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PRICE STRUCTURE AND NETWORK EXTERNALITIES IN THE TELECOMMUNICATIONS INDUSTRY: EVIDENCE FROM SUB-SAHARAN AFRICA

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Abstract

Many developing countries have experienced significant developments in their telecommunications network. Countries in Africa are no exception to this. The paper examines what factor facilitates most network expansion, using micro data from 45 fixed-line and mobile telephone operators in 18 African countries. In theory the telecommunications sector has two sector-specific characteristics: network externalities and discriminatory pricing. It is found that many telephone operators in the region use peak and off-peak prices and termination-based price discrimination, but are less likely to rely on strategic fee schedules, such as tie-in arrangements. The estimated demand function based on a discrete consumer choice model indicates that termination-based discriminatory pricing can facilitate network expansion. It also shows that the implied price-cost margins are significantly high. Thus, price liberalization could be conducive to development of the telecommunications network led by the private sector. Some countries in Africa are still imposing certain price restrictions. Importantly, however, it remains a policy issue how the authorities should ensure reciprocal access between operators at reasonable cost.

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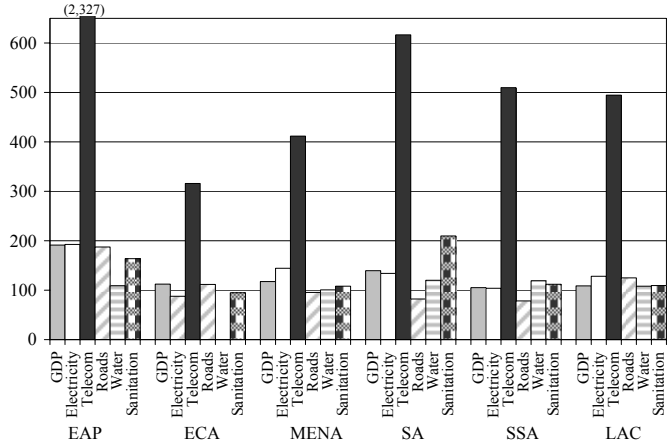
I. INTRODUCTION

The telecommunications industry is experiencing one of the most rapid and dynamic developments in developed and developing countries, owing to recent regulatory evolution and technological advance, particularly in mobile telecommunications and the Internet. Without exception, all regions have increased telecommunications service provision, compared with other infrastructure services (Figure 1).[1] Even in Sub-Saharan Africa, which has been largely lagging behind in infrastructure development, the number of subscribers to telecommunications services increased more than five times in the past 10 years, despite the levels of service access remaining very low.

Figure 1. Recent Developments in Infrastructure by Region, 1992-2002



Source: *World Development Indicators*.

However, these aggregate figures are somewhat misleading. In Africa, particularly, there are significant divergences in development of telecommunications network. As shown in Table 1, the access rates to telecommunications services do not seem to have converged across African countries. Relative to the regional average, the standard deviation of telephone penetration rates in Sub-Saharan Africa has only marginally changed. By contrast, the declining standard deviation in Latin America and Caribbean implies the

[1] In the figure, "GDP" reads GDP per capita in constant 2000 U.S. dollars; "Electricity," electric power consumption in kWh per capita; "Telecom," fixed line and mobile phone subscribers per 1,000 people; "Roads," percentage of paved roads in total; "Water," percentage of population with access to improved water sources; and "Sanitation," percentage of population with access to improved sanitation facilities. The road data are in 1999 (1990=100). The water and sanitation data are also based on 1990=100.

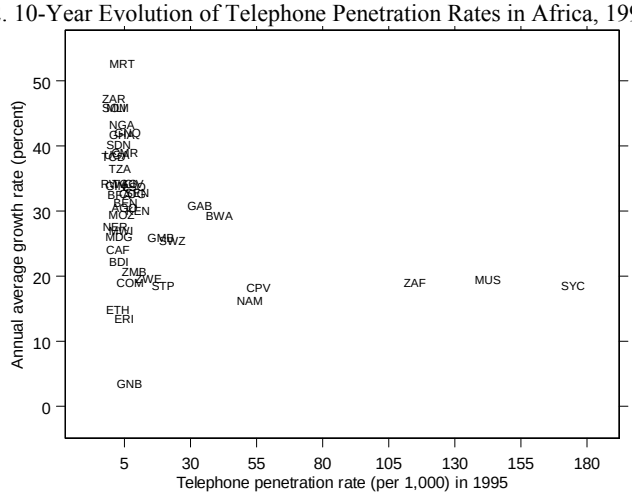
region's rapid convergence of telephone penetration rates.[2] In the past 10 years, some countries in Africa, such as the Democratic Republic of the Congo, Equatorial Guinea, Ghana, Mali, Mauritania, Nigeria and Somalia, experienced a marked improvement of telephone penetration with more than 40 percent of annual growth rates, but the growth in other countries, such as Eritrea, Ethiopia, Guinea-Bissau and Namibia, was much more moderate at less then 15 percent per annum (Figure 2). Notably, this is not simply because the initial levels of installed network were low in the former group of countries. By regional standards, the telephone penetration rates in Botswana and Gabon were not so low in 1996, but their growth has been kept relatively high at about 30 percent a year.[3] Certainly, some countries that had higher subscription rates at the initial stage are faced with quick market saturation (e.g., Namibia, South Africa, and Seychelles). There are several countries that are confronted by a serious challenge of poor initial conditions coexisting with slow growth, e.g., Eritrea, Ethiopia and Guinea-Bissau.

Table 1. Total Telephone Subscribers per 1,000 by Region, 1983-2003

	1983		1993		2003	
	Average	Std. dev.	Average	Std. dev.	Average	Std. dev.
East Asia and Pacific	94.2	121.7	174.3	191.7	573.1	568.8
Latin America and Caribbean	66.2	67.6	132.3	121.1	421.7	238.6
Sub-Saharan Africa	8.1	14.6	15.8	29.4	105.3	168.3

Source: *World Development Indicators*.

Figure 2. 10-Year Evolution of Telephone Penetration Rates in Africa, 1995-2005



Source: *International Telecommunication Union*.

[2] Africa's dynamic evolution in telecommunications provision is also evident in comparison with other infrastructure services, as illustrated by Estache (2005).

[3] Botswana's governance and institutions are among the best by regional and global standard. The quality of regulation is generally acceptable; of particular note, the Botswana Telecommunications Authority (BTA) of 1996 has been praised as one of the first independent regulatory authorities in Africa (ITU, 2001).

The current paper attempts to document recent developments in African telecommunications and examine what factors could facilitate network development in the region. Particular attention will be paid to the price structure, which has rarely been investigated in the existing literature. Aggregate data on penetration and certain standardized prices, e.g., costs of a three minute local call, are fairly available, but the fact that the pricing in the telecommunications sector is highly complex is overlooked and makes it difficult to interpret actual telecommunications prices. Moreover, it remains unknown what type of price discrimination is used on the operational level. The analysis relies on new data on the tariff structure from 45 fixed-line and mobile operators in 18 African countries, rather than using country-level aggregate data.[4] It finds that discriminatory pricing facilitates network expansion. A policy implication is straightforward: price liberalization could be conducive to developing the telecommunications network. Some countries in Africa are still imposing certain price control on telephone operators. It is also shown that the implied price-cost margins (PCM) are very high in Africa's telecommunications markets. This implies that there is a good potential for counting on private telephone companies expanding telecommunications access. However, the authorities still need to address a remaining policy issue: how to ensure reciprocal access between operators at reasonable costs.

In the African context, understanding how the telecommunications sector has been developing is particularly important to accelerate economic growth and encourage vigorous private investment in the region. The empirical growth literature indicates that the contribution of telecommunications infrastructure services to GDP is most substantial among infrastructure sectors (e.g., Easterly and Levine, 1997; Esfahani and Ramírez, 2003; Calderón and Servén, 2004).[5] In addition, telecommunications is deemed one of the infrastructures that can be led primarily by the private sector. Like other regions, the

[4] My sample includes Botswana, Ghana, Kenya, Lesotho, Malawi, Mauritius, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Uganda, and Zimbabwe.

[5] Easterly and Levine (1997) quantify the positive impact of the stock of infrastructure—including telecommunications—on economic development. Esfahani and Ramírez (2003) and Calderón and Servén (2004) address the same issue using the structural estimation and GMM techniques, respectively.

telecommunications sector attracted the majority of foreign direct investment (FDI) in Africa (Estache, 2005). In terms of levels of foreign investment, however, many African countries are still lagging behind in attracting investment even in the telecommunications sector.[6] It will be reaffirmed that further price liberalization and a sound business environment are necessary for developing commercial-based infrastructure and promoting a wave of private investment in the continent, given the evidence that a variety of pricing innovations could work effectively to improve social welfare.

Various factors potentially affect infrastructure developments; some are common across infrastructure sectors, and others are specific to telecommunications. First, geography matters in general.[7] It is intuitively plausible that population density or the concentration of population in urban areas determines the extent to which economies of scale are exhibited—thus the cost of developing the infrastructure network (Wallsten, 2001; Esfahani and Ramírez, 2003).

The regulatory frameworks and government competition policies are also expected to affect market performance; telecommunications is no exception. Privatization combined with an independent regulator is important to improve telecommunications performance (Wallsten, 2001). Not only privatization and regulation but also the sequence matters; it is shown that countries that established separate regulatory authorities prior to privatization could increase investment in telecommunications (Wallsten, 2002).

There are two other factors characteristic of the telecommunications industry: network externalities and complex price schedules. It is essentially because telecommunications services are two-sided unlike other infrastructure services. In theory the telecommunications markets must exhibit traditional (installed-base) network

[6] The Latin America and the Caribbean region attracted more than half of total foreign direct investment (FDI) in telecommunications over 1990-2003; Europe and Central Asia received about a quarter. Africa merely received about 6 percent of total FDI (World Bank, 2006).

[7] Bloom *et al.* (2003), in the empirical growth context, show that geographic variables affect economic growth particularly for countries in a low-level equilibrium. Sachs and Warner (1997) also find that in Africa the proximity of land to the coast has a positive impact on national income and a high air temperature has a negative impact.

externalities (e.g., Farrell and Saloner, 1986; Katz and Shapiro, 1994; Laffont *et al*., 1997). No one would have a telephone installed if there had been few connected numbers. Using cross-country data on the subscription rate for cellular phone services, Ahn and Lee (1999) estimate access demand for mobile networks and show that per capita GDP and the size of the existing fixed-line network increase the probability of people subscribing to mobile telephone services. Okada and Hatta (1999) also find interdependent network externalities between the mobile and ground-based telephone networks, with regional panel data on aggregate income and consumption in Japan.

The price structure of telecommunications services appears to become increasingly complicated, including peak/off-peak and multipart pricing and strategic discriminatory price schedules. In general, unregulated price competition enhances social welfare, as long as the access prices are reciprocal and reasonably low. A variety of price schedules could induce telephone subscribers to reveal their preferences and thus improve economic efficiency.[8] Termination-based discriminatory pricing, which is among the most common price mechanisms in advanced telecommunications markets, may be a powerful instrument to increase the number of telephone subscribers due to its indirect network externalities (Laffont *et al*., 1998b; Fu, 2004).[9] However, there may be a raising-each-other's-cost effect under the assumptions of the balanced calling pattern and reciprocal access pricing (Laffont *et al*., 1998a).

A structural model with micro data, rather than conventional reduced-form cross-country regressions, needs to be employed for investigating into the causality issue among income, prices and penetration. Apparently, an increase in teledensity could stimulate economic growth, because telecommunications is an important determinant of economic

[8] A simple pricing model suggests that many forms of price discrimination, such as a two-part tariff and quantity-dependent prices, work to expand the output chosen by firms, thus lowering the deadweight loss of the economy. However, price dissemination more or less transfers surplus from consumers to firms. Therefore, the resultant distributional inequality may remain open to argument. See, for instance, Pepall *et al*. (1999).

[9] It is also referred to as tariff-mediated network externalities or pecuniary externality (Economides *et al*., 1996).

productivity (Röller and Waverman, 2001).[10] On the other hand, more people could afford telecommunications services as the income level increases. Similarly, price and quantity are jointly endogenous variables (Trajtenberg, 1989; Berry, 1994; Nevo, 2001; Iimi, 2005). Many African countries have a relatively small number of telephone subscribers and considerably high tariffs together. People cannot afford telecommunications services because of high prices. At the same time, however, the existing high prices may be attributable to the current narrow installed bases. This is a typical demand-and-supply endogeneity problem.

This paper, applying a simple discrete consumer choice model, estimates the demand function for telecommunications services, which are allowed to be differentiated across telephone operators. To examine the reasons for large divergences in Africa's telecommunications development, the model mainly accounts for network externalities and the termination-based price discrimination effect. Other factors, such as demographics, regulation and market structure, are briefly discussed but not formally taken into account in the model, because these factors primarily affect supply conditions and are reflected in observed market prices. For instance, low population density would likely increase the production costs of telecommunications and thus retail prices. Monopoly and weak regulatory frameworks may also tend to result in higher prices. From the consumer perspective, however, no one makes his telephone subscription decision looking at the regulatory or market structure.

The paper is organized as follows. Section II illustrates recent telecommunications developments in Africa, based on a simple correlation analysis. Section III discusses the price discrimination practices in the region. Section IV discusses the empirical model and several econometric issues. Section V describes data to be used. Section VI then shows the estimated demand equation and the effects of price discrimination and network externalities. The implied price elasticities and price-cost margins are also computed. In

[10] Röller and Waverman (2001), using a structural and simultaneous approach, estimate the impact of telecommunications infrastructure on economic growth in favor of the causal link from infrastructure to growth. However, their analysis still relies on country-level aggregate data.

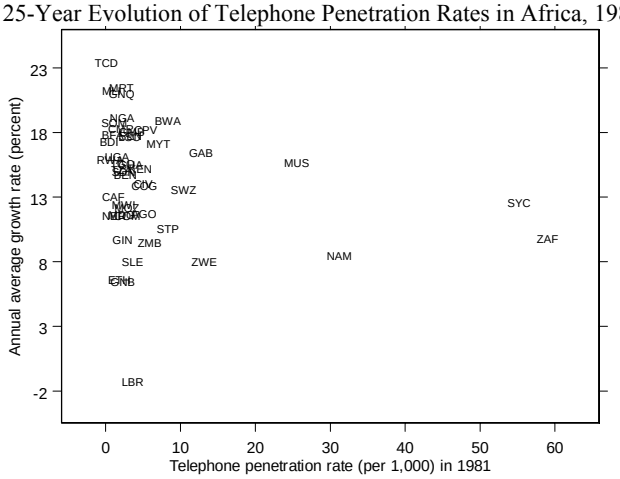
connection with actual regulatory practices in some selected countries, Section VII discusses some policy implications for telecommunications authorities in the region.

II. INFORMAL OVERVIEW OF RECENT TELECOMMUNICATIONS EVOLUTION IN AFRICA

Quantity

Many African countries have considerably improved access to telecommunications services with the regional average of teledensity increasing from 19 per 1,000 people in 1995 to about 130 in 2004.[11] However, cross-country *unconditional* convergence appears to have been weak in the region, even if the long-run data is used (Figure 3).[12] In addition to Ethiopia and Guinea-Bissau as mentioned above, Guinea, Liberia, Sierra Leone, São Tomé and Principe, Zambia, and Zimbabwe are among the countries that have suffered from poor initial penetration and relatively low growth in the long run.

Figure 3. 25-Year Evolution of Telephone Penetration Rates in Africa, 1981-2005



Source: *International Telecommunication Union*.

Mobile telecommunications can explain most of the recent telecommunications developments in Africa. While the number of mobile subscribers increased by 90 percent per annum over the last 10 years, the average growth rate of fixed-line teledensity was merely 6 percent a year (Table 2). In 2005, mobile telecommunications accounted for some 70-80 percent of total telephone subscribers in the region. In addition, such rapid growth in mobile telecommunications network was largely associated with prepaid subscription, rather than monthly contracts. In the region, notably, fixed-line and mobile

[11] The tentative figure for 2005 is about 220, when 19 countries whose data are available are considered.

[12] For several countries whose recent data are unavailable, the annual average growth rates are calculated on a shorter period basis. This treatment is applied to Liberia and Sierra Leon. Eritrea is omitted from the figure because of lack of data in the 1980s.

telecommunications may not be complements but substitutes. In fact, 15 African countries experienced negative growth of fixed-line teledensity over the past five years. This phenomenon may not be characteristics of Africa. From regional data in the Republic of Korea, Sung and Lee (2002) estimate the demand equation for new fixed-line connections, finding that the substitution effect of the rapidly growing mobile network on the conventional ground-based telephone network is significant, with estimated elasticities between -0.179 and -0.097. Rodini *et al*. (2003) also find the significant fixed-mobile substitutability, using a U.S. household survey in 2000-2001. The following empirical model will analyze substitutability between fixed-line, prepaid mobile, and contract-based mobile telecommunications services.

Table 2. Average Teledensity in Sub-Saharan Africa, 1995-2005

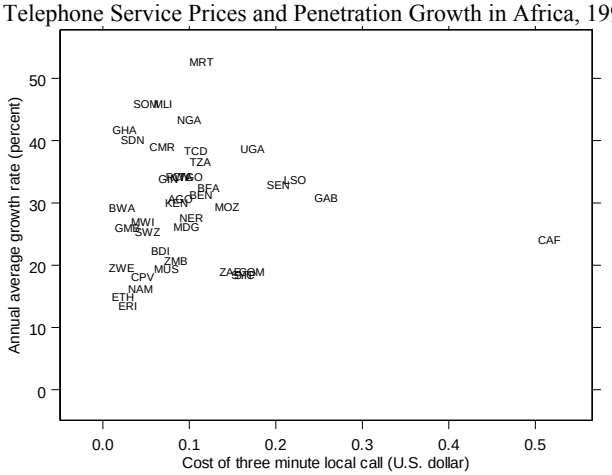
	Teledensity (per 1,000)			Annual growth (percent)	
	1995	2000	2005	1995-2005	2000-05
Total subscribers	18.6	53.5	219.0	30.0	42.1
Fixed-line	17.9	27.5	39.9	5.7	3.9
Mobile	1.5	29.0	145.6	90.7	74.0
Prepaid	0.0	13.8	124.5	…	77.4
Contract	0.7	8.8	12.1	…	15.8

Sources: *International Telecommunication Union*; and *EMC*.

Prices

It is difficult to capture the level of telecommunications prices by any single dimension. Indeed, there is no significant correlation between a standard price measured by the unit cost of a local call and penetration rate growth in Africa (Figure 4). This is possibly because the tariff structure of telecommunications services is becoming more complex with a variety of forms of price discrimination. Another reason for the weak relationship may be that price and quantity is jointly dependent on each other. The interdependency has to be solved as a system of structural equations.

Figure 4. Telephone Service Prices and Penetration Growth in Africa, 1995-2005

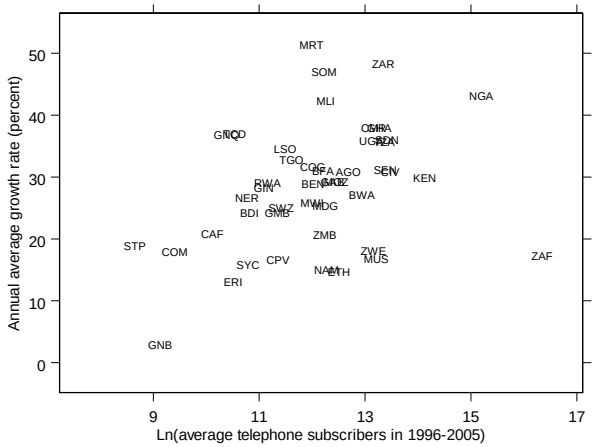


Source: *International Telecommunication Union*.

Network externalities

As expected in the traditional telecommunications sector literature, network externalities seem to play a certain role in explaining network expansion. There is a significant correlation between the absolute size of telecommunications network and its growth rate. To account for the skewness of the country-size distribution, Figure 5 takes the number of total telephone subscribers in logarithm on the horizontal axis.

Figure 5. Network Externalities of Telecommunications in Africa, 1995-2005



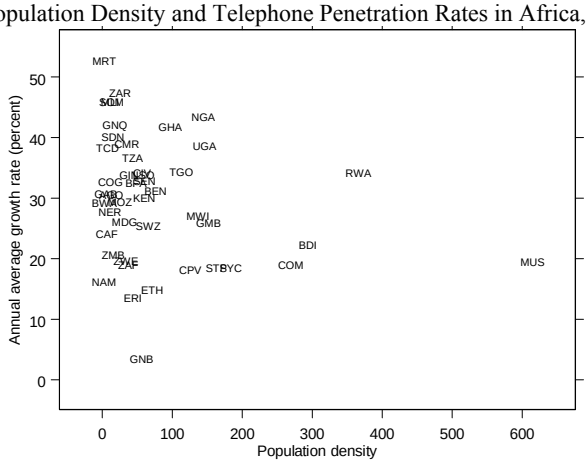
Source: *International Telecommunication Union*.

Demographics

The relationship between demographics and telephone access improvement appears to have been insignificant in Africa. Intuitively, urbanization or high population density is

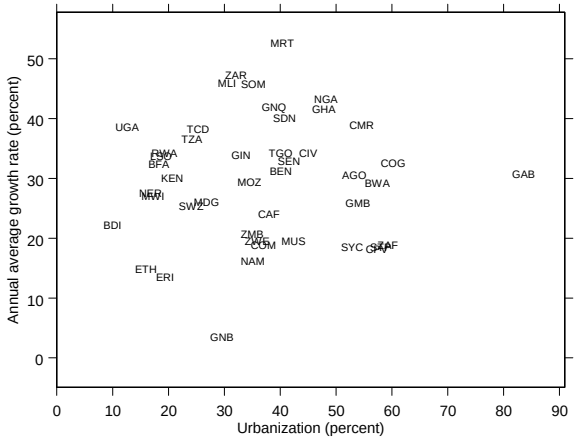
expected to allow easier and cheaper access to infrastructure, particularly telephone and electricity (Fay and Yepes, 2003). As illustrated in Figures 6 and 7, however, neither population density nor urbanization is associated with telecommunications access improvement. This is interpreted to mean that geographic conditions might become less important for network expansion when the mobile network overwhelms the ground-based telecommunications.[13]

Figure 6. Population Density and Telephone Penetration Rates in Africa, 1995-2005



Sources: *International Telecommunication Union*; and *World Development Indicators*.

Figure 7. Urbanization and Telephone Penetration Rates in Africa, 1995-2005



Sources: *International Telecommunication Union*; and *World Development Indicators*.

[13] In fact, the linear correlation between population density and the rate of total telephone penetration growth, as shown in Figure 6, is significantly negative, but the correlation with the fixed-line growth is positive, though still insignificant.

III. PRICE DISCRIMINATION PRACTICES IN AFRICA

Price differentiation and competitive pricing flexibility are potentially valuable tools for achieving adequate revenue and expanding services to the poor (World Bank, 2004). Africa is no exception to the emerging worldwide trend that telecommunications prices are increasingly differentiated at various levels. There are five price mechanisms commonly observed in the telecommunications industry, although the possible combination of some of them may make the classification more complicated at the practical level (Table 3). First, peak load pricing is a traditional instrument to redistribute demand from peak periods to off-peak periods. This rate design, which allows consumers to save their expenditure and firms to reduce capital costs, is especially important if there is a supply constraint and substantial fixed costs are required to add capacity.

Second, two-part pricing, also referred to as nonlinear pricing, is one of the most effective ways to accomplish first-degree price discrimination.[14] This pricing policy consists of a fixed membership fee that entitles consumers to purchase goods/services, and a usage fee charged for each unit the consumers buy. In the case of telecommunications, a monthly or connection fee is usually deemed the fixed part.

Third, a widely diffuse tie-in arrangement, which bundles a lump-sum fee and an option of purchasing a certain volume of goods/services, is a special case of the two-part tariff scheme to make the pricing package incentive compatible and strengthen effectiveness of discriminatory pricing for heterogeneous consumers. Bundling is very conducive to inducing consumers to self-reveal their preferences, because they can benefit from cheaper prices only if they commit themselves to make a certain number of calls or spend a certain amount of money on telecommunications each month.[15] In the telecommunications sector, a monthly fee and free-minutes are often bundled. A multiple-circuit-holders discount is a classic example of quantity-dependent pricing,

[14] For the basics of two part tariffs for infrastructure services, see Berg (1998).

[15] A fundamental problem of using second-degree discrimination is that firms cannot distinguish types of consumers. If the per-unit charge is not bundled with a fixed part of the tariff, all consumers would claim to be low-demand types and apply low-fixed charges.

which is another familiar phenomenon in many applications of second-degree price discrimination. The discount offered to consumers who keep using the same carrier over the long term can be considered an intertemporal version of quantity discounts. It is referred to as keep-them-loyal discrimination (Jensen and Waldman, 1998).

Fourth, when telephone operators have enough information to identify each group of customers, third-degree price discrimination can be implemented. There are two popular forms in the telecommunications sector: discount for business enterprises and family discount. Both types of consumers are easily identified and thus charged different unit prices.

Finally, termination-based price discrimination is particularly characteristic of the recent telecommunications industry where fixed-line and mobile operators are competing against each other. The so-called friend discount allows customers to pay cheaper tariffs of calling to pre-registered numbers on the same network. The family discount—which is applicable when more than one family member subscribe to the same telephone carrier—has the same effect as the friend discount, but it is also regarded as a form of third-decree price discrimination focusing on a particular group of customers, i.e., family.

Table 3. Typical Pricing Mechanisms in Telecommunications

Peak load pricing (peak, off-peak, and off-off-peak)
First -degree price discrimination
Two-part pricing (monthly fee and unit prices)
Second-degree price discrimination
Tie-in arrangement (bundling package with free-minutes and monthly fee)
Multiple circuits holders discount
Long-term contract discount
Third-degree price discrimination
Business discount
Family discount
Termination-based discrimination
Friend discount
On/off-net discriminatory prices

In Africa, in general many telephone companies use a relatively simple price schedule, compared with advanced economies. The role of discriminatory pricing still remains limited in the region, but both peak load pricing and termination-based price

discrimination are somewhat widely used. Based on the sample data from 45 telephone operators in 18 African countries, more than 70 percent of mobile operators employ two- or three-zone peak load pricing (Table 4).[16] Fixed-line operators are less likely to rely on peak pricing; 4 out of 10 operators are using a flat rate scheme. Note that a three-zone tariff includes peak, off-peak, and off-off-peak periods. The last is usually applicable for midnight to very early morning.

About 80 percent of mobile operators take advantage of termination-based discriminatory pricing between on- and off-net calls. All fixed-line operators differentiate the unit rate of calling to fixed-line terminations from the rate of calling to mobile terminations. This is natural because of additional access costs between the two networks. However, some mobile operators offer the same rate for intra- and inter-mode connections; they typically charge a high monthly fee and apply a flat per-unit rate to all calls, independently of their terminating networks. The adoption rates of inter-mode discrimination are 77 percent and 70 percent for prepaid and contract-based mobile carriers, respectively.

Table 4. Adoption Rates of Pricing Mechanisms in Selected African Countries

	Fixed-line (10 operators in sample)		Prepaid mobile (35 operators in sample)		Contract mobile (33 operators in sample)	
	Obs.	Diffusion rate (%)	Obs.	Diffusion rate (%)	Obs.	Diffusion rate (%)
Peak load pricing 1/						
Flat rate	4	40.0	5	14.3	9	27.3
Two-part	6	60.0	17	48.6	14	42.4
Three-part	0	0.0	13	37.1	10	30.3
Two-part pricing (monthly charges)	10	100.0	3	8.6	21	63.6
Business discount	2	20.0	5	14.3	14	42.4
Friend discount	1	10.0	10	28.6	10	30.3
Tie-in arrangement	0	0.0	1	2.9	11	33.3
On/off-net discrimination 2/	…	…	29	82.9	26	78.8
Inter-mode discrimination 2/ 3/	10	100.0	27	77.1	23	69.7

1/ Based on on-net per unit rates.
2/ Based on peak prices.
3/ Relative to on-net per unit rates.
Source: Author's calculations based on data collected through telephone operator websites.

While the two-part tariff is common for fixed-line telephone services, in mobile telecommunications the absence of monthly charges is a typical feature of prepaid services. About 65 percent of contract-based mobile operators use a two-part pricing scheme. Table 5 shows the levels of monthly and per-unit costs in the region. Many

[16] When a telephone operator has more than one billing plan/package, the cheapest one is selected. See the details in Section V.

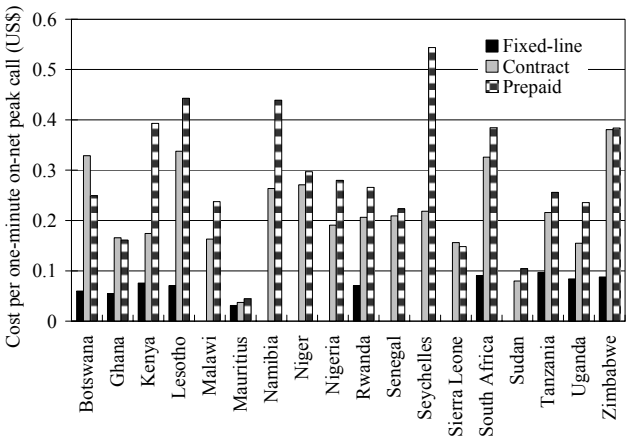
prepaid mobile services do not have the fixed part of the tariff but have significantly high unit charges, which average 27 U.S. cents per minute. This is four times as high as the average unit price of a fixed-line local call. Contract-based mobile services tend to require much high monthly charges but offer relatively low unit costs of calling to a wider range of terminations. By country, Mauritius has the lowest unit rates for any types of telecommunications services.[17] Figure 8 depicts the country-level average unit rates by network.[18] Tanzania has the highest fixed-line tariff in the sample, which is about 10 U.S. cents. While Zimbabwean contract-based mobile rate is the highest at 38 U.S. cents, Seychelles has the highest prepaid mobile unite rate of 54 U.S. cents.

Table 5. Average Monthly and Per-Unit Costs of Telecommunications in Africa

	Monthly charges (US$)		Unit cost per minute (on-net, peak; US$)	
	Mean	Std.Dev.	Mean	Std.Dev.
Fixed-line	6.013	4.400	0.072	0.020
Prepaid	0.871	3.425	0.275	0.111
Contract	8.003	9.832	0.221	0.091

Source: Author's calculations.

Figure 8. Average Per-Unit Rate by Network



Source: Author's calculations.

The diffusion rates of other strategic discriminatory prices remain low in Africa (Table 4). Contract-based mobile subscribers may have good potential for benefiting from some of discriminatory pricing. About 30 to 40 percent of contract-based mobile carriers have a

[17] This is consistent with other existing data on telecommunications prices for Mauritius. According to the World Bank (2006), the price basket for mobile services was estimated at US$4.8 per month, which is extremely low compared with other African countries, e.g., Malawi (US$20.0) and Lesotho (US$14.3).

[18] These average rates may have to be interpreted carefully, because they are calculated from only available observations in my sample. The coverage varies from country to country.

business and friend discount as well as tie-in arrangements. In the sample, there are few operators offering long-tern contracts with low fee schedules.[19] Based on the Japanese experience in the late 1990s, these forms of price discrimination diffused quickly among mobile telecommunications carriers after the telecommunications reforms—which include privatization and unbundling of the incumbent carrier, NTT, and liberalization of entry and pricing. For instance, the rate of mobile operators offering a family discount increased from 35 percent in 1996 to 97 percent in 1999 (Iimi, 2005).

The extent to which telephone operators take advantage of discriminatory pricing varies between mobile and fixed-line services. In terms of peak load pricing, mobile carriers, which are more likely to offer a peak pricing tariff than fixed-line operators, maximize the discrimination effect by increasing differentials between peak and off(-off)-peak unit rates. Some fixed-line telephone operators also differentiate between peak and off-peak prices, but the extent of differentiation is marginal. The average difference between peak and off-peak prices of fixed-line telecommunications is only about one U.S. cent, and on the other hand, the peak prices of mobile telecommunications services are on average 5 to 6 U.S. cents higher than off-peak prices. Off-off-peak prices are furthermore discounted by a couple of cents. In an extreme case, any on-net call over the midnight is free—which is offered by some of mobile carriers in Ghana and Tanzania. In cross-country comparison, the largest off-off-peak discount for fixed-line unit prices is observed in Ghana, which is about 5 U.S. cents. For contract mobile services, Botswana and Lesotho have more than 20 U.S. cents discounts for calls during off-off-peak hours. For prepaid mobile services, Namibia and Seychelles take advantage of peak pricing policies to the greatest extent, offering 27 U.S. cents discounts for off-off-peak calls.

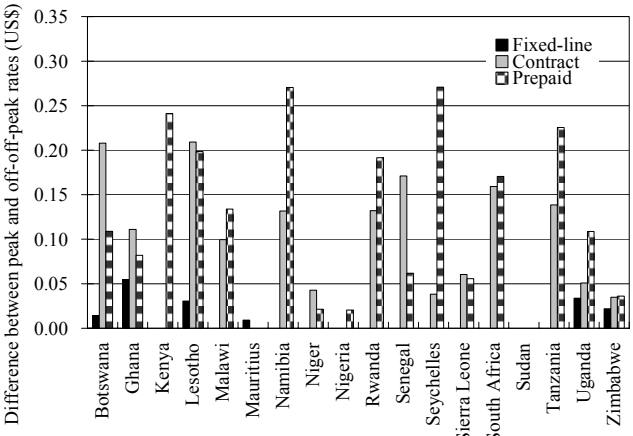
[19] This does not mean that there is no operator using keep-them-loyal-type discriminatory pricing in the African region. Some telephone operators excluded from the sample may employ such a pricing policy. In addition, benefits provided to long-term subscribers could take a variety of forms. For instance, a mobile operator in Botswana grants free handset vouchers to consumers who make a one- or two-year contract.

Table 6. Average Degree of Peak Load Pricing in Africa
(In U.S. dollar)

	Difference between peak and off-peak		Difference between peak and off-off-peak	
	Mean	Std.Dev.	Mean	Std.Dev.
Fixed-line				
On-net	0.011	0.013	0.016	0.019
To mobile	0.034	0.045	0.034	0.045
Prepaid				
On-net	0.064	0.079	0.116	0.090
Off-net	0.050	0.108	0.073	0.116
To fixed-line	0.061	0.078	0.082	0.091
Contract				
On-net	0.054	0.065	0.086	0.081
Off-net	0.059	0.075	0.068	0.078
To fixed-line	0.056	0.069	0.066	0.078

Source: Author's calculations.

Figure 9. Degree of Peak Load Pricing by Countries



Source: Author's calculations.

Regarding termination-based discriminatory pricing, first, the access charges between fixed-line and mobile networks seem to be asymmetric (Table 7). The access cost of calling from a fixed-line to a mobile telephone is much more expensive than the other direction. The possible reason is that the excessively low ground-based on-net unit rates are subsidized by the inter-mode connection fee. Second, for many mobile subscribers in the region, the unit rate of calling to a fixed-line number is lower than or equal to the cost of making an off-net mobile call. As shown in Table 7, the additional charges of calling to a fixed-line telephone number during peak hours are on average 6.1 and 5.6 U.S. cents for prepaid and monthly subscribers, respectively. On the other hand, the implied access charges of connecting to off-net telephones are 6.7 U.S. cents for both prepaid and contract-based mobile subscribers. However, this does not always hold. In Uganda, for instance, one mobile operator offers a termination-based discriminatory fee schedule in favor to inter-mode calls, but two other operators offer cheaper rates of off-net calls to

rival mobile carrier subscribers. Of particular note, several mobile carriers in Sudan, Tanzania, Uganda and Zimbabwe *partially* set cheaper rates on a mobile-to-fixed call than an on-net call.[20] Finally, in comparison between prepaid and contract mobile services, the former has a greater degree of discrimination than the latter, particularly during off- and off-off-peak hours. This means that prepaid mobile subscribers are generally paying higher prices but their on-net calls tend to be largely discounted. In this context, prepaid mobile operators appear to exploit the termination-based price discrimination scheme to the greatest extent.

At the country level, Kenyan mobile operators providing contract-based services appear to exploit the termination-based discrimination to the largest extent. Figure 10 depicts the average differentials between on- and off-net unit rates. The Kenyan differential is estimated at about 20 U.S. cents, meaning that off-net calls cost 20 U.S. cents more than on-net calls. For prepaid mobile services, the off-net rates are relatively expensive in Kenya, Mauritius and Senegal.

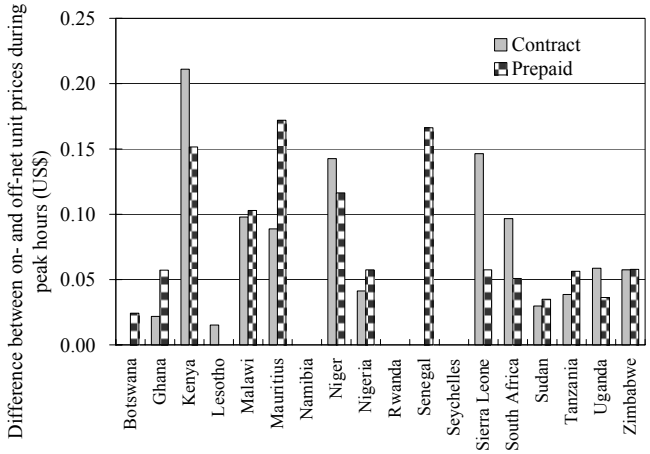
Table 7. Average Degree of Termination-Based Discriminatory Pricing in Africa

	Peak		Off-peak		Off-off-peak	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
Fixed-line						
Difference between on-net and fixed-to-mobile costs	0.146	0.068	0.122	0.058	0.128	0.059
Prepaid						
Difference between on- and off-net unit prices	0.067	0.083	0.081	0.073	0.109	0.098
Difference between on-net and mobile-to-fixed costs	0.061	0.085	0.063	0.085	0.095	0.109
Contract						
Difference between on- and off-net unit prices	0.067	0.062	0.062	0.059	0.085	0.077
Difference between on-net and mobile-to-fixed costs	0.056	0.086	0.054	0.085	0.076	0.105

Source: Author's calculations.

[20] In Zimbabwe, the unit cost of calling from a mobile to a fixed-line telephone is systematically lower than the on-net mobile unit prices.

Figure 10. Degree of Termination-Based Discriminatory Pricing by Countries



Source: Author's calculations.

IV. METHODOLOGY

Following the industrial organization literature, e.g., McFadden (1974), Trajtenberg (1989), Nevo (2001) and Ohashi (2003), the demand equation for differentiated telecommunications services is estimated by a simple discrete consumer choice model. Suppose that each telephone operator, $f = 1,\cdots,F$, produces some subset, Γ_f, of the different telecommunications subscription plans, $j = 1,\cdots,J$, in market (or country) $t = 1,\cdots,T$. Three types of plans are identified: fixed-line, prepaid mobile, and contract-based mobile telecommunications services. An *additional* consumer, $i = 1,\cdots,I$, is supposed to choose a subscription plan *j* in market *t*. Consumer choice is based on a two-stage decision making, which allows us to have flexible and plausible substitution patterns, removing strong restrictions that would be imposed in a single-stage consumer choice model (Berry, 1994; Nevo, 2000). Consumers are assumed to first choose a telephone operator and then select one contract type. The indirect utility function of consumers is written by the following conventional quasi-linear form:

$$u_{ijt} = \alpha p_{jt} + x_{jt}'\beta + \gamma \ln N_t + \xi_{jt} + \zeta_{ift} + (1-\sigma)\varepsilon_{ijt} \qquad (1)$$

where x_{jt} is a set of the observable product characteristics, and ξ_{jt} is unobservable characteristics. N_t denotes the installed-base of total telecommunications network, and thus γ captures the conventional network externality effect. ε_{ijt} is an idiosyncratic error term. All contract *j* are divided into exhaustive and mutually exclusive clusters, $\Gamma_f \in \{\Gamma_0,\cdots,\Gamma_F\}$, depending on who is the supplier.[21] ζ_{ift} is a cluster-specific error term, which is a common function of σ within a cluster Γ_f. When the product *j=0* denotes the outside option in the market, such as the choice of not consuming any telecommunications services, the only outside option belongs to cluster $\Gamma_f = \Gamma_0$.

A standard telephone charge, p_{jt}, is specified by:

[21] The current analysis ignores prepaid fixed-line telephone services. By construction, therefore, any cluster for fixed-line services is a singleton.

$$p_{jt} = \ln m_{jt} + \sum_k \lambda TS_{jt}^k \ln c_{jt}^k \quad (2)$$

Under the balanced-traffic assumption Equation (2) can be interpreted as the average tariff of contract *j* per month.[22] m_{jt} is a monthly fee, and c_{jt}^k is a unit cost of calling to a differentiated termination $k = \{Onnet, Offnet, FixedMobile\}$, when a consumer subscribes to contract *j*. There are three different terminations. On-net calls are referred to as telecommunications within the same telephone operator's network. Off-net means that a telephone call is terminated to the different operator's network within the same mode. Finally, fixed-mobile calls, denoted by *FixedMobile*, are inter-mode telecommunications. λ is a constant term representing the average number of calls people make a month. TS_{jt}^k is a cumulative share of subscribers on termination *k* from the viewpoint of consumers who are using plan *j*. Note that when a telephone operator offers a single type of service *j* in the market, the share of on-net subscribers, TS_{jt}^{Onnet}, is equal to the cumulative share of subscribers with contract *j* in total telephone users, $N_{jt} \Big/ \sum_j N_{jt}$. If a telephone operator *f* supplies both prepaid and contract-based services, the on-net market share is the sum of the two types of subscribers under the same carrier. That is, $TS_{jt}^{Onnet} = \sum_{j \in \Gamma_f} N_{jt} \Big/ \sum_j N_{jt}$, where N_{jt} denotes the number of consumers with contract *j* in market *t*.

Equation (2) can be rewritten by:

$$p_{jt} = \ln m_{jt} + \lambda \ln c_{jt}^{Onnet} + \lambda TS_{jt}^{Offnet} \Delta \ln c_{jt}^{Offnet} + \lambda TS_{jt}^{FixedMobile} \Delta \ln c_{jt}^{FixedMobile} \quad (3)$$

where $\Delta \ln c_{jt}^k \equiv \ln c_{jt}^k - \ln c_{jt}^{Onnet}$. Equation (3) implies that the level of telecommunications prices is a function of the degree of termination-based discrimination, $\Delta \ln c_{jt}^k$, and the cumulative market share of rival operators. If unit rates are not differentiated between

[22] The balanced-traffic assumption means that the percentage of calls termination on net is equal to the fraction of consumers subscribing to the network (Laffont *et al.*, 1998b).

terminations, i.e., $\Delta \ln c_{jt}^{k}$ is zero, the cumulative market share does not matter in the demand system. There is no indirect network effect, which is also referred to as tariff-mediated network externalities (Laffont *et al.*, 1998b). However, if termination-based discrimination is implemented, the tariff is perceived increasing with the rival carriers' market shares.

When ε_{ijt} is independently and identically distributed according to Type I extreme value distribution, the conventional demand share equation is derived from Equations (1) and (3) as follows:[23]

$$\begin{aligned} \ln MS_{jt} - \ln MS_{0t} = {} & \alpha_1 \ln m_{jt} + \alpha_2 \ln c_{jt}^{Onnet} + \alpha_3 TS_{jt}^{Offnet} \Delta \ln c_{jt}^{Offnet} \\ & + \alpha_4 TS_{jt}^{FixedMobile} \Delta \ln c_{jt}^{FixedMobile} + x_{jt}' \beta + \gamma \ln N_t + \sigma \ln MS_{jft} + \xi_{jt} \end{aligned} \tag{4}$$

where MS_{jt} is the market share of contract j in market t, and MS_{jft} is the within-cluster share of subscription plan j, i.e., the share of j in total subscribers under carrier f. The mean utility level of the outside alternative is normalized to zero.

To estimate Equation (4), there are three econometric issues. The first is that it is ex ante unknown whether the imposed nesting structure is valid in the current case, though the sequence of consumer decision making seems reasonable. A standard statistical test allows us to examine ex post if it fits data (Trajtenberg, 1989; Ohashi, 2003). If σ is indifferent from zero, the imposed two-stage choice structure is invalid. The demand equation could be estimated by a simple logit model. If σ is close to unity, the hypothesis that different carriers belong to the same decision tree could be rejected, meaning that cross-elasticities across carriers are zero.

In the case of the current empirical analysis, the extent to which this nesting structure makes sense varies from country to country, depending on each country's market structure. Provided that there is one mobile operator in a country, like Namibia in my

[23] See Cordell (1997) for the formal derivation.

sample, the nest may play a small role because consumers by any means have only three choices: fixed-line, prepaid mobile, and contract-based mobile. On the other hand, Nigeria and Tanzania currently have four mobile operators. In these countries, the nested decision tree with the first node for brand selection makes more sense.

The second issue is that the within market share as well as price variables are in general correlated with unobservable product characteristics in ξ_{jt}. The presence of unobserved product characteristics makes estimators crucially biased (Trajtenberg, 1989; Berry, 1994; Nevo, 2001). To deal with this problem, two types of instrument variables (IVs) are used. First, following Berry *et al*. (1995) and Nevo (2000), the mean values of product characteristics offered by other firms are employed. This is conventional instruments for differentiated products. The identification assumption is that product characteristics are mean independent of unobserved characteristics. In theory the equilibrium price is determined by the distance from neighboring products in a differentiated market. Second, the tariffs of the same subscription type in other markets are valid instruments once controlling for the product-specific means (Hausman, 1997; Nevo, 2001). The reason is that in the supply equation, the marginal cost for service *j* is common across markets, but the idiosyncratic error is uncorrelated between markets. Intuitively, this requires that there be no common demand shock across markets. In the current context, the underlying telecommunications technology—thus production cost—is likely to be the same across countries. Indeed, many telecommunications carriers in the African region are operating in more than one country. On the other hand, there is not likely to be the common demand factor over the continent, such as region-wide advertising campaigns. The four price variables are instrumented by the average monthly fee and unit rates—all peak, off-peak, on-net, and off-net rates—of the same subscription plan in other markets as well as the mean values of other product characteristics.

Finally, the third issue is the endogeneity associated with installed network size. To solve the endogeneity problem, following the earlier network externalities literature, such as Ohashi (2003), the one-year lagged number of total subscribers is taken as N_t, and TS_{jt}^{k} is also calculated based on the lagged network sizes. It means that new subscribers are

assumed to assess each network attractiveness based on the existing network in selecting a telephone subscription plan.

Under the assumption of full competition among operators, the price-cost margins (PCMs) are calculated from the estimated demand parameters. For each telephone operator *f* supplying some subset Γ_f of telecommunications service *j*, the profit function is:

$$\pi_f = \sum_{j \in \Gamma_f} (p_j - MC_j) \lambda MS_j(p) - FC_f \tag{5}$$

where MC_j and FC_f are the marginal and fixed costs of production, respectively. The first-order conditions result in the following mark up equations in the matrix expression:[24]

$$\frac{p - MC}{p} = \left(\Omega \bullet \Phi\right)^{-1} \frac{MS(p)}{p} \tag{6}$$

where Ω and Φ are both $J \times J$ matrix. Note that $\Omega \bullet \Phi$ denotes an element-by-element product of the two matrices, rather than matrix multiplication.

$$\Omega_{jr} = \begin{cases} 1 & \text{if } \exists \{r, j\} \subset \Gamma_f \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

$$\Phi = \begin{pmatrix} -\frac{\partial MS_1}{\partial p_1} & \cdots & -\frac{\partial MS_J}{\partial p_1} \\ \vdots & \ddots & \vdots \\ -\frac{\partial MS_1}{\partial p_J} & \cdots & -\frac{\partial MS_J}{\partial p_J} \end{pmatrix} \tag{8}$$

[24] For the detailed derivation, see Nevo (2001) and Ohashi (2003).

V. DATA

The sample data are collected from 45 fixed-line and mobile operators in 18 African countries. Data on the number of fixed-line telephone subscribers are available in ITU database. EMC database contains the number of mobile subscribers on an operator basis. The mobile data are also disaggregated between prepaid and monthly-based users. There is no such disaggregated data available for fixed-line subscription. The current analysis assumes that all fixed-line users are charged on a monthly payment basis, because the majority of fixed-line operators rely on the post paid contracts. However, it is noteworthy that the prepaid system is technically applicable for fixed-line services as well. In fact, there are a few cases in the sample where the prepaid fixed-line telephone services are available. For example, the Tanzania Telecommunications Company Limited (TTCL) offers both prepaid and post paid tariffs for fixed-line telecommunications.

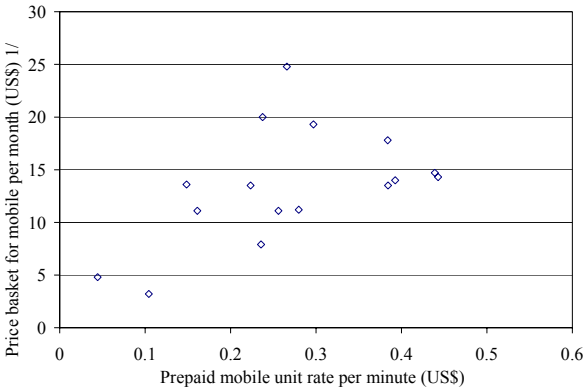
The market share MS_{jt} is calculated by dividing the net change of the number of subscribers with contract j in 2005 by the potential market size. The potential market is defined by the total population who do not subscribe to any telephone services at the beginning of the sample period. For simplicity, the potential market size is measured by total population minus total subscribers at the end of 2004.[25] In case the number of subscribers to a particular subscription plan declines, the market share is assumed to be a sufficiently small but strictly positive number. It aims to avoid the logarithm of negative numbers.

The price and produce characteristics data are collected from the websites of individual telephone operators in the region. Potentially, more than one tariff schedule may be offered by a telephone operator. If it is the case, one of the lowest packages, meaning a plan with the minimum free minutes and/or the lowest monthly fee, is taken. This criterion is not perfect to capture the whole pricing structure but is expected to help standardize heterogeneous price attributes across carriers to a certain extent. Figure 11

[25] There is no available data on gross increases/decreases in subscribers. In the Africa's context, however, it seems that few people have changed their telephone carriers.

confirms broad consistency, though far from perfect, between the collected sample price data and one of the existing comprehensive data sources for telecommunications prices (World Bank, 2006).

Figure 11. Consistency Check for Collected Price Variables



1/ Price basket for mobile is calculated based on the prepaid price for 25 calls per month spread over the same mobile network, other mobile networks and mobile to fixed calls and during peak, off-peak and weekend times. The basket also includes the price of 30 text messages per month.

Sources: World Bank (2006); and author's calculations from various telephone operator websites.

Telecommunications services are assumed to be differentiated and characterized by availability of financial schemes, such as business and friend discount and tie-in arrangements, and value-added functions such as voice mail and international roaming services. These dummy variables indicate whether such characteristics are available if a consumer chooses subscription plan *j*. It may or may not be relevant to whether subscribers are actually using those characteristics. Unfortunately, there is no product-characteristic-based quantity data available.

VI. ESTIMATION RESULTS AND POLICY IMPLICATIONS

Six IV regressions are performed; the results are shown in Table 8. First, the hypothesized nesting structure is valid. σ is significantly different from zero, and the hypothesis of σ being one is also rejected. Thus, new consumers are first selecting a favorite telephone operator and then choosing a type of subscription plan.

Second, termination-based price discrimination works effectively to increase the number of telephone subscribers, particularly in the peak and off-peak time zones. In the first column model, for instance, the price differential coefficients are both positive at about -17, meaning that a 1 percent reduction in the rival operators' market share would lead to an *additional* 0.17–0.26 percent increase in the own market share—which includes the outside option—because of *positive* indirect network externalities.[26] Given discriminated tariffs, consumers have to bear additional costs of making a call which terminates to other networks.

Although pricing flexibility including termination-based discrimination has a positive impact on network expansion, the authorities need to ensure reciprocal and cheap access between telephone operators. Otherwise, there is the danger that telephone operators might overexploit the discrimination effect to increase their own subscribers, as Laffont *et al*. (1998a) warn. In addition, if an incumbent operator can exploit indirect network externalities (or tariff-mediated network externalities) to reinforce a dominant position, the authorities may have to regulate this type of price discrimination for competition policy purposes. In this regard, there are a number of litigations in European countries. Many Latin American countries also failed to set clear interconnection policies and enforce fair interconnection rates, even though they opened and liberalized their telecommunications markets (World Bank, 2004).

[26] These indirect network externality effects are evaluated at the sample means of MS_j and $\Delta \ln c^k$. While the indirect effect through off-net price discrimination is estimated at 0.165, the effect through inter-mode discrimination is 0.258.

Third, the coefficient of monthly charges is always negative, as expected. With product-specific fixed-effects excluded from the model, the monthly fee coefficient is statistically significant ranging from -0.26 to -0.51, depending on the time zone. On the other hand, when product-specific fixed-effects are included, the coefficient associated with monthly fees becomes insignificant, and the significance of the fixed-line dummy variable is markedly improved. This can be understood to mean that fixed-line telecommunications is no longer attractive in the African region, and that such unpopularity could be largely attributable to relatively high monthly fees.

Fourth, the conventional network effect is positive but may be weak. The coefficient of the lagged number of total telephone subscribers is estimated at 0.7 to 1.3. However, only one case has a significant coefficient; with product-specific effects included in the off-peak unit rate model, the coefficient is estimated at 1.3, which is significant at the 10 percent level. This is consistent with a piece of existing evidence that direct network externalities have a limited role to play in the differentiated telecommunications market (Iimi, 2005).

Fifth, advanced price discrimination is still underutilized in Africa. Most financial schemes employed as a part of product attributes have positive but insignificant coefficients. However, the business discount scheme, which has the significant positive coefficients in several cases, may be appreciated by consumers. Despite theory, therefore, the introduction of business discount pricing could increase consumer welfare.[27] Some of the discriminatory pricing schemes—particularly tie-in arrangements and quantity-dependent pricing—may also be useful to be exploited further to enhance social welfare.[28]

[27] In theory the efficiency effects of third-degree price discrimination, including a business discount, are very ambiguous. Third-degree discrimination may amount to monopoly pricing in two or more separate markets, thus possibly deteriorating welfare (Pepall *et al*., 1999).

[28] In the case of Africa where prepaid mobile phones are a dominant telecommunications standard, some price discrimination tools may not be applicable. Moreover, if the distribution market of charge cards is informal, as it is in many African countries, the scope of price discrimination would be more limited. For instance, it may be difficult to introduce business discounts to prepaid mobile circumstances, because the business usage is not identifiable.

A potential risk of complex tariff structures is that consumers might misunderstand their own preferences and subscribe to inappropriate tariff plans. Consumers must of necessity spend a considerable amount of time to avoid such a situation, and the authorities may have to oblige telephone operators to inform their customers of the potential advantages and disadvantages of each tariff structure.

Table 8. IV Estimation Results for Termination-Based Discriminatory Effects

	Peak		Off-peak		Off-off-peak	
	(1)	(2)	(3)	(4)	(5)	(6)
σ	0.61 **	0.70 ***	0.64 **	0.71 ***	0.78 **	0.64 **
	(0.25)	(0.19)	(0.26)	(0.20)	(0.30)	(0.26)
lnMonthly	-0.08	-0.26 *	-0.15	-0.39 **	-0.02	-0.51 ***
	(0.13)	(0.14)	(0.14)	(0.15)	(0.13)	(0.16)
$\ln c^{Onnet}$	-2.98	0.26	-6.15 **	-4.63	-0.25	-0.28
	(2.57)	(2.75)	(2.75)	(2.95)	(0.63)	(0.80)
$TS^{Offnet}\Delta \ln c^{Offnet}$	-17.82 *	-3.56	-28.39 ***	-10.65	-0.31	-0.63
	(10.62)	(10.10)	(8.64)	(8.02)	(1.00)	(1.19)
$TS^{FixedMobile}\Delta \ln c^{FixedMobile}$	-17.47 *	-21.38 ***	17.70	-24.34 ***	0.70	-0.23
	(9.80)	(5.55)	(14.59)	(6.34)	(0.97)	(1.21)
lnN	1.02	0.99	1.30 *	0.92	0.74	1.05
	(0.75)	(0.74)	(0.79)	(0.78)	(0.78)	(0.95)
D(Prepaid)	4.23		3.03		1.39	
	(3.91)		(4.04)		(4.19)	
D(Fixed)	-7.02		-40.33 ***		-19.99 ***	
	(9.02)		(12.37)		(4.21)	
Business discount	3.93 *	2.97	4.05 *	3.68	0.43	1.14
	(2.43)	(2.45)	(2.40)	(2.48)	(2.22)	(2.86)
Friend discount	1.60	1.70	0.80	1.76	2.03	1.53
	(1.99)	(2.02)	(2.08)	(2.12)	(1.97)	(2.52)
Bundling	1.89	1.92	0.13	1.90	1.37	5.15
	(3.21)	(2.87)	(3.39)	(3.05)	(3.56)	(3.93)
Voice mail	-6.07 *	-7.03 **	-1.14	-6.23 *	-3.46	0.10
	(3.18)	(3.11)	(3.75)	(3.34)	(3.18)	(3.57)
International roaming	-0.21	-0.81	-3.27	-1.21	-1.48	-0.06
	(2.37)	(2.42)	(2.47)	(2.47)	(2.64)	(3.38)
Constant	-21.83 *	-16.49	-33.14 **	-24.84 **	-14.49	-30.46 **
	(12.67)	(11.45)	(13.43)	(12.39)	(11.72)	(13.14)
Obs.	78	78	78	78	78	78
R-squared	0.717	0.694	0.692	0.660	0.720	0.518
F-statistics	8.19	9.54	7.95	8.02	7.94	4.55
Ho: no termination-based discriminatory effects						
F-statistics	3.80 **	7.79 ***	5.42 ***	7.38 ***	0.76	0.16
Prob > *F*	0.028	0.001	0.007	0.001	0.474	0.852

Note: The dependent variables is the logarithm of market share; The standard errors are shown in parentheses
* 10% level significance; ** 5% level significance; and *** 1% level significance.
Source: Author's calculations.

The implied own-price elasticities are relatively high in absolute terms, compared with earlier studies. Based on the estimated parameters, the own- and cross-elasticities associated with monthly fees are calculated (Table 9). The average own elasticities are estimated at -0.26 and -0.56 for fixed-line and mobile telecommunications, respectively.[29]

[29] The price elasticities are dependent on the estimated demand parameters, α_1, and σ, as well as actual individual and within market shares (Ohashi, 2003).

Traditionally, the telephone demand is considered very inelastic and even positive, based on the prior expectation that access to the telephone network is a basic necessity for all people (Eisner and Waldon, 2001; Sung and Lee, 2002; Fu, 2004). However, it seems to be case by case. Duffy-Deno (2001) estimates the own elasticity for U.S. residential telephone services at -0.59. In the Japanese case, Okada and Hatta (1999) estimate at -1.41 and -3.96 for fixed-line and mobile, respectively. The elasticities estimated in the current paper are not negligible but more moderate than Okada and Hatta's evidence. Meanwhile, the cross-elasticities are generally low. Particularly, there is almost no cross elasticity between fixed-line and mobile demand in an economic sense. The cross-elasticity within subscription plans offered by the same telephone operator is not zero but marginal (the average is 0.025). These results are correspondent with the fact that the vast majority of telephone subscribers in the African region use prepaid mobile telecommunications services. Prepaid mobile users in Africa do not regard fixed-line telecommunications as an alternative option.

Table 9. Implied Price Elasticity

	Average	Max 1/	Min 1/
Own elasticity	-0.520	-0.883	-0.125
Fixed-line	-0.262	-0.262	-0.258
Mobile	-0.558	-0.883	-0.125
Cross elasticity			
Within-cluster	0.025	0.134	0.000
Cross-cluster	0.003	0.065	0.000
Inter-mode	0.0004	0.004	0.000

1/ In absolute terms.
Source: Author's calculations.

The implied price cost margins (PCMs) are very high. Recall that the PCMs do not tell us anything about capital investment, which is in fact the center of interest for infrastructure development. In the above model, firm-specific fixed costs have no explicit role to play. Nonetheless, these high profit margins may indicate the good change of private-sector-led telecommunications development in Africa, though greenfield investments are generally assessed as very risky in the region. For instance, suppose infrastructure capital investment is US$580 per subscriber (Benitez et al., 2002; Fay and Yepes, 2003). The more recent rule of thumb may be even lower at about US$100–200 per subscriber, given a continued cost reduction in this area. The PCMs estimated at 2.6 will yield the fact that capital investment would be recovered in about 50 months or four years, when assuming

a monthly fee is the sample mean, i.e., US$4.5.[30] It would take even more time, because the PCMs associated with future investments are likely to be lower than the current minimum profit margin, 2.6. In principle less profitable markets remain to be developed. In addition, this calculation *does* ignore non-incremental operation and maintenance costs. However, less than 10 years appear commercially acceptable. Obviously, sound business environment needs to be established for supporting long-term private investments in the telecommunications sector.

Table 10. Implied Price Cost Margins

	Average	Max	Min
Fixed-line	3.832	4.848	3.283
Mobile	3.866	7.984	2.624
Prepaid	3.820	7.984	2.624
Contract	3.914	7.980	3.092

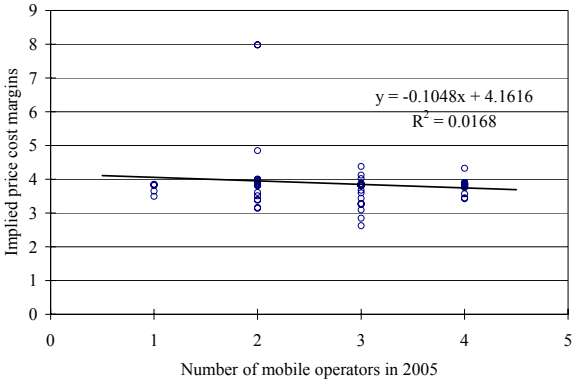
Note that there are four negative price cost margins calculated from the estimated demand paramters; those cases are excluded from the above figures.

Source: Author's calculations.

The implied PCMs appear irrelevant to the intensity of market competition (Figure 12). This is good news and bad news for policy makers. The good news is that intensified market competition does not erode the profit margins of telephone operators. Thus, more private investment in the telecommunications sector could be expected in the region. The bad news is that market competition may not be working effectively, possibly due to insufficient deregulation and explicit and implicit price control by the authorities. In theory more competition must reduce the profit margins in equilibrium, unless products/services are significantly differentiated. Thus, price and entry liberalization may need to be accelerated.

[30] This does not sound prohibitively long, given the fact that in Latin America, incumbent telecommunications operators were granted exclusivity periods of four to ten years in the 1990s (World Bank, 2004).

Figure 12: Implied Price Cost Margins and Market Competition



Source: Author's calculations.

VII. DISCUSSION

Given the fact that (termination-based) discriminatory pricing helps to achieve telecommunications network expansion, a real question to be asked from the policy point of view is how discriminatory prices are really regulated in Africa. To answer this question, a simple questionnaire survey was conducted in cooperation with regulatory authorities of sample countries; it simply asked how they regulate (i) general tariff changes, (ii) termination-based discrimination, and (iii) strategic pricing, such as "family plan." Half the sample countries replied.

The answers show that the degree of price regulation varies from country to country (Table 11).[31] While Malawi responded that there was no control in these three aspects, Seychelles prohibits termination-based discrimination and obliges operators to obtain formal approval when adopting strategic pricing. Not surprisingly, telephone operators are more likely to differentiate their tariffs based on network terminations, if price setting is more liberalized (Figure 13). While countries with tight price regulation, such as Lesotho and Seychelles, have undifferentiated tariffs, those who more liberalized tariff setting, such as Malawi and Mauritius, tend to have larger tariff differentials between networks (also see Figure 10). Thus, price liberalization should be encouraged to expand the telecommunications network through price discrimination.

[31] In order to keep the questionnaire simple, it was not specified at what level the authorities are regulating price discrimination (e.g., tariffs before or after the connection rate). Rather, it was simply asked whether "termination-based discriminatory pricing, i.e., different tariffs between own network calls and inter-operator calls is (a) prohibited, (b) required to obtain approval from the authorities, (c) generally accepted but needs to report, or (d) not controlled. Therefore, the result may have to be interpreted with caution.

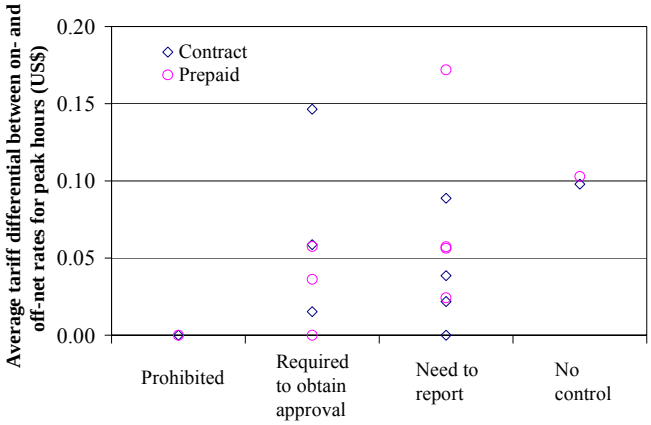
Table 11. Questionnaire Survey on Price Regulations in Selected Sample Countries

Country	Question 1	Question 2	Question 3
	General tariff changes	Termination-based discrimination	Strategic pricing, such as "family plan"
Botswana	(b)	(c)	(b)
Ghana	(b) fixed; (d) mobile	(c)	(c)
Lesotho	(b)	(b)	(c)
Malawi	(d)	(d)	(d)
Mauritius	(b)	(c)	(c)
Namibia	(c)	(e)	(e)
Seychelles	(b)	(a)	(b)
Sierra Leone	(b)	(b)	(c)
Tanzania	(c)	(c)	(d)
Uganda	(b) fixed; (c) mobile	(b)	(c)

Note that five choices are provided to Questions 2 and 3: (a) prohibited, (b) required to obtain approval from the authorities, (c) generally accepted but need to report to the authorities, (d) no control, and (e) other. For Question 1, only the last four choices are given to answerers.

Source: Author's questionnaire survey to telecommunications regulatory authorities.

Figure 13. Termination-Based Discrimination and Regulation in Selected Sample Counties



Source: Author's questionnaire survey to telecommunications regulatory authorities.

This survey result is by and large consistent with several existing data sets relevant to price regulation. First of all, at the general level, the ITU Tariff Policies database tells us that African countries are relatively likely to control mobile tariffs and unlikely to regulate fixed-to-mobile interconnection rates, compared with countries in other regions (Table 12).[32] About 45 percent of countries in Africa are controlling mobile prices. This

[32] In regional comparison Asia is most likely to have price control over mobile tariffs and interconnection rates.

is significantly high compared with North and Latin America with less than 30 percent. About 50 percent of African countries are regulating mobile-to-fixed access with price controls. The database also indicates that 4 out of 26 countries answered that domestic (local and long-distance calls and interconnection) tariffs are determined by "the state." This does *not* mean that only a small fraction of countries in the region control telecommunications prices. Rather, prices are actually regulated and determined by "independent" or "autonomous" regulatory authorities in most countries. Regulatory autonomy does not directly mean liberalized prices, but it is generally expected that more market-friendly and diverse pricing would be promoted under autonomous regulators.

Table 12. Price Control Practices by Region, 2005

	Mobile services			Access from fixed to mobile			Domestic tariff setting		
	No. of sample	With price controls	Share (%)	No. of sample	With price controls	Share (%)	No. of sample	By government	Share (%)
World	66	29	43.9	93	54	58.1	97	33	34.0
Africa	11	5	45.5	23	11	47.8	26	4	15.4
Americas	7	2	28.6	10	6	60.0	10	7	70.0
Asia	24	13	54.2	26	18	69.2	28	12	42.9
Europe	23	8	34.8	33	19	57.6	31	10	32.3
Oceania	1	1	100.0	1	0	0.0	2	0	0.0

Note that the sample data are unbalanced and that the figures may not be consistent because of possible multiple answers in the survey.

Source: ITU Tariff Policies Database.

According to another ITU database, Regulators Profile, only half of the African countries exclusively delegate the (maximum) price regulation to autonomous regulatory authorities (Table 13).[33] There are only two countries, Liberia and Mozambique, where no ceiling is imposed on telecommunications prices. In the sample countries the above econometric analysis examined, 11 out of 18 countries are curbing prices through exclusively autonomous regulators. The rest of the countries have some price controls by line ministries, which are possibly deemed relatively vulnerable to politically motivated intervention. In terms of interconnection rates, more autonomous regulators seem to have exclusive responsibility for network access supervision (Table 14).

[33] The figures in the table are subject to available data and may not reflect the latest regulatory framework of each country.

Table 13. Maximum Price Regulation in Africa, 2001-2005

	Sample countries		All in Africa	
	Obs	Share (%)	Obs	Share (%)
Not regulated	0	0.0	2	4.5
Regulated by:				
Regulatory authority	12	66.7	28	63.6
Of which, autonomous regulatory authority	11	61.1	22	50.0
Line ministry	3	16.7	9	20.5
Regulatory authority and line ministry	2	11.1	4	9.1
Regulatory authority and other ministry	1	5.6	1	2.3
Total	18	100.0	44	100.0

Source: ITU Regulatory Knowledge Centre: Regulators Profile Database.

Table 14. Interconnection Rate Regulation in Africa, 2002-2005

	Sample countries		All in Africa	
	Obs	Share (%)	Obs	Share (%)
Not regulated	0	0.0	1	3.6
Regulated by:				
Regulatory authority	12	85.7	24	85.7
Of which, autonomous regulatory authority	11	78.6	19	67.9
Line ministry	2	14.3	3	10.7
Total	14	100.0	28	100.0

Source: ITU Regulatory Knowledge Centre: Regulators Profile Database.

However, it may be questionable how to define regulatory autonomy in Africa. Among my sample countries, Uganda has been praised as its well designed regulatory authority, Uganda Communications Commission (UCC) (Shirley *et al*. 2002). However, it is not still fully independent of the ministry; the budget and commissioner appointment are approved by the line minister. In the case of Senegal, the telecommunications regulatory authority, Agence de Régulation des Télécommunications (ART), is more independent in financial and personnel terms, because ART generates its own resources absolutely from spectrum fees and the president appoints the head of the agency (ITU Regulators Profile database). The Botswana Telecommunications Authority, which is the first independent regulatory authority in the region, has also been applauded for its financial and operational independency (ITU, 2001). To the contrary, Ghana's regulatory authority, National Communications Authority (NCA), is called autonomous but may be relatively weak and subservient to the Ministry of Communications, even though its financial resources are earmarked and the head is appointed by the president (Haggarty *et al*. 2003).

Discriminatory pricing is more common when countries have autonomous regulators. Table 15 relates the price discrimination practices in my sample countries to the ITU Regulators Profile database. Although the indication of regulatory autonomy is not a perfect measure for the extent to which discriminatory pricing is allowed, the shares of

telephone operators practicing termination-based price discrimination are always higher in countries with exclusively autonomous regulators.[34] These pieces of evidence suggest that sound autonomous regulation would likely be one of the important factors facilitating diverse and discriminatory pricing, which could in turn accelerate network development through inducing consumers to reveal their preferences.

Table 15. Share of Telephone Operators Practicing Termination-Based Discrimination

	Countries with exclusively autonomous price regulators			Countries without exclusively autonomous price regulators		
	Peak	Off-peak	Off-off	Peak	Off-peak	Off-off
Fixed-line						
Difference between on-net and fixed-to-mobile costs	1.000	1.000	1.000	1.000	1.000	1.000
Prepaid						
Difference between on- and off-net unit prices	0.857	0.857	0.857	0.786	0.714	0.714
Difference between on-net and mobile-to-fixed costs	0.905	0.810	0.714	0.571	0.571	0.571
Contract						
Difference between on- and off-net unit prices	0.800	0.900	0.900	0.769	0.692	0.769
Difference between on-net and mobile-to-fixed costs	0.800	0.800	0.750	0.538	0.462	0.538

Source: Author's calculations.

[34] Regulatory authorities are considered as *exclusively autonomous* when they are called autonomous and have exclusive responsibility for regulating maximum prices in the ITU Regulators Profile database.

VIII. CONCLUSION

The paper examined what factor is the most important to develop the telecommunications network. In particular, it focused on the effect of termination-based price discrimination on network expansion, because price discrimination, in theory, induces customers to reveal their preferences and allow telephone operators to exploit more revenue opportunities.

Data from 45 fixed-line and mobile telephone operators in 18 African countries reveal that peak load pricing and termination-based discriminatory pricing are widely used. Advanced price discrimination instruments may remain to be exploited in the future.

The estimated demand function for telecommunications services shows that traditional network externalities are very weak, but the termination-based discrimination effect is significant particularly for peak and off-peak hours. Essentially, it is found that an instantaneous reduction of 1 percent in a rival's market share would result in a 1 percent increase in own market share as a direct counterpart and an additional 0.2 percent increase due to the indirect network effect through differentiated tariffs.

To enhance access to telecommunications services and improve social welfare, discriminatory pricing has a potential to be developed. However, a significant termination-based discrimination effect, as estimated in this paper, might raise concern about the raising-each-other's-cost problem. The authorities need to deregulate telecommunications pricing carefully to encourage telephone operators to take advantage of various price mechanisms. At the same time they have to contain access charges between telephone networks at a reasonable level.

The implied price cost margins (PCMs) are very high, ranging from 2.6 to 7.9. These estimated profit margins imply that telephone operators could expect to recover their investments within the order of 5-10 years. This indicates a great possibility of the private sector developing the telecommunications network even in Africa, however, the

authorities need to maintain a sound business environment for supporting long-term private investments.

In order to facilitate price discrimination, price setting should be liberalized as promoted by some countries in the region, such as Malawi and Mauritius. However, whether to adopt differentiated tariffs defers to individual operators' decisions. In any case, the opportunities should be enhanced up front. The evidence indicates that telephone carriers are willing to take advantage of the opportunities. This positive discrimination effect may be expedited by establishing an independent regulatory authority.

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