation (1) and Table 3 presents the results of equation (2). Most of the results are consistent with our expectations. The competition variables in both equations are positive and significant, and all competitive markets grow faster than monopoly markets; however, no evidence is found to support the hypothesis that triopoly markets grow faster than duopoly markets. Triopoly markets, in fact, grow slower than duopoly markets when a separate regulator is introduced in the sector, suggesting the presence of a regulatory capture as markets become more competitive. A separate regulator also tends to decelerate mobile diffusion in both monopoly and duopoly markets, though the effects are not statistically significant. Evidence of pre-emptive behaviors in competitive sequential entries is also found. However, no evidence is found to support significant differences between simultaneous and sequential entries. In sequential entries, the major effect of competition on mobile growth occurs after the actual year of entry.

Moreover, privatization of the incumbent fixed line operator significantly accelerates mobile growth while the presence of an incumbent-owned cellular significantly slows down the growth of mobiles. The latter result is consistent with the theory of the abuse of a dominant position by the dominant operator. As far as technology is concerned, digitalization is positive and significant. Furthermore, urbanization and main lines are positive and significant from among the country characteristics variables selected for the study. Income (measured by real GDP per capita in US$) and population, which are traditionally perceived to be correlated with mobile growth, are not significant. The insignificance of the income variable could be partly because of its high and positive correlation with the main lines variable. All of the empirical results remain robust with different specifications of the model. I will thoroughly discuss the estimation results in the following sub-sections.

The effect of competition and regulation

Table 2 presents the results of equation (1) which defines the competition variable as number-of-cellular-operators. The variable is significantly correlated with mobile growth, and the result suggests that adding one more mobile operator increases the total mobile subscribers by about 57 percent on average. Table 3 presents the results of equation (2) which defines the competition variable slightly differently by introducing separate dummy variables for monopoly, duopoly, and triopoly markets to test for any significant differences in mobile growth among the different market structures.[8] The coefficients of the market structure dummies, which are reported in column V of Table 3, suggest that duopoly and triopoly markets grow significantly faster than monopoly markets; however, there is no sufficient evidence to support any significant differences in the speed of mobile growth between duopoly and triopoly markets. Although the speed of mobile growth in duopoly markets appears to be higher than that of triopoly markets, a Wald test conducted to test for differences between these coefficients did not find any significant differences. When splitting markets merely into competitive and monopoly, however, the coefficient of the competitive market dummy suggests that mobile growth in a competitive market in general is about 194 percent higher than that of a monopoly market. This effectively means that if a monopoly market grows by X percent, then a competitive market grows by 2.94X percent {=X+1.94X} (see column I of Table 3).[9] This strongly supports the effectiveness of competition to speed-up the diffusion of mobiles.

However, the introduction of a separate sector regulator in triopoly markets significantly slows down mobile diffusion.[10] As presented in column III of Table 3, the

[8] Although the triopoly market dummy covers markets with three operators by definition, it also includes five data points of four operators markets in Ghana, Madagascar, and Tanzania in our case. This is because the number of observations with four operators markets is so low that it does not justify a separate dummy variable.

[9] Competitive in this case is defined as the presence of two or more mobile operators in the market. exp(1.077) – 1 = 1.94

[10] The introduction of a separate regulator also tends to slow down mobile diffusion in monopoly and duopoly markets, but the effect is not statistically significant.

coefficient of the triopoly dummy is not significant when the duopoly dummy and the interaction terms are excluded, suggesting that mobile growth in triopoly markets is not different from that in duopoly markets. Nevertheless, when the interaction term between regulation and the market structure dummy is included in the same specification, the triopoly coefficient becomes negative and significant, regulation becomes negative and significant, and the interaction term between regulation and the triopoly dummy becomes positive and significant (see column IV of Table 3). Therefore, I conduct the following joint-coefficient test in order to determine the joint significance of the three variables when the interaction term is included:

$$b_3 + b_6 + b_7 = 0, \qquad \textit{Where } b_3 \textit{ is the coefficient of the triopoly dummy, } b_6 \textit{ is the coefficient of the interaction term, and } b_7 \textit{ is the coefficient of the regulation variable.}$$

The Chi-square value of the above restriction using a Wald test is significant at 7 percent significance level, indicating that the coefficients, which add up to negative 0.575 (= -1.098 + 1.057 - 0.534), are jointly significant and are different from zero. Therefore, this suggests that mobile growth in triopoly markets slows down when a separate regulator is introduced, further suggesting either the presence of a regulatory capture as markets become more competitive or the failure of the regulatory bodies to manage the increasing competition perhaps because of organizational weaknesses. The result is consistent with the numerous anecdotal evidence on the presence of a regulatory capture and the failure of many regulators to manage the increasing telecommunications competition in Africa partly because of organizational weaknesses.

This finding is also theoretically plausible because the chances of competition-related intricacies that could slow down mobile growth increase as the number of operators increases.[11] The increase in the incidence of these intricacies in turn makes the regulator more susceptible to regulatory capture by various interest groups, particularly

[11] The competition-related intricacies include, but not limited to, access to bottleneck facilities, interconnection, equipment co-location, numbering plans, spectrum allocations, and restricted services. These intricacies can slow down growth by themselves unless properly handled by an impartial regulator.

by the incumbent operator that may be interested to abuse its dominant position. Alternatively, the regulators may not have the required resources and skills to deal with the rising competition-related intricacies as the number of operators increases, resulting in the slow down of mobile growth as markets become more competitive, i.e. for triopoly or more markets.

The effect of mode of competitive entry

Equation (2) incorporates various entry variables to identify the effects, if any, of different modes of entries, such as simultaneous or sequential entries, and the presence of pre-emptive behavior in sequential entries. The result, as shown in column VIII of Table 3, suggests the presence of pre-emptive behavior in competitive sequential entries; however, no significant differences are found between simultaneous and sequential entries. The coefficient of the pre-emptive dummy suggests that the incumbent mobile operator increases its mobile subscriber size by about 38% in the year just prior to the actual entry of a second new entrant because of the threat of competition. This could be accomplished through substantial price cuts and/or expansion of coverage. Gruber and Verboven (2000) also reported the presence of pre-emptive behaviors in sequential entries in their global mobile communications study.

Furthermore, the absence of significant differences between simultaneous and sequential entries seems to be consistent with other findings. Gruber and Verboven (2000) reported that sequential entry is more effective in accelerating growth than simultaneous entry in their global mobile communications study; however, Gruber (2001) later found that simultaneous entry is more effective to speed up mobile diffusion in his CEE study. Therefore, our finding of the absence of significant differences between sequential and simultaneous entries is in a way consistent with the prior inconsistent findings. In sequential entries, the major effect of competition occurs after the actual year of entry. The coefficients of the sequential entry variables suggest that a mobile market grows, *ceteris paribus,* by 0.997 in the year of competitive sequential entry, but it grows by 1.423 after the year of the actual entry (see column VIII of Table 3).

The effect of technologies

In the technology discussion in section one, it is stated that digital systems are more efficient than analog ones by a factor of 3 to 6. This suggests that digital systems have less capacity constraint than analogs, and hence can bring, *ceterius paribus,* faster mobile growth. Digitalization in some countries in Africa started well before the introduction of the GSM technology, and these early digitalizers started with DAMPS and CDMA. Therefore, digitalization here refers to these three technologies although it is highly dominated by the GSM standard.

As presented in both Tables 2 and 3, digitalization is positive and significant in all specifications. The coefficient of the digitalization variable suggests that when countries adopt a digital technology, mobile growth increases by about 66% on average. This suggests that countries that adopt a digital technology grow faster than those with other technologies. However, digitalization has mixed effects in other studies. Gruber and Verboven (1999) found digitalization to be positive and significant in their EU study, but same authors (2000) found digitalization to be insignificant in their Global Mobile Telecommunications study. Consistent with the latter finding, Gruber (2001) found digitalization to be insignificant in his Central and Eastern European study. Interestingly, our finding on digitalization is consistent with that found in the EU study which is also dominated by the GSM standard.

The effect of privatization and incumbent-owned cellular

Incumbent fixed line operators are the dominant players in African telecommunications markets. Thus, the involvement of the incumbent in cellular operations and changes in the management and ownership of the incumbent, for instance privatization, that are likely to improve its competitive edge theoretically affect the growth of mobiles. Some argue that allowing the incumbent to have its own cellular in a competitive market would defeat the very purpose of competition because (1) competition between un-equals is not likely to bring the expected results, (2) the

incumbent can easily cross-subsidize between its monopoly and competitive services to force cellular competitors out of the market, and (3) the incumbent can discriminate between its cellular subsidiary and competitors in providing access to bottleneck facilities.

The discrimination in the third argument can take different forms, such as discrimination in the quality of the point of interconnections, in the prices of interconnections, and refusal to co-locate equipment that could potentially drive the investment and operational costs of competitors. The weakness or absence of telecommunications regulators in Africa further strengthens the validity of this argument. On the other hand, privatization gives incumbent operators better incentives to improve performance, but it could also further strengthen the incumbent to better exploit available opportunities through the above potential discriminatory practices. Therefore, the effect of privatization on mobile growth could be either positive or negative while the presence of an incumbent-owned cellular is expected to slow down mobile growth.

Consistent with our expectation, the presence of an incumbent-owned cellular is negatively correlated with mobile growth in both equations (1) and (2) while privatization of the incumbent is positively correlated with mobile growth in both equations. This suggests that the presence of an incumbent-owned cellular in a mobile market significantly slows down mobile growth while the privatization of an incumbent operator accelerates it. The negative effect of an incumbent-owned cellular on mobile growth suggests the presence of an abuse of a dominant position by incumbent fixed-line operators. In competitive markets, the abuse of a dominant position could take the form of subtle denials of bottleneck facilities and subsidization of competitive services to stifle competition as discussed above. In monopoly markets, however, the abuse could take the form of investment inefficiency and under investment. It should be remembered here that incumbent fixed-line operators in Africa in general have a very dismal record in the provision of telecommunications services, and most still suffer from rampant inefficiencies.

Furthermore, I introduce an interaction term between the incumbent-owned cellular dummy and the privatization dummy in order to better understand the effect of these variables when interacted. When the interaction term is included, the coefficient of the incumbent-owned cellular dummy remains negative and significant, the interaction term becomes positive and significant while the privatization dummy becomes insignificant (see column VIII of Table 3). This suggests that the positive effect of privatization comes not just simply from privatization of the incumbent fixed-line operator, but rather from privatization of the incumbent fixed-line operator that is involved in cellular. Overall, the results suggest that the negative effect of having an incumbent-owned cellular in the market can be mitigated through privatization. This is also consistent with the conventional wisdom that privatization improves performance.

The effect of country characteristics

Country characteristics variables, such as income, population, urbanization and main lines, are included in both equations and all specifications as presented in Tables 2 and 3. From among these country characteristics variables, urbanization and main lines are positive and significant while income (as measured by GDP per capita) and population are not significant. [12] The fact that urbanization is positive and significant suggests that the diffusion of mobiles is mainly concentrated in urban centers, and hence highly urbanized countries grow faster. This looks fairly reasonable as people living in urban centers are believed to have a better income, standard of living, and a higher propensity to adopt new technologies. Regarding main lines, its positive significance suggests that mobiles complement fixed line networks, further suggesting that mobiles are mainly getting into the hands of people who already have some form of access to the fixed network. The positive significance of main lines could also be due to positive network externalities from the fixed network that is that mobile becomes more attractive

[12] The coefficients of the main lines and GDP per capita variables should be interpreted with some caution as the two are highly positively correlated. The correlation of these two variables in our data is about 0.94; therefore, the insignificance of income in our study could be because of the main lines variable. It is interesting to note that both become significant when they are run separately (see Columns IX and X of Table 3).

than before with the expansion of the fixed network because of the possibility of calling more people. In general, the coefficients of the urbanization and main lines variables are consistent with each other and both indicate that mobiles are following the footsteps of the incumbent fixed-line operators which don't have much presence in rural areas.

Other authors reported mixed findings on the effect of main lines and income on mobile growth. Gruber and Verboven (2000) reported positive and significant coefficient for both income and main lines in their global mobile communications study; however, same authors (1999) found main lines to be negative and significant and income to be positive and significant in their EU study. In another study, Gruber (2001) found main lines to be positive and significant and income to be insignificant in his study of the diffusion of mobiles in Central and Eastern Europe. These findings suggest that mobiles are perceived as substitutes for fixed lines in developed markets, such as the EU, while they are perceived as complements to fixed lines in relatively less developed markets, such as Central and Eastern Europe. The coefficient of the main lines parameter in our study is also consistent with this categorization.

VI. Conclusion

This paper has analyzed the determinants of mobile telecommunications diffusion in Africa in a fixed-effects model. The determinants of mobile diffusion that this study has identified can be categorized into six major themes, including competition, regulation, technological change, privatization, and the presence of an incumbent-owned cellular. Policy differences in relation to these themes affected the diffusion of mobile telecommunications in Africa quite differently, explaining the mobile growth variations among countries in the region.

First, mobile competition (as measured by the number of cellular operators) is positive and significant, and the result suggests that mobile subscribers increase by about 57 percent as an additional operator enters the market. Both triopoly and duopoly markets grow faster than monopoly markets; however, no evidence is found to support significant mobile growth differences between duopoly and triopoly markets. Triopoly

markets, in fact, grow slower than duopoly markets when a separate regulator is introduced, suggesting either the presence of a regulatory capture as the number of operators increases or the failure of the regulators to manage the increasing competition as markets become more competitive. The latter could be because of lack of the required resources and skills by the so-called separate regulators to deal with the rising competition-related intricacies as markets become more competitive. The presence of a separate regulator in monopoly and duopoly markets also seems to have some negative effect on the growth of mobiles, but the effect is not statistically significant. This could be because the incidence of competition-related intricacies and the chances of a regulatory capture are low in such markets.

Second, evidence of pre-emptive behavior is found in competitive sequential entries. The coefficient of the pre-emptive dummy suggests that the incumbent mobile operator increases its subscriber size by 38 percent just in the year prior to the actual entry of a second mobile operator. This result is consistent with the threat of competition argument. On the other hand, no significant evidence is found to support differences between simultaneous and sequential entries. In sequential competitive entries, the major effect of competition on mobile growth occurs after the actual year of entry. Other studies reported inconsistent results on competitive mode of entries: Gruber and Verboven (2000) found sequential entry to be more effective in their global mobile communications study while Gruber (2001) found simultaneous entry to be more effective in his CEE study.

Third, digitalization is positive and significant. The coefficient of the digitalization dummy suggests that the speed of mobile diffusion accelerates as countries adopt a digital technology. Gruber and Verboven (2000) also found digitalization to be positive and significant in their EU study. However, Gruber and Verboven (1999) and Gruber (2001) did not find digitalization to have an appreciable impact on the diffusion of mobiles . Our finding is consistent with the finding of the EU market study which is also dominated by the GSM standard.

Fourth, the presence of an incumbent-owned cellular is negative and significant, suggesting that the involvement of the incumbent fixed-line operator in mobile operations slows down the growth of mobile telecommunications. This is consistent with the theory of an abuse of a dominant position, and with the dismal performance record of African incumbent fixed-line operators. Privatization of the incumbent fixed-line operator is; however, positive and significant, suggesting that privatization accelerates mobile growth. Further analysis indicates that it is the privatization of the incumbent fixed-line operator that is involved in cellular, not just the privatization of the incumbent *per se*, that accelerates the growth of mobiles. This is also consistent with the notion that privatization improvers performance. Therefore, while the presence of an incumbent-owned cellular decelerates mobile growth, the privatization of an incumbent fixed-line operator that is involved in cellular mitigates that negative effect.

Finally, urbanization (as measured by the % of urban population) and main lines are positive and significant; the rest of the country characteristics variables, such as income and population, are not significant. The positive significance of the urbanization variable suggests that mobile services in Africa are mainly concentrated in urban centers. Similarly, the positive significance of the main lines variable suggests that mobiles are perceived as complements to fixed lines; alternatively, it also suggests the presence of positive network externalities from the fixed network. The fact that urbanization and main lines are positive and significant are consistent with each other, and both indicate that mobiles are following the footsteps of the incumbent fixed-line operators which don't have much presence in rural areas.

Furthermore, as far as the relationship between mobiles and fixed lines is concerned, findings from other studies suggest that mobiles are perceived as substitutes for fixed lines in developed markets, such as the EU, while they are perceived as complements to fixed lines in relatively less developed markets, such as Central and Eastern Europe. Interestingly, the coefficient of the main lines parameter in our study is consistent with these findings, i.e. mobiles in Africa are perceived as complements, at least at this stage, to fixed lines.

All of the above findings have relevant policy implications, and it is my hope that telecommunications policy makers in Africa can learn important lessons from this study. In the future, it is interesting to explore how competition, regulatory qualities, investor qualities, and other policy variables affect prices, access to the poor and qualities of services. It will also be interesting to consider regulatory and investor quality measures, which we have not included in this study because of the paucity of data, in future mobile diffusion studies. Also, one may want to model the mobile diffusion problem using the logistic model, which is widely used in diffusion studies, as a sensitivity analysis to the results found in this study. The author of this paper has plans to explore these issues.

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Table 2: The Estimation Results of Equation One

Dependent variable: LN (# of Mobile Subscribers)

	I	II
Number of operators	**0.474 * (4.12)**	**0.424 * (3.64)**
Separate regulator	0.103 (0.59)	0.098 (0.57)
Incumbent-Owned Cellular	**-1.426 * (-3.65)**	**-1.390 * (-3.58)**
Privatization	**0.604 * (2.59)**	**0.621 * (2.68)**
Digitalization	**0.563 * (3.13)**	
GSM		**0.681 * (3.73)**
% of urban population	**0.087 ** (2.17)**	**0.085 ** (2.14)**
LN (Main lines)	**1.007 * (3.24)**	**0.941 * (3.04)**
LN (Population)	0.661 (0.20)	1.372 (0.42)
LN (GDP per capita)	0.780 (0.73)	0.876 (0.82)
Time trend	**0.016 * (4.12)**	**0.015 * (3.96)**
Country fixed-effects (average)		
Adj. R^2	0.89	0.89
F-stat	257	262
Number of countries	41	41
Total observations	279	279

Note: t-stats in parentheses.

*Significant at 1% significance level.

*~ Significant at 2% significance level.

**Significant at 5% significance level.

***Significant at 10% significance level.

Table 3: The Estimation Results of Equation Two

Dependent variable: LN (# of Mobile Subscribers)

	I	II	III	IV	V	VI	VII	VIII	IX	X
Monopoly market			**-1.132 * (-6.42)**	**-1.558 * (-6.20)**						
Duopoly market					**1.132* (6.42)**	**1.558* (6.20)**	**1.203* (6.90)**			
Triopoly market			-0.281 (-1.237)	**-1.098 *~ (-2.56)**	**0.851* (3.41)**	0.460 (1.20)	**0.928* (3.77)**			
Competitive	**1.077* (6.31)**	**1.254* (5.64)**							**0.952* (5.52**)	**1.079* (6.35)**
Separate Regulator	0.006 (0.039)	0.138 (0.70)	0.030 (0.18)	**-0.534 *** (-1.86)**	0.030 (0.18)	0.165 (0.84)	0.001 (0.01)	0.052 (0.31)	0.125 (0.74)	-0.007 (-0.04)
Separate Regulator * Monopoly				**0.699** (2.18)**						
Separate Regulator * Duopoly						**-0.699 ** (-2.18)**				
Separate Regulator * Triopoly				**1.057** (2.29)**		0.358 (0.89)				
Separate Regulator * Competitive		-0.343 (-1.24)								
Incumbent-Owned Cellular (IOC)	**-1.441 * (-3.92)**	**-1.318 * (-3.47)**	**-1.380 * (-3.73)**	**-1.148 * (-3.00)**	**-1.380 * (-3.73)**	**-1.148 * (-3.00)**	**-1.847 * (-4.71)**	**-1.464 * (-3.95)**	**-0.832*~ (-2.43)**	**-1.443 * (-3.93)**
Incumbent OC * Privatization							**1.209* (3.17)**			
Privatization	**0.670* (3.02)**	**0.696* (3.13)**	**0.700* (3.14)**	**0.705* (3.18)**	**0.700* (3.14)**	**0.705* (3.18)**	-0.079 (-0.24)	**0.508** (2.23)**	**0.773* (3.41)**	**0.665* (3.01)**
Digitalization	**0.474* (2.78)**	**0.498* (2.91)**	**0.513* (2.97)**	**0.547* (3.18)**	**0.513* (2.97)**	**0.547* (3.18)**	**0.502* (2.96)**	**0.531* (3.13)**	**0.604* (3.51)**	**0.471* (2.78)**
Simultaneous entry (-1)								**1.509* (3.97)**		
Pre-emptive								**0.324** (1.95)**		
Sequential entry (0)								**0.997* (4.85)**		
Sequential entry (-1)								**1.423* (5.82)**		
% of urban population	**0.112* (2.89)**	**0.112* (2.87)**	**0.116* (2.97)**	**0.113* (2.92)**	**0.116* (2.97)**	**0.113* (2.92)**	**0.113* (2.96)**	**0.133* (3.38)**	**0.129* (3.24)**	**0.111* (2.88)**
LN (Main lines)	**1.159* (3.88)**	**1.123* (3.75)**	**1.164* (3.90)**	**1.035* (3.45)**	**1.164* (3.90)**	**1.035* (3.45)**	**1.216* (4.15)**	**1.136* (3.84)**		**1.198* (4.57)**
LN (Population)	1.004 (0.32)	1.100 (0.35)	1.320 (0.42)	1.990 (0.64)	1.320 (0.42)	1.990 (0.64)	0.886 (0.29)	1.375 (0.44)	**5.058** * (1.67)**	0.854 (0.28)
LN (GDP per capita)	0.288 (0.28)	0.449 (0.43)	0.107 (0.10)	0.630 (0.60)	0.107 (0.10)	0.630 (0.60)	0.489 (0.48)	0.372 (0.36)	**2.182 *~ (2.34)**	
Time trend	**0.014* (3.62)**	**0.013* (3.57)**	**0.013* (3.45)**	**0.012* (3.31)**	**0.013* (3.45)**	**0.012* (3.31)**	**0.013* (3.51)**	**0.011* (2.89)**	**0.012* (3.23)**	**0.014* (3.81)**
Country fixed-effects (average)										
Adj. R^2	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.91	0.92
F-stat	284	256	256	218	256	218	243	219	299	320
Number of countries	41	41	41	41	41	41	41	41	41	41
Total observations	279	279	279	279	279	279	279	279	279	279

Note: t-stats in parentheses

*Significant at 1% significance level.

*~Significant at 2% significance level.

**Significant at 5% significance level.

***Significant at 10% significance level.

Table 4 : Cellular Entry and Technologies in Africa (countries selected for the study)

	1985	1986	1987	1989	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Analog=0, Digital=1	# of Operators
Algeria				NMT900								GSM900 [1]		GSM900	0,1	2
Angola							AMPS800						CDMA [2]	GSM900	0,1	2
Benin								AMPS800					GSM900 (2)		0,1	3
Botswana											GSM900 (2)				1	2
Burkina Faso									GSM900					GSM900 (2)	1	3
Burundi						AMPS800							GSM900 (2)		0,1	3
Cameroon							GSM900					GSM900			1	2
Cape Verde											GSM900				1	1
CAR								AMPS800	AMPS800						0	2
Congo								DAMPS				GSM900(2)			1	3
Cote d'Ivoire									GSM900(3)						1	3
Djibouti									GSM900						1	1
Egypt			MATS								GSM900(2) [3]				0,1	2
Ethiopia												GSM900			1	1
Gabon [4]					AMPS							GSM900	GSM900 (2)		0,1	3
Gambia					TACS									GSM900	0,1	2
Ghana					TACS			AMPS	GSM900			*GSM900*	GSM900		0,1	4
Guinea							AMPS	AMPS	AMPS	GSM900(2) [5]		*GSM900*	GSM900 [5]		0,1	3
Kenya					ETACS				GSM900 [6]				GSM900		0,1	2
Lesotho								GSM900						*GSM900*	1	2
Madagascar							AMPS			GSM900 (2)	GSM900				0,1	4
Malawi								GSM900				GSM900			1	2
Mali									GSM900				GSM900		1	2
Mauritius				ETACS					GSM900			GSM900 [7]			0,1	2
Morocco			NMT500				GSM900 [8]						GSM900		0,1	2
Mozambique										GSM900	GSM1800 [9]				1	1
Namibia								GSM900							1	1
Niger										AMPS800				GSM900 (2)	0,1	3
Nigeria					ETACS									GSM900 (3)	0,1	4
Rwanda											GSM900				1	1
Senegal					RC2000 (AMPS800)				GSM900 [10]			GSM900			0,1	2
Seychelles								GSM900			GSM900				1	2
South Africa		C-NETZ450					GSM900(2) [11]							*GSM900*	0,1	2
Sudan										GSM900					1	1
Swaziland											GSM900				1	1
Tanzania							NMT900/ ETACS	GSM900				GSM900	GSM900(2) [12]	GSM900	0,1	5
Togo										GSM900			GSM900		1	2
Tunisia	NMT450								GSM900 [13]		FULL GSM				0,1	1
Uganda								GSM900			GSM900			GSM900	1	3
Zambia								AMPS	CDMA		GSM900	GSM900 [14]			0,1	3
Zimbabwe										GSM900	GSM900 (2)				1	3

Source: African Telecommunications Research Project, World Bank

Note: The numbers in parentheses represent the number of entrants in that particular year, and the ones in italics represent just licensing only.

1. The incumbent operaotr migrated from NMT900 to GSM.
2. Angola Telecom migrated from AMPS to CDMA.
3. The incumbent mobile operator also migrated to GSM when another operator entered the market.
4. Two cellular operators have already been licensed recently.
5. Spacetel Guinea which started operation in 1995 with AMPS migrated to GSM. SOTELGUI and Telecel also migrated to GSM.
6. The incumbent mobile operator migrated from ETACS to GSM.
7. Emtel migrated to GSM
8. The NMT500 opertaotr migrated to GSM in 1994.
9. The incumbent operator acquired a GSM1800 standard.
10. The incubent operator migrated to GSM.
11. The incumbent cellular operator migrated from C-NET to GSM as MTN entered the market.
12. Vodacom entered and MIC Tanzania migrated to GSM.
13. The incumbent cellular operator started migrating to GSM in 1996 and became fully GSM in 1998.
14. Telecel migrated from CDMA to GSM