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The Economic Impacts of New Technologies in Africa

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[–] Abstract and Keywords

The proliferation of information and communication technologies (ICTs) presents a unique opportunity for economic development in Africa. By improving the flow of information and providing a platform for other services, ICTs have the potential to correct market failures and remove constraints to development. Whether these benefits are realized depends critically on the context in which the technology is situated, including the presence of complementary infrastructure and policies designed to foster the effective use of ICTs. This chapter provides an overview of recent trends in adoption and use of ICTs in Africa, describes a simple framework for understanding how mobile phones might affect economic development, and surveys existing empirical evidence of the impact of mobile phones on economic development in sub-Saharan Africa. It concludes with a discussion of several of the challenges and opportunities for future research in this area.

Keywords: mobile phones, information and communications technology, economic development, Africa, ICTD

1 Introduction

Since the 1960s, a variety of welfare-enhancing technologies have been introduced into developing countries, in sectors ranging from agriculture and health to medicine and energy. Few technologies, however, have spread as quickly as the mobile phone. Over the past decade, mobile phone coverage has expanded rapidly in Africa, Asia, and Latin America; from largely non-existent networks at the turn of the century to a point where over 70 percent of the population of sub-Saharan Africa is covered by the mobile network (GSMA 2013). Coinciding with this increase in mobile network coverage has been an increase in mobile phone adoption and usage: it is estimated that one-third of the population of sub-Saharan Africa has an active mobile phone subscription (GSMA 2013). Roughly 55 percent of the world's 2.3 billion mobile-broadband subscriptions are also based in developing countries, with coverage rates in Africa reaching close to 20 percent in 2014, as compared with 2 percent in 2010 (ITU 2014).

The rapid spread of the mobile phone in developing countries, and sub-Saharan Africa in particular, offers a unique opportunity for economic development. Mobile phones have significantly reduced communication and transfer costs for the rural and urban poor as compared with traditional technologies. This cost reduction may not only improve households' access to public and private information, but can also reduce the transaction costs associated with private and public transfers (Aker and Mbiti 2010). While the potential for these technologies to impact economic development is considerable, the empirical evidence of this impact is relatively recent. Existing studies have demonstrated that the magnitude and extent of impact depends critically on the context, the type of technology and the presence of other market failures.

The rest of this chapter proceeds as follows. Section 2 provides an overview of the growth in mobile phone

coverage and adoption in sub-Saharan Africa and discusses some of the determinants of technology adoption. Building upon the work of Aker and Mbiti (2010), Section 3 provides a simple framework for understanding how mobile phones might affect economic development, both as a communications device and as a platform for other phone-based services. Section 4 surveys existing empirical evidence of the impact of mobile phones on economic development in sub-Saharan Africa, and Section 5 describes several promising areas of ongoing and future research. Section 6 concludes.

2 Information Technology: Coverage, Adoption and Usage in Africa: 1998–2013

2.1 Mobile phone coverage and adoption

Despite limited infrastructure investments in sub-Saharan Africa for much of the twentieth century, investment in information technology—and mobile phones in particular—has grown quite substantially. Between 1999 and 2014, the percentage of the population with access to mobile phone coverage grew from 10% to 90% (ITU 2014; GSMA 2013). An estimated 800 million mobile subscriptions have been sold in Africa (Ericsson, 2013; GSMA 2013), reaching roughly 400 million unique subscribers, or approximately one-third of the population in sub-Saharan Africa (GSMA 2013). Growth of the worldwide subscriber base is fastest in these regions, with four out of five new connections being made in the developing world, and 880 million unique developing-market subscribers estimated to register new accounts by 2020 (GSMA 2013).

One of the more remarkable features of this rapid growth of mobile telephony is that is has been driven largely by the private sector. Whereas other technologies have required significant investment and coordination from the public sector, the expansion of mobile networks has been fueled by intense competition between operators for new subscribers. This growth has not been uniformly accessible to all segments of society, and indeed the adoption base has been more traditionally skewed toward a wealthier, educated, urban and predominantly male population (Aker and Mbiti 2010, Blumenstock and Eagle 2012). However, “last mile” regulatory policies designed to connect marginalized individuals are now commonly included in the licenses granted to mobile operators, and current adopters come from all segments of society (Aker and Mbiti 2010).

For urban and rural consumers in sub-Saharan Africa, the mobile phone presents a compelling technology. As originally outlined in Aker (2010b), several factors have helped to enable phones to quickly reach a “critical mass” of adoption (cf. Rogers 1962), even in relatively impoverished areas: First, unlike many “single-use” technologies (such as seeds, fertilizer, or chlorination), the mobile phone serves as a multi-use platform for other services. Beyond simple person-to-person communication via voice and SMS, mobile phones can provide access to the internet, financial services, and other services that can translate into diverse economic and social benefits. Second, many of these benefits are tangible and immediate, thereby allowing people to quickly determine the magnitude of those benefits. For example, unlike an improved seed variety, it is not necessary to wait for the harvest to see the benefits of the yield; in many cases the benefit is delivered instantaneously to the adopter. Third, the costs of using mobile phones are relatively low and largely incremental. Most mobile phone subscriptions in sub-Saharan Africa are pre-paid and billed per-second, thereby allowing credit-constrained users to buy mobile phone airtime as they need it, and for increasingly small amounts. Fourth, basic feature phones are easy to use, even for individuals with little formal education. The interface and software can be adapted, but more commonly the basic features are simply repurposed to fit the needs of the local population and context. And finally, there are spillovers to mobile phone adoption: since multiple individuals can use a mobile phone, its cost can be shared among multiple users, and multiple individuals can benefit from one person’s use.

2.2 Mobile money and value-added services

Historically, the primary function of the mobile phone has been as a communications device over voice and Short Message Service (SMS) protocols. More recent innovations, however, have utilized the mobile phone network as a platform for other services that facilitate innovation in several sectors, from healthcare and education to finance and governance. More recently, a set of phone-based financial services has been developed, called “mobile money” (or m-money). First introduced in 2005, basic m-money applications allow clients to store value in an account accessible by a handset, convert cash in and out of the stored value account, and transfer value between individual users, as well as between individuals and firms (Aker and Mbiti 2010). As of 2013, over 140

mobile phone operators in over 80 countries worldwide had m-money platforms, with over half in sub-Saharan Africa (GSMA 2013).

While basic mobile telephony was rapidly adopted across sub-Saharan Africa, uptake of m-money has been much less pronounced, with some notable exceptions (e.g., M-Pesa in Kenya and Tanzania). The reasons for these differential trends in adoption are not well understood, and a nascent body of empirical research seeks to identify the binding constraints to m-money adoption (Aker and Wilson 2013; Batista and Vicente 2013). Yet qualitative evidence and much of the policy discourse focuses on a handful of factors that are thought to limit the uptake of m-money (cf. Dzokoto et al. 2011, Aker and Wilson 2013Ω), including:[1]

- *Understanding of benefits:* Unlike simple mobile phone operations, with which many households might have been familiar, electronic person-to-person transfers are a relatively new technology.[2] As a result, households might not know what the technology is or its potential uses and benefits.
- *User knowledge*: Effective use of the mobile money network requires that users register a PIN code and navigate a series of text-based menus, which may be difficult for individuals with limited literacy skills.
- *Physical access:* While mobile network coverage is generally widespread, m-money operations (cash-in and cash-out) require access to a secure and reliable mobile agent network.
- *Regulation and registration requirements*: While growth of early m-money networks was largely unregulated, many deployments are now subject to regulations such as Know-Your-Customer (KYC) requirements, which require that individual SIM cards be registered to national identity cards (Davidson 2011).
- *Trust*: To effectively use the m-money system, the user must convert cash to m-money, which requires trust and confidence in the m-money ecosystem.
- *Network effects:* For interpersonal transfers and point-of-sale payments, individuals benefit little from adopting if their network of contacts have not yet adopted, suggesting that a critical mass of users is needed.

3 Information Technology and Development: Channels of Impact

This widespread growth of mobile phone coverage and adoption in sub-Saharan Africa has spurred significant interest in the potential of this technology to affect development outcomes. Building upon work by Aker and Mbiti (2010) and Aker (2011), we outline the primary channels through which information and communications technologies—and mobile phones in particular—are likely to affect economic development in Africa. We focus on the four primary ways in which mobile phones are being used in Africa: as a communication device to share (public and private) information; as a transfer device to exchange (public and private) transfers; as a savings device; and as an educational tool for school-aged children and adults.

3.1 Information asymmetries and communication

3.1.1 Private information and market efficiency[3]

A central tenet of economic theory is that for markets to function efficiently, different market agents – producers, consumers, and traders – must have access to perfect information. However, in many real-world markets, and particularly in countries with limited infrastructure, it can be costly for such actors to obtain information (Stigler 1961, Jensen 2007). Traditionally, information is obtained through personal travel, local social networks, radio, and, to a much lesser extent, landlines, letters, newspapers, and television (Aker and Mbiti 2010). However, these mechanisms are often costly, sporadic, and at times unreliable. As a result, imperfect information - on input prices, output prices, weather patterns, jobs, potential buyers and sellers, natural disasters, new technologies, politics, and so on – distort markets, creating waste, price and wage dispersion (cf. Fafchamps 1992, Jensen 2007, Aker 2010).

Compared to traditional methods for searching for information, mobile phones offer several distinct advantages. Relative to personal travel, the transport and opportunity costs of using a mobile phone are quite low. Information transmission is on-demand and immediate, and is not dependent on the timing of radio broadcasts, newspapers or letters (Aker and Mbiti, 2010).[4] This reduction in search costs should, in theory, allow market actors to search more quickly and over a greater geographic area (Baye et al. 2004; Reinganum 1979; Stahl 1989; Aker 2008, Aker and

Mbiti 2010). In theory, this reduction in search costs should decrease equilibrium price dispersion and improve market efficiency, although these predictions depend upon a certain set of assumptions (Reinganum 1979; Stahl 1989).[5]

An example might help to fix ideas (Jensen 2007; Aker and Mbiti 2010). If search costs are prohibitively high, then market agents (e.g., grain traders) will not engage in spatial arbitrage. With the introduction of mobile phones, search costs should decrease, thereby reducing the informational barriers to learning about prices. In theory, this should facilitate the movement of agricultural goods from surplus to deficit markets and reduce inter-market price dispersion for the same good. While this should result in net welfare gains under standard assumptions, the extent of that impact depends upon whether asymmetric information is a market failure and whether other market failures are at play (Burrell and Oreglia 2012).[6] In addition, how these gains are distributed among consumers, producers and firms is theoretically ambiguous (Jensen 2007, Aker and Mbiti 2010). This simple model has also been extended to labor markets (Autor 2001).

3.1.2 (Quasi-) public information

Beyond the reduction in search costs associated with transmitting private information, mobile phones offer a promising and cost-effective method for the dissemination of public or quasi-public information, such as that provided by the public sector or a private sector "clearinghouse" (Aker 2011).[7] In the past decade, there has been a proliferation of such services, with Nigeria, Ethiopia, and Rwanda leading the pack in sub-Saharan Africa (Rotberg and Aker 2013). About one-third of these have been in the area of mobile health (m-health), followed by agricultural and market information systems (22%), governance (11%), emergency response (6%), and education (5%).

The model for predicting the potential impacts of mobile-based "public" information platforms – especially in the area of agricultural market prices or wages - is similar in spirit to that of the reduction in search costs for private information. For instance, Aker (2011) shows that the mobile phone is far cheaper than traditional agricultural extension visits for disseminating agricultural information, and is as cost-effective as providing the same information via radio. Such innovations, which reduce the cost and difficulty of disseminating technical information, have the potential to increase the scope, scale and quality of agricultural extension (Aker 2011). This could also improve the quality and value of the information provided by ensuring that technical advice or market prices are provided in a more timely manner. In theory, price or labor market information provided via the mobile phone should reduce the costs associated of obtaining that information for a subset of the population, thereby increasing market efficiency (Varian 1980; Baye and Morgan 2002).[8]

In other areas – such as weather or health --the impacts of publicly-provided information are more difficult to predict. If information on droughts, natural disasters or epidemics is provided via public information services, this could enable farmers to better predict the risks associated with particular crops and allocate their resources accordingly, or allow households to make more optimal investments in preventative health measures. Furthermore, the provision of civic education information might enable households to participate more fully in the political system by choosing a candidate that best meets their political preferences or monitoring the performance of those candidates (Callen and Long 2013, Aker, Collier and Vicente 2013). Finally, providing information on agricultural input use could allow farmers to learn from others more quickly, which could increase or reduce the rate of adoption, depending upon the presence and extent of learning externalities (Foster and Rosenzweig 1995, 2010, Aker 2011).

3.1.3 Information, demand uncertainty, and coordination

By reducing communication costs, mobile phones could assist farmers, traders, and firms in identifying potential buyers (suppliers) for their products over larger geographic areas and at crucial moments (Aker and Mbiti 2010, Aker 2011). For example, by improving communication between firms and their suppliers, mobile phones can enable firms to manage their supply chains more effectively and streamline their production processes (Hardy 1980; Röller and Waverman 2001; Aker and Mbiti 2010). Similarly, improved communication between farmers and traders could reduce the uncertainty associated with the demand of certain goods and facilitate the provision of inputs to rural areas, thereby avoiding costly stock-outs (Aker and Mbiti 2010, Debo and Van Ryzin 2013). [9]

3.1.4 Monitoring and moral hazard in risk sharing

Households in Sub-Saharan Africa are prone to a variety of covariate and idiosyncratic shocks. In the absence of formal insurance arrangements, informal risk sharing practices have arisen to mitigate the adverse consequences of these shocks (Townsend 1995; Udry 1994; Rosenzweig and Stark 1989). Such informal contracts, however, are fraught with moral hazard, as commitment is limited by one party's ability to monitor and enforce state-contingent transfers (Thomas and Worrall 1990; Coate and Ravallion 1993). More pragmatically, efficient risk-sharing requires that one household is able to observe when another has suffered an idiosyncratic shock. As a result, traditional risk-sharing networks do not typically function over long distances (Udry 1994; Fafchamps and Gubert 2007). By improving communication among members of a social network, as well as increasing the possibility of monitoring and enforcement, mobile phones can potentially increase geographic scope of risk-sharing networks (Blumenstock et al. 2014). More generally, mobile phones can lead to improved information transmission within social networks, which can in turn increase the likelihood of social learning. Social learning has been linked to higher rates of technology adoption, especially of cash crops (Bandiera and Rasul 2006; Conley and Udry 2010; Bjorkegren 2014).

3.2 Transfers[10]

By providing a platform for electronic transfers, mobile phones can dramatically reduce the costs of sending and receiving money relative to traditional mechanisms such as Western Union, MoneyGram, and the bus. This reduction in transaction costs can, in turn, allow individuals to transfer money when and where they need it (Jack and Suri 2014; Aker et al 2013; Blumenstock et al. 2014), potentially increasing the frequency and amount of transfers received and allowing households to smooth consumption in the face of shocks.

Beyond the potential impact of m-money on private transfers, m-money could also reduce the costs associated with implementing public transfer programs, such as social protection programs, or salaries. In addition to potential mechanisms cited above, if the m-transfer mechanism reduces program recipients' costs involved in obtaining the transfer or reduces uncertainty with respect to these costs, this could reduce the opportunity costs associated with obtaining the transfer (Aker et al 2013). Alternatively, if m-money makes it more difficult for program recipients to access their cash due to the limited geographic scope of m-money agents, this could increase costs for program recipients (Aker et al. 2013).[11]

In addition, since m-transfers reduce the observability of the cash transfer, this could affect inter-household sharing, thereby leaving more income available for the household (Jakiela and Ozier 2012, Aker et al 2013). Changing the observability of the transfer could, in turn, affect the intra-household allocation of resources, especially if these transfers are primarily provided to women (Lundberg et al. 1997; Duflo and Udry 2004; Doepke and Tertilt 2014, Aker et al 2013).

3.3 Savings and financial services

In the rural areas of sub-Saharan Africa, less than 20% of the population has access to any type of formal financial institution (Aker and Wilson 2013). Households in such contexts typically share risk by self-insurance, including at home savings (under the mattress), saving with deposit collectors (*susus* and money guards), or rotating savings clubs (Aker and Wilson 2013). While these strategies are important risk-sharing mechanisms for rural households, they are not without cost, including theft, restricted access, fees, high transaction costs, or societal pressures for sharing.

Beyond money transfers, m-money could be used to create a secure place to save, where individuals can deposit smaller savings amounts for more immediate needs (Mas and Mayer 2012; Aker and Wilson 2013)). As the "account" is password-protected, m-money might offer greater security while increasing access. In addition, m-money could encourage individuals to save for particular objectives, thereby serving as a form of mental accounting. Finally, combined with m-money, mobile phones could be potentially used to transfer individual or group-based savings to more formal financial institutions or serve as a gateway through which unbanked households could access financial services (Mbiti and Weil 2013).

3.4 Education

In addition to the provision of educational content via the mobile phone, mobile phones have the potential to facilitate the acquisition of educational skills by adults or school-aged children (Aker, Ksoll and Lybbert 2012). For example, individuals may be able to practice their reading and writing skills by sending and receiving SMS or using m-money applications, all of which require familiarity with numbers and letters (Aker, Ksoll, and Lybbert 2012). In addition, mobile phone technology could also affect current and future returns to education (Aker, Ksoll and Lybbert 2012). Finally, the development of mobile phone-based educational applications, even for simple mobile phones, could be used as a teaching device in classrooms, or, in some cases, substitute for teachers in remote rural areas.

3.5 Data collection

Simple mobile phones can be used as a means of collecting both farmer and agent-level data, thereby improving the accountability of extension services (Dillon 2011, Aker 2011). Voice and SMS can be used to collect data on farmers' adoption, costs, and yields on a more frequent basis, rather than waiting for annual agricultural surveys, when recall data on costs and production are often subject to measurement error (Dillon 2011). In addition, mobile phones can be used to verify agents' visits, similar to what has been done with cameras in Indian schools (Duflo et al. 2012). Both of these applications could improve the monitoring of extension systems, an oft-noted constraint.

4 Information Technology and Development: What Do and Don't We Know?

The macro-evidence on the links between information technology and development is quite limited, though Roller and Waverman (2001) and Waverman, Meschi, and Fuss (2005) point to a causal link between telecommunications infrastructure and economic growth. There is, however, a growing body of micro literature investigating the impact of information technologies on economic development, which we describe below. While the sum total of empirical evidence generally indicates that mobile phones are having a positive economic effect on the targeted individuals and households in Africa, it is important to note that these benefits do not appear to be uniformly distributed across the population. In fact, economic theory predicts that even if phones can help make markets more efficient, the distribution of these gains across different actors is unclear. In fact, striking disparities exist between the population of mobile phone owners and non-owners, with one study showing that phone owners in Rwanda had roughly twice the per-capita income of non-owners (Blumenstock and Eagle 2012). A further cause for concern is that significant heterogeneity exists *within* the population of mobile phone owners, such that the privileged members of society appear best poised to capitalize on the welfare improvements brought by mobile telephony and other ICTs. For instance, Blumenstock et al. (2014) showed that it is the wealthiest individuals who are most likely to receive interpersonal m-money transfers after idiosyncratic negative shocks.

4.1 Agricultural markets and prices

Overall, existing evidence suggests that mobile phone coverage is associated with greater efficiency of agricultural markets, as defined as a reduction in price dispersion (Jensen 2007; Aker 2010; Aker and Mbiti 2010, Aker and Fafchamps 2014). Jensen (2007) found that mobile phones are associated with a reduction in fish price dispersion in India, whereas Aker (2010) and Aker and Fafchamps (2014) found that mobile phones are associated with a reduction in consumer and producer price dispersion for agricultural crops in Niger.

While welfare should improve with more efficient markets, the distribution of welfare gains among consumers, producers and traders is ambiguous. Some studies have found an increase in farm-gate prices (Jensen 2007; Goyal 2010; Nakasone 2013), whereas others have found little to no effect on farm-gate prices (Aker and Fafchamps 2014; Fafchamps and Minten 2012; Mitra et al. 2013). These seemingly contradictory findings can be explained, at least in part, by differences in the type of information or service provided via the information technology, the degree of information asymmetry and the presence of other market failures.

Beyond the impact of improved access to information on market efficiency and prices, there is a substantial body of literature measuring the empirical effect of mobile phone technology on agents' behavior. For example, Muto and Yamano (2009) found that mobile phone coverage increases the likelihood that farmers sell their commodity, primarily for a perishable crop. Fafchamps and Minten (2012) found that Indian farmers who participated in a private sector mobile information service were more knowledgeable about crop prices, but did not change their

crop choice. Yet Cole and Fernando (2012) found that the provision of mobile phone-based agricultural extension information in India encouraged farmers to switch to more optimal inputs and to adopt higher value cash crops. Similarly, Aker and Ksoll (2013) found that farmers who participate in a mobile phone-based adult education program in Niger were more likely to increase the diversity of their crops planted, primarily marginal cash crops grown by women. Finally, Casaburi et al (2014) found that sending SMS messages containing agricultural advice increased sugar cane yields by 11.5%, with relatively larger effects for farmers with no agronomic training.

4.2 Interpersonal transfers

By allowing for more efficient transfers within social networks, m-money has been linked with improvements in households' ability to share risk. Jack and Suri (2014) showed that households with access to the m-money network are able to smooth consumption completely in the face of idiosyncratic shocks, whereas households without access to m-money face a 7% reduction in consumption. Consistent with the theory that these efficiencies result from reductions in transfer costs for remittances, they further show that households with access to m-money are more likely to receive remittances, and that these remittances are larger and come from a more diverse set of senders.

Blumenstock, Eagle, and Fafchamps (2014) provided further empirical evidence that m-money facilitates person-to-person transfers in response to negative shocks, and that such m-money transfers often flow over vast geographic distances. By analyzing the records of millions of interpersonal exchanges of m-money in Rwanda, they showed that a small but significant amount of money is sent to individuals affected by earthquakes and other natural disasters. Consistent with a model of risk-sharing under dynamic limited commitment, the transfers are most common in relationships with a history of reciprocity.

4.3 Payments and salaries

With the potential reduction in transaction costs associated with m-money, there has been growing interest in using m-money for social protection programs and salary payments. In the area of social protection programs, Aker et al. (2014) found that using m-money in the context of an unconditional cash transfer program in Niger reduced the implementing agency's variable costs of distributing those transfers and reduced program recipients' costs of obtaining those transfers. Those program recipients who received the transfer via m-money also used the transfer to purchase more diverse types of food items, and had higher diet diversity, primarily due to cost reduction associated with obtaining the transfer (Aker et al. 2014).

In the context of salaries, Blumenstock, Callen, and Ghani (2013) similarly find that m-money can provide significant cost-savings to firms in contexts where the costs of cash transactions are large. Through a field experiment in Afghanistan in which a random subset of employees of a large firm were transitioned from cash payments onto a m-money salary payment system, they found that the firm was able to reduce costs by approximately 50%, but only in areas where adequate coverage existed for both the mobile network and m-money agents. The disbursement costs were largely reduced by transferring the costs of managing cash liquidity from the firm to the mobile operator, who already operated a network of m-money agents.

4.4 Savings

While considerable optimism exists surrounding the potential for the mobile phone to serve as an effective savings device, these features of m-money accounts have not yet gained widespread popularity. In a field experiment in which employees were encouraged to use a phone-based savings account, Blumenstock, Callen, and Ghani (2013) found that employees who received salaries via m-money were slightly more likely to save money on their phone, but that such effects depended on an individual's access to m-money agents. The authors also find that demand for m-money balances decreased (and demand for cash balances increased) when employees reported higher subjective beliefs for future violence, but that this effect was concentrated in areas with few m-money cash-out agents. However, they find no effect on other measures of employee welfare.[12]

4.5 Education

Traditionally, the use of ICT as an educational device has primarily focused on computers and laptops, with more limited use of mobile phone-based learning. Aker et al. (2012) conducted a randomized adult education program in Niger, where a mobile phone-based component ("ABC") was added to an otherwise standard adult education program.[13] Overall, the mobile phone technology substantially improved learning outcomes: Adults' writing and math test scores were 0.19–0.25 standard deviations (s.d.) higher in the mobile phone education villages immediately after the program, with a statistically significant effect. While these skills depreciated in both groups after the end of the program, the relative educational improvements in ABC villages seem to persist over time, particularly for math.

4.6 Accountability and governance

By providing more frequent and transmission of information between citizens and the state, mobile phones can impact the political economy of developing countries. While much of the evidence for such impact is qualitative (Howard and Hussain 2013) several studies have begun to document the quantitative effects that mobile phone technology on governance. For example, a simple camera phone-based intervention that photographed election return forms at polling centers in Afghanistan substantially reduced fraud and improved electoral integrity (Callen and Long 2013). In the 2012 elections in Uganda, a similar experiment decreased the vote share for the incumbent, the candidate most likely to benefit from rigging, and decreased other measures of fraud (Callen et al. 2013). In the 2009 elections in Mozambique. Aker, Collier and Vicente (2013) found that the provision of civic education via SMS, as well as a mobile phone hotline to report electoral fraud, increased individuals' knowledge about the electoral process and increased voter turnout.[14]

5 Challenges to Measuring Impact

While the body of empirical evidence described above provides preliminary evidence of the impact of mobile phone technology in sub-Saharan Africa and elsewhere, there are considerable gaps in our understanding. These gaps are important, and offer a cautionary tale in terms of using existing empirical findings to develop mobile phone-based development policy. The fact that the rollout or adoption of ICTs is generally non-random poses a significant obstacle to identifying the causal effect of mobile phone technology—and ICT more broadly—on development outcomes. Usage of ICTs is highly correlated with other socioeconomic and demographic factors (Blumenstock and Eagle 2012), and decisions regarding expansion of ICT infrastructure and ICT-based programs are typically driven by private sector or policy criteria. As a result, the majority of empirical studies have relied on randomized evaluations, instrumental variables (cf. Jack and Suri 2014), or psuedo-random or natural experiments with a difference-in-differences estimation strategy (cf. Jensen 2007; Aker 2010; Aker and Fafchamps 2014, Jack and Suri 2014).

A second challenge associated with measuring the impact of mobile phone technology on development outcomes is disentangling the effects of the mobile phone from impact of the content or services provided (Aker 2011). If a mobile phone-based intervention seeking to promote agricultural technology adoption also facilitates participants' access to a mobile phone, then mobile phone ownership or usage might have a wealth effect, thereby decreasing the relative costs of an agricultural technology or increasing the benefits associated with it (Aker 2011). Several experimental studies attempt to address this by providing phones to the control group (Aker et al. 2013; Blumenstock, Callen, and Ghani 2013; Nakasone 2013), thereby allowing them to disentangle the impact of the handset from the content or service provided.

A third challenge associated with measuring the impact of mobile phone technology is associated with the multiple uses of information technology. If participants are participating in a SMS-based agricultural extension or price information program, in theory, they can use the mobile phone handset for a variety of other (non-SMS and non-price) uses. While it is possible to empirically identify the impact of this program on economic outcomes, it can be challenging to measure the mechanisms behind this effect. Some studies have attempted to overcome this constraint by limiting the mobile phone to only provide specific services (Mitra et al. 2013; Nakasone 2013).

A fourth challenge associated with this line of research is understanding the type of information or service being provided (Aker 2011). In most mobile phone-based agricultural extension or health programs, there can be multiple types of services provided, depending upon the mechanism used for disseminating the information (e.g., SMS or

voice). The primary challenge is how to interpret the treatment effect; for example, each intervention may not only differ in how it is disseminated, but also the *type* (*or quality) of information provided* (Aker 2011). While SMS can provide timely technical reminders or provide content, voice-based services permit farmers or health workers to ask open-ended questions and receive more detailed information; the quality of the technical advice provided by voice services can vary considerably by the type of person providing the service. This implies that the empirical impact of the program will capture the impact of both the mechanism (SMS, voice) and the information conveyed.

A final challenge in measuring the impact of mobile phone technology on economic outcomes is the presence of spillovers. With mobile phones, farmers are able to contact members of their social networks more easily, thereby increasing the likelihood of inter-village spillovers (Aker 2011) or encouraging farmers or traders to start selling in different markets. Similarly, health workers with access to disease information could start funneling potential patients to different clinics that are better suited to care for those patients. All of these factors could also lead to broader general equilibrium effects, thus making it more difficult to identify the impact of the mobile phone-based policy or intervention on individual, household and market-level outcomes.

6 What Does the Future Hold?

How will mobile phone coverage, adoption and services change over the course of the next ten years in sub-Saharan Africa? And how will this affect economic development? Will mobile phone coverage reach the last mile via the private sector, or will particular policy interventions be required? Will information technology go beyond mobile phone technology to Internet, computers, and smart phones? And how will the development of mobile phone applications reach the continent?

One area of particular promise for development researchers and policymakers is the fact that the rapid proliferation of mobile phones and other ICTs has enabled new forms of empirical research on economic development. Namely, the “digital trace” data generated in the everyday use of technology can provide a powerful instrument for observing the behavior of individuals and households (cf. Lazer et al. 2009). For instance, the data generated by mobile phone users and automatically collected by mobile phone operators can be used to produce high-resolution estimates of poverty and wealth, track patterns of mobility and migration, and predict the transmission and spread of diseases (Blumenstock et al. 2010; Blumenstock 2013; Eagle et al. 2010; Frias-Martinez and Virseda 2012; Wesolowski et al. 2012). In addition, a growing number of mobile applications are being deployed to track respondents and monitor programs. Such applications allow for high-frequency data collection, custom data validation, and low-latency feedback to respondents (Hartung et al. 2010).

Yet there are some important issues about the potential of mobile phones and ICTs as a poverty-reduction device in developing countries in general, and sub-Saharan Africa in particular. First, while evidence on the impact of mobile phone technology and development has grown considerably over the past few years, these studies are for particular countries, products and markets, and still represent a small percentage of what we should know about their impact for policy decisions (Aker and Mbiti 2010).

Second, while reduced communication and transfer costs can make markets more efficient, this does not necessarily imply that all agents are better off. Having a more efficient agricultural market does not immediately imply that poor farmers will receive higher prices, as existing empirical evidence suggests. In addition, while social networks can certainly expand with mobile phones, they can also weaken existing ones or potentially lead to social exclusion (Burrell 2010).

Third, mobile phones will only address market failures that are associated with asymmetric information and high transactions costs or, in some cases, missing insurance and credit markets. In the presence of other market failures, mobile phones might not have the intended effects (Aker and Mbiti 2010, Aker 2011). For example, even if a farmer is able to obtain price information more quickly and cheaply, if there is an uncompetitive market structure, improved information will not translate into higher farm-gate prices. This therefore suggests that any mobile phone or ICT-based development policy must ensure that public goods are provided or address complementary market failures.

Fourth, using mobile phones for economic development not only requires “hardware”—for example, the handset, application or service—but also an enabling environment that fosters the adoption and use of that technology.

Among the 140 m-money programs worldwide, adoption of m-money services remains surprisingly low, except in a few high-profile geographies. What this implies for mobile phone operators, as well as public and private mobile phone for development programs, is that the "hardware" must be developed from the end-users' perspective: In other words, the product or service addresses the individuals' needs, for a phone that is locally available, and can be easily learned or used.

And finally, even if mobile phones improve certain development outcomes, it is not clear that this will translate into improved economic growth or higher per capita incomes in sub-Saharan Africa (Aker and Mbiti 2010). Whether there exists a causal relationship between mobile phone coverage and economic growth is an area of active debate, and one that cannot easily be answered.

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Notes:

([1]) Among these factors, access to m-money agents, high cost and limited trust in formal financial systems are frequently cited as the most common reasons for limited initial usage.

([2]) There are a variety of electronic and non-electronic transfer systems within sub-Saharan Africa, such as Western Union, MoneyGram, the post office, and via bus. Nevertheless, these systems are not necessarily person-to-person—they usually require some intermediary to enact the transfer.

([3]) This section draws heavily from Aker and Mbiti (2010).

([4]) Aker and Mbiti (2010) outline the relative costs of other search mechanisms, such as radios, newspapers and Internet. While radios can be used across all segments of the population, they provide a more limited range of information. Newspapers are primarily concentrated in urban areas, are expensive, and are inaccessible to illiterate populations. Landline coverage is also limited, with less than one landline subscriber per 1000 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.

([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.

([6]) The reduction in search costs could not only affect market efficiency, but also farmers' and consumers' adoption of other potentially welfare-enhancing technologies. For example, the traditional model of "learning from others" model assumes that the farmer can without cost observe the experiments from his or her neighbors, but with error (Foster and Rosenzweig 1995). As a result, the variance is inversely related to the number of persons in the social network who use the technology and the farmer observes. With mobile phones, this could speed up or increase farmers' contact with other adopters in a social network, thereby allowing farmers to learn from more "neighbors'" trials of a new technology or observe those trials more frequently. While this could potentially increase the rate of technology adoption, it could also reduce the rate of adoption in the presence of learning externalities (Aker 2011; Foster and Rosenzweig 1995; Foster and Rosenzweig 2010).

([7]) A clearinghouse is a either a private or public institution that provides information (or financial services) publicly, at least to a subset of the population. Thus, rather than rely upon members of a social network, an individual can consult the clearinghouse.

([8]) With any of these models, a Diamond Paradox could result, which results in monopoly pricing. This would lower price dispersion across markets but would increase (decrease) consumer (producer) prices than the competitive market equilibrium.

([9]) The impact of information on stock-outs depends upon the quality of information provided and whether there is consumer heterogeneity.

([10]) This section draws from Aker et al (2013).

([11]) If m-money allows households to "cash out" from any m-transfer agent, this may affect the way in which households spent the cash transfer. For example, if program recipients obtain their cash from an agent and kiosk-

owner within the village, program recipients might start to change the timing and location of their expenditures (Aker et al. 2013; Blumenstock, Callen, and Ghani 2013).

([12]) A set of recent studies has shown that although the mobile phone may not yet be commonly used as a savings device *per se*, it can be used to alleviate other savings constraints (cf. Karlan et al., 2012). Karlan et al. (2012) and Karlan and Zinman (2013) study the extent to which SMS reminders to save can increase rates of savings in several countries, and find that such reminders can increase the likelihood of saving and savings balances.

([13]) The experiment provided simple mobile phones—which primarily have voice and SMS capability—as opposed to smart or multimedia phones—which often have internet or video capability. In both developed and developing countries, a number of authors have found that computers either have no or mixed effects on learning outcomes (Osario and Linden 2009; Fairlie and Robinson 2013; Banerjee et al. 2007).

([14]) These effects are not limited to electoral accountability in democratic regimes. Shapiro and Weidmann (2014) provide evidence that mobile communications reduced insurgent violence in Iraq, both at the district level and for specific local coverage areas. By lowering the transaction cost of cooperating with the government, the authors argue that mobile phones made it easier for non-combatants to cooperate with counter-insurgent forces, and that the information provided by non-combatants had a strong negative effect on conflict.

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