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Are Main Lines and Mobile Phones Substitutes or Complements? Evidence from Africa

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Abstract

Many developed and developing countries have approached telecommunications reform by opening the market for mobile telephones to private participation and competition. One result of this strategy is the astounding worldwide growth in mobile communications, with developing countries accounting for the fastest growth. It is believed that mobile phones are complementary to fixed-line telephony in developed countries, but they appear to be substitutes for main lines in developing regions where access is low or non-existent. This paper examines the relationship between mobile and main-line telephones by accounting for reverse causality between them in an environment with low levels of development. The results suggest that mobile telephones act as a competitive force encouraging fixed-line providers to improve access. However, overtime, as mobile usage becomes more widespread, it becomes less of a complement in consumption and its role as a substitute starts to emerge. Between 1985 and 1997, the complementary effect outweighs the substitution effect even where fixed-line access is low.

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1. INTRODUCTION

Mobile telephone subscriptions have been growing rapidly since the 1980s in both developing and developed regions. Subscriptions to fixed telephones have also grown, but at a slower rate than cellular in many regions of the world (ITU, 1999). For instance, by 1997, mobile subscriptions in Lebanon accounted for 76 percent of total telephone subscriptions (World Development Indicators, 2000). If cellular continues to grow rapidly, it is likely that its subscription will surpass fixed-line access in the near future. Currently, developing countries are experiencing the highest levels of mobile growth (ITU, (1999).

The increasing use of mobile telephony has implications for main-line access in developed countries and in regions where access to traditional wire-line telephones is relatively low. The growth of mobile subscription may reflect its role as a substitute for main lines. However, it is not uncommon for calls to be connected between a fixed line and a mobile telephone, so the services may in fact be complementary to each other.

Despite the growing importance of mobile telephony, very little is empirically established regarding its position vis-à-vis fixed-line telephony as stimulus to connectivity. Since the fastest growth in mobile is occurring in developing countries, this study examines its role in fixed-line development in Africa, illustrating the impact of mobile provision in many developing regions. As one of the emerging markets, Africa shows high growth and increasing competitiveness in mobile communications. It is also a region with very low access to fixed-line telephones. During the 1980s, cellular provision was practically nonexistent in Africa. Today, virtually all countries in the region have access cellular service, and many have at least two operators, one of which is usually privately owned. These characteristics are evident in many developing countries.

Typically, cellular usage and main line access are both growing rapidly. In many cases, regions with rapid growth in one service also experience rapid growth in the other (compared to regions with slower growth). Regardless of the pace of growth, or level of telephone access, mobile usually grows faster than main line access. For instance, South Africa enjoys growth in

main line access of about 3 9 per thousand, per year, but enjoys growth of 4.5 per thousand, per year in mobile access. The trend is similar in cases where access to main-telephone lines tend to be relatively low. In Tanzania, main line access grew by less than 0.1 per thousand people, per year, while mobile subscriptions increased by 0.3 per thousand each year. Looking at South Africa and Tanzania together, suggest that individuals may be using mobile, not necessarily as a substitute for fixed lines, but for other reasons such as joint use. In other words, as individuals become more sophisticated in their use of telephones, they tend to behave more like users in developed countries.

While mobile growth in Tanzania may appear to be negligible, in actuality it is substantial, given that mobile usage in that country started only in 1995. By 2001, mobile subscriptions in Tanzania outweighed that of main line access. This story is also true for Morocco, which enjoys relatively high main line access. Between 1985 and 1997 main-line access grew by an average of 2.9 per thousand individuals per year, while mobile access increased by only 0.27 per thousand individuals per year. By 2001, however, access to mobile telephones surpassed that of main lines, at least in urban areas. This occurred as a result of the introduction of privatization and competition in the mobile sector. Mobile access, therefore, appears to be growing rapidly across the continent of Africa, regardless of the stage of main line development. For this reason, it is difficult to determine what the relation is between the two services, by just comparing access trends.

Today, virtually all countries in the region have access to cellular service, and many have at least two operators, one of which is privately owned. This is happening as a first step towards telecom sector privatization, since most countries, although allowing private participation in cellular services, still support state-owned main line provision. In these markets, the only potential threat to fixed line provision is competition from cellular. The question of the role of mobile is thus interesting in the case where the mobile provider is privatized and not owned by the incumbent. Real competition can only occur in a situation like this, because if the incumbent

is also the sole provider of mobile services, then the potential for competition is diminished to the extent that the incumbent controls the mobile/main line trade off from the supply side. In this scenario, the relation in consumption would be difficult to determine. Even in cases where mobile provision is privatized and competition exist, conceptually it remains unclear whether mobile is a substitute or complement for main lines in consumption.

A popular argument for the view that mobile usage is substituting for fixed lines is its prevalence where access to main lines is low or unreliable[1]. For instance, cellular phones may be an attractive alternative where it is difficult to install fixed-line networks. Because mobile networks can be installed more rapidly than fixed networks, they can alleviate waiting time for potential subscribers (Minges, 1999) and reduce unsatisfied demand.

The use of pre-paid cards by mobile users also supports the view that mobile is a substitute for main lines. With the use of pre-paid cards, users who otherwise would not qualify for a phone can now access the service. This is especially important for users in developing regions where it is not uncommon for people to lack credit histories. For individuals with poor credit histories, the option to pre-pay is an important development, since people are not automatically disqualified from using the service because of bad credit. The pre-paid alternative also provides the opportunity for individuals to manage their telephone expenses, since the number of calls that can be made is restricted. The result is that more people than ever now have access to mobile telephones. The increased supply of cellular service allows an attractive alternative to fixed-line telephony.

Just like users in developed countries, some people in developing areas are attracted to mobile not because there are no alternatives, but because of the convenience of mobile phones (Frempong and Atubra, 2001); furthermore, mobile phones are often used in conjunction with

[1] According to the ITU (1999) report, mobile telephones are used in developed countries to complement existing fixed lines but are emerging as a substitute for fixed lines in developing countries.

fixed-line telephones. Fixed lines are usually used at home, while mobile phones are used to keep in touch with home or office when individuals are on the road. In fact, calls from cellular phones are commonly made to fixed lines as opposed to another cellular phone (Jha and Majumdar, 1999). In such instances, mobile and fixed lines are used in a complementary fashion. A larger fixed-line penetration increases the value of mobile service.

The high cost of cellular service relative to the nominal price of main lines can make cellular phones unlikely to substitute for main lines[2]. Even though the cost of cellular has been falling, it remains high relative to the cost of fixed telephones. In regions where income is low, cellular phones may be out of reach for most consumers. In cases like this, mobile subscriptions may be confined to the wealthy, a relatively small group within a country. The preceding suggests that the role of mobile is ambiguous, at least at a conceptual level. Thus, the question of substitutability versus complementarity has to be solved empirically.

[2] The price of main-line service has not generally been a strong factor affecting its demand because the price elasticities of demand for main lines tend to be low. Ahan and Lee (1999) found that the demand for mobile is positively correlated with per capita GDP, although the price effects on mobile tend to be weak. Their research suggests that even where income is low and costs high, subscribers may not respond very much to the price of mobile. If this is true, then the high cost of mobile to the subscribers should not be a strong enough factor to seriously restrict the number of individuals willing to become cellular subscribers. It is therefore feasible that individuals unable to access main lines would be willing to use mobile phones whenever they are available.

2. RECENT EMPIRICAL STUDIES

A large body of research involving the development of telephone network has focused on the role of institutions. These researchers found that a strong institutional framework is essential for network development and expansion. Other studies examining the effects of new market conditions for utilities have focused mainly on industry privatization and competition. The general consensus is that competition and privatization tend to be associated with increased efficiency and growth. However, privatization is not always associated with network expansion.

Table 1: Overview of empirical analyses of telecommunications development (international studies)

Study	Period/Method	Questions	Conclusions
Kwoka (1993)	1947-1987 U.S. and the U.K.	What is the incremental impact of of privatization and competition on the total factor productivity growth of AT&T and British Telecom?	AT&T's total factor productivity increased more rapidly as it faced stronger competition. Privatization is positively associated with gains in productivity.
Henisz (1998)	1960-1992 – World Non-linear least squares	How do cross national differences in the levels of checks and balances on executive discretion (created by variations in political structures) affect the relative rates of basic telephone infrastructure deployment?	There is a direct relation between penetration rates (given political constraints) and future penetration growth rates. Countries with poor penetration will begin to "catch up". Political and institutional factors are significantly related to telephone deployment.
Henisz and Zelner (2001)	1975-1994 - World Non-linear least squares	How does the role of political constraints on executive discretion determine cross-national variation in the diffusion of basic telecom infrastructure?	Countries with poor telephone penetration begin to "catch up" quickly if the country's institutional environment is able to limit policy change. Political constraints result in reduced rent seeking, which in turn leads to reduced investment risk and increased growth in basic infrastructure.
Guiterrez (1999)	1980-1997 – Latin America Panel data analysis	What are the effects of privatization, competition, and regulatory reform on telecommunications penetration and efficiency levels?	The regulatory framework is positively associated with telephone network deployment and efficiency levels. Privatization is not a significant determinant of penetration.
Ros (1999)	1986-1995 – World Fixed-effects model	What are the effects of privatization and competition on telephone network expansion and efficiency?	Countries with greater than 50% of their telecommunications asset in the private sector have higher penetration levels and growth. Privatization does not appear to lead to higher *growth* in telephone penetration in countries with per capita GDP of less than $10,000. Competition has no effect on network expansion. Both privatization and competition are positively associated with network efficiency.

Study	Period/Method	Questions	Conclusions
Wallsten (1999)	Latin America and Africa Fixed effect	How do regulation, privatization and competition affect telephone network expansion?	Regulation by itself has no statistically significant impact on fixed-line penetration. Penetration along with competition is positively and significantly correlated with network development. Competition by itself is also important.
Jha and Majumdar(1999)	1980-1985 OECD	What is the effect of mobile diffusion on the productive efficiency of the Telecom sector?	Cellular technology diffusion is positively associated with productive efficiency. Productive efficiency is enhanced when the monopoly operator is privatized and when the competitive environment is liberalized.
Guiterrez & Berg (2000)	1986, 1990, 1995 Latin America Panel fixed effect	How do the economic, demographic, institutional and regulatory factors affect the level of telephone penetration in Latin America?	These factors play important and positive roles in the modernization of the sector. A strong regulatory framework has a significant and positive impact on penetration growth.
Singh (2000)[3]	Asia	What are the effects of institutional environment (which establishes property rights) on network expansion and efficiency?	Market competition is better for growth than privatization alone. Network expansion and efficiency occur when adequate property rights and enforcement mechanisms are in place.

[3] Singh (2000) is more of a descriptive than an empirical paper in the sense that he used case studies rather than formal statistical techniques that are typically used in empirical papers.

All of these studies except Wallsten (1999)[4] examine the role of competition in basic services, rather than competition between mobile and fixed-line provision. Ros (1999) included some African countries in his data set to provide insight into the role of competition on main-line access as well as efficiency in the telecom sectors of these countries. The present study examines competition solely from the perspective of developing regions, using data from Africa. In addition, it recognizes the importance of mobile as a competitive force in a context where more competition occurs via cellular provision than via privatization of incumbent wire-line providers.

The role of competition in the telecommunications sector is seldom viewed from the perspective of how mobile provision affects basic service. However, the astounding growth of mobile communications makes it one of the largest forces in emerging markets. A better understanding of whether mobile is a substitute for or a complement of basic services is important for policy makers as they attempt to reform the telecommunications market to improve access and increase efficiency.

3. HYPOTHESES

Mobile Competition and Main-Line Performance

The relation between mobile competition and access to main line telephones is ambiguous. Mobile and main line correlation may be perceived as positive or negative, depending whether they are complements or substitutes. When the two services are

[4] Wallsten (1999) looked at the relation between mobile and fixed-line access, but the data used have two main drawbacks. The first is that it lumps together two dissimilar regions with different levels of growth and telephone development in terms of main-line access. It is likely that there are larger variations across these regions, which may affect how confidently the results are to be interpreted regarding any one region. In addition, only 15 of the 55 countries in Africa were included in the sample, and five of those had monopoly mobile providers. These monopolies are usually at least partially owned by the incumbent wire-line firm. A single country from Northern Africa was included, which raises a question as to whether the sample was representative of the African region as a whole. In contrast, this study focuses on a single region and uses a more representative sample of countries from all parts of Africa. Instead of using the number of cellular providers to measure mobile competition, this study uses the actual level of mobile subscriptions.

complements, the increased usage of cellular phones will be associated with increased access to main lines. On the other hand, if mobile subscriptions are substituting for fixed lines (for instance, by covering unsatisfied demand for fixed lines), a negative relation is expected. [5]

Other Considerations

The relation between telephone access and other factors, such as per capita GDP, institutions and political regime has been established in other studies.[6] The general consensus is that strong institutions and stable political systems are positively correlated with increased access to basic telecommunications. Likewise, as individual income increases, the demand for telephones should rise, especially in situations where individuals are poor to begin with and suffer from lack of access because of the inability to pay. The relation between per capita GDP and telephone access may, however, be small in situations where lack of access is attributable to insufficient supply rather than low demand.

4. BACKGROUND

Competition Policies

Historically competition in basic services has been nonexistent in Africa. Even though there has been some privatization in the 1990s [7], providers of basic services remain monopolies in most of Africa. In contrast, the mobile sector in Africa opened rapidly to competition, and Africa was one of first regions to adopt mobile service (Leblanch-Wohrer and Lewington, 2000). As

[5] It is possible for mobile and main lines to be strategic substitutes rather than substitutes in consumption. Fixed-line penetration in Africa may be growing because incumbent providers think that increasing access is the best response to the competition it faces from mobile providers. If the services are strategic substitutes then the relation between the two will be positive. Likewise the two services may be complements in consumption or strategic complements. In the first instance individuals get connected because of an increase in the value of being connected as more and more people have access to fixed lines. It is important to be able to distinguish the different types of substitutes and complements for the purposes of proper interpretation of the relationship between mobile and main lines.

[6] See Henisz (1998), Gutierrez (1999), Hamilton (2001) and Singh (2000).

[7] By 1997, Cote d'Ivoire, Gabon, Ghana, Madagascar, South Africa and Tanzania had partially privatized their communications, but most of these were still largely state-owned. See Hamilton (2001).

Table 2 shows, a number of countries currently sustain multiple (at least two) providers (over a wide range per capita GDP).

Both foreign and private-sector participation are becoming commonplace. Ghana, for example, is just one of the many countries that has recently opened its market to mobile competition. CellTel Ghana has nationwide coverage, as does Anglo Telecom. Likewise, Vodacom is well established in southern Africa. In South Africa, cellular service has created competition in the sector. Most African countries now have access to cellular service, at least in the major cities. The use of mobile may indicate the development of a competitive sector and may substitute for main wire lines where penetration (teledensity) is low. For example, Uganda has one of the lowest levels of penetration of telephone lines in Africa, but enjoys nationwide coverage in cellular service provided by Anglo Telecom.

Table 2. The Level of Mobile Competition in Africa by 1997

Country	**Legally Permissible Competition**	**Country**	**Legally Permissible Competition**	**Country**	**Legally Permissible Competition**
Algeria	M	Ethiopia	M	Niger	C
Angola	M	Gabon	M	Nigeria	C
Benin	M	Gambia, The	M	Rwanda	M
Botswana		Ghana	C	Sao Tome	
Burkina Faso	M	Guinea	C	Senegal	C
Burundi	C	Guinea Bissau		Seychelles	
Cameroon	M	Kenya	M	Sierra Leone	C
Cape Verde	C	Lesotho	M	Somalia	
C. African Rep	C	Liberia		South Africa	C
Chad	D	Libya	M	Sudan	
Comoros		Madagascar	C	Swaziland	M
D. R. of Congo	C	Malawi	M	Tanzania	C
Congo	M	Mali	M	Togo	D
Cote d'Ivoire	C	Mauritania	M	Tunisia	M
Djibouti	D	Mauritius	M	Uganda	D
Egypt	D	Morocco	D	Zambia	C
E. Guinea	M	Mozambique	M	Zimbabwe	C
Eritrea	C	Namibia	M		

M-monopoly, D-Duopoly, C-More than two providers
Source: Leblanc-Wohrer and Lewington (2000) and Minges (1999)

One has to be cautious, however, in using the increase in cellular networks across Africa as an indication of the growth in private-sector participation and competition. In fact, some cellular ventures (Angola and Algeria for example) are still state-owned or monopolies. Furthermore, the existence of cellular operators may not be a perfect measure of competition since cellular service is often available only to the wealthy,[8] who represent only a small portion of African economies. The price of the service may limit its ability to act as a strong competitive force where incomes are low. Nevertheless, in villages call aggregators can play a role in providing access (if not ownership) for low-income demanders.

Mobile versus Fixed Lines

As cellular networks continue to emerge, both fixed-line and wireless services have been growing at a rapid pace in Africa. Table 3 shows the relative size of a country's mobile and main-line markets using the 23 countries in our sample.

Table 3: Relation Between Mobile and Main Lines

	1987	**1992**	**1997**
Total Main-Line Penetration (per 1,000)	11.29	15.702	22.341
Total Mobile Subscription (per 1,000)	0.004	0.056	2.565
Ratio of Mobile to Main Line	0.00033	0.00359	0.111
Percent of New Mobile to Main Line		1.100	37.800
Mobile as a Percent of Total Subscription	0.033	0.358	10.285

Between 1987 and 1997, access to fixed lines almost doubled, growing from 11.29 per 1,000 inhabitants to 22.341 per 1,000. In 1987, South Africa, Tunisia and Algeria accounted for more than 50 percent of all fixed-line telephones in the sample. Ownership patterns had shifted

[8]Main-line access and mobile subscriptions tend to be significantly higher in middle-income countries compared to low-income countries in Africa. (Table 5 in the data analysis section gives a comparison of telephone subscriptions in middle- and low-income countries in Africa). However, over time, as the price of cellular provision falls, this becomes less true. Uganda and Cote d'Ivoire are examples of countries with per capita income below $1,000 and with at least two cellular operators. Cellular operators can be potential threats to incumbent firms, since they can increase penetration at relatively low cost per additional subscriber. The threat of competition may be enough to give the incumbent the incentive to improve service. The potential threat is enough to provide the impetus for telecom growth.

little by 1997, so that South Africa, Tunisia, Botswana and Egypt accounted for 56 percent of main-line access across the sample. The trend shows that countries that were doing relatively well in early years continue to lead the way in the late 1990s. Some of the same countries appear to be leaders in the mobile market. Over the same period, (1987-97), mobile subscription grew from close to 0 per 1,000 people to 22.34 per 1,000 people. South Africa, Tunisia, Morocco and Gabon are among the countries that have the highest subscription rates. Gabon moved from having zero mobile subscriptions in 1987 to having the second highest subscription level of 8.35 per one thousand individuals. South Africa, by far, has had the most success in increasing access to mobile phones. By 1997 access to mobile phones in South Africa was 36 per thousand, which accounted for sixty-three percent of all cellular subscription in Africa. This rapid rate of growth in cellular subscriptions may be attributed to the influx of new mobile providers, both foreign and local.

While mobile subscriptions still lag behind fixed-line access, the gap between the two has been closing over time. The ratio of new mobile subscriptions to new main-line access is increasing over time to just under forty percent in 1997.

5. THE DATA

Annual data used in the analysis represent 23 African countries, 1985-97[9]. The time period and number of countries used was determined by constraints on the data available for some of the variables. The role of mobile competition in determining fixed-network development is assessed by using main line per 1,000 inhabitants as the dependent variable. The variables used in this analysis are shown in Table 4.

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[9] The countries included in the sample are Algeria, Botswana, Cameroon, Republic of Congo, Cote d'Ivoire, Egypt, Gabon, Ghana, Kenya, Madagascar, Malawi, Mali, Morocco, Niger, Nigeria, Sierra Leone, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

Table 4: Data Definitions and Sources

Variable	Definition	Source
Main lines per 1000 inhabitants	This is the first dependent variable. It is the (# of main telephone lines/population)*1000	World Bank's World Development Indicators (1999)
Demand for main lines	This is the second dependent variable. It is the (# of main telephone lines + # of unmet applications/population)*1000	World Bank's World Development Indicators (1999)
Per capita GDP	(Real Gross domestic product in constant 1990 U.S. dollar)/population	World Bank's World Development Indicators (1999)
Institutional Factors	Institutional features which capture country risk factors. It is the sum of the following: corruption of the political system (CORRUP), rule of law (LAW), bureaucratic quality (BUREAU), security of contract (CONTRACT) and risk of expropriation (EXPROP).	IRIS-3 file of International Country Risk Guide (ICRG) data, 1982-1997 constructed by Stephen Knack and the IRIS center.
Economic Freedom	Two variables are used from this index: government operations (GOVOP), which measure the extent to which personal choice and markets, rather than political planning and coercion direct resources. The second variable is discriminatory taxes, (DISCTAX), which measures the extent to which government protects property rights in terms of low transfers and subsidies.	Economic Freedom of the World annual report, 1997. Compile by James Gwartney and Robert Lawson.
Democracy	Indicator of political regime type on a scale of 0 to 10, 0 being the least democratic. (DEMOC)[10]	Polity III: Regime Change and Political Authority 1800-1994. Compiled by Keith Jaggers and Robert Gurr.
Mobile Subscriptions	(# of cellular subscriptions/population)*1000. (MOBILE)	World Bank's World Development Indicators (1999)
Urban percent	(urban population)/total population (URBAN)	World Bank's World Development Indicators (1999)
Trade	(imports+exports)/GDP lagged one period. (LTRADE)	World Bank's World Development Indicators (1999)

[10] The level of Democracy is assumed to be constant between 1994 and 1997.

Descriptive Results

Table 5 summarizes access to telephones in based on regional differences and income. The data indicate North Africa having lower access to both main lines and mobile than Sub-Saharan Africa. The higher level of mobile subscription in sub-Saharan Africa is primarily due to access in South Africa (36.95 in 1997), compared to the highest rate in North Africa of 2.7 in Tunisia in the same year. South Africa is also the reason for the high fixed-line access in Sub-Saharan Africa. Once South Africa is excluded, mobile access in sub-Saharan Africa falls, but remain above that of North Africa. Although the difference seems negligible, the pattern suggests that countries with low access to fixed-line telephones tend to have relatively high access to cellular phones. This result concurs with the view that mobile is satisfying unmet demand for main lines.

Table 5 also shows that main line access is about nine times higher in middle-income countries compared to low income ones. When South Africa is excluded from the sample, mobile subscription falls by almost one third, but access in middle-income countries remain higher than that of low-income countries. This pattern suggests that the ability to pay for mobile may be an important consideration even while cellular costs are falling. One explanation for this may be that providers incorrectly perceive that lower incomes reduce the willingness of individuals to pay for the service. In other words, they may view this as a factor that limits market size. Such providers would therefore target higher income markets. Lower access in this case would be a supply side problem.

Finally, Table 6 provides summary statistics based on regional differences and the level of mobile competition within a country by 1997. As expected, countries that allow mobile competition invest more in mobile communications. Interestingly, these same countries, on average, tend to invest less in main lines. According to the data, countries that allow mobile competition invest in mobile approximately two times as much as countries with monopolies in

mobile service. At the same time mobile monopoly countries on average invest in main lines by just under one and one half times more than countries that allow mobile competition. One implication of this is that mobile competition allows cellular providers to be better able to pick up the slack where main lines are under-supplied.

Table 5: Regional Differences, Income and Telephone Access 1985-1997

	North Africa	**Sub-Saharan Africa**	**Sub-Sahara without South Africa**
Middle Income	34.63 (0.234)	45.794 (2.685)	25.420 (0.852)
Low Income	-	4.580 (0.068)	4.580 (0.068)

The first number in each cell represents average main-line penetration. The numbers in parentheses are mobile subscription per thousand individuals.

Table 6: Main-Line Penetration, Income and Mobile Provision

	Market Structure for Mobile	
	Monopoly	**Competition**
Middle Income	32.50 (0.528)	87.069 (6.354)
Low Income	3.349 (0.021)	6.00 (0.062)
All Income	21.569 (0.338)	10.736 (0.527)

The first number in each cell represents average main-line penetration. The numbers in parentheses are mobile subscription per thousand individuals.

The difference between mobile subscriptions in low-income countries is miniscule when compared to that of middle income ones. This result suggests that the ability of customers to pay appears to be an important factor in determining mobile access.

6. THE EMPIRICAL MODEL

Estimation

In this section we use panel data estimation techniques to analyze the impact of MOBILE competition on MAINLINE access. The model is estimated using pooled data from 1985 to 1997. We begin our data set in 1985 because the mid 1980's marked the take off of rapid telecom reform in Africa as well a the introduction of cellular phones

Before estimating the panel data, some cross sectional analyses are conducted to compare the attributes of the explanatory variables at different points in time. The impact of MOBILE on MAINLINE development is assessed for a cross section of countries in 1987[11], 1993 and at the end of the sample period in 1997. The following equation was estimated for each of the three years:

(1) $MAINLINE ? ? ? ?_K X ? ?$,

Where X is a vector of independent variables, containing LOGGDPC, LTRADE, URBAN, CORRUP, LAW, BUREAU, CONTRACT, EXPROP, GOVOP, DISCTAX, DEMOC and MOBILE.

(2) $? MAINLINE ? ? ? ?_K ? X ? ?$,

Where, ? indicates that the variables are expressed as their 1997 values minus those of 1987.

Equation 3 is estimated to account for cross-country variation using the panel data approach.

(3) $MAINLINE_{CT} ? ?_{CT} ? ?_K X_{CT} ? ?_{CT} ? ?_{CT}$,

Where, X_{CT} is the same vector of independent variables as in equation 1 for country C in year T. $?_{CT}$ are country dummies that account for unobserved differences across countries that may affect the dependent variable. $?_{CT}$ captures year effects that take care of possible variations of

[11] 1987 as opposed to 1985 was used for the first cross sectional estimation because there were not enough observations of MOBILE in 1985 to generate meaningful results.

the omitted variables through time. Equation 3 is estimated by expressing the variables as deviations from their group means. This approach picks up any constant differences on a country-specific level through time. The model is estimated using fixed effects.[12] A parsimonious specification in which mobile subscription per 1000 individuals is the only right-hand-side variable is first estimated in order to establish the relation between mobile and main line assess, and between mobile and main line demand in isolation of other independent variables. The standard errors of all estimations are adjusted for cross observation error dependence using the Huber/White variance estimator.

Sample Selectivity

Only twenty-three out of over fifty countries in Africa are included in the sample used in this analysis. This raises the concern that the results of the study may not be generalized to include the excluded countries. In order to check this possibility, we compare the excluded countries in cross-section with those included in the analysis along observable lines. Per capita GDP, main line and mobile access, trade and urban percentage are used as the basis for comparison. Table A in the appendix compares the overall means of these variables with and without South Africa as well as with and without Seychelles and Mauritius.[13] Table A shows that at the mean, the included countries tend to be similar to those excluded. For instance, the biggest difference between main line access is only about 2 per 1000 individuals. The difference in mobile access is negligible at less than 0.1 per thousand. Average per capita GDP tends to be slightly higher in the included countries, but both groups tend to have an average income in the lower income category.

[12] The fixed effect model assumes that the counties in our sample, each have characteristics that are unique and do not change over time. These differences are captured in differences in the constant term.

[13] South Africa, Seychelles and Mauritius have significantly higher access to main lines than the rest of Africa (107, 203,and 195 respectively in 1997). These countries also tend to have higher income levels than the rest of Africa. Except for Botswana, they are the only other upper-middle income countries in Africa.

To further check the possibility of selectivity bias reduced fixed effects regressions (using the same observable variables) were conducted for both groups of countries. Table B in the appendix shows the results. Apart from the trade variable, which is insignificant for the countries excluded, the regression results were quantitatively similar. Finally, the reduced regression was conducted using all the countries in Africa. Again, the results were quantitatively similar (in terms of sign and significance), to the results using just the 23 countries in our sample. This informal sensitivity analysis (by itself), suggest that selectivity may not be an important problem, at least qualitatively.

Endogeneity

MOBILE captures the competition effect in markets where direct telephony is a monopoly. Competition is, however, a result of regulatory considerations, and monopoly firms often have control over the regulatory regimes in Africa through the ministry. Often there is no separation of regulatory functions and operation because both may be operating under the same ministry. Mobile and direct lines are therefore jointly determined. If MOBILE is endogenously determined, it will be correlated with the error term. Under this condition, ordinary least squares (OLS) estimations will tend to attribute changes in the dependent variable (MAINLINE) caused by the error term to MOBILE. As a result, the coefficient on MOBILE will be biased upward or downward, depending on the sign of the correlation between MOBILE and the error term. In addition, if MOBILE and MAINLINE are jointly determined, MOBILE cannot be considered fixed in repeated samplings and there is a potential bias in all the estimated coefficients. Consider the coefficient of URBAN ($?_3$) for instance. Note that $?_3$ is supposed to be the estimated effect of URBAN on MAINLINE, holding MOBILE and all other right-hand-side variables constant. MOBILE is, however, not held constant when changes in MAINLINE takes place. Therefore, $?_3$ may actually measure some mix of the effects of both URBAN and MOBILE.

Because of the potential problems that may result when OLS is used, it is vital to consider alternative estimation techniques to reduce the simultaneity bias.

We use the instrumental variable (IV) technique to reduce the potential biases in the estimation of Equation 3. To use this technique, we replace MOBILE with a new variable (instrumental variable), which should be highly correlated with MOBILE but uncorrelated with the error term.

Until 1997 only six of the twenty-three countries in the sample had allowed some private participation in fixed-line telephone service provision. All governments, except for Cote d'Ivoire, which sold 51% of its shares to the private sector in 1997, had maintained majority ownership. Private ownership of wire-line phones was therefore practically nonexistent in the sample. In contrast, private individuals are usually licensed to provide cellular service. The nature of ownership made it more likely that private sector credit directed toward investment in telecommunications would go into mobile communications rather than fixed-line development. Thus, when main lines are publicly owned, credit to the private sector will not determine public investment. We identified PRIVCRED (the ratio of private sector credit to GDP) as an instrumental variable for MOBILE and use two-stage least squares to estimate Equation 3.[14]

It may be argued that an increase in PRIVCRED implies a reduced capacity for the government to fund telephone investment. If true, PRIVCRED would be correlated with both MAINLINE and MOBILE. Historically, however, telecom reform is financed largely by loans from international lending agencies as part of their mandate to aid in the improvement of infrastructure in lesser-developed countries. Local investors in mobile communications are likely

[14] Although PRIVCRED is defined as credit to the private sector as a fraction of GDP, it may also randomly include some credit to the public sector as well. Measurement errors introduced by this are assumed to be captured as part of the random error term since the inclusion of public sector credit is not systematic.

to be more dependent on domestic credit[15].

Some analysts argue that some reverse causality exists between GDP per capita and infrastructure (telecom) investment. (Colier and Gunning, 1999). Kerf and Smith (1996) suggest that the poor quality of Africa's infrastructure constrains private investment in other activities and thus is an obstacle to economic growth. That is, countries with proper infrastructure are expected to attract investors, which in turn generate a higher per capita GDP. (Madden and Savage, 1998). This potential is unlikely to be present because the region studied is comprised of nations that are plagued with instability and represent relatively high-risk projects. An increase in telecommunications investment will not be sufficient to attract non-infrastructure investment that would significantly affect GDP.

The Dependent Variable Redefined

As discussed in section 3, it is not entirely clear whether MOBILE is a substitute or a complement for MAINLINE. The supply of mobile phones have grown rapidly, mainly because many governments tend to be more willing to introduce privatization and competition in the market for cellular rather than fixed lines. While the supply of mobile has been growing, so has the supply of fixed lines and more people are using both fixed lines and wireless phones. It is, however, not clear how much of the new cellular subscriptions are by individuals who also have access to fixed-line telephones.

[15] Because only one instrument is identified, a formal test of its validity could not be conducted. Instead, we performed a sensitivity analysis by comparing the R^2s of the restricted regression (without PRIVCRED as a regressor) with the unrestricted regression (including PRIVCRED), using MAINLINE as the dependent variable. The R^2 remained unchanged once PRIVCRED was added to the regression. Likewise, a test of first-stage correlation was conducted with MOBILE as the dependent variable. When PRIVCRED was added as an explanatory variable, the R^2 improved noticeably, by 8%. The results of these tests indicate that PRIVCRED may be used as an instrument for MOBILE. The results are of course based on the current specification of MAINLINE. It may be possible that PRIVCRED would not survive these tests for a different specification of mainline development.

A positive sign could indicate that the two services are complements. In this case, it may be that the same individuals have access to both fixed lines and cellular phones. A positive sign may, however, result even if the services are substitutes in consumption. Cellular operators can be potential threats to incumbent firms, since they can increase penetration at a relatively low cost per additional subscriber, and in less time. The threat of competition may be enough to give the incumbent the initiative to improve service. It is also unusual to observe a decline in the level of teledensity in countries where access is already low. Both MOBILE and MAINLINE access are therefore expected to grow. It is therefore not entirely clear how to interpret a positive coefficient on MOBILE when we estimate the model using a supply side definition of MAINLINE[16].

To check our interpretation of the relation between MOBILE and MAINLINE, we redefine the dependent variable to be actual total access demand for wire line telephones, rather than just satisfied demand. The new dependent variable is DEMAND, which measures the total number of applications for fixed-line service.[17] The equation estimated is:

[16]MAINLINE access per 1,000 inhabitants is a measure of how many telephone lines the respective governments or incumbent wire line firm actually make available to the public. This is usually lower than its demand. In essence main line access measures the portion of demand for main lines that have been met. Since there is usually a shortage, this is in effect satisfied demand. Ros (1999) argued that the low number of main lines is a supply rather than demand-side constraint. Because of the absence of rate rebalancing, residential access prices are likely to be below their economic costs. An increase in supply is overwhelmed by demand, mainly because of long waiting lists as well as low price elasticities of demand.

[17] This is just main line access per thousand individuals waiting list per thousand. Waiting list captures the number of applications for connection to a main telephone line that have been unmet. Specifically, $DEMAND = \left(\frac{applications}{population}\right) * 1000$, where applications is unmet demand for main lines + the supply of main lines.

(4) $DEMAND_{CT} \; ? \; ?_{CT} \; ? \; ?_{K} X_{CT} \; ? \; ?_{CT} \; ? \; ?_{CT}$,[18]

Equation 4 measures the effect of satisfied demand for mobile on total demand for main lines. Since the model is expressed in terms of demand relations, we can infer more clearly the relation between mobile and fixed lines. If the coefficient on MOBILE is positive, then the result can be interpreted to mean that fixed lines and cellular phones are complements. On the other hand, a negative coefficient may be interpreted to suggest that the two services are substitutes.

An increase in MOBILE usage could have externality effects, resulting in increased MAINLILNE demand. The growing MAINLINE usage could, however, have the same effects. To separate the externality effects of MOBILE usage from that of MAINLINE usage itself, we introduce MAINLINE access lagged one period (LMAINLINE) as an independent variable in the DEMAND equation.

Finally, is possible that as mobile subscriptions increase, its relation with demand for wire-lines may change. To account for this possibility, we introduce mobile squared (SQMOBILE) as an independent variable in the demand equation.

Estimated Results

Table 7 presents the results of the cross-sectional estimations. In 1987, MOBILE, was not significantly associated with MAINLINE access, but had a large positive coefficient. This insignificant relation may have occurred because although growing, the level of MOBILE subscriptions was too small in 1987 to have any real effect on MAINLINE development. By

[18] The dependent variable is now a demand side variable and so is not determined by policy. Although MOBILE is still a policy variable, it is not simultaneously determined with the new dependent variable (DEMAND). If MOBILE was the total demand for cellular phones, then the two variables would be simultaneously determined, by virtue of the fact that MOBILE and DEMAND for main lines are related services. MOBILE, however, measures just the part of its demand that is satisfied. In other words, it measures demand constrained by actual supply of cellular phones. It is therefore not a complete measure of demand. It is in fact the supply of cellular phones, which is captured by this variable. If this is true, then we can assume that although MOBILE is a policy variable, it is not jointly determined with total main line demand.

1997, however, MOBILE had cemented its presence in the African telecom market enough to be significantly and positively associated with MAINLINE. This is also shown in the last column of Table 7, which captures how the growth in MOBILE access between 1987 and 1997 affected fixed-line growth for a cross-section of countries. This could suggest that while in earlier years cellular provision was inconsequential in the telecommunications market, it is becoming more of a competitive force as its usage grows. The real impact of MOBILE on MAINLINE, however, appears to be very small between 1987 and 97. In this estimation, the mobile coefficient corresponds to an elasticity that is close to zero.

Generally, the large changes in the size of the coefficients as well as variation in their significance levels over the three years reported, indicate that the variables included in the model are not constant overtime. These cross sectional results are also suffer from omitted variable bias, so the coefficient size and significance may not be precise when country specific elements are omitted. The fixed-effect model that is later estimated takes care of the omitted variable problem and accounts for any constant level differences in the explanatory variables over time.

Table 7: Cross-Sectional Regression Results for 1987[a], 1997 and the Change Between 1985 and 1997. (Dependent Variable: MAINLINE per 1,000 individuals)

Variable	**1987 Cross-section.**	**1993 Cross-section**	**1997 Cross-section.**	**Change between 1987 and 1997 Cross-section.**
LOGGDPC	-3.548 (-0.875)	10.814* (1.875)	10.772** (2.308)	22.126 (1.363)
LTRADE	-0.104 (-1.107)	-0.005 (-0.027	-0.229** (-2.025)	-0.160** (2.208)
URBAN	0.559** (2.261)	0.024 (0.592)	0.599** (2.044)	0.426 (0.861)
CORRUP	2.391 (0.766)	11.526** (2.213)	3.348 (0.891)	4.930** (1.985)
LAW	-6.811*** (-3.401)	-3.353 (-1.528)	3.307 (0.989)	-1.416 (-0.496)
BUREAU	4.551* (1.800)	-7.969*** (-2.872)	-6.312** (-2.510)	-4.379** (-1.777)
CONTRACT	3.057 (1.211)	0.550 (0.212)	1.798 (1.195)	5.475*** (2.732)

EXPROP	-0.900 (-0.308)	2.885 (0.821)	2.946 (1.242)	-0.263 (-0.125)
GOVOP	-0.150 (-0.353)	1.015** (2.022)	0.932* (1.627)	1.046 (1.130)
DISCTAX	-0.531* (-1.638)	0.135 (0.446)	-0.371 (-0.996)	0.788* (1.636)
DEMOC	4.049** (2.546)	-1.401 (-1.535)	-0.102 (-0.010)	-1.975** (-2.183)
MOBILE	185.949 (1.531)	31.986* (1.678)	1.308*** (4.135)	0.503** (2.474)
N	23	23	23	23
R^2	0.90	0.87	0.95	0.85
F Stat	*10.29*	*10.79*	*107.14*	*49.61*

Note: a: Prior to 1987 there was not sufficient data on MOBILE to run cross sectional regressions. T-stats are shown in brackets * = significant at 10%. ** = significant at 5%, *** = significant at 1%.

Table 8 shows the result of the regression in which MOBILE is isolated from all other independent variables. The results indicate a positive and significant correlation between mobile usage, and the two dependent variables (MAINLINE and DEMAND).

Table 8: Parsimonious Specification of Panel Regressions Controlling for Country-Level Differences. Data: 23 countries, 1985-97

Variable	**Dependent Variable: MAINLINE access per 1,000 people**	**Dependent Variable: DEMAND for main lines per 1,000 people**
MOBILE	0.931*** (4.951)	0.853*** (5.150)
N	299	239
R^2 with fixed effects and other independent variables[19]	0.91	0.93
R^2 with only fixed effects	0.89	0.89
F-Stat	*24.51*	*26.52*

Note: t-stats are shown in brackets * = significant at 10%. ** = significant at 5%, *** = significant at 1%.

Tables 9 and 10 show the results of the pooled time series, cross-sectional estimations. Table 9 shows the fixed and instrumental variable estimation results using MAINLINE as the dependent variable. All estimations show a positive and significant correlation between MOBILE

[19] The R^2s of 0.91 and 0.93 indicates that the model explains much of the variation in the dependent variables. Specifically up to four percent more of the variation in MAINLINE and DEMAND is explained by MOBILE.

and MAINLINE. This result suggests that cellular subscriptions may be playing a complementary role to fixed telephone lines. It is also reasonable to interpret the

Table 9: Panel Regressions Controlling for Country-Level Differences. Data: 23 countries, 1985-97

	Dependent Variable: MAINLINE access per 1,000 people		
Variable	**Fixed Effects**	**Fixed effects with Interactions**	**Instrumental Variable:** PRIVCRED used as a proxy for MOBILE.
LOGGDPC	7.593*** (2.740)	6.646** (2.398)	8.262*** (3.063)
LTRADE	-0.115*** (-6.252)	-0.111*** (6.300)	-0.113*** (-5.996)
URBAN	0.624*** (7.043)	0.641*** (7.307)	0.647*** (7.027)
CORRUP	-0.067 (-0.138)	-0.167 (-0.342)	-0.270 (-0.553)
LAW	1.295** (2.500)	0.905** (1.972)	1.265** (2.073)
BUREAU	-2.296*** (-4.310)	-1.696*** (-3.508)	-1.500** (-1.805)
CONTRACT	2.119*** (4.811)	1.819*** (4.406)	2.000*** (4.411)
EXPROP	0.060 (0.156)	0.242 (0.687)	0.068 (0.177)
GOVOP	0.422*** (2.975)	0.412*** (2.975)	0.493*** (3.245)
DISCTAX	0.184*** (2.658)	0.162** (2.378)	0.176*** (2.330)
DEMOC	-0.441*** (-4.302)	-0.407*** (4.088)	-0.467*** (-4.241)
MOBILE	0.438*** (4.579)	5.229*** (3.930)	0.799** (2.211)
MOBINC		-0.0002 (-1.486)	
MOBSUB		-3.923** (-2.520)	
LMAINLINE			
N	299	299	289
R^2 with fixed effects and other variables	0.97	0.97	0.97
R^2 with only fixed effects	0.89	089	0.89
F-Stat	*32.55*	*34.91*	*304.73*

Note: T-stats are shown in brackets * = significant at 10%. ** = significant at 5%, *** = significant at 1%. A test of the significance of a time trend could not be rejected. As a result, the time trend was excluded from our estimations.

positive sign in terms of competition within the industry[20]. The use of cellular phones act as a competitive force, which encourages increased investment in direct lines.

It is possible that main lines and mobile phones may be complements sometimes and substitutes in other cases. For instance it may be possible for mobile and main lines to be complements in consumption in countries where income is relatively high and less so in areas with lower income levels. To further explore this potential differential relationship, the relation between main lines and mobile, we interact MOBILE with per capita GDP (MOBINC), and with a regional dummy which equals 1 if countries are Sub-Saharan and 0 if they are Northern African (MOBSUB). The results show that the interaction of MOBILE with per capita GDP is insignificant. However, the marginal effect of increased mobile subscription on mainline access is more than 2 times lower in Sub-Saharan Africa, than in Northern Africa. Although this result cannot be interpreted to mean that some countries in Sub-Saharan Africa use mobile as a substitute for, rather than a complement of main line, we can conclude that mobile varies in its degree of complementarity. It may be that mobile is used both as a substitute for and a complement of MAINLINE in some regions of Africa, but its use as a complement outweighs its role as a substitute. This is feasible especially in areas where access rates vary dramatically, not only across countries, but also within countries themselves. For instance it is not uncommon for professionals to own both mobile and fixed lines. At the same time, it is becoming increasingly commonplace to have access to one or the other for various different reasons.[21] Mobile can play

[20] Ahan and Lee (1999) estimated the demand for mobile networks using data from sixty-four countries in both developed and developing countries and found that mobile demand is positively correlated with the number of fixed lines per person.

[21] When South Africa is excluded, the marginal effect of increasing MOBILE on MAINLINE is reduced when income is higher. (Second column of Table C in the appendix). Since MAINLINE is a supply side measure, this result may be indicating that providers of fixed service will find it strategic to focus more on cellular provision in high income areas, rather than on fixed line expansion, which is relatively time consuming. From the demand side perspective, (where the dependent variable is DEMAND in Table C), MOBINC is not significant and the result for MOBSUB is quantitatively the same as for the other estimations in Tables 9 and 10.

the role of both a substitute and a complement of main line in the same country at different points in time.

Although the various estimations show MOBILE as highly significant, large changes are necessary to affect main-line development noticeably. Using the fixed-effects coefficients from Table 9, if Gabon increased its cellular subscriptions by 10 per 1,000 people, main-line access would increase in that country by 22.83 telephones per 1,000 inhabitants[22]. This corresponds to an elasticity of only 0.204 in 1997[23]. A low mobile elasticity indicates that direct line and cellular subscriptions are not close complements. Cellular might be too costly for individuals with per capita incomes below $1,000. Only the elite can afford cellular telephones. In addition, many countries' regulatory frameworks are not yet equipped to deal with the emerging competitive markets.

Results from the instrumental variable estimation, with PRIVCRED used as an instrument for MOBILE, show that the impact of the competition variable (MOBILE) remains positive and statistically significant. The coefficient is larger, but the real impact of cellular competition remains small, with elasticity close to zero.

Table 10 shows the results using DEMAND for main lines as the dependent variable. The results for MOBILE competition are quantitatively the same as those in the MAINLINE estimations. The positive and significant coefficient on MOBILE in this case lend more support

[22] An increase of 22.83 does not represent a large increase in MAINLINE. This is because mobile subscription in Africa was only 2.67 per 1,000 individuals while MAINLINE access was 22.34. This is 8.7 times higher than mobile access. When mobile is increased by 10, mainline access in Gabon increased by only 2.2 times more than the increase in mobile even though mainline access was almost nine times higher in 1997.

[23] MAINLINE elasticity is calculated using 1997 values for each country. That is, ?*[MOBILE / MAINLINE].

for the view that cellular and main-line telephones may in fact be complements.[24]

Table 10: Panel Regressions Controlling for Country-Level Differences. Data: 23 countries, 1985-97

Dependent Variable: DEMAND for main lines per 1,000 people						
Variable	**Fixed Effects without lagged MAINLINE**	**Fixed Effects with lagged MAINLINE**	**Fixed effects with Interactions**	**Fixed Effects with lagged MAINLINE and Interactions**	**Fixed Effects with SQMOBILE**	**Fixed Effects with lagged SQMOBILE and Interactions**
LOGGDPC	3.957 (1.109)	3.661 (1.215)	2.717 (0.784)	2.827 (0.960)	4.020 (1.323)	3.230 (1.085)
LTRADE	-0.089*** (-3.646)	-0.057*** (-2.884)	-0.083*** (-3.535)	-0.055*** (-2.797)	-0.057*** (-2.881)	-0.055*** (2.798)
URBAN	0.951*** (10.149)	0.887*** (10.274)	0.961*** (10.421)	0.898*** (10.429)	0.886*** (10.336)	0.897*** (10.492)
CORRUP	0.046 (0.069)	0.600 (1.165)	-0.130 (-0.196)	0.443 (0.835)	0.695 (1.344)	0.550 (1.030)
LAW	0.632 (1.127)	0.359 (0.736)	0.245 (0.459)	0.111 (0.237)	0.238 (0.492)	-0.013 (-0.027)
BUREAU	-1.597** (-2.148)	-1.311** (-2.174)	-1.047 (-1.437)	-0.952* (1.606)	-1.275** (-2.117)	-0.924 (-1.555)
CONTRACT	1.941*** (3.868)	1.653*** (4.112)	1.616*** (3.328)	1.449*** (3.692)	1.669*** (4.150)	1.467*** (3.728)
EXPROP	-0.211 (-0.544)	-0.354 (-1.162)	0.048 (0.131)	-0.167 (-0.562)	-0.362 (-1.193)	-0.178 (-0.599)
GOVOP	0.629*** (3.170)	0.631*** (3.992)	0.600*** (3.084)	0.611*** (3.932)	0.623*** (3.954)	0.603*** (3.884)
DISCTAX	0.132 (1.218)	0.088 (0.875)	0.077 (0.711)	0.053 (0.526)	0.089 (0.880)	0.055 (0.536)
DEMOC	-0.402*** (-2.759)	-0.283** (-2.337)	-0.333** (-2.348)	-0.244** (2.043)	-0.285** (-2.344)	-0.248** (-2.060)
MOBILE	0.496*** (5.280)	0.399*** (5.591)	3.966*** (3.397)	2.775*** (2.837)	0.770*** (3.732)	3.226*** (3.360)
SQMOBILE					-0.011** (-2.299)	-0.010** (-2.310)
MOBINC			0.00003 (0.148)	0.00002 (0.110)		-0.00004 (-0.228)
MOBSUB			-3.541*** (-2.816)	-2.418** (-2.434)		-2.336** (2.406)

[24] We also ran a fixed-effects regression (result not reported) using the six countries in the sample where there is a single cellular provider, who is also the incumbent. The result of the regression using MAINLINE as the dependent variable shows a positive (but insignificant) coefficient on MOBILE. If the incumbent is also the only cellular provider, then the competitive pressure of a substitute that would result in an increase in main line access (when the mainline and mobile are substitutes) does not exist. In cases where the incumbent is the clear provider of mobile a negative correlation between main line access and cellular subscriptions would indicate that the two services may be substitutes. If the correlation is positive, it lends support to the view that the positive correlation found in our estimations indicate that the services are complements in consumption.

LMAINLINE		0.171*** (3.189)		0.160*** (3.059)	0.168*** (3.166)	0.158*** (3.043)
N	239	238	239	238	238	
R^2 with fixed effects and other variables	0.98	0.98	0.98	0.99	0.99	0.99
R^2 with only fixed effects	0.92	0.92	0.92	0.92	0.92	0.92
F-Stat	*41.11*	*67.14*	*42.25*	*67.41*	*57.98*	*59.87*

Note: T-stats are shown in brackets * = significant at 10%. ** = significant at 5%, *** = significant at 1%. A test of the significance of a time trend could not be rejected. As a result, the time trend was excluded from our estimations.

The second column of Table 10 accounts for the increase in value that may result from MAINLINE usage. Once the externality effect of MAINLINE usage is accounted for (by introducing LMAINLINE), the result indicate that the two services may in fact be complements in consumption. The positive coefficient on MOBILE may be interpreted to mean that an increase in satisfied demand for MOBILE is associated with an increase in total demand for main lines and the two services are used together. The result may be capturing the effect where two or more telephone users connect with each other, with at least one party using a cellular phone.

The coefficient on SQMOBILE (although small), suggests that when mobile usage is low, (below 35 per thousand), it may be playing the role of a complement for main line. However, as usage becomes more widespread, its role switches to be that of a substitute. This scenario does a good job of describing the evolution of cellular usage in these developing economies, and concurs with earlier suggestions that it is possible for the service to be play both the role of a complement and that of a substitute. As a new innovation in the mid to late-1980's, cellular service was relatively expensive. It is quite possible that at this stage, only professionals and private individuals with higher incomes (usually in urban areas) would utilize the service. These users tend to use cellular service in conjunction with fixed line phones. As the relative price of cellular service falls overtime, usage spreads to other users including rural, and lower income subscribers. When mobile becomes available in regions where main line access in non-existent or low, it becomes a substitute for main line. Currently, the net effect of mobile on main

line demand is greater than zero at the level of mobile access for most countries in the data set. As such the complementary effect outweighs the substitution effect. However, as mobile subscription increase, its role as a substitute will begin to dominate.

Generally, the results show that both access to MAINLINES and the DEMAND for main lines tend to be higher where income levels are relatively high. The institutional environment is important for telecommunications development (Bergara, Henisz and Spiller, 1998). The institutional variables are also important in determining main-line demand. Rule of law (LAW), security of contracts (CONTRACT), and role of markets (GOVOP) all affect penetration in a positive manner. Political institutions appear to be important, but democracy has a negative coefficient. Clearly, modeling these features warrants more attention in future research. In particular, modifications could be made to consider the possibility that the measures of the institutional environment used, may not readily combine in a linear model for their impact upon the relation between main line and mobile subscription.

6. CONCLUSION

Some research has found evidence that competition generally tends to improve industry performance and productivity. Studies that looked at the telecommunications industry have also found competition in basic services is associated with increased telecom growth and development. This study examine the role of MOBILE competition rather than competition in basic services. This issue is of interest particularly since mobile competition tends to be more widespread than competition in basic services. Many countries are privatizing, but most have stopped short of allowing multiple provision. Mobile competition is expanding its role in many developing countries, even where access to fixed-line telephones is very low.

The empirical results support the theory that credible institutions, including stable legal structures are important driving forces behind the surge of modernization in Africa's telecommunications sector. The effect of mobile competition on main-line development and

demand, though relatively weak is significant. At different stages of cellular development, mobile play the role of both a substitute for, and a complement of main-line demand. From the supply side perspective, the pressure on incumbent firms to improve service provision increase with mobile operators present, possibly leading to improvements in main-line quality as well. The empirical results presented here suggest that competition is important in fostering telecom development: it induces investment by wire-line investors. As more private participation and competition are allowed, competition is expected to have a much larger effect on wire-line investments.

The important lesson is that, although there is some substitution between mobile and main line, mobile's role as a complement dominates. As a result, mobile is not just picking up the slack where demand for main lines is unmet. A market for cellular phones exists beyond reducing the waiting list for traditional wire line phones. This possibility is important for private investors and governments, since the potential market size for both types of service is immense. People in developing countries do not demand cellular phones only as a second-best solution to becoming connected. A significant impetus for mobile demand could simply be due to its convenience (or its implications for social status). Thus, fixed-line providers should not expect a reduction in demand, even as cellular usage continues to expand. Competition from mobile can do much to improve main-line access.

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APPENDIX

Table A: Comparison of Means across Counties included and excluded from the sample

Variable	Countries Included	Countries Excluded	Countries Included Without South Africa	Countries Excluded without Seychelles and Mauritius
MAINLINE	15.206	16.350	11.94	9.338
MOBILE	0.439	0.349	0.170	0.100
Per capita GDP	1000.507	811.978	882.776	492.73
LTRADE	59.570	77.908	60.059	74.065
URBAN	35.547	32.286	34.938	31.194

Table B: Comparison of fixed effect regressions across Counties included and excluded from the sample. Dependent variable: MAINLINE per 1000 individuals.

Variable	Countries Included	Countries Excluded	Countries Included Without South Africa	Countries Excluded without Seychelles and Mauritius	All of Africa	Africa without South Africa, Mauritius and Seychelles
MOBILE	0.818*** (6.028)	4.476 (11.104)*	1.0671** (2.189)	1.958*** (6.445)	2.435*** (3.356)	1.781*** (4.032)
LOGGDP	12.367*** (4.276)	17.867 (3.954)*	13.807*** (4.848)	3.916** (2.556)	22.530*** (5.285)	7.607*** (4.778)
LTRADE	-0.052*** (-3.067)	-0.027 (-1.072)	-0.049*** (-2.900)	-0.080 (-0.645)	-0.038** (-1.987)	-0.026** (-2.549)
URBAN	1.059*** (12.318)	0.989* (4.621)	1.009*** (12.052)	0.826*** (3.800)	1.017*** (8.707)	0.945*** (10.272)

Note. The t-stats are shown in brackets. *** = significant at 1%. ** = significant at 5%.

Table C: Pooled time-series and cross-sectional regression controlling for country-level differences. Data: 1985-97 excluding South Africa.

Variable	Dependent variable: MAINLINE per 1,000 people		Dependent variable: DEMAND for main lines per 1,000 people	
	Fixed-Effect Estimation	Fixed effect estimation with interactions	Fixed effect estimation with interactions	Fixed effect estimation with lagged main line and interactions
LOGGDPC	9.572*** (3.579)	8.797*** (3.285)	2.718 (0.784)	2.827 (0.960)
LTRADE	-0.115*** (-6.262)	-0.112*** (-6.272)	-0.083*** (-3.535)	-0.551*** (-2.797)
URBAN	0.577* (6.156)	0.595*** (6.382)	0.961*** (10.421)	0.898*** (10.429)
CORRUP	0.421 (0.962)	0.344 (0.766)	-0.130 (-0.196)	0.443 (0.835)
LAW	1.187** (2.365)	0.783* (1.753)	0.245 (0.459)	0.111 (0.237)
BUREAU	-2.839*** (4.942)	-2.250*** (-4.234)	-1.047 (-1.437)	-0.952* (-1.606)
CONTRACT	1.982*** (4.773)	1.700*** (4.339)	1.616*** (3.328)	1.449*** (3.692)
EXPROP	0.312 (0.860)	0.465 (1.385)	0.048 (0.131)	-0.167 (-0.562)
GOVOP	0.347** (2.299)	0.299** (2.322)	0.600*** (3.084)	0.611*** (3.932)
DISCTAX	0.118* (1.771)	0.113* (1.759)	0.080 (0.711)	0.053 (0.526)
DEMOC	-0.398*** (-3.816)	-0.381*** (-3.708)	-0.334** (-2.348)	-0.244** (2.403)
MOBILE	1.098** (2.652)	6.121*** (5.309)	3.966*** (3.397)	2.775*** (2.837)
MOBINC		-0.0004* (1.823)	0.00003 (0.148)	0.00002 (0.110)
MOBSUB		-3.512** (-2.320)	-3.541*** (-2.816)	-2.418** (2.434)
LMAINLINE				0.160*** (3.059)
N	286	286	239	238
R^2	0.94	0.95	0.98	0.99

Note: T-stats are shown in brackets. ***= significant at 1%. ** = significant at 5%, * = significant at 10%. A test of the significance of a time trend could not be rejected. As a result, the time trend was excluded from estimations.