Mobile Phones and Economic Development in Africa

Jenny C. Aker and Isaac M. Mbiti

Abstract

We examine the growth of mobile phone technology over the past decade and consider its potential impacts upon quality of life in low-income countries, with a particular focus on sub-Saharan Africa. We first provide an overview of the patterns and determinants of mobile phone coverage in sub-Saharan Africa before describing the characteristics of primary and secondary mobile phone adopters on the continent. We then discuss the channels through which mobile phone technology can impact development outcomes, both as a positive externality of the communication sector and as part of mobile phone-based development projects, and analyze existing evidence. While current research suggests that mobile phone coverage and adoption have had positive impacts on agricultural and labor market efficiency and welfare in certain countries, empirical evidence is still somewhat limited. In addition, mobile phone technology cannot serve as the "silver bullet" for development in sub-Saharan Africa. Careful impact evaluations of mobile phone development projects are required to better understand their impacts upon economic and social outcomes, and mobile phone technology must work in partnership with other public good provision and investment.

This paper is forthcoming in the *Journal of Economic Perspectives.*

Center for Global Development
www.cgdev.org

Working Paper 211
June 2010

Mobile Phones and Economic Development in Africa

Jenny C. Aker

Isaac M. Mbiti

Jenny C. Aker is Assistant Professor of Development Economics, Fletcher School and Department of Economics, Tufts University, Medford, Massachusetts, and a Non-Resident Fellow, Center for Global Development, Washington, D.C. Jenny.Aker@tufts.edu. Isaac M. Mbiti is Assistant Professor of Economics, Southern Methodist University, Dallas, Texas. IMbiti@smu.edu. We are grateful to the GSM Association, Wireless Intelligence the Financial Sector Deeping Trust of Kenya (FSD Kenya) for providing data. We also thank David Autor, Chad Jones, Michael Klein, Daniel Millimet, Delia Furtado, Heinrich Hock, Emily Oster, Andrei Shleifer, Timothy Taylor, David Weil and seminar participants at the Center for Global Development, Université d'Auvergne, the NBER Africa Project conference and Stanford University for helpful comments and suggestions. All errors are our own.

CGD is grateful for contributions from the William and Flora Hewlett Foundation and the Australian Agency for International Development in support of this work.

Jenny C. Aker and Isaac M. Mbiti. 2010. "Mobile Phones and Economic Development in Africa." CGD Working Paper 211. Washington, D.C.: Center for Global Development. http://www.cgdev.org/content/publications/detail/1424175

Center for Global Development
1800 Massachusetts Ave., NW
Washington, DC 20036

202.416.4000
(f) 202.416.4050

www.cgdev.org

The Center for Global Development is an independent, nonprofit policy research organization dedicated to reducing global poverty and inequality and to making globalization work for the poor. Use and dissemination of this Working Paper is encouraged; however, reproduced copies may not be used for commercial purposes. Further usage is permitted under the terms of the Creative Commons License.

The views expressed in this paper are those of the author and should not be attributed to the board of directors or funders of the Center for Global Development.

Electronic copy available at: http://ssrn.com/abstract=1693963

Sub-Saharan Africa has some of the lowest levels of infrastructure investment in the world. Merely 29 percent of roads are paved, barely a quarter of the population has access to electricity, and there are fewer than three landlines available per 100 people (ITU, 2009; World Bank, 2009). Yet access to and use of mobile telephony in sub-Saharan Africa has increased dramatically over the past decade. There are ten times as many mobile phones as landlines in sub-Saharan Africa (ITU, 2009), and 60 percent of the population has mobile phone coverage. Mobile phone subscriptions increased by 49 percent annually between 2002 and 2007, as compared with 17 percent per year in Europe (ITU, 2008).

Mobile telephony has brought new possibilities to the continent. Across urban-rural and rich-poor divides, mobile phones connect individuals to individuals, information, markets, and services. In Mali, residents of Timbuktu are able to call relatives living in the capital city of Bamako --or relatives in France. In Ghana, farmers in Tamale are able to send a text message to learn corn and tomato prices in Accra, over 1,000 kilometers away. In Niger, day laborers are able to call acquaintances in Benin to find out about job opportunities without making the US$40 trip. In Malawi, those affected by HIV and AIDS can receive text messages daily, reminding them to take their medicines on schedule. Citizens in countries as diverse as Kenya, Nigeria and Mozambique are able to report violent confrontations via text message to a centralized server that is viewable, in real time, by the entire world.

These effects can be particularly dramatic in rural Africa, where in many places mobile phones have represented the first modern telecommunications infrastructure of any kind. Mobile phones have greatly reduced communication costs, thereby allowing individuals and firms to send

and to obtain information quickly and cheaply on a variety of economic, social and political topics. An emerging body of research shows that the reduction in communication costs associated with mobile phones has tangible economic benefits, improving agricultural and labor market efficiency and producer and consumer welfare in specific circumstances and countries (Jensen, 2007; Aker, 2008; Aker, 2010; Klonner and Nolen, 2008). As telecommunication markets mature, mobile phones in Africa are evolving from simple communication tools into service delivery platforms. This has shifted the development paradigm surrounding mobile phones from one that simply reduces communication and coordination costs to one that could transform lives through innovative applications and services.

The rapid adoption of mobile phones has generated a great deal of speculation and optimism regarding its effect on economic development in Africa. Policymakers, newspapers and mobile phone companies have all touted the poverty-eradicating potential of mobile phones (Corbett, 2008). Paul Kagame, President of Rwanda, said: "In 10 short years, what was once an object of luxury and privilege, the mobile phone, has become a basic necessity in Africa" (Connect Africa Summit, October 29, 2007). An article in the *Economist* (2008) similarly reported: "A device that was a yuppie toy not so long ago has now become a potent force for economic development in the world's poorest countries." Do such sentiments and slogans reflect the reality of the consequences of the mobile phone for economic development in Africa?

This paper first examines the evolution of mobile phone coverage and adoption in sub-Saharan Africa over the past decade. We then explore the main channels through which mobile phones can effect economic outcomes and appraise current evidence of its potential to improve economic development. We conclude with directions for future research and outline the necessary conditions for mobile phones to promote broader economic development in Africa.

Mobile Phone Coverage in Africa: What a Difference a Decade Makes

Mobile phone coverage in Africa has grown at staggering rates over the past decade. In 1999, only 10 percent of the African population had mobile phone coverage, primarily in North and South Africa (GSMA, 2009). By 2008, 60 percent of the population (477 million people) had mobile phone coverage, and an area of 11.2 million square kilometres had mobile phone service -- equivalent to the United States and Argentina combined.[1] By 2012, most villages in Africa will have coverage, with only a handful of countries – Guinea Bissau, Ethiopia, Mali and Somalia – relatively unconnected (GSMA, 2008).

There have been huge disparities in the geographic rollout of this coverage, prompting concerns over an intra-African digital divide (ITU, 2008). In 1999, most African countries had no mobile phone coverage, and only Egypt, Morocco, Senegal and South Africa had coverage rates of over 40 percent. By 2008, however, over 65 percent of the African population had access to mobile phone coverage, with 93 percent in North Africa (Algeria, Egypt, Libya, Morocco and Tunisia) and 60 percent in sub-Saharan Africa. Overall, the expansion of mobile phone coverage has been the lowest in Ethiopia, Somalia and the landlocked countries of Central and West Africa.

While the telecommunications industry in the United States, Canada and Europe invested in landlines before moving to mobile phone networks, the mobile phone has effectively leapfrogged the landline in Africa. After all, landlines require that wires be installed on every road and into every community, with smaller lines into every household. This can be prohibitively expensive, especially in countries with poor roads, vast distances and low population densities. Mobile phone coverage in

[1] For comparison, there were approximately 8.2 million fixed telephone lines in Africa in 1998, covering 1.4 percent of the population. Between 1998 and 2008, a mere 2.4 million additional landlines were installed (ITU, 2009).

sub-Saharan Africa, by contrast, is primarily provided via a network of specialized base stations, which can provide service to a 5-10 kilometer radius. Due to unreliable electricity supplies across Africa, the base stations are primarily powered by diesel generators.

What Factors Determine the Spread of Mobile Phone Coverage?

The growth of mobile phone coverage across Africa has shown a strong positive correlation with population density, but other factors matter as well. Using a spatially disaggregated dataset of mobile phone coverage and geographic characteristics, Buys, Dasgupta, Thomas and Wheeler (2009) find that the probability of having a mobile phone tower in a particular location is strongly and positively associated with potential demand factors, such as population density and per capita income, as well as the competitiveness of the mobile phone sector within the country. They also find that factors associated with higher costs – namely, higher elevation, steeper slopes, and distance from a main road and major urban centers -- are negatively associated with mobile phone coverage. Empirical evidence suggests that these factors partially explain the rollout of mobile phone service within countries as well, but depend upon the topographical features of a particular country.[2]

Adopting Mobile Phones on Less than a Dollar per Day

The rapid adoption of mobile phones in some of the poorest countries in the world has far exceeded expectations. In 1999, for example, the Kenyan-based service provider Safaricom projected that the mobile phone market in Kenya would reach three million subscribers by 2020. Safaricom, alone, currently has over 14 million subscribers (Safaricom, 2009).

[2]Detailed regression results and maps showing the spatial rollout of mobile phone coverage in Mozambique and Niger over time are available by request.

Mobile phone subscriptions on the continent have risen from 16 million in 2000 to 376 million in 2008 – or one-third of sub-Saharan Africa's population, as shown in Figure 1. However, these figures potentially overestimate the actual number of mobile phone users, because many individuals own several handsets or have multiple subscriber identity module (SIM) cards. At the same time, there could potentially be more than 376 million mobile phone users, as sharing mobile phones is a common practice in Africa.

The increase in mobile phone subscriptions is all the more surprising considering the prevalence of poverty in sub-Saharan Africa and the price of mobile phone handsets and services. Approximately 300 million Africans are classified as poor (living on less than US$1 per day), with 120 million classified as "ultra-poor" (living on less than US$0.50 per day) (IFPRI, 2007). The price of the cheapest mobile phone in Kenya, for example, costs half the average monthly income, whereas the price of cheapest mobile phone in Niger is equivalent to 12.5 kilograms of millet, enough to feed a household of five for five days.

Figure 2 shows the number of subscribers as a percentage of the population, by country. The countries are sorted in ascending order by their ranking on the UN's Human Development Index (HDI) (which combines measures of income, health and education), from 182nd (Niger) to 81st (Mauritius) (UNDP 2009). Even in those countries with a HDI ranking of lower than 160, where the GDP per capita is less than US$761 (in PPP), an average of 23 percent of the population has mobile phone subscriptions.

Who are the Mobile Phone Adopters in Africa?

Coinciding with the growth in mobile phone coverage and adoption in developing countries over the past decade, a rich body of literature has emerged examining the determinants of mobile

phone adoption. However, as Donner's (2008) survey shows, very little of this research has been conducted by economists, and economic studies of the subject have often focused on diffusion rather than individual adoption (Baliamoune-Lutz, 2003; Kshetri and Chung, 2002). The limited economics literature on mobile phone adoption appears to be related to two factors. First, mobile phone adoption data are often limited or inaccurate, as they report subscriptions rather than individual handset or subscriber identity module (SIM) ownership, which can result in serious measurement error. Second, finding credible estimation strategies to address the omitted variable bias, particularly when estimating the effect of neighbors and peers, is a significant challenge (Manski, 1993).

Despite these constraints, we use data from East Africa to gain further insights into individual and firm-level mobile phone adoption. Using firm-level data from the World Bank Enterprise Surveys for Kenya, Tanzania and Uganda, we find that a large percentage of firms had already adopted mobile phones in 2003, ranging from 83 to 93 percent. This high level of adoption appears to be correlated with the poor quality of landline services. For example, Kenyan firms reported an average of 36 days of interrupted landline service per year, with interruptions lasting an average of 37 hours. This was also the case in Tanzania and Uganda. Many firms also faced challenges in even obtaining landline service. On average, Kenyan firms had to wait 100 days to obtain landline service, with a majority of firms paying bribes to facilitate this connection. (The average bribe was reported to be worth US$117, compared with a GDP per capita of US$780). Thus, explicit and implicit landline costs could have provided powerful incentives for firms to adopt mobile phones.

While Kenyan firms rapidly adopted mobile phones, the individual adoption rate has been significantly lower. Using data from the FinAccess surveys, we examine some basic patterns of

individual mobile phone adoption in Kenya. Between 2006 and 2009, the percentage of the Kenyan population with mobile phone coverage remained relatively static, but the number of subscriptions tripled – reaching 17 million by 2009 (GSMA, 2009). The adoption of mobile phone handsets increased by 74 percent during this period, from 27 percent in 2006 to 47 percent in 2009, as shown in Table 1. One-third of Kenyans shared their mobile phones with friends or relatives, supporting qualitative evidence of free-riding and the use of mobile phones as a common property resource in sub-Saharan Africa. At the same time, such patterns could also reflect cost-sharing, especially among poorer rural households for whom the cost of handsets and services is still prohibitively expensive. For these reasons, reported data on mobile phone subscriptions could significantly underestimate the number of mobile phone users; in fact, while only 47 percent of individuals owned a phone, 80 percent reported having access to a mobile phone through direct ownership or sharing.

The first mobile phone adopters were primarily male, educated, young, wealthy and urban populations, as the initial costs of handsets and services were relatively high, as shown in Table 2. But secondary adopters span the demographic spectrum -- young and old, rich and poor, urban and rural. By 2009, mobile phone ownership included more poor, elderly and rural individuals, in part facilitated by the introduction of lower-priced handsets and lower denomination airtime cards.

Consequences of Mobile Phones for Economic Development in Africa

We identify five potential mechanisms through which mobile phones can provide economic benefits to consumers and producers in Sub-Saharan Africa. First, mobile phones can improve access to and use of information, thereby reducing search costs, improving coordination among agents and increasing market efficiency. Second, this increased communication should improve firms' productive efficiency by allowing them to better manage their supply chains. Third, mobile phones create new jobs to address demand for mobile-related services, thereby providing income-generating opportunities in rural and urban areas. Fourth, mobile phones can facilitate communication among social networks in response to shocks, thereby reducing households' exposure to risk. Finally, mobile phone-based applications and development projects—sometimes known as "m-development"—have the potential to facilitate the delivery of financial, agricultural, health and educational services. We address this final mechanism in a separate section.

In all of these cases, the evidence on mobile phones in Africa is quite recent, and so the available studies necessarily focus on specific sectors, countries, and examples. In this section, we present existing evidence. Later in the paper, we offer some thoughts about the research agenda that will unfold as mobile phones continue to spread and their medium- and long-term effects become more apparent.

How Mobile Phones can Reduce Search Costs and Improve Markets

Examples of imperfect and asymmetric information abound in markets in sub-Saharan Africa. As a result, households and firms use numerous avenues to search for information in a variety of areas: input prices, output prices, jobs, potential buyers and sellers, natural disasters, new technologies, politics, and the status of friends and family members. Traditional search mechanisms

include personal travel, radio and, to a much lesser extent, landlines, letters, newspapers and television. Of these, personal travel has often been the most common mechanism used—primarily due to limited access to other alternatives. In Niger, for example, 89 percent of grain traders surveyed preferred obtaining price information by visiting weekly grain markets, rather than listening to the weekly radio program (Aker, 2008). However, personal travel requires transport and opportunity costs, which can be relatively high with a combination of long distances and poor roads.

The rollout of mobile phones in sub-Saharan Africa over the past decade has introduced a new search technology that offers several advantages. First, mobile phones greatly reduce search costs. While mobile phones require an initial fixed cost, the variable costs associated with their use are significantly lower than equivalent travel and other opportunity costs. In Niger, for example, an average trip to a market located 65 kilometers away can take 2-4 hours roundtrip, as compared to a two-minute call. Using a local daily wage of 500 CFA francs ($1 U.S.) per agricultural laborer in Niger, mobile phones reduce search costs by 50 percent as compared with personal travel. Mobile phones can also allow people to obtain information immediately and on a regular basis, rather than waiting for weekly radio broadcasts, newspapers or letters. Furthermore, rather than being passive recipients of information, mobile phones allow individuals and firms to take an active role in the search process, enabling them to ask questions and corroborate information with multiple sources.

Finally, mobile phones are more accessible than other alternatives in terms of cost, geographic coverage and ease of use. While radios can be used across all segments of the population (over 55 percent of sub-Saharan African households listen to the radio weekly), they generally provide a limited range of information.[3] Newspapers are primarily concentrated in urban areas, are

3 Summary statistics for radio and newspaper usage are computed from the Demographic and Health Surveys (DHS) data for 20 Sub-Saharan countries.

expensive (the cost of private newspapers in Mozambique average $1 U.S.), and are inaccessible to illiterate populations. Less than 19 percent of individuals in sub-Saharan Africa read a newspaper at least once per week, with a much smaller share in rural areas. As previously discussed, landline coverage has been limited, with less than one landline subscriber per 1,000 people in 2008 (ITU, 2009). Access to other search mechanisms, such as fax machines, e-mail and internet, is similarly low, primarily due to their dependence upon landline infrastructure. On average, less than 4.2 percent of the African population has access to internet (ITU, 2009).[4]

Search theory predicts that lowering search costs for output prices will change market agents' reservation prices and increase the number of markets over which consumers and producers search (Baye, Morgan, and Scholten 2007; Reinganum, 1979; Stahl, 1989; Aker, 2008). The market equilibrium results of these models can be ambiguous, depending upon different assumptions with respect to consumers' demand and the fixed or sequential nature of search and firm cost heterogeneity (Baye, Morgan, and Scholten, 2007). Nevertheless, in general, the sequential search models of Reinganum (1979), Stahl (1989) and Aker (2008) predict that a reduction in search costs will decrease the variance of equilibrium prices, thereby improving market efficiency.[5] While improvements in information will result in net welfare gains under standard assumptions, how these gains are distributed among consumers, producers and firms is theoretically ambiguous. For example, lower search costs could improve traders' welfare in the short-term as they take advantage of spatial arbitrage opportunities, but reduce some of their welfare in the longer-term as markets approach the Law of One Price. Similarly, in markets where traders have local monopoly pricing

[4] There are a number of challenges to the development of the fixed broadband in Africa and hence internet usage. Installation of broadband internet access via Asymmetric Digital Subscriber Lines (ADSL) is constrained by the limited number of fixed telephone lines on the continent. 3G mobile cellular networks may hold greater potential for many countries in the region. For example 98 percent of Kenya's 1.7 million internet subscribers access the internet using the mobile phone network (CCK, 2009)

[5] Reinganum (1979) develops a model of sequential search and firm cost heterogeneity, whereas MacMinn (1980) develops a model of fixed sample search and firm cost heterogeneity. MacMinn (1980) shows that a reduction in search costs can increase price dispersion.

power, increased access to information could improve consumer welfare by disrupting this monopoly power, but reduce traders' welfare.

Figure 3 provides the intuition for effects of mobile phone coverage (and hence lower search costs) on price dispersion and welfare under the assumption of perfectly inelastic supply. Prior to the introduction of mobile phones, search costs are prohibitively high and traders (or farmers) do not engage in arbitrage between high (H) and low (L) production areas. Once mobile phones are introduced, traders are able to learn about prices in each region and begin trading. In the low-production region, consumers gain $A + B$ while traders lose A and gain C. This is a net gain of $B+C$, a transfer of A from producers to consumers. In the high-production region, consumers lose $D + E$, while traders gain D and lose F, representing a net loss of $E + F$ and a transfer of D from consumers to traders. The sum of consumer and producer surplus rises with the reduction in search costs – suggesting that the overall net change is positive -- but the distributional effects are ambiguous. In a market with a highly perishable commodity, such as fish or vegetables, lower search costs would also coincide with less wastage, which is Pareto-improving.

Although the evidence on Africa is quite recent, an emerging body of literature assesses the role of information technology on market efficiency in developing countries, primarily in agricultural markets (Abraham, 2007; Jensen, 2007; Aker, 2008; Aker, 2010; Muto and Yamano, 2009; Goyal, 2010). These studies primarily focus on the relationship between mobile phone coverage and specific outcomes, such as price dispersion across markets (Overa, 2006; Jensen, 2007; Aker, 2010), market agents' behavior (Aker, 2008; Muto and Yamano, 2009) and producer and consumer welfare (Jensen, 2007; Aker, 2008).

A central concern in estimating the effect of mobile phones on market efficiency is omitted variables bias, as it can be difficult to attribute changes in the outcomes of interest to mobile phone coverage rather than to unobservable factors. In addition, estimates can be subject to reverse causality, as changes in the dependent variable could influence the geographic location or speed of mobile phone coverage. To address these concerns, existing economic studies typically rely upon panel data and the quasi-experimental nature of the rollout of mobile phone service to identify the effect of mobile phones on development outcomes.

Jensen (2007) and Aker (2008, 2010) both exploit the staggered introduction of mobile phone coverage to estimate the impact of mobile phones on agricultural markets in developing countries. Examining the effect of mobile phones on the fisheries sector in Kerala, India, Jensen finds that the expansion of mobile phone coverage leads to a significant reduction in the dispersion of fish prices across markets, as well as a decline in waste. He shows that this leads to important welfare improvements for both fishermen and consumers; fishermen's profits increased by 8 percent, consumer prices declined by 4 percent and consumer surplus increased by 6 percent. With improved access to information via mobile phones, fishermen are better able to take advantage of spatial arbitrage opportunities, thereby improving allocative efficiency.

Examining the impact of mobile phones on grain markets in Niger, Aker (2010) finds that the introduction of mobile phones reduces dispersion of grain prices across markets by 10 percent. The effect is stronger for those market pairs with higher transport costs, namely, those that are farther apart and linked by poor quality roads. The effect is also stronger over time, suggesting that there are networks effects similar to those found by Brown and Goolsbee (2002). While the effect is smaller in magnitude as compared to Jensen (2007), it is perhaps more surprising, because grains are a storable commodity. The primary mechanism through which mobile phones improve market

efficiency is a change in traders' (middlemen) marketing behavior: grain traders operating in mobile phone markets search over a greater number of markets, sell in more markets and have more market contacts as compared with their non-mobile phone counterparts (Aker, 2008). Aker (2008) also finds that the introduction of mobile phones is associated with increased trader and consumer welfare. The introduction of mobile phones led to a reduction in the intra-annual coefficient of variation, thereby subjecting consumers to less intra-annual price risk. Mobile phones also increased traders' welfare, primarily by increasing their sales prices, as they were able to take advantage of spatial arbitrage opportunities. The net effect of these changes was an increase in average daily profits, equivalent to a 29 percent increase per year. However, the impacts of mobile phones upon farmers' welfare were not measured.

Muto and Yamano (2009) similarly estimate the impact of mobile phones on agricultural markets in Uganda, focusing on farmers' market participation rather than market efficiency. Using a panel dataset on farm households between 2003 and 2005, they find that mobile phone coverage is associated with a 10 percent increase in farmers' probability of market participation for bananas, although not maize, thereby suggesting that mobile phones are more useful for perishable crops.[6] This effect was greater for farmers located in communities farther away from district centers. While the authors do not empirically explore the specific mechanisms behind their results, they suggest that improved access to price information reduced marketing costs and increased farm-gate prices, increasing productive efficiency.

[6] Muto and Yamano (2009) estimate the effect of both household-level mobile phone adoption and village-level mobile phone coverage on household participation. To correct for the endogeneity of the adoption variable, the authors use village-level mobile phone coverage and household time-invariant characteristics as instruments. One of the household-level instruments used is farm assets, which could be strongly correlated with mobile phone adoption and market participation, the dependent variable. Thus, the validity of the instrument is of some concern for household-level results.

Mobile phones should similarly reduce search costs in labor markets. Labor market search theory predicts that a reduction in search costs should increase workers' reservation wage, increase the job arrival rate, and reduce unemployment. Mobile phones should therefore decrease the equilibrium dispersion of wage offers and could potentially increase equilibrium wages and productivity if they raise the reservation match quality of both employers and workers (Autor, 2001).

Klonner and Nolen (2008) assess the effect of mobile phone coverage on rural labor market outcomes in South Africa. Similar to other countries in sub-Saharan Africa, South African labor markets are characterized by low wages, high rates of under- and unemployment and significant search costs. To address the endogenous placement of mobile phone towers, the authors use topographical data as an instrument for tower placement. They find that the introduction of mobile phone coverage is associated with a 15 percent increase in employment, with most of the effect due to increased employment by women. They also find a significant shift in occupational patterns: with the availability of mobile phone coverage, employment shifts away from agricultural occupations, with no significant shifts between self-employment and wage-employment.[7]

How Mobile Phones can Improve Coordination among Firms

Information technology has the potential to increase productivity growth in Africa, especially of small-scale firms. In the literature from industrialized countries, Litan and Rivlin (2001) found that the internet improved management efficiency of U.S. firms. By improving communication between firms and their suppliers, mobile phones can enable firms to manage their supply chains

[7]The definition of self-employment used in the article differs across datasets, suggesting potential measurement error in the dependent variable. If this is measured with random error, then the coefficient will not be biased but standard errors will be larger.

more effectively, streamline their production processes and engage in new activities (Hardy, 1980; Roller and Waverman, 2001). This would reduce stock-outs and interruptions in production, which are of particular concern for small-scale firms in rural areas with limited supply options. While there are no empirical studies of the impact of mobile phones on supply-chain management in Africa, qualitative research in South Africa and Egypt suggests that mobile phones were associated with increased profits, significant time savings and improved communication with suppliers for small-scale firms (Samuel, Shah, and Handinham, 2005).

How Mobile Phones can Generate Additional Employment

One of the most direct economic impacts of mobile phones in Africa is through job creation. With an increase in the number of mobile phone operators and greater mobile phone coverage, labor demand within these sectors has increased. For example, formal sector employment in the private transport and communications sector in Kenya rose by 130 percent between 2003 and 2007 (CCK, 2008), suggesting that mobile phones have contributed to job creation.

The mobile phone sector has also spawned a wide variety of business and entrepreneurship opportunities in the informal sector. While we would expect job creation in any new growth sector, many of these employment opportunities are directly related to the specific business strategies of mobile phone companies in Africa. For example, because most Africans use pre-paid phones (or "pay as you go"), mobile phone companies had to create extensive phone credit distribution networks in partnership with the formal and informal sector.[8] Thus, small shops that have traditionally sold dietary staples and soap now sell mobile phone credit (airtime), particularly in small

[8] Mohammed Ibrahim, the Sudanese businessman who established Celtel, a pan-African mobile group now owned by Zain, stated that "Mobile phones could not work in Africa without prepaid because it's a cash society." (*The Economist*, September 24, 2009).

denominations. Young men and women are often found selling airtime cards in the streets. Numerous small-scale (and often informal) firms have also opened shops to sell, repair and charge mobile phone handsets, either using car batteries or small generators. In the early years of mobile phone usage, entrepreneurial individuals started businesses to rent mobile phones, especially in rural areas. While Klonner and Nolen (2009) suggest that mobile phone coverage has been successful in generating employment opportunities, to date, there have not been studies examining impact of mobile phones on both formal and informal job creation.

How Mobile Phones Can Reduce Risk

Sub-Saharan Africa is an inherently risky environment. Covariate shocks, such as natural disasters, conflicts and epidemics, routinely affect households. Kinship ties play both important social and economic functions in African society, specifically in creating informal insurance networks, increasing access to credit and savings and reducing risk (Grimad, 1997; de Weerdt and Dercon, 2006). At a basic level, mobile phones improve communications among members of a social network both within a country and across international boundaries. The reduction in communication costs can increase the speed of information flows within the network, thereby allowing them to respond better to shocks. Mobile phones also allow households to obtain information about potential shocks, allowing them to use such information to make planting and harvesting decisions, which can have important effects on yields (Rosenzweig and Binswanger, 1993). Finally, improved communications among members of a social network can also affect social learning, which can in turn influence the rate of technology adoption, especially of cash crops (Bandiera and Rasul, 2006; Conley and Udry, 2009). Existing economic evidence on the impacts of

mobile phones and social networks is limited, but this has been extensively discussed in the field of sociology (de Bruijn, Nyamnjoh, and Brinkman, 2009).

How Mobile Phones Can Provide Services and Innovative Development Projects

The potential for using mobile phones as a tool for economic development has not gone unnoticed by African governments, donors, mobile phone companies and non-governmental organizations. An emerging trend is the development of mobile phone-based services and products that go beyond basic voice calls and text messaging. While these services have often focused on entertainment applications ("apps") in wealthier countries, these applications are providing opportunities for disseminating agricultural price information, monitoring health care and transferring money in poorer countries. Some mobile-based services are being provided entirely by the telecommunications sector, some entirely by the public sector, and some a partnership between the two.

We do not provide a comprehensive examination of mobile phone services and development projects in Africa, but rather explore some current initiatives in key thematic areas. Many of the innovations in these contexts are quite new, and so available information focuses on emerging research in specific countries. As mobile phone networks evolve to third-generation (3G) and fourth-generation (4G) systems and more advanced yet inexpensive phones become available, the scope, sophistication and impact of mobile application and services will continually expand.

Banking the Unbanked? Mobile Money

Since 2005, mobile financial applications (known as "m-money" or "m-banking") have emerged in a variety of developing countries. The systems usually involve a set of applications that facilitate a variety of financial transactions via mobile phone, including transmitting airtime, paying bills and transferring money between individuals. There are also currently a few m-money systems in developing countries that allow international money transfers. Different institutional and business models provide these services; some are offered entirely by banks, others entirely by telecommunications providers and still others involve a partnership between a bank and a mobile phone service provider (Porteous, 2006). Most m-money systems allow the user to store value in an account accessible by the handset, convert cash in and out of the stored value account, and transfer value between users by using a set of text messages, menu commands, and personal identification numbers (PINs). A "pseudo account" can be established by purchasing "electronic money" (e-money) from an agent, usually a third party or someone who works for the mobile phone operator or bank. The user can then send e-money to another recipient with a phone, who then withdraws the e-money from their local transfer agent. Fees are generally charged for each transaction.

M-money applications have emerged in Asia, Latin America and Africa.[9] Yet the Kenyan mobile money program, M-Pesa, has received the most attention. Introduced in 2007, M-Pesa ("M" for Mobile, "Pesa" for "Money" in Swahili) is a mobile phone application that facilitates a variety of financial transactions for its users, such as purchasing airtime, transferring money and paying bills. As of September 2009, M-Pesa had 8 million subscribers and a network of 13,000 agents, with almost 40 percent of Kenyans ever having used the service to send and receive money (Table 2).

[9] A full list of countries with mobile money applications is provided at <http://www.wirelessintelligence.com/mobile-money/>.

Since its inception, the cumulative value of the money transferred via M-Pesa was over US$3.7 billion -- almost 10 percent of Kenya's annual GDP (Safaricom, 2009).

Although M-Pesa has been touted as "banking the unbanked", on average, M-Pesa users are wealthier, better educated, urban and "already banked" (Table 2). Moreover, the data suggest that most of the transfers are occurring within urban areas. M-Pesa and other m-money systems have recently transitioned from a pure money transfer system into a payment platform that allows non-governmental organizations, schools, hospitals and firms to send and receive payments.

The rapid uptake of M-Pesa and similar m-money services is not surprising when one considers the level of financial development in Kenya and in sub-Saharan Africa. Less than 30 percent of the population in East and Southern African has a formal bank account, ranging from 9 percent in Tanzania to 63 percent in South Africa (FinMark Trust, 2008). In 2006, Kenya had only 450 bank branches and 600 automatic teller machines, or less than two bank branches per 100,000 people (Vaughan, 2007). In the absence of formal financial systems, Kenyans primarily sent money by one of three mechanisms: via Western Union or post office, via intermediaries (such as bus drivers), or via friends or relatives. Wire transfers via Western Union are secure but often prohibitively expensive, and are not always available in remote rural areas. Sending money via transport services or friends and relatives is more accessible, but carries a high risk of theft. By contrast, the cost of sending 1000 Kenya Shillings (US$15) from Nairobi to the Western provinces via M-Pesa in 2008 was two-fifths the post office rate and one-fifth the cost of sending it via bus (Morawczynski 2009).

A variety of qualitative studies provide some insights into the characteristics, patterns and potential impacts of M-Pesa usage. For example, Morawczynski and Pickens (2009) find that users

often keep a balance on their M-Pesa accounts, thereby using the system as a rudimentary bank account. M-Pesa users also send smaller but more frequent remittances, suggesting that the system might allow informal insurance networks to function more effectively. Jack and Suri (2009) suggest that that the inconspicuous nature of M-Pesa transfers could allow individuals to increase their personal savings, because friends and relatives would be less likely to know about the timing or amount of transfers. Wilson, Harper and Griffith (2010) find that members of informal savings groups in Nairobi are using M-Pesa to deposit individual savings into their group account.

What are the consequences of m-money systems for economic development? A large body of theoretical and empirical literature suggests that the expansion of banking and financial systems can have significant impacts on economic growth and poverty in developing countries (Banerjee and Newman, 1993; Banerjee, 2004; Burgess and Pande, 2005; Levine, 2005). Yet many m-money systems in developing countries are not technically banking from either a financial or legal perspective: they do not provide interest on savings, facilitate access to credit from formal financial institutions, nor insure the value stored in the mobile account. Thus, such systems do not yet provide the full range of financial services required for economic development. While m-money systems have effectively expanded the breadth and reach of money transfer systems for the rural and urban poor—as well as provided a gateway to formal financial services—questions remain regarding the nature and extent of m-money's effect on the welfare of poor users in developing countries.

Other Mobile Phone Development Projects (m-Development)[10]

[10] These projects are more commonly referred to as "Information and Communication Technology for Development", or ICT4D.

In response to increases in mobile phone coverage and adoption in Africa, mobile phone-based development projects have proliferated in a variety of sectors, including agriculture, health, education, emergency response and governance. The objective, target group, and use of mobile phones in each project differ significantly, but the underlying belief is that mobile phones can offer a useful platform for providing information and services.

Health practitioners have often been at the forefront of using mobile phones as a development tool in Africa, with a variety of mobile health (m-health) projects on the continent. These projects range in variety and scope, from monitoring measles outbreaks in the Zambia, to supporting diagnosis and treatment by health workers in Mozambique, to sending health education messages in Benin, Malawi and Uganda. In Kenya, Malawi, and South Africa, mobile phones are being used to send several reminders a day to HIV-positive patients about their anti-retroviral therapy schedule, as well as allow community health workers to send information about HIV patients' status. Mobile phones are also extending the reach of medical workers and medical services. In the Democratic Republic of Congo, mothers can call a hotline to ask questions about their child's health status. Mobile phones have been used is in the collection, measurement and monitoring of health data, such as monitoring and tracking epidemics. For example, low-cost medical imaging systems have used mobile phone technology to transmit data and images to a central processor (Granot, Ivorra, and Rubinsky, 2008).

Mobile phones are facilitating access to agricultural market information, in many cases replacing the message boards and radio programs of traditional market information systems (MIS). In the Francophone countries in West Africa, for example, consumer prices for staple grains are broadcast weekly via radio for the largest markets in the country. Yet in many cases, farmers live tens of kilometers from the nearest large market and the data is up to six days old. Farmers in

countries as diverse as Niger, Senegal and Ghana can now type in a code, send a text message, and receive the price of a variety of goods immediately. Mobile phones are also extending the reach of agricultural extension services; in Kenya, Uganda and India, farmers can call or text hotlines to ask for technical agricultural advice.

Mobile phones have also been used as a regular part of election campaigns around the world, from the United States to Thailand and Spain. Yet they have served as a powerful tool to assist with election monitoring on the continent, often overcoming logistical challenges of organizing volunteers and verifying results. Prior to 2005, so called "parallel vote tabulation" (PVT) systems—an electoral observation methodology that uses a representative sample of polling stations to monitor and verify election results independently—received information from trained observers via phone calls, radio or messengers on motorbikes. In countries with limited infrastructure and communications systems, this verification process could take days, even weeks. During the elections in Ghana, 1,000 locally-trained PVT observers were able to transmit voting results via text message to a central system, resulting in almost instantaneous independent verification of the election. It has been argued that the absence of parallel vote tabulation and the timely and credible independent information it provides contributed to the post-election violence in Kenya.

Mobile phones have been used in other ways to foster good governance, mainly via voter education and citizen-based monitoring often called "crowdsourcing". Crowdsourcing—the idea of outsourcing a task to a large community or group of people—allows regular citizens to report election abnormalities and violent confrontations via text message or calls to a centralized server. In Kenya, such citizen-based monitoring was mapped via a software called "Ushahidi" ("testimony" in Swahili) to allow Kenyans to report post-election unrest via voice, text message, and Internet and to

map it, in real time, to the entire world.[11] However, such systems depend primarily upon verification by other users, which raises possible questions about their accuracy.

Simple and affordable mobile phones are being used as a means to promote literacy for adults in Africa (Aker, 2009). Despite the fact that text messages are one-seventh the price of voice calls in Niger, the use of text messages has been relatively limited, in part due to high illiteracy rates. In addition to the normal literacy curriculum, adult learners in Niger are taught where to find letters and numbers on a mobile phone and how to send and receive text messages. Within one cycle of classes, students are able to send text messages in local languages to their friends and family, thereby allowing them to practice their newly-acquired literacy skills. In a country without local language newspapers and village-level libraries, text messaging makes literacy functional. Preliminary results suggest that the mobile phone-based participants are learning faster than students in normal literacy classes, achieving levels that are 30 percent higher (Aker, 2009). Similar mobile literacy projects are starting in Senegal, and others in India are using smart phones and mobile games for children.

Mobile Phones, Economic Development and Future Research

Existing empirical evidence on the effect of mobile phone coverage and services suggests that the mobile phone can potentially serve as a tool for economic development in Africa. But this evidence, while certainly encouraging, remains limited. First, while economic studies have focused on the effects of mobile phones for particular countries and markets, there is little evidence showing

[11] More recently, Ushahidi has been used for search, rescue and recovery operations following the January 2010 earthquake in Haiti. Individuals in Haiti sent text messages to report the locations of survivors, which was then mapped and used by search and rescue teams. Additional information is available at <http://haiti.ushahidi.com/alerts>.

that this has translated into macroeconomic gains. Second, while the proliferation of mobile-based services and projects has the potential to promote economic development, there is a tendency for development agencies and donors to "jump on the information technology bandwagon" without properly assessing its effects. Consequently, we need to assess what works and what does not, potentially using impact evaluations of mobile-based projects. Finally, communications technology cannot replace investments in public goods such as education, power, roads and water—especially when access to mobile phones and services still remains out-of-reach for the poor.

Mobile Phones and Economic Growth: Are the Estimates Credible?

Existing micro- and macro-level evidence suggests that mobile phones can improve consumer and producer welfare in developing countries (Jensen 2007, Aker 2008, Klonner and Nolen 2009). Yet can mobile phones serve as an engine for economic growth? The effect of mobile phones on changes in GDP and growth, especially in sub-Saharan Africa, is still relatively unexamined. Roller and Waverman (2001) assessed the impact of telecommunications infrastructure on economic development in 21 OECD countries and found that a 10 percent increase in the telecommunications penetration rate increased economic growth by 1.5 percent. Waverman, Meschi and Fuss (2006) conducted a similar analysis in developing countries, finding that 10 percent increase in mobile penetration levels was associated with a 0.6 percent increase in growth rates.

But while these studies provide some evidence of the positive relationship between mobile phones and economic growth, they are plagued by endogeneity problems. Mobile phone penetration rates are subject to significant measurement error, leading to potential bias in the coefficient estimates. Perhaps more importantly, finding credible exogenous instruments for mobile phone penetration in the context of a cross-country growth regression is a challenge. Waverman,

Meschi and Fuss (2006) attempt to address these concerns by using lagged landline penetration as an instrument for current mobile penetration. Yet the same (unobservable) factors that caused certain countries to have high lagged landline penetration could also drive current mobile adoption and growth. This raises questions about the validity of the instrument and hence the direction of causality. If we want to identify the magnitude of the impact of mobile phones on GDP growth in Africa, more research addressing these endogeneity concerns is required. Yet to the extent that mobile phone adoption is associated with increases in consumer surplus – as the current micro-level evidence seems to suggest – changes in measured GDP will not capture the true welfare gains this technology.

A Research Agenda for Mobile Phones and Economic Development

To ascertain whether and how mobile phones can be an effective-poverty reduction tool in Africa, we need to identify our current knowledge, unanswered questions and potential areas of future research. Of the five potential mechanisms through which mobile phones could impact economic development, current research primarily focuses on the short- to medium-term effect of mobile phones on search costs, market agents' behavior, and price dispersion. This work is useful, but it is a small subset of what could and should be known. Here, we identify what we see as the primary areas of future research in the short, medium and long-term.[12]

Whereas other technologies introduced in sub-Saharan Africa – such as improved seeds, solar cook stoves and agricultural techniques – have been used to varying degrees, mobile phone adoption has occurred at a staggering rate on the continent. Yet few empirical economic studies

[12]In each of the areas discussed, there will be short- and long-term impacts. For example, while mobile phone technology improves market efficiency in the medium-term, firms and farmers may respond to this improved efficiency by adopting different production processes.

examine mobile phone adoption. This could be due to a variety of factors, including unreliable or non-existent data on individual-level adoption (leading to measurement error), the multiple economic and social benefits of mobile phones (making it difficult to assess the relevant benefits versus costs) and the impact of neighbors and peers on individual-level adoption. All of these factors make it difficult to develop an estimation strategy to circumvent omitted variables bias and the reflection problem (Manski, 1993). Nevertheless, identifying the determinants of the level and rate of mobile phone adoption in Africa can provide important insights into future demand for mobile-based services and products, as well as demand for non-mobile technologies.

While mobile phones can facilitate communication among members of social network, they also have the potential to fundamentally change the way these networks function. Both Olken (2009) and Jensen and Oster (2010) have found that new technologies—in these cases, radio and television—have had positive and negative impacts on social relationships and individuals' behavior in developing countries. Aker, Klein, O'Connell, and Yang (2010) find that the introduction of mobile phones reduces the magnitude of a "border effect" across different ethnic regions in Niger. Will mobile phones change the nature of these relationships in Africa, and if so, how? Mobile phone technology can strengthen some social networks by allowing individuals to communicate more frequently, and broaden other networks as traders and firms conduct business in new markets. At the same time, mobile phone technology could potentially weaken local social networks as individuals are able to reach beyond their inner circle to access credit and services. Understanding the effects of mobile phones on these networks—and hence households economic and social outcomes—will be of primary importance.

The impact of m-money systems on microeconomic and macroeconomic outcomes is a rich area of research, especially as these systems expand their geographic coverage and range of services.

While m-money systems have the potential to create a new class of currency as they grow in magnitude, the largest potential impact of these systems is in the area of international money transfers. The World Bank estimates that officially recorded remittance flows to developing countries reached US$338 billion in 2008, with US$21 billion in transfers to sub-Saharan Africa (World Bank, 2009). M-money transfer systems could change the duration, frequency and magnitude of these remittances, thereby affecting households' business opportunities, educational investments and income (Yang, 2008). The introduction of m-money transfers in sub-Saharan African provides a unique opportunity to measure the impact of this service on migration patterns, remittance flows and welfare outcomes.

Finally, mobile phone-based development projects are often based upon the assumption that mobile phones can improve communication, coordination and service delivery. Yet the use of mobile phone technology in these contexts may not always be Pareto-improving. Some non-governmental organizations have begun using mobile phones as a mechanism for distributing cash transfers. While this approach could be more efficient, it is not without risks: it could potentially target the wrong populations (if individuals do not have mobile phones) or increase beneficiaries' risk (if they must travel to find an agent to withdraw the cash). Furthermore, the mobile-based approach might have a lower cost-benefit ratio than the "low-tech" approach. While this provides one example, it suggests that rigorous impact evaluations of m-development projects, in some cases using randomized evaluations, are needed to determine whether, how and under what conditions mobile-based solutions are superior to their traditional counterparts.

There are two primary challenges to addressing this research agenda: data and identification. To measure the determinants of mobile phone adoption, as well as its impacts on social networks, access to financial services and remittances, reliable and accurate data at the individual, household

and village-level are needed. Yet obtaining access to mobile phone coverage and usage data, even at aggregate levels, is notoriously difficult and often bound by strict rules of non-disclosure and privacy concerns. In such cases, researchers will need to partner with mobile phone service providers and local institutions to collect such data, especially in Africa.[13] Furthermore, in the absence of quasi-experiments or randomized rollout of mobile phone coverage and services, credibly establishing causality is difficult, especially for economy-wide services such as M-Pesa. Nevertheless, as non-governmental organizations, mobile phone service providers and donors pilot new interventions, there are opportunities for researchers to partner with such organizations to use conduct evaluations of these projects using experimental or non-experimental techniques.

Mobile Phones and IT Markets

If mobile phones are to be a transformative development tool, what policies can increase their usage? As mobile phones can have positive spillovers on non-users, universal adoption is not required to generate significant benefits. But even with rapid increases in adoption over the past decade, adoption rates are still quite low in many parts of sub-Saharan Africa, ranging from 2 percent (in Ethiopia) to 98 percent (in Botswana) (Figure 1). This is partly due to the cost: the technology is still financially out of reach for about half of the continent's population. In Niger, the cost of a one-minute call off-network is US$0.38 per minute, representing 40 percent of a household's daily income. (Consumers have adapted to this situation in creative ways; individuals will "beep" or "flash" friends and family members to let them know that they want to be called).

[13] The MIT Reality Mining Project, for example, has successfully partnered with mobile phone companies and collected mobile phone usage data from users in Rwanda and Kenya.

The telecommunications regulatory environment can play a key role in fostering increased mobile phone adoption. In 1997, over 75 percent of countries in sub-Saharan Africa had no mobile phone network, while all of the existing networks were monopolies. By 2009, a mobile phone network existed in every country, with 49 percent of markets fully liberalized, 24 percent partially deregulated and 26 percent as monopolies (Figure 4). Certain countries have maintained monopolistic structures (such as the Central African Republic, Chad and Ethiopia), whereas others have tried to reestablish monopolies (including Benin, Sierra Leone and Zimbabwe).

There is a strong correlation between mobile phone coverage, the types of services offered, the price of such services, and the telecommunications market structure for a particular country. In markets with limited competition, we would expect profit-maximizing firms to offer more limited services at higher prices. GSMA (2006) found that, on average, prices decreased and services increased following market liberalization; average call prices fell by a minimum of 31 percent with partial liberalization and by up to 90 percent following full liberalization. Liberalization was also associated with an increase in international traffic volumes and improved call quality. Under monopoly conditions in Central Africa, for example, calls between Kinshasa and Brazzaville (a distance of three kilometers), were routed via London or New York. After the market was liberalized in 2006, prices between the countries plummeted and call volumes spiked (GSMA, 2006). Overall, these patterns suggest that more competitive telecommunications environments can be beneficial for poor consumers.[14]

[14] A particular government might not want to support liberalized telecommunications markets, as they could improve access to information and threaten their authority. This could be the case in certain countries in sub-Saharan Africa: 27 percent of non – democracies had a monopolistic telecommunications structure, as compared with 15 percent of democracies. (Many of the monopolies in democratic countries are island countries, where multiple carriers might not be appropriate). Yet even democracies struggle with mobile communication: In 2007, the Kenyan government briefly considered shutting down text messaging as it was being used to incite violence (Goldstein and Rotich, 2008). Democracies also had higher mobile coverage rates as compared to non-democracies: 43 percent mobile phone coverage, as compared with 31 percent for non-democracies.

Yet even if mobile phones can enhance access to resources and information, they cannot replace investments in public goods such as roads, power and water. In fact, they are less effective without them. Without roads, a trader might be able obtain better price information, but still be unable to transport goods to the market. Without power, a firm might be able to receive customer orders via mobile phone, but need to reduce its work hours due to available sunlight. In Nigeria, one mobile phone company had to deploy its own power supply using generators in its 3,600 base stations due to continuing electricity problems—burning 450 liters of diesel every second to keep its mobile towers operational. For economic development to occur, complementarity between mobile phones and these other forms of capital is needed.

Conclusion

Mobile phone usage in sub-Saharan Africa has grown significantly over the past decade and now cover 60 percent of the population. Empirical evidence shows that mobile phones have the potential to benefit consumer and producer welfare, and perhaps broader economic development.

As the prices of both handsets and airtime continue to fall, the mobile phone will complete its transformation from an elite status symbol to a necessity for adults at nearly all income levels. Indeed, mobile operators are continuing to innovate in their push to reach more subscribers. The price of handsets has also fallen and new solar powered phones have recently been introduced into the market. The challenge is now to ensure complementary access to public goods and the

development of appropriate policies to evaluate and propagate the benefits of mobile phones throughout the continent.

Acknowledgements

We are grateful to the GSM Association, Wireless Intelligence and the Financial Sector Deeping Trust of Kenya (FSD Kenya) for providing data. We thank the editors, David Autor, Chad Jones and Timothy Taylor, for extensive comments on earlier drafts. We also thank Delia Furtado, Heinrich Hock, Michael Klein, Daniel Millimet, Emily Oster, Andrei Shleifer, David Weil and seminar participants at the Center for Global Development, Université d'Auvergne, the NBER Africa Project conference and Stanford University for helpful comments and suggestions. The authors acknowledge financial support from the NBER Africa Project.

Bibliography

Abraham, Reuben. 2007. "Mobile Phones and Economic Development: Evidence from the Fishing Industry in India," *Information Technologies and International Development*, 4(1): 5-17.

Aker, Jenny C. 2008. "Does Digital Divide or Provide? The Impact of Mobile Phones on Grain Markets in Niger." *BREAD Working Paper # 177.*

Aker, Jenny C. 2009. "Mobile Phones and Economic Development in Africa." Invited presentation at the Center for Global Development, Washington, D.C. http://www.cgdev.org/doc/events/08.25.09/Cell_Phone_Survey_CGD_26aug09_Final_Public.pdf

Aker, Jenny C. Forthcoming. "Information from Markets Near and Far: The Impact of Mobile Phones on Agricultural Markets in Niger." *American Economic Journal: Applied Economics.*

Aker, Jenny C., Michael Klein, Stephen O'Connell and Muzhe Yang. 2010. "Border or Barriers? The Impact of Borders on Agricultural Markets in West Africa." *NBER Working Paper.*

Ashurst, Mark. 2001. "Africa: Now, a 'Quiet Revolution'" *Newsweek*. August 27, 2001

Autor, David. 2001 "Wiring the Labor Market" *Journal of Economic Perspectives.* 15(1): 25-40

Baliamoune-Lutz, M. 2003. "An analysis of the determinants and effect of ICT diffusion in developing countries." *Information Technology for Development.* 10: 151–169.

Bandiera, Oriana and Rasul, Imran. 2006 Social networks and technology adoption in Northern Mozambique. *The Economic Journal.* 116 (514). pp. 869-902

Burgess, Robin and Rohini Pande. 2005. "Do Rural Banks Matter? Evidence from the Indian Social Banking Experiment." *The American Economic Review*, 95(3): 780-795

Buys, Piet, Susmita Dasgupta, Timothy S. Thomas and David Wheeler. 2009. "Determinants of a Digital Divide in Sub-Saharan Africa: A Spatial Econometric Analysis of Cell Phone Coverage." *World Development.* 37(9).

Communications Commission of Kenya (CCK). 2009. *Sector Statistics Report April-June 2008/09*. Nairobi, Kenya.

Communications Commission of Kenya (CCK). 2008. *Communications Statistics Report 2008.* Nairobi, Kenya.

Communications Commission of Kenya (CCK). 2007. *Communications Statistics Report 2007/8.* Nairobi, Kenya. http://www.cck.go.ke/annual_reports/CCK_Annual_Report07-08.pdf

Conley, Timothy and Christopher Udry. 2009 Learning About a New Technology: Pineapple in Ghana, with Tim Conley. *American Economic Review.*

Corbett, Sara. 2008. "Can the Cell Phone Help End Global Poverty?" *New York Times*, April 13, 2008

de Bruijn, Mirjam, Francis Nyamnjoh and Inge Brinkman. 2009. *Mobile Phones: The New Talking Drums of Everyday Africa.* Langaa Publishers / ASC.

De Weerdt, Joachim, and Stefan Dercon. 2006 "Risk-sharing networks and insurance against illness" *Journal of Development Economics*, 81(2): 337-356

Donner, John. 2008. "Research approaches to mobile use in the developing world: a review of the literature." *The Information Society, 24*(3), 140–159.

Ewing, Jack. 2007. "Upwardly Mobile in Africa." September 11, 2007, *Business Week*.

The Economist. 2005a "Calling Across the Divide" March 10, 2005.

The Economist. 2005b "The Real Digital Divide" March 10, 2005

The Economist. 2008. "Halfway There: How to promote the spread of mobile phones among the world's poorest." May 29, 2008.

The Economist. 2009. "Mobile Marvels: A Special Report on Telecoms in Emerging Markets." September 26, 2009.

FinMark Trust. (2008*) Finscope In Africa*, 2008.
http://www.finscope.co.za/documents/2008/FSAfricaBrochure08.pdf

Foster, Andrew and Mark Rosenzweig. 1995. "Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture" *The Journal of Political Economy*. 103(6), pp. 1176-1209

Gabel, Katy. 2008. "Kenya: Low-Cost Phones Revolutionize Africa," *AllAfrica.com*, September 18, 2009.
http://allafrica.com/stories/200809180964.html

Garreau, Joel. 2008 "Our Cells, Ourselves: Planet's Fastest Revolution Speaks to The Human Heart" *Washington Post*, February 24, 2008

Goldstein, Joshua and Juliana Rotich. 2008 "Digitally Networked Technology in Kenya's 2007–2008 Post-Election Crisis" Berkman Center Research Publication No. 2008-09

Goodman, James and Ved Walia. 2007. "Airtime transfer services in Egypt." In: *The Transformational Potential of M-transactions,* Vodaphone Policy Paper Series, No.6. Online http://www.vodaphone.com/m-transactions

Goyal, Aparajita. "Information, Direct Access to Farmers and Rural Market Performance in Central India." *American Economic Journal: Applied Economics* (forthcoming).

Granot Y, Ivorra A, Rubinsky B. 2008. *A New Concept for Medical Imaging Centered on Cellular Phone Technology.* PLoS ONE 3(4): e2075. doi:10.1371/journal.pone.0002075

Grimard, Franque. 1997. "Household consumption smoothing through ethnic ties: evidence from Cote d'Ivoire" *Journal of Development Economics*. 53:2, 391-422.

Howard, Philip N and Mazaheri, N. 2009. "Telecommunications Reform, Internet Use and Mobile Phone Adoption in the Developing World", *World Development*, 37(7): 1159-1169.

Jensen, Robert. 2007. "The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector." Quarterly Journal of Economics, 122(3): 879−924.

Jensen, Robert T. and Emily Oster. 2009. "The Power of TV: Cable Television and Women's Status in India (with Robert Jensen." *Quarterly Journal of Economics.* 24(3): 1057-1094,

IFPRI. 2007. "The World's Most Deprived: Characteristics and Causes of Extreme Poverty and Hunger." *2020 Discussion Paper No. 43.* IFPRI: Washington, D.C.

International Telecommunication Union. 2003. *Trends in Telecommunication Reform 2003: Promoting Universal Access to ICTs – Practical Tools for Regulators.* Geneva: International Telecommunications Union.

International Telecommunication Union. 2007. *World Telecommunication Indicators Database.* Geneva: International Telecommunications Union.

International Telecommunication Union. 2008. *World Telecommunication Indicators Database.* Geneva: International Telecommunications Union.

International Telecommunication Union. 2009. *Information Society Statistical Profiles 2009 Africa.* Geneva: International Telecommunications Union

Jack, William and Tavneet Suri. 2009 "Mobile Money: The Economics of M-Pesa" MIT Sloan School of Management Working Paper

Jensen, Robert T. 2007. "The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector," *Quarterly Journal of Economics*, 122(3): 879 − 924.

Kamssu, A. J. 2005. Global connectivity through wireless network technology: A possible solution for poor countries. *International Journal of Mobile Communications*, 3(3): 249–262.

Klonner, Stefan and Patrick Nolen. 2008. "Does ICT Benefit the Poor? Evidence from South Africa." Unpublished mimeo.

Kshetri, N., & Cheung, M. K . 2002. "What factors are driving China's mobile diffusion?". *Electronic Markets*, 12(1):22–26.

Levine, Ross. 2005 "Finance and Growth: Theory and Evidence." in *Handbook of Economic Growth*, Eds: Philippe Aghion and Steven Durlauf, The Netherlands: Elsevier Science, 2005.

Litan, Robert and Alice Rivlin. 2001. "Projecting the Economic Impact of the Internet" *The American Economic Review Papers and Proceedings* 91(2): 313-317

Manski, Charles. 1993. "Identification of Endogenous Social Effects: The Reflection Problem." *The Review of Economic Studies.* 60(3): 531-542

Mas, Ignacio and Olga Morawczynski. 2009 "Designing Mobile Transfer Services: Lessons from M-Pesa" *Innovations.* (Forthcoming)

Mbarika, Victor and Irene Mbarika. 2006. "Africa Calling," *IEEE Spectrum*. May 2006. Online http://www.spectrum.ieee.org/telecom/wireless/africa-calling/0

McIntosh, Craig. 2009. "Tracking the Introduction of the Village Phone Product in Rwanda." forthcoming *Information Technology for International Development.*

Morawczynski, Olga. 2009. "Exploring the usage and impact of "transformational" mobile financial services: the case of M-PESA in Kenya." *Journal of Eastern African Studies*. 3(3):509-525.

Morawczynski, Olga and Mark Pickens. 2009. "Poor People Using Mobile Financial Services: Observations on Customer Usage and Impact from M-PESA" CGAP Brief Online http://www.cgap.org/gm/document-1.9.36723/BR_Poor_People_Using_Mobile_Financial_Services.pdf

Mureithi, Muriuki. 2004. "Kenya Telecommunications Sector Performance Review: 1999-2003" *Research ICT Africa Report.*

Muto, Megumi and Takashi Yamano. 2009. "The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda" *World Development.*

Minges, M. 1999. "Mobile cellular communications in the southern African region." *Telecommunications Policy*, 23(7–8): 585–593.

Olken, Benjamin. 2009. "Do Television and Radio Destroy Social Capital? Evidence from Indonesian Villages." *American Economic Journal: Applied Economics*. 1(4): 1-33

Oster, Emily and Rebecca Thornton. 2009. "Determinants of Technology Adoption: Private Value and Peer Effects in Menstrual Cup Take-Up." *NBER Working Paper Number 14828.*

Ramachandran, Vijaya. 2008. "Power and Roads for Africa." Washington, D.C.: Center for Global Development.

Roller, Lars-Hendrik and Leonard Waverman. 2001. "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach." *American Economic Review*. 91: 4, 909-923

Rosenzweig, Mark and Hans Binswanger. 1993. "Wealth, Weather Risk and the Composition and Profitability of Agricultural Investments." *The Economic Journal.* 103(416): 56-78

Rovinen, P., Yla¨-Antilla, P. 2004. "Little Finland's transformation to a wireless giant." In S. Dutta, B. Lanvin, F. Paua, (Eds.), *The global information-technology report – towards an equitable information society*. Oxford University Press with World Economic Forum: New York & Oxford.

Safaricom. 2009. *Industry Update*. March 12, 2009. http://www.safaricom.co.ke/fileadmin/template/main/downloads/investor_relations_pdf/Industry%20Update%20120309.pdf

Samuel, Jonathan, Niraj Shah and Wenona Hadingham. 2005. "Mobile Communications in South Africa, Tanzania and Egypt: Results from Community and Business Surveys in Africa: The Economic Impact of Mobile Phones." *Vodafone Policy Paper Series*, Number 3.

Stigler, George J. 1961. "The Economics of Information," *Journal of Political Economy* 69(3): 213-225.

Vaughan, Pauline. 2007. "Early lessons from the deployment of M-PESA, Vodafone's own mobile transactions service" In *The Transformational Potential of M-transactions, Vodaphone Policy Paper Series*, No.6. Online http://www.vodaphone.com/m-transactions

Vodafone. 2005. "Africa: The Economic Impact of Mobile Phones." Vodafone Policy Paper Series, Number 3, Online http://www.vodafone.com/etc/medialib/attachments/cr_downloads.Par.78351.File.tmp/GPP_SIM_paper_3.pdf

Waema, Timothy. 2007. "2007 Kenya Telecommunications Sector Review: A Supply-Side Analysis of Policy Outcomes" *Research ICT Africa Report*. Online http://www.researchictafrica.net/new/images/uploads/RIA_SPR_Kenya_07.pdf

Waverman, L., Meschi, M., Fuss, M. 2005 "The Impact of Telecoms on Economic Growth in Developing Countries" in *Africa: The Economic Impact of Mobile Phones*. Vodafone Policy Paper Series, Number 3.

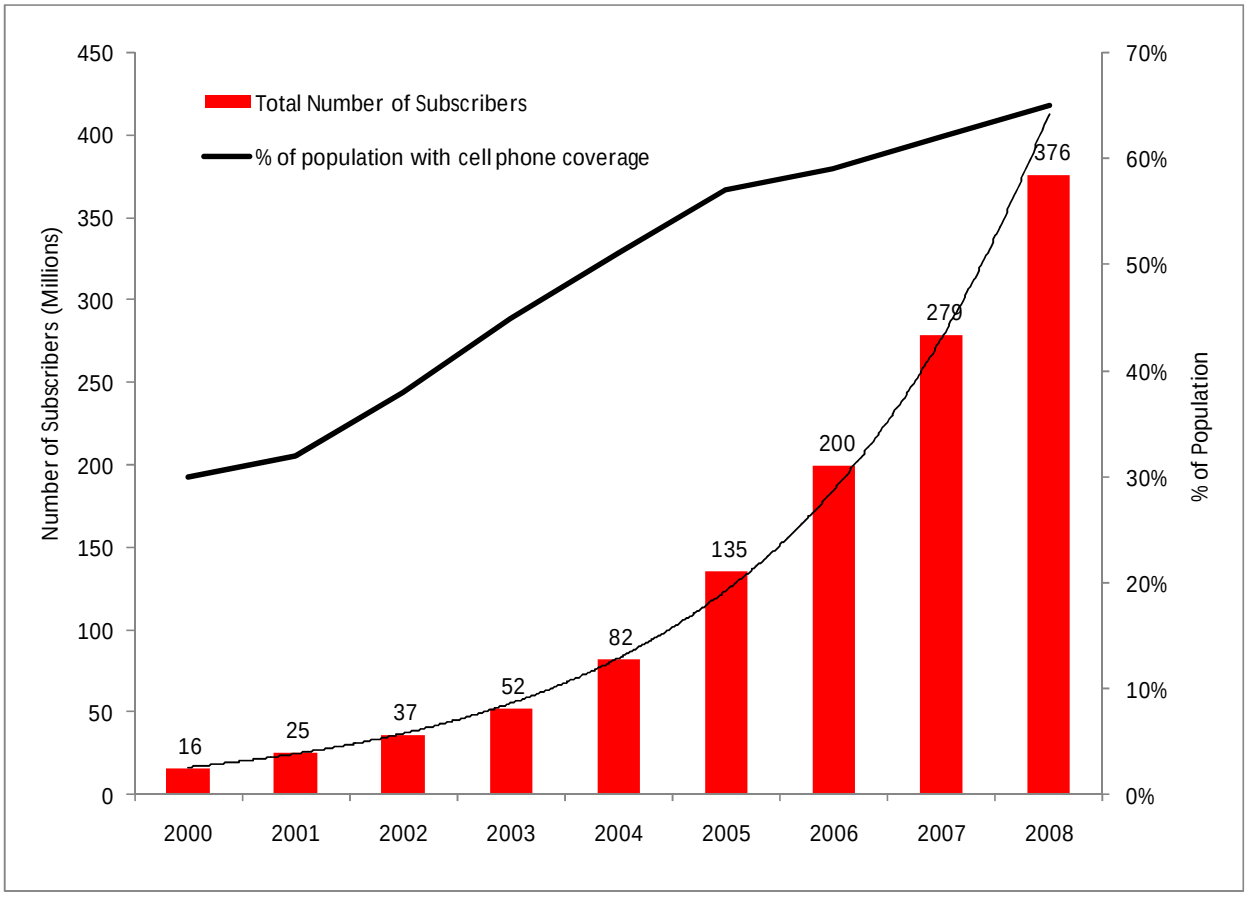
Wilson, Kimberly, Malcom Harper and Griffith. Forthcoming. *Financial Promise for the Poor: How Groups Build Microsavings*. Kumarian Press.

World Bank. 2009a. *World Development Indicators*. Washington, D.C.: World Bank. Online http://publications.worldbank.org/WDI/

World Bank. 2009b. "Migration and Remittances Trend 2009." *Migration and Development Brief 11*. World Bank: Washington, D.C.

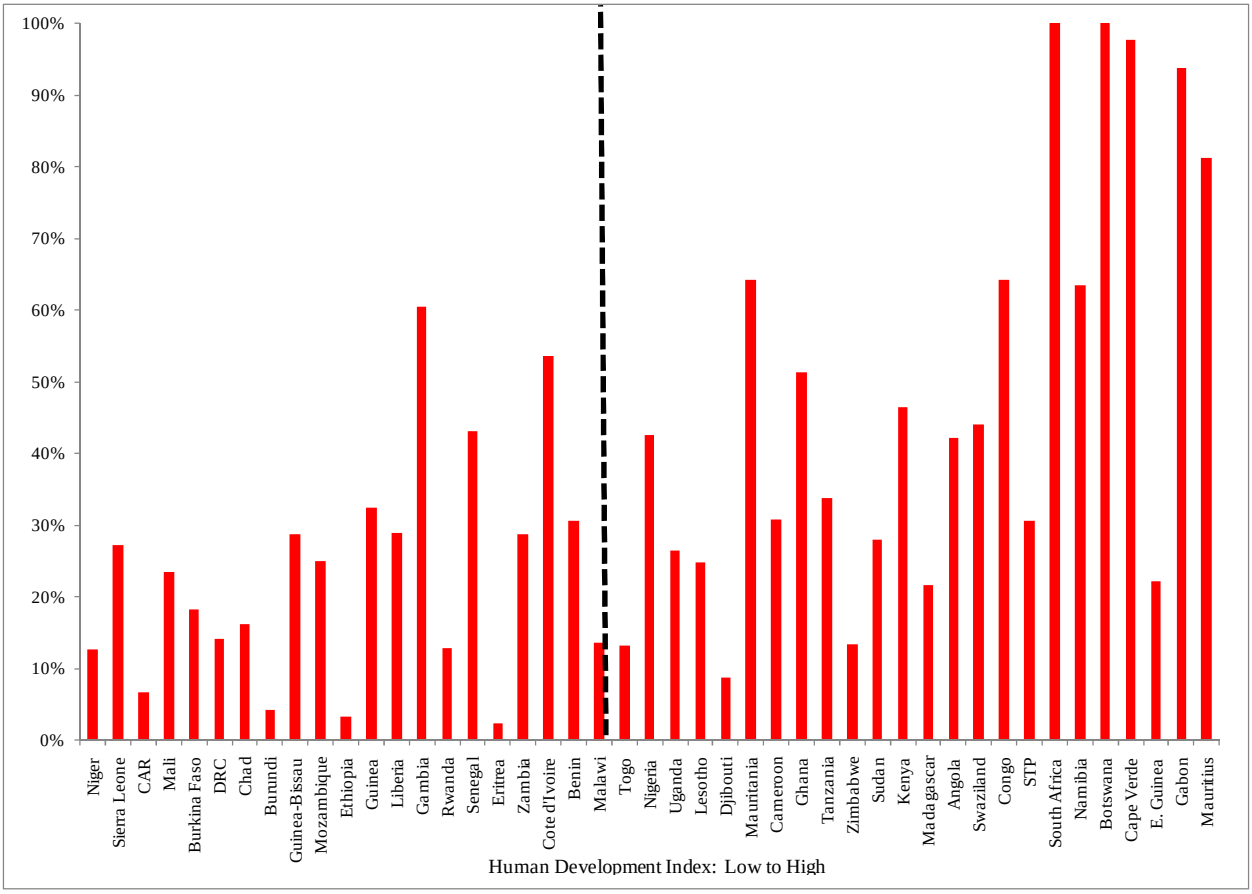
Yang, Dean. 2008. "International Migration, Human Capital, and Entrepreneurship: Evidence from Philippine Migrants' Exchange Rate Shocks". *The Economic Journal*. 118: 591–630

Figure 1. Number of Cell Phone Subscribers and Cell Phone Coverage in Africa 2000-2008



Notes : Mobile phone subscription data are provided by Wireless Intelligence. The percentage of the population with mobile phone coverage is provided by GSMA. "Mobile phone subscribers" are active SIM cards rather than individual subscribers. One individual could have multiple SIM cards for different cell phone service providers, thereby potentially inflating the total number of individual users within a particular country.

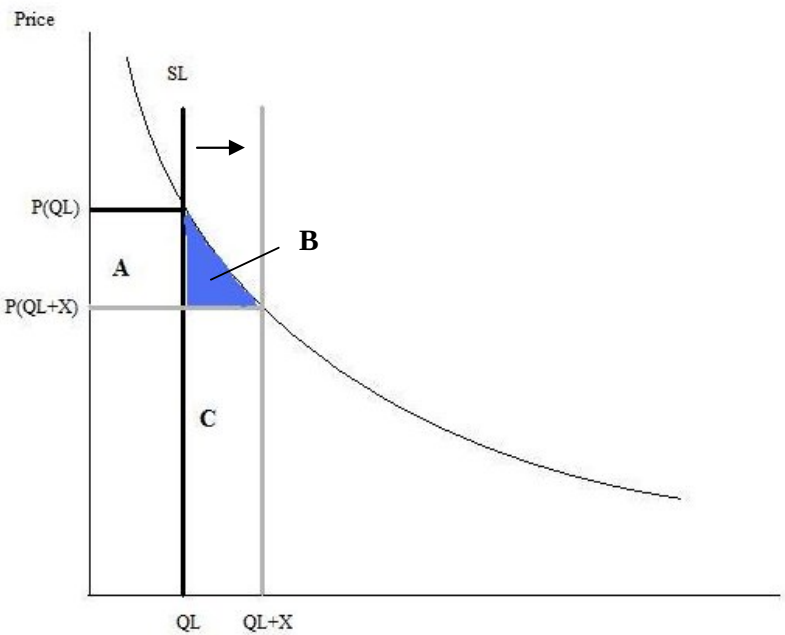
Figure 2. Number of Mobile Phone Subscribers as a Percentage of the Population 2008



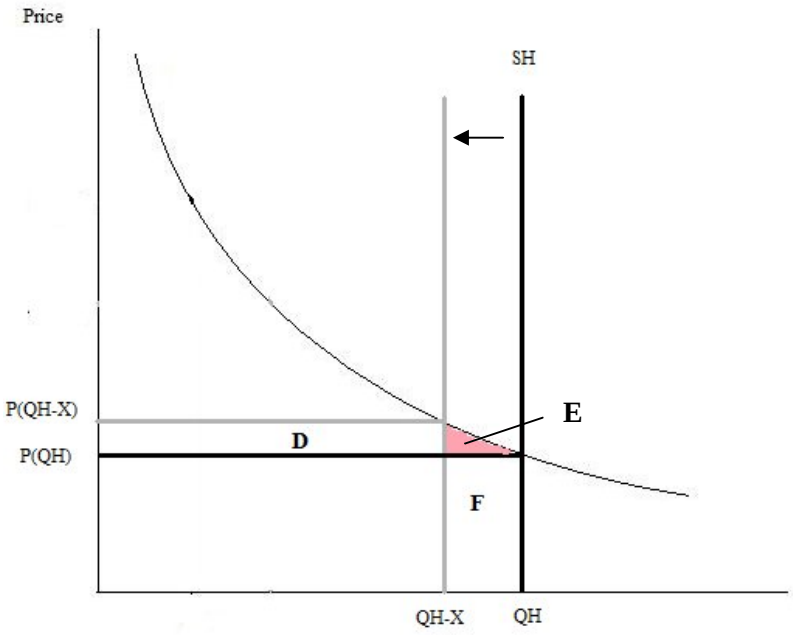
Notes: Data on the number of mobile phone subscribers by country provided by Wireless Intelligence. The graph reflects the percentage of mobile phone subscribers as a function of the total population in the country (2008). Countries are sorted (by descending order) by ranking on the UN's Human Development Index, from a high of 74 (Mauritius) to 179 (Sierra Leone).

Figure 3. Mobile Phones, Search Costs, Arbitrage and Welfare

Low Production Zone



High Production Zone



With Arbitrage

Consumers: A + B

Producers: C-A

Net Change: B+C

Transfer: A

With Arbitrage

Consumers: -D-E

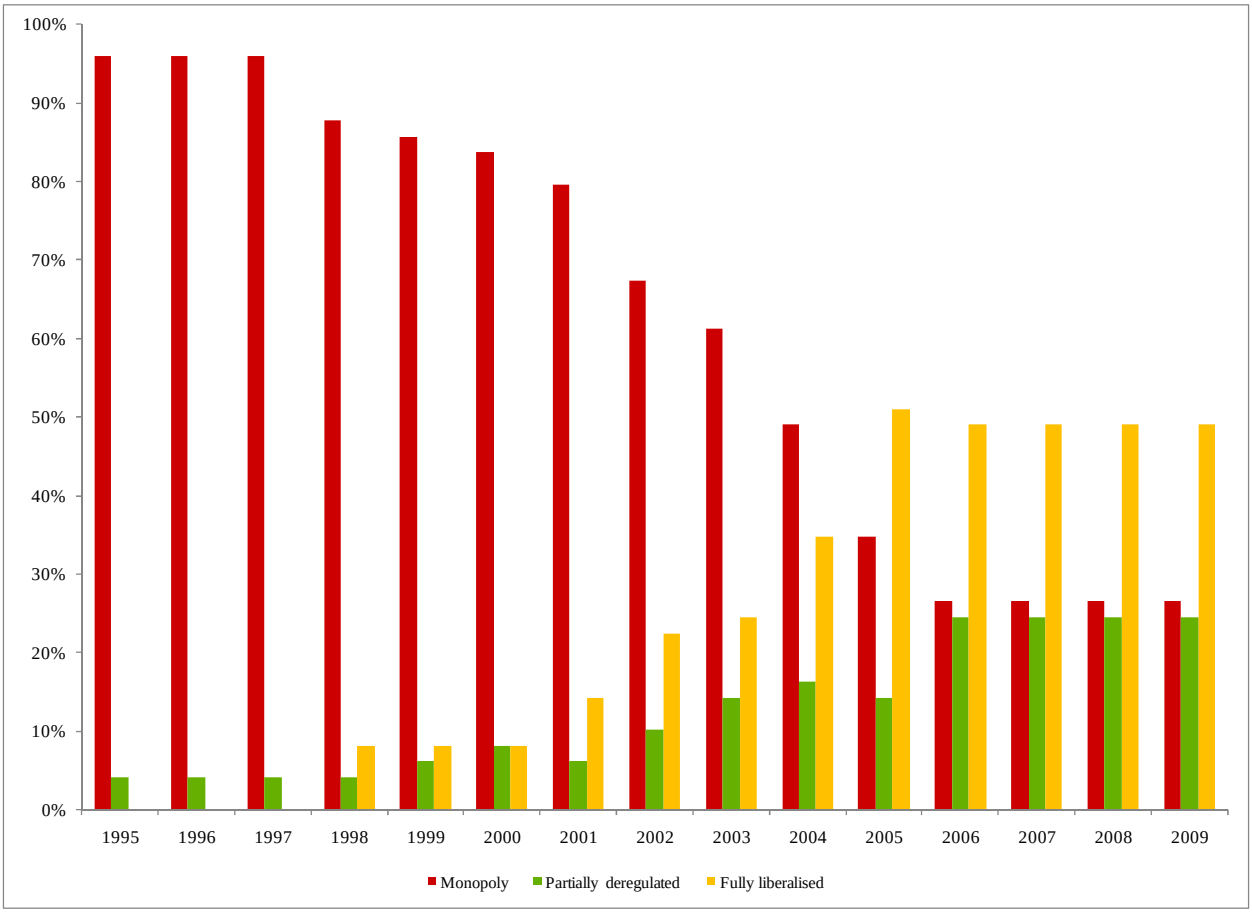
Producers: D-F

Net Change: -E-F

Transfer: D

Notes: This graph is a modification of the graph provided in Jensen (2007) and is a replication of a graphic in an earlier presentation by Jensen on the same subject.

Figure 4. Evolution of Cell Phone Market Structure in Africa, 1995-2009



Notes : Data are provided by the GSMA for various years. Monopolies are those countries whereby all international mobile traffic was through an incumbent. "Partially deregulated" are countries where markets are deregulated (but no licenses were issued) or operators must send their mobile traffic through another fixed operator. Fully Liberalized are defined as markets where market operators are granted their own international gateway licenses.

Table 1: Summary Statistics of Mobile Phone Adoption and Use in Kenya

	2006	2009
	Mean	Mean
Has Mobile Phone	0.272	0.467
Shares Mobile Phone	0.266	0.334
Has Mobile Phone Access	0.537	0.801
Has Landline	0.028	0.021
Has Multiple SIM Cards	.	0.081
Transfers Airtime	0.208	0.350
Sends Text Messages	0.292	0.411
Buys Ringtones	0.079	0.090
Uses phone to surf Web	.	0.050
Pays Bills by Phone	.	0.036
M-Pesa User	.	0.383
M-Pesa recipient	.	0.339
M-Pesa sender	.	0.291
Age 25 to 39	0.393	0.375
Age 40 to 54	0.213	0.224
Age Over 55	0.145	0.183
Male	0.440	0.413
Married	0.610	0.602
Completed Primary	0.314	0.315
Completed Secondary	0.161	0.165
Completed College	0.089	0.085
Has bank account	0.165	0.244
Urban	0.319	0.285
No of observations	4,418	6,598

Notes: Data from FinAcess 2006 and 2009 Surveys in Kenya. "-" implies that the service was not available in 2006, and therefore there were no adopters.

Table 2:Adoption and Use of Mobile Phones and M-Pesa

	Own Mobile Phone		Use M-Pesa	Receive Money with M-Pesa	Send Money with M-Pesa
	2006	2009	2009	2009	2009
Wealth					
Not poor	42.0%	64.6%	52.4%	46.0%	43.2%
Poor	7.0%	21.6%	18.7%	17.1%	9.4%
Gender					
Female	23.0%	41.6%	35.5%	32.1%	24.7%
Male	32.4%	53.9%	42.5%	36.6%	35.3%
Residence					
Rural	16.8%	35.9%	28.8%	25.9%	18.8%
Urban	49.2%	73.7%	62.2%	54.1%	54.8%
Education					
Less than primary	8.9%	22.8%	16.4%	14.1%	9.4%
At least primary school	41.1%	65.0%	55.2%	49.2%	44.3%
Age					
Under 55	29.3%	50.9%	42.4%	37.4%	32.9%
Over 55	14.5%	27.7%	20.2%	18.4%	11.9%
Financial Access					
No Bank account	18.2%	33.9%	27.5%	23.9%	17.8%
Bank account	72.7%	86.3%	71.9%	65.2%	64.0%
Sample Size	4,418	6,598	6,598	6,598	6,598

Notes: Data from FinAcess 2006 and 2009 Surveys in Kenya. "Poor" is defined as individuals in the bottom two wealth quintiles of an asset index