Dial "A" for Agriculture: Using Information and Communication Technologies for Agricultural Extension in Developing Countries

JENNY C. AKER[1]

Tufts University

October 2010

Abstract.

Agriculture can serve as an important engine for economic growth in developing countries. Yet yields in developing countries have lagged far behind those in developed countries for decades. One potential mechanism for increasing yields and hence agricultural production is the use of improved technologies, such as fertilizers, improved seeds and cropping techniques. Traditional public-sector programs have attempted to overcome barriers to technological adoption by using agricultural extension services at the village or farm level. Yet despite decades of experience with a variety of extension programs and new technologies, adoption rates still remain relatively low in low-income countries. The rapid spread of mobile phone coverage in developing countries provides a unique opportunity to facilitate technological adoption via ICT-based agricultural extension programs. This paper provides a review of the current programs using ICT for agriculture, with a particular focus on agricultural extension and market information systems. It addresses some of the potential constraints to such programs in terms of design and implementation, and provides a summary of the initial findings. We then conclude with some recommendations for implementing field-based research on the causal impact of ICT-based agricultural extension programs on farmers' knowledge, technological adoption and welfare in developing countries and directions for future research.

[1] Jenny C. Aker, Tufts University, Economics Department and Fletcher School, Medford, MA 02155. Jenny.Aker@tufts.edu.

1. Introduction

The role of agriculture in economic development has long been recognized (Byerlee, de Janvry and Sadoulet 2009). Agriculture can play a unique role in reducing poverty and serve as an important engine for growth in developing countries. This is, in part, due to the sheer numbers of poor people engaged in it. Around 75 percent of those surviving on less than US$1 a day lived in rural areas in 2002 (IFAD 2001, Byerlee, de Janvry and Sadoulet 2009), and it is estimated that 70 percent of the labor force in sub-Saharan Africa, and 67 percent of the South Asian labor force, work in agriculture (Maxwell 2001).

Yet despite the potential role of agriculture in growth, agricultural production and yields have lagged far behind those in developing countries over the past few decades (Figure 1). Stagnating growth in yields could be attributed to various factors, such as resource constraints in land, labor and capital and population growth. One potential explanation is underutilization of improved agricultural technologies, such as cultivars, fertilizers and techniques.[2] Figure 2 shows the adoption of new varieties by region (Evenson and Gollin 2003), painting a picture of low adoption in developing countries, especially those in sub-Saharan Africa.[3]

Numerous studies on the adoption of agricultural and other technologies have attempted to identify the determinants of technology adoption and potential barriers to it (Feder, Just and Zilberman 1985, Foster and Rosenzweig 1995, Foster and Rosenzweig 2010). While the specific determinants of technology adoption depend upon the setting and the technology type, there are some common factors that have been identified both in the theoretical and empirical literature. These include education levels, wealth, tastes, risk preferences, complementary inputs (land, labor and credit) and access to information and learning – either learning by doing or learning from others. Of these, the role of information and social networks has received particular attention.

Governments and international organizations have attempted to overcome some of the perceived information failures related to adoption via agricultural extension services, generally defined as the delivery of information inputs to farmers (Anderson and Feder 2007).[4] There were approximately 500,000 agricultural extension personnel worldwide in 2005, with 95 per cent of these working in public agricultural extension systems (Anderson

[2] To the extent that technology raises agricultural productivity, it should be the major factor in having a positive effect on per capita income. Thirtle *et al (2003) explored the relationship* between agricultural productivity and poverty. They drew on observations between 1985 and 1993 in 48 developing countries and found that a 1% improvement in crop yields reduced the proportion of people living on less than US$1 per day by between 0.6 and 1.2%

[3] Low levels of adoption do not necessarily indicate "under-adopton" – defined as a situation in which there are substantial unrealized gains to the use of a new technology or expansion of input use, and reflected in high returns to adoption (Foster and Rosenzweig 2010).

[4] More specifically, agricultural extension seeks to transfer knowledge and advice from researchers to farmers. The definition and model has expanded over the years, allowing for more community-level and grassroots knowledge transfer.

and Feder 2007). Yet despite decades of investment in and experience with a variety of public extension programs, evidence of their impact upon agricultural knowledge, adoption and productivity remains limited. Furthermore, the systems themselves have been in general "decay", primarily due to high costs, problems of scale and low levels of accountability.

The rapid spread of information and communication technologies (ICT) in developing countries over the past decade offers a unique opportunity to transfer knowledge via private and public information systems. Over the past decade, mobile phone coverage has spread rapidly in Africa, Asia and Latin America (Figure 4). As of 2009, over half of the populations in sub-Saharan Africa, Asia and Latin America had access to mobile phone coverage, representing 60, 67 and 77 percent, respectively. Mobile phone coverage has greatly exceeded investments in other infrastructures in these countries, namely, electricity, roads and landlines. Coinciding with this increase in mobile phone coverage has been an increase in mobile phone adoption, even in some of the world's poorest countries. As of 2008, there were about 4 billion mobile phone subscribers worldwide, with 374 million subscriptions in Africa, 1,791 in Asia and 460 million in Latin America (ITU 2009). While initial adoption was primarily by the wealthy, urban and educated residents, mobile phones are currently being adopted by the rural poor in some of the world's poorest countries (Aker and Mbiti 2010).

Mobile phones significantly reduce communication and information costs for the rural poor in developing countries. This not only provides new opportunities for rural farmers to obtain access to information on agricultural technologies, but also to use ICTs in agricultural extension systems.[5] Since 2007, there has been a proliferation of mobile phone-based applications and services in the agricultural sector, providing information on market prices, weather, transport and agricultural techniques via voice, short message service (SMS) and internet. While such programs are innovative, they are not without challenges, and it is not yet clear that they will substitute for existing agricultural extension systems. Furthermore, as many of these projects are fairly recent, empirical evidence on their success is still largely anecdotal. In order to measure the impact of such services on farmers' knowledge, adoption and welfare, as well as the cost-effectiveness of such services, rigorous impact evaluations are needed.

The rest of this paper proceeds as follows. Section II provides an overview of the rationale for and impact of agricultural extension programs in developing countries,

[5]Increased access to information – either via learning by doing or learning from others – will not necessarily lead to higher rates of adoption. As Foster and Rosenzweig (2010) point out, learning that a new technology is not efficacious will therefore reduce adoption in the next period. Similarly, Foster and Rosenzweig (1995) show that there are two potential opposing effects of social networks on the adoption decision: an individual farmers' incentive to adopt increases as the number of members in social network use the new technology, but this also creates an incentive to delay adoption due to free-riding behavior and information spillovers.

including some of the weaknesses of these systems. Section III identifies the potential mechanisms through which mobile phones could improve farmers' access to information and agricultural adoption in general, and facilitate the delivery of agricultural extension systems in particular. Section IV surveys existing ICT-based agricultural extension programs and identifies potential challenges to such programs in terms of design and implementation. Section V outlines the difficulties with measuring the causal impact of such programs, and provides some recommendations for implementing field-based experiments. Section VI concludes.

2. Technology, Adoption and Agricultural Extension

2.1. Technology Adoption, Agriculture and Growth

The potential role of agriculture as an engine for economic development has long been recognized (Byerlee, de Janvry and Sadoulet 2009). Since the seminal contributions of Schultz (1964), Hayami and Ruttan (1971), and Mellor (1998), there has been a large body or theoretical and empirical literature on the potential multiplier effects of agricultural growth on non-agricultural sectors (Byerlee, de Janvry and Sadoulet 2009). Cross-country and country-specific econometric evidence has indicated that GDP growth generated in agriculture can be particularly effective in increasing expenditures and incomes of the poor (Ligon and Sadoulet 2007, Bravo-Ortega and Lederman 2005, Ravallion and Chen 2007).[6]

Despite the importance of agriculture for economic development, agriculture has yet to perform as an engine of growth in many developing countries – especially sub-Saharan Africa (Byerlee, de Janvry and Sadoulet 2009). Agricultural yields have only shown slight increases in sub-Saharan Africa and Latin America since the 1960s, despite the development of important agricultural innovations during that time (Figure 1). Yet data on adoption of improved agricultural technologies paint a picture of low levels of adoption in developing countries, particularly sub-Saharan Africa.

Broadly speaking, technology is the "relationship between inputs and outputs" (Foster and Rosenzweig 2010), or the set of hardware (physical) and software (techniques) tools that allow for a different mapping of inputs to outputs. In the context of agriculture, hardware refers to improved cultivars (seeds), fertilizers and pesticides, whereas software refers to practices such as inter-cropping, mulching, and integrated pest management.[7] In this context, technology adoption is therefore defined as the "use of new tools or techniques that relate inputs to outputs and the allocation of inputs" (Foster and Rosenzweig 2010).

[6] Ligon and Sadoulet (2007) find that 1% GDP growth originating in agriculture increased the expenditures of the five poorest deciles on average by 3.7% in 42 developing countries. Bravo- Ortega and Lederman (2005) find that an increase in GDP originating from agricultural labor productivity is more effective in raising the incomes of the poorest quintile in developing countries than an equivalent increase in GDP coming from non-agricultural labor productivity.

[7] Anderson and Feder (2007) refer to hardware as the "technology gap" and software as the "management gap".

The low rates of adoption of agricultural technologies in developing countries have been well-documented, and there is widespread theoretical and empirical literature attempting to identify the determinants of agricultural technology adoption in different contexts (Feder, Just and Zilberman 1985, Foster and Rosenzweig 1995, Suri 2009, Conley and Udry 2010, Duflo, Kremer and Robinson 2010).[8] While the findings differ according to the technology and context, there has been some general consensus on the determinants of – or constraints to – technology adoption, particularly in the agricultural context. This includes levels of education, wealth, risk preferences, expected returns, tastes and access to information and learning.[9]

2.2. Information, Agricultural Extension and Technology Adoption

The complexities of the agricultural production function imply that farmers need information on a variety of topics, at a variety of stages, before adopting a new technology. Figure 5 provides a stylized representation of the stages of agricultural production process, including "deciding", seeding, preparing and planting, growing, harvesting, packing and storing, and selling (de Silva and Ratnadiwakara 2008, Ghandi, Mittel and Tripathi 2009).[10] Farmers have different types of information needs during each stage, ranging from weather forecasts, pest attacks, inputs (seeds and fertilizer), improved cultivation practices, pest and disease management and prices.

Farmers can obtain information from a number of sources, including, among others, their own trial and error and from members of their social network. Yet while traditional economic theory assumes that searching for such information is costless, in developing countries, in reality, information is neither symmetric nor costless. This is partly due to the cost of obtaining that information via personal travel, radio, newspaper, which can be relatively expensive in the context of limited infrastructure and vast distances. As a result,

---

[8] Duflo, Kremer and Robinson (2010) find that the returns to small quantities of fertilizer are high in Kenya, and suggest that fertilizer is under-utilized. Suri (2009) indicates that some farmers with high returns to adopting hybrid seeds do not adopt, and attributes this in part to poor infrastructure. Yet Foster and Rosenzweig (2010) posit that this does not indicate a lack of knowledge about returns, as the Kenyan environment (where both studies are based) is fairly stable.

[9] Foster and Rosenzweig (1995, 2010) develop a model of learning by doing and learning from others, defining learning as taking place when "new information affects behavior and results in outcomes for an individual that are closer to the (private) optimum." Learning can therefore reduce uncertainty about the profitability of a new technology, as well as help the individual to obtain information about how to optimally manage the new technology. Learning from others can also lead to learning externalities and sub-optimal allocation of a new technology via free-riding behavior). As Foster and Rosenzweig (2010) point out, learning does not necessarily imply that technology adoption will increase – if an individual finds that the technology is not beneficial or efficacious, then this could lead to less use.

[10] The first stage is "deciding", whereby farmers decide on what crop to grow, how much land to allocate for each crop and also arrange working capital financing. The second stage is "seeding", whereby farmers either purchase seeds or prepare their own seeds based on the crop they have earlier decided to grow. During the "preparing and planting" stage, farmers prepare the land using own or hired labor or land preparation machinery and subsequently plant the seeds. The fourth stage is "growing", where the application of water, fertilizer and pesticides take place (depending upon the crop). The "harvesting, packing and storage" stage requires that farmers find labor for harvesting and storage. During the final stage, and depending upon the crop, farmers sell, thereby requiring some price and market information to decide when and where to sell

information asymmetries are often an important constraint to adoption in developing countries.

Since the 1960s, agricultural extension has been put forth as a means of reducing the information asymmetries related to agricultural technology adoption in both developed and developing countries. Broadly speaking, agricultural extension is the "delivery of information inputs to farmers" (Anderson and Feder 2007), and refers to a form of education that introduces new knowledge and technology to farmers. The general approach uses specialists to provide a range of services to farmers, from technology transfers, to advisory work and human resource development.[11] In some cases it has also sought to connect researchers directly to the field in order to develop new technologies targeted to the specific conditions of agricultural communities.

Agricultural extension models can take several forms, and are typically supported by governmental and non-governmental organizations.[12] The most common approaches are Training and Visit (T&V), Farmer Field Schools (FFS) and fee for service. In the T&V approach, specialists and field staff provide technical information and village visits to selected communities. In many cases the field agents train and work directly with "contact farmers", or farmers who have successfully adopted new technologies and who are able to train others in their communities. T&V was promoted by the World Bank and applied in more than 70 countries between 1975 and 1995 (Anderson, Feder and Ganguly 2006).[13] Farmer field schools (FFS), on the other hand, were specifically designed to diffuse integrated pest management (IPM) methods in Asia. FFS also utilize contact farmers who train others and disseminate information, relying on participatory training methods that build farmer capacities. Fee-for-service extension comprises both public or private initiatives with some public funding. In these programs, farmer groups contract extension agents with specific information and service requests, either from the public or private sector.

While agricultural extension services are primarily financed and implemented by the public sector, it is not always clear that the type of information provided is always a public good.[14] Table 1 shows the different types of information provided via agricultural extension

---

[11] Information provided via agricultural extension can include prices, research products, knowledge about techniques involved in using particular inputs, such as the intensity and timing of fertilizers.

[12] Agricultural extension has expanded in developing countries since the 1960s with significant public sector financing. It is estimated that there are approximately 500,000 agricultural extension workers worldwide, and 80 percent of these are publicly funded and delivered by civil servants. NGOs represent about 12 percent, and the private sector 5 percent (Anderson and Feder 2007).

[13] The decentralized T&V approach is essentially the same, but the responsibility for delivery is given to local governments. The decentralized T&V approach has been adopted in Latin America between the 1980s and 1990s, as well as Uganda (Crowder and Anderson 2002).

[14] Excludability occurs when some farmers who are not willing to pay for a service can be excluded from its benefits (ie, tailor-made farm management advice). Rivalry occurs when one farmer, by using advice, reduces the availability to others, such as commercial products. Other types are club goods (high excludability and low rivalry, where some farmers can be excluded from access, even though their value is not diminished by use); and common pool goods (low excludability and high rivalry). Its value can also be determined by time and place (ie,

systems, and their classification as private, public, club or common pool goods (Anderson and Feder 2007). While information disseminated via the mass media can be thought of as a public good (non-rival and non-excludable), input-specific information (similar to those under the fee for service system) has the characteristics of a private good. Characterizing agricultural information in this way suggests that different mechanisms might be needed to disseminate information.[15]

2.3. Does Agricultural Extension Work?

Despite decades of investment in agricultural extension services, hundreds of thousands of technicians trained and hundreds of millions of farmers receiving these services, there are surprisingly few rigorous impact evaluations of the subject. Evenson (2001) and Anderson and Feder (2007) provided a review of the impacts of agricultural extension services, with mixed results according to the program, context and the outcome variable. Table 2 provides an overview of many of these studies, based upon the type of agricultural extension (T&V, FFS, fee for service and social networks) and the outcome variable of interest (knowledge, adoption, yields, rates of return and general livelihoods). The impact record of these services on farmers' outcomes is mixed and highly dependent upon the type of program and context.[16]

Why is it so difficult to measure the impact of agricultural extension programs? Evaluating the impact of extension services usually depends on measuring the relationship between interventions and farmers' knowledge, adoption, inputs, productivity, incomes, and ultimately some measure of well-being. Yet there are several problems with these evaluations. First, there is often measurement error in the outcome variable of interest (adoption, returns inclusive of costs). While this will not introduce bias, it can reduce precision, which can therefore make detecting a statistically significant effect more difficult. Second, observable and unobservable factors (prices, credit constraints, weather conditions, and other sources of agricultural information) often vary across extension and non-extension communities, as well as users and non-users, which makes identifying the causal effect of treatment difficult. Third, given the differences in the types of agricultural extension models (T&V, fee for service, FFW) and the types of information provided via these models, cross-country (or cross-model) comparisons of agricultural extensions programs become meaningless.

---

market prices becomes less valuable as it is more widely disseminated) and weather, which has zero value after an event (Anderson and Feder 2007).

[15] For example, Umali-Deininger (1996) and Anderson and Feder (2007 suggest that information closely associated with private goods is best left to the private sector; information associated with toll goods can be provided by public-private partnerships; information related to common pool or public goods, where information failures are high, should be financed by the public sector.

[16] For example, earlier studies on the impact of agricultural extension (T&V) in India found that T&V had no significant impact on rice production but increased economic returns in wheat by 15 percent (Feder and Slade 1986, Feder, Lau and Slade 1987). Yet similar studies of T&V in Pakistan found only small impacts on wheat (Hussein, Bylerlee and Heisey 1994).

While many of these studies do not provide causal mechanisms behind the weak treatment effects of agricultural extension, the weak functioning of such systems could be a potential answer. A worldwide review of public extension systems by Rivera, Qamara and Crowder (2001) found that many agricultural extension systems were in a state of disarray or barely functioning at all. Anderson and Feder (2007) identified several different reasons for this state of affairs, including:

- Limited scale and sustainability: In countries where the farm sector is comprised of small-scale farmers, extension clients often live in geographically dispersed areas who require face-to-face interaction. This results in high costs, limited geographic scale and poor sustainability.
- Policy environments in many developing countries not only dictate the type of information provided, but also the relative importance of agriculture within the economy. If the terms of trade are tilted against agriculture, infrastructure is poor and there are inadequate input supplies, this reduces the value of the information provided via extension.
- Weak linkages between research centers, universities and agricultural extension systems. While extension services in the US and Europe are often linked with the university system, this is often not the case in developing countries. Consequently, the incentives of these institutes are often not aligned with agricultural priorities in the country, research-extension linkages are generally weak (Purcell and Anderson 1997) and technologies are not always locally adapted or appropriate
- Low motivation and accountability of field staff. As is the case with all public servants (doctors, nurses and teachers), it is difficult to track the presence and motivation of extension staff. This is particularly difficult in agriculture, where field agents work in different geographic regions and performance indicators are based upon inputs that are difficult to verify (ie, number of trainings, number of attendees). Lack of monitoring can result in absent or poor-quality field staff, further reducing the utility of agricultural extension services.
- Little rigorous evidence of the impacts of such extension on farmers' welfare. The lack of reliable evidence on the impact of agricultural extension exacerbates problems related to funding, extension agents' motivation and having appropriate technologies that improve yields, productivity and welfare.

In this environment, it is not only unclear whether agricultural extension systems are functioning, but whether these systems are truly overcoming information asymmetries for small-holder farmers related to agricultural technology.

3. How ICTs Could Affect Agricultural Adoption and Extension in Developing Countries[17]

3.1. Mobile phone coverage and adoption in the developing world

Agricultural extension systems were conceived of and developed in response to information asymmetries for poor farmers, particularly those without access to other sources of communication (landlines, newspapers and radios). While infrastructure investments still remain problematic in developing countries, one of the dramatic changes over the course of the past decade has been an increase in mobile phone coverage and adoption in developing countries. Nowhere has the effect been as dramatic as in sub-Saharan Africa. In 1999, less than 10 percent of the population had mobile phone coverage, increasing to over 60 percent of the population (477 million people) in 2008. By the time of the British Olympics in 2012, it is estimated that most villages will have coverage (Aker and Mbiti 2010).[18]

Coinciding with this growth in coverage has been an increase mobile phone adoption and usage. Despite the relative and absolute poverty in sub-Saharan Africa and Asia, mobile phones have been adopted at a surprising rate by many of the poor. While there were 16 million subscribers in sub-Saharan Africa 2000, the number grew to 376 million in 2008, representing 1/3 of the population. Similar rates of mobile phone adoption have been observed in Latin America and Asia (Jensen forthcoming).[19] The number of mobile phones per 100 people in developing countries often exceeds access to other information technologies, such as landlines (Jensen forthcoming), newspapers and radios (Aker and Mbiti 2010).

3.2. The Impact of ICTs on Information, Agricultural Adoption and Agricultural Extension

The rapid growth of mobile phones in developing countries over the past decade has introduced a new search technology that offers several advantages over other alternatives in terms of cost, geographic coverage and ease of use (Aker and Mbiti 2010). 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. Newspapers are primarily concentrated in urban areas, are expensive (the

[17] ICT is an umbrella term that includes any communication device or application, such as radio, television, mobile phones, computers and network hardware and software. In the context of this paper, I will primarily focus on mobile phone technology, given its relative growth in developing countries and high rates of adoption. Internet penetration is still relatively limited in Africa.

[18] While the growth in coverage has not been evenly spaced throughout the continent, as of 2008, over 40 percent of the population had access to mobile phone coverage in a majority of countries on the continent.

[19] There are issues with these data as mobile phone adoption, as it represents the number of active SIM cards in a country. This could either overestimate the number of subscribers (as one individual could have multiple SIM cards) or underestimate the number (as multiple people can use one phone and SIM).

cost of private newspapers in Mozambique average US$1), 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. 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. And finally, personal travel to different villages and markets to obtain information not only requires transport costs, but also the opportunity costs of an individual's time. This can be substantial in the context of unpaved roads and vast distances.

Aker and Mbiti (2010) provide an overview of the mechanisms through which mobile phone telephony can affect economic development in sub-Saharan Africa, including access to information, coordination among agents, job creation, social networks and improved services. In that vein, I identify six potential mechanisms through which mobile phones could potentially improve farmers' access to information about agricultural technologies and adoption more generally, and access to and use of agricultural extension services in particular. Some of these are directly related to agricultural extension, whereas other are outside of the agricultural extension system but still relatively for agricultural technology adoption.

How Mobile Phones can Improve Access to (Private) Information

Mobile phones can improve access to and use of private information about agricultural technologies, thereby potentially improving farmers' learning. As previously discussed, farmers have information needs at various stages and on various topics for the agricultural production process. Traditionally, farmers in developing countries have obtained such information from personal visits, radio and to a lesser extent, landlines and newspapers. Mobile phones, by contrast, can reduce costs of obtaining this information as compared with other information mechanisms. Figure 6 shows the per-search costs of using a mobile phone as compared with landlines, radio, personal visits and newspapers in Niger. Mobile phones are significantly less expensive than the equivalent per-search opportunity and transport costs or obtaining the same information from a newspaper. While they are more expensive than landlines or radio, these two search mechanisms are not readily available in most regions of the country, or only provide specific information. This reduction in search costs suggests that mobile phones could increase farmers' access to (private) information, especially via their social networks. This could speed up or increase farmers' contact with other adopters in a social network, thereby allowing farmers to virtually "observe" more neighbors' trials of a new technology or to observe these trials more frequently. The overall impact on farmers' technology adoption, however, might be ambiguous, due to learning externalities (Foster and Rosenzweig 1995, Foster and Rosenzweig 2010). [20]

[20] In addition to the impact of mobile phones on obtaining information on an agricultural technology, mobile phones could speed up information flows within a social network, increase access to informal credit, savings and

How Mobile Phones can Increase Access to Information via Agricultural Extension Services

Reduced communication costs could not only increase farmers' access to (private) information, but also public information provided via agricultural extension services. This is primarily due to a reduction in the extension system's costs of providing such information. Figure 7 shows the cost (borne by the extension system) of providing market information, either via extension agent's visits, radio, SMS or a call-in hotline. The marginal cost of providing market information via SMS and a hotline is much cheaper than additional an extension visit, and is equivalent of providing the same information via radio.[21] Reducing the costs of disseminating technical information could increase the extension system's geographic scope and scale, and allow for contact between field agents and farmers at more crucial moments. This could, in turn, improve the quality (or value) of the information services provided.

How Mobile Phones can Improve Farmers' Management of Input and Output Supply Chains

Several studies have pointed to risk and supply-side constraints (related to poor infrastructure) as barriers to agricultural technology adoption (e.g., Suri 2009). By reducing communication costs, mobile phones could assist farmers in identifying potential buyers for their products over larger geographic areas and at crucial moments, thereby reducing risk and potentially increasing net benefits to technology. Improved communication between farmers and traders could also facilitate the provision of inputs to rural areas, thereby avoiding costly stock-outs.

Mobile Phones can facilitate the Delivery of Other Services

Over the past few years, mobile phone operators have developed a variety of mobile services and applications in developing countries, such as mobile money transfers (e.g., G-Cash in the Philippines or M-Pesa in Kenya) or insurance. These applications can therefore facilitate the delivery of other services to farmers (such as credit or savings via m-banking services, or insurance in Kenya), which can overcome some of the "missing markets" that constrain technology adoption (Foster and Rosenzweig 2010).

How Mobile Phones can Increase Accountability of Extension Services

Simple mobile phones can be used as a means of collecting both farmer and agent-level data, thereby improving the accountability of extension services. Voice calls and SMS

---

insurance and thereby affect a farmer's adoption decision (Grimard 1997, De Weerdt and Dercon 2006, (Aker and Mbiti 2010).

[21] While radio is about the same cost as mobile phone technology, in many cases, the costs of constructing the radio tower and disseminating the messages are borne by the international organization. If these infrastructure costs are included, then radio is relatively more expensive as compared with mobile phone technology, whose infrastructure costs are usually borne by the private sector.

between farmers and extension agents can be used to collect data on the use of new technologies, 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. In addition, mobile phones can be used to verify agents' visits, as has been done with cameras in schools in India (Duflo, Hanna and Ryan 2007). Both of these applications could improve the monitoring of extension systems, an oft-noted constraint.

How Mobile Phones can Increase Communication Linkages with Research Systems

By improving the communication flows, mobile phones could potentially strengthen the link between farmers, extension agents and research centers, and vice versa – thereby overcoming criticism of the "disconnect" between the two in many developing countries.

4. Using ICTs in Agricultural Extension

With these mechanisms in mind, how can ICTs be used for agricultural extension? For decades "traditional" forms of ICTs have been used in advisory service provision. Radio and TV programs regularly feature weather and agricultural information in developing countries, and rural telecenters have provided information on education and agricultural issues (see Goyal 2010 in India). In some cases, especially in India and East Africa, national ministries of agriculture have attempted to integrate ICTs into information delivery, specifically by establishing district information centers. With the growth of mobile phone coverage, many of these initiatives have moved away from "traditional" ICTs to the use of mobile phones, including voice, SMS and internet-based services. Table 3 provides an overview of many of these projects, focusing on voice-based services, radio broadcasts, SMS-based extension and data collection and e-learning.

- Voice-based information delivery services include a telephone-based information delivery service that provides advice on farming methods and market access (e.g., a hotline). Some use call-in centers for agricultural extension support (ie, Cameroon). More complex voice technology uses a simple telephone – community fixed phone or mobile – as the medium of information exchange while sophisticated communication technology and computing applications have been configured at the back-end platform for the provision of the requisite information service.
- Radio dial-up and broadcasts include regular radio broadcasts that provide market prices or other agricultural information and dial-up radio that feature a series of short segment audio programs that provide small-scale farmers telephone access to relevant information through an automated voice system. This radio system is an information hub featuring a regularly updated, diverse menu of pre-recorded agricultural content. In some cases, the systems allow farmers to ask questions via SMS and the responses are disseminated via the radio.
- SMS-based extension services essentially use message-based platforms to collect and disseminate information. This includes data collection via a simple SMS-based

questionnaire; sending an SMS-based code to request potential information (on market prices or for simple agricultural questions) and receiving the response via SMS; and receiving mass SMS on agricultural topics.

- E-learning typically involves the development of telecenters that allow farmers to access computers and internet resources.

The types of information provided via these different mechanisms are diverse, including market prices, weather and natural shocks, technical advice on agricultural practices and inputs, and supply and buyers in local markets. Most of these projects focus primarily on market prices, weather and transport, most likely because they are "low hanging fruit" -- easy to collect and disseminate, fairly objective, less prone to measurement error and useful (albeit quickly outdated and constantly changing). Information on agricultural practices, and inputs, is less frequent and often used in agricultural "hotlines", possibly because such information is more nuanced and difficult to convey.

While all of these mechanisms offer potential alternatives to or variations of traditional agricultural extension, they are not without their challenges. First, the use of ICT-based agricultural extension is highly dependent upon the type of information demanded and provided. For example, while market information and weather might be easily disseminated via mobile phones (and replace traditional extension mechanisms), more nuanced information (on practices, inputs) might be complements to existing extension. Second, SMS-based platforms – which are the easiest to set up – can only hold limited information and often require some literacy (and technological literacy) on behalf of users. While they can be useful in providing some "low level" types of information (ie, weather or market prices) or standardized information, they are not as adaptable for more complex information exchanges. Third, while voice-based Q&A services are probably the most attractive, as they overcome the limitations of text-based platforms, they can be complicated to develop or require machines to produce natural speech. In some cases, audio files are made accessible to farmers through the use of mobile phones (Kenya, Uganda and Zimbabwe), but such initiatives have just started or have yet to begin. Fourth, because many of these applications and services are best developed, maintained and run by the private sector, most of these initiatives will require some sort of public-private partnership. Finally, using ICT-based initiatives this requires inter-operability of different platforms – in other words, allowing two or more systems to exchange data – which is not always evident when working in the private sector. All of these challenges call for the need for rigorous impact evaluations in order to determine whether ICT-based approaches are more effective and efficient in providing information to farmers in developing countries.

5. Measuring the Impact of ICT-Based Agricultural Extension Programs

5.1. Threats to Identifying the Impact of ICT-Based Agricultural Extension

With any new approach, there is a tendency to consider that technology as the silver bullet for development. Mobile phones are one technique among many for disseminating information to the rural poor, and, as other approaches, must be evaluated by using rigorous empirical techniques. In general these impact evaluations should address the following issues:

- The causal impact of ICT-based agricultural programs on farmers' knowledge, agricultural adoption and welfare (the "black box")
- The causal mechanisms behind the treatment effect, in particular, what aspects of ICT-based agricultural extension are more effective in terms of providing information to farmers.
- Heterogeneous treatment effects, not only by farmer-level characteristics but also by the types of information provided
- The cost-effectiveness of this approach as compared with traditional mechanisms, and the potential for sustainability
- Whether ICT-based approaches are substitutes or complements to traditional extension programs

A simple impact evaluation of an ICT-based agricultural extension program might involve a regression of the following form:

$$Y_{it} = \alpha + \beta d_{it} + X_i\gamma + \theta_t + \theta_v + \theta_i + u_{it} + \varepsilon_{vt} \quad (1)$$

Where Y_{it} is outcome variable of interest, such as farmers' agricultural knowledge, adoption of the agricultural technology, yields or welfare; d_{it} is an indicator variable for assignment into the ICT agricultural extension program at time t; X_i is vector of farmer-level baseline characteristics; θ_t is a time trend, θ_v is a village-level fixed effects, u_{it} is unobserved farmer ability or idiosyncratic shocks and ε_{vt} is common village-level error (or extension agent-level) component. The equation could be modified in a variety of ways, including controlling for θ_{it} (an interaction between farmer fixed effects and season fixed effects) (Foster and Rosenzweig 2010) or learning (by including a quadratic for the number of adopters in a farmer's social network).[22]

Assuming that the potential outcomes are independent of the treatment indicator variable, or the conditional independence assumption holds, then β will measure the treatment effect of d_{it} on Y_{it}. Nevertheless, given the nature of such programs, this is often a strong assumption, and overcoming selection bias is not the only identification problem.

[22] In most cases, and given the nature of the program, β will estimate the intention to treat, which has a causal interpretation if there is random assignment. However, this equation does not include a model of learning (ie, the number of adopters) nor does it capture general equilibrium effects.

There are potential problems with identifying the treatment effect of a ICT-based agricultural extension program, as outlined below. Some of these are threats to internal validity, whereas others affect the interpretation of the treatment effect results. The first three points are problems with measuring the impact of any agricultural extension program, whereas the latter three are often specific to ICT-based agricultural extension programs.

- Measurement error in the dependent variable. As is the case with all agricultural extension and adoption models, there is often measurement error in the dependent variable, especially when measuring returns to adoption (inclusive of costs). While this isn't any different with ICT-based agricultural extension programs, this can affect the precision of the estimates.
- Going beyond the black box of ICT programs. Although identifying the causal impact of an ICT-based agricultural extension program is of primary interest, it is also important to disentangle the mechanisms behind this effect, and to ensure that this is conditional on other information channels through which farmers might get information about a new technology.
- Serial correlation. As is the case with any learning models, learning or knowledge in the previous period will be correlated with outcomes in the next period – resulting in serial correlation problem in a fixed effects model.
- Mobile phone effects versus ICT-based agricultural extension effects. Getting access to a mobile phone via an ICT-based program might create a wealth effect, thereby decreasing the relative costs of a new agricultural technology or increase the benefits associated with that technology. This can therefore make it difficult to disentangle the other benefits of mobile phones – and their impact upon the agricultural adoption decision – from the ICT-based agricultural extension program.
- Mobile phone adoption versus agricultural adoption. Depending upon the type of program, it can be difficult to disentangle the adoption decision for the mobile phone from the agricultural technology adoption decision. In most traditional agricultural extension programs, accessing information only requires the opportunity costs of the person's time but no additional costs. In the case of ICT-based agricultural extension, obtaining information not only requires the opportunity cost of a person's time, but also learning how to use the new mobile phone technology.
- Spillover effects. Spillover effects *within* villages are common for traditional agricultural extension programs. If the treatment effect is at the village level, this is usually not a concern. However, such programs usually have minimal spillover effects *between* villages (unless the program has farmer-to-farmer visits, or an agricultural extension agents shares learning between villages). With ICT, the likelihood of spillover is much greater. Such learning and non-learning externalities must be taken into consideration with data collection and analysis.

There are some general and specific ways in which we can address these potential problems. These include tracking mobile phone usage data and monitoring the quality of the technical advice provided (to identify causal mechanisms), ensuring that one group has placebo phones (to net out the mobile phone wealth effect), collecting social network data and baseline data (to identify learning effects), collecting GIS data (at the village and household level) to control for spillover effects and assigning treatment at the village level (given individual spillover effects). Yet in order to identify the treatment effect with a high degree of internal validity, field experiments using random assignment will be a first-best solution in the short-term.

5.2. Potential Field Experiments in ICT-Based Agricultural Extension

While using field experiments in ICT-based agricultural extension programs might seem easy in theory, in practice, this will require models that go beyond our "standard" field experiments with two groups (treatment and control). Two examples and potential field experiment setups are provided below.

A SMS-Based Market Information System Experiment

Let us first take the example of an agricultural MIS system that allows farmers to obtain market information via SMS. A field experiment with three groups (SMS-based MIS, regular MIS and no market information), would allow us to compare the treatment with the control (the black box). However, it does not address the potential wealth effect of mobile phones, the effective demand for these information services, or how price information is shared within the village.

In order to address these issues, the experimental design of the program needs to go beyond a three-group comparison. Figure 8 shows a potential experimental setup. First, the program would need to randomly assign villages to three treatments and one control:

- Treatment 1: Regular market information system offered
- Treatment 2: Regular market information system offered and placebo phones distributed
- Treatment 3: SMS-based market information system offered and mobile phones distributed
- Comparison: No treatment

The randomized assignment of these treatments would ensure independence between the indicator variable and potential outcome variables, and therefore allow us to have a causal interpretation of the intention to treat effect. Further, since individuals in T2 would receive mobile phones but not access to the SMS-based MIS, this would allow us to disentangle with wealth effect of the phone from the impact of the information system. We could further estimate the demand for such services by varying the price of the MIS in T3, by randomly assigning groups to full cost (the cost of a SMS) or free (Cohen and Dupas 2010).

Depending upon how the field experiment is structured, we could better understand how the treatment effect varies by educational levels and control for spillover effects. For example, if eligible participants are identified within each village and selected at random, then we could measure information spillovers between users and non-users within the village. Similarly, if beneficiaries are divided between men and women, then we could calculate the conditional treatment effect based upon gender. And finally, if we want to understand how usage of the service (and agricultural practices) varies by educational levels, we could stratify by educational levels or, even further, randomly assign farmers within a village to a literacy training.

Even in the context of the "basic" field experiment in Figure 8, we would have a minimum of six groups. This would result in a sample size between 200-300 villages, depending upon the power calculations. The field experiment would also require additional data collection, such as data on the usage of the mobile phone service and, ideally, the traditional service.

An Agricultural Hotline Experiment

A similar approach could be used for other ICT-based extension programs, such as caller hotlines, mass SMS messages or others. With these types of programs, however, the field experiment would need to be careful about harmonizing the type of information provided and the type of extension program offered (T&V, FFS, fee for service) to ensure that the treatments only vary in the mechanism by which they are provided.

Take the example of the agricultural hotline. A key question here is whether the hotline is a complement or substitute for in-person extension services. For these reason, the hotline should ideally cross-cut the agricultural extension system and exist as a separate treatment. A potential experimental setup could be the following:

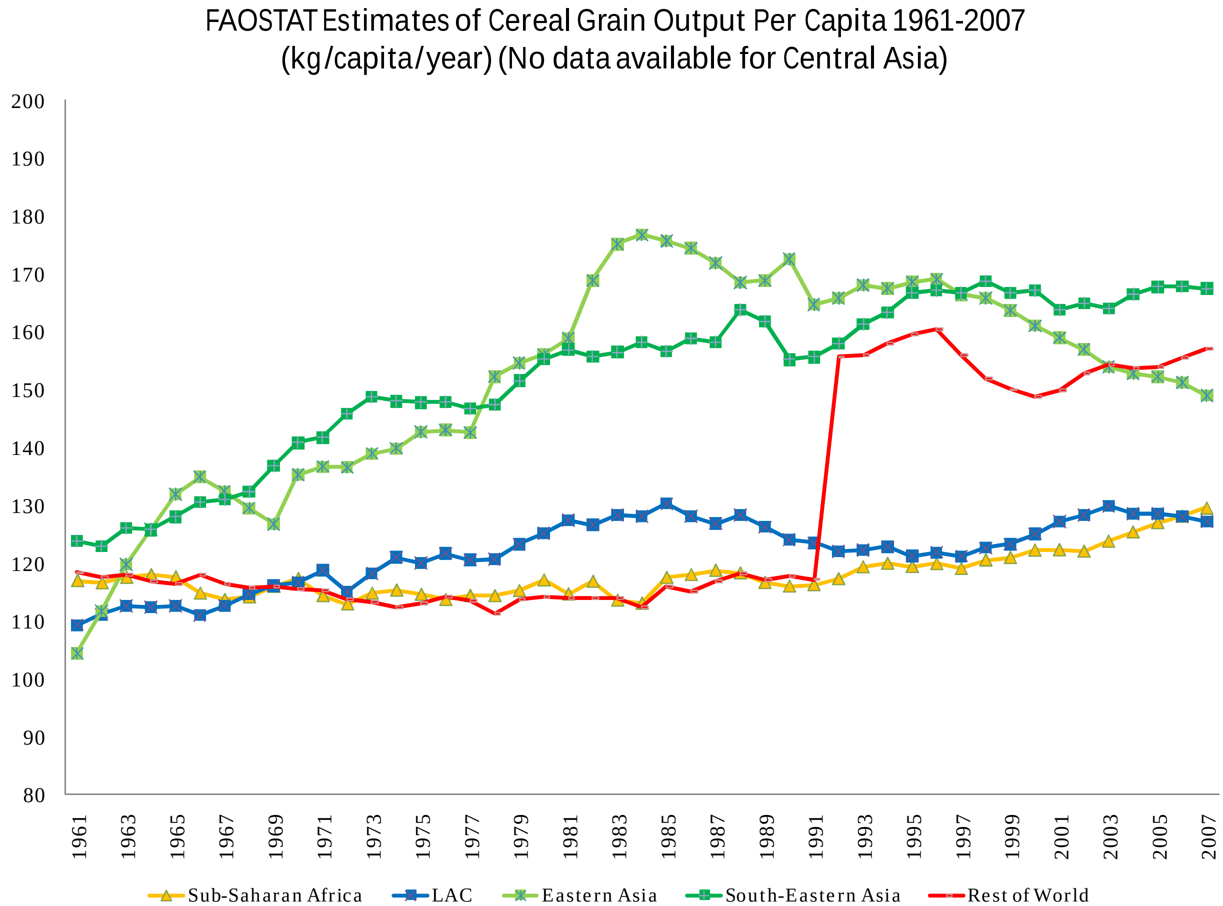
- Treatment 1: Caller hotline + phones
- Treatment 2: Caller hotline + FFS + phones
- Treatment 3: FFS + phones
- Treatment 4: FFS
- Comparison group

If the prices of the hotline are varied within the hotline groups, then the number of groups would be eight, increasing our sample size. Not all of these groups are required to ask the questions of interest, and they should be designed for the specific intervention. We could imagine, for example, that hotlines are extremely useful for time-sensitive but technically simple technologies, but less useful for technologies that are more difficult to learn or use.

V. Conclusion and Directions for Future Research

The growth of ICT in developing countries offers a new technology and new opportunities for accessing information in poor countries. One of the mechanisms is sharing information via agricultural extension, which has long been plagued with problems related to scale, sustainability, relevance and responsiveness. There are various pilot programs in India, Bangladesh and East Africa trying these new approaches. But like traditional agricultural extension, ICT-based agricultural extension risks becoming unsustainable, a "fad" and with limited impact on knowledge, adoption and welfare of poor households. For this reason, pilot programs need to be assessed using rigorous impact evaluations, which not only assess the causal impact, but also its mechanisms; determine whether such approaches are complements or substitutes for traditional extension; identify the types of information which are besteds suited for these programs; calculate the demand for such services and hence their potential sustainability; and calculate their cost effectiveness.

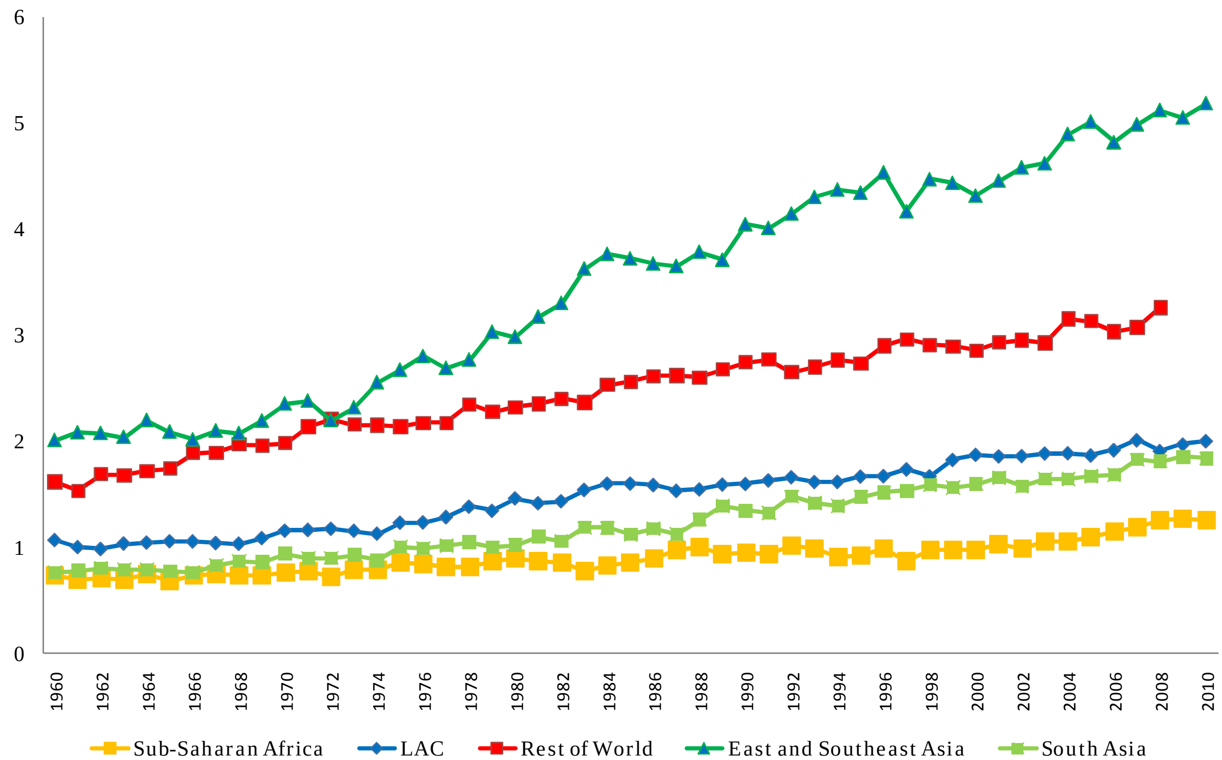
Figure 1.



Source : Author's calculations based upon data from FAOSTAT.

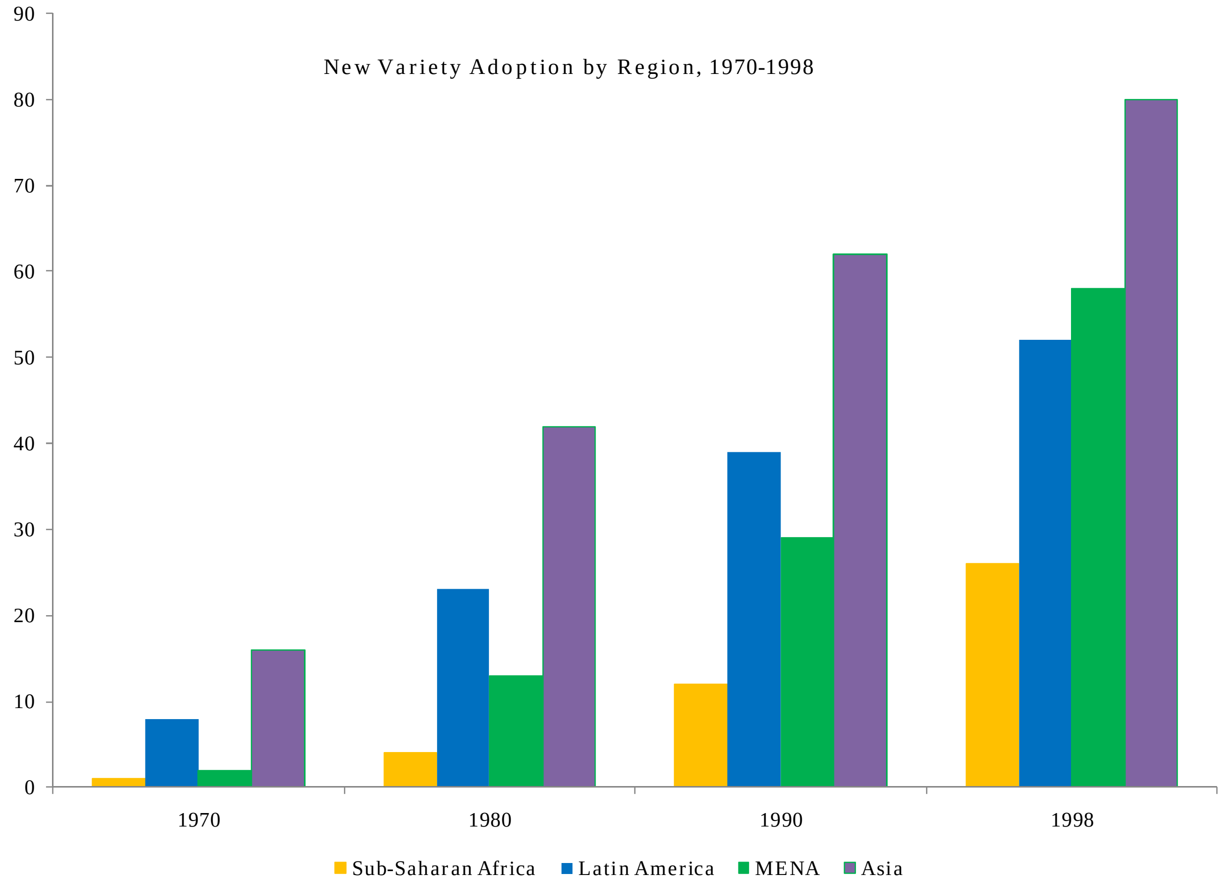
Figure 2.

Estimates of Cereal Grain Average Yield by Region
1960-2010 (MT/ha)



Source : Author's calculations based upon data from FAOSTAT. Figure adapted from Masters (2010).

Figure 3. New Variety Adoption by Region, 1970-1998



Source: Calculated from data in R.E. Evenson and D. Gollin, 2003. *Crop Variety Improvement and its Effect on Productivity*. Cambridge, MA: CABI. Figure adapted from Masters (2010).

Figure 4. Area and Population with Mobile Phone Coverage in 2009, by Region

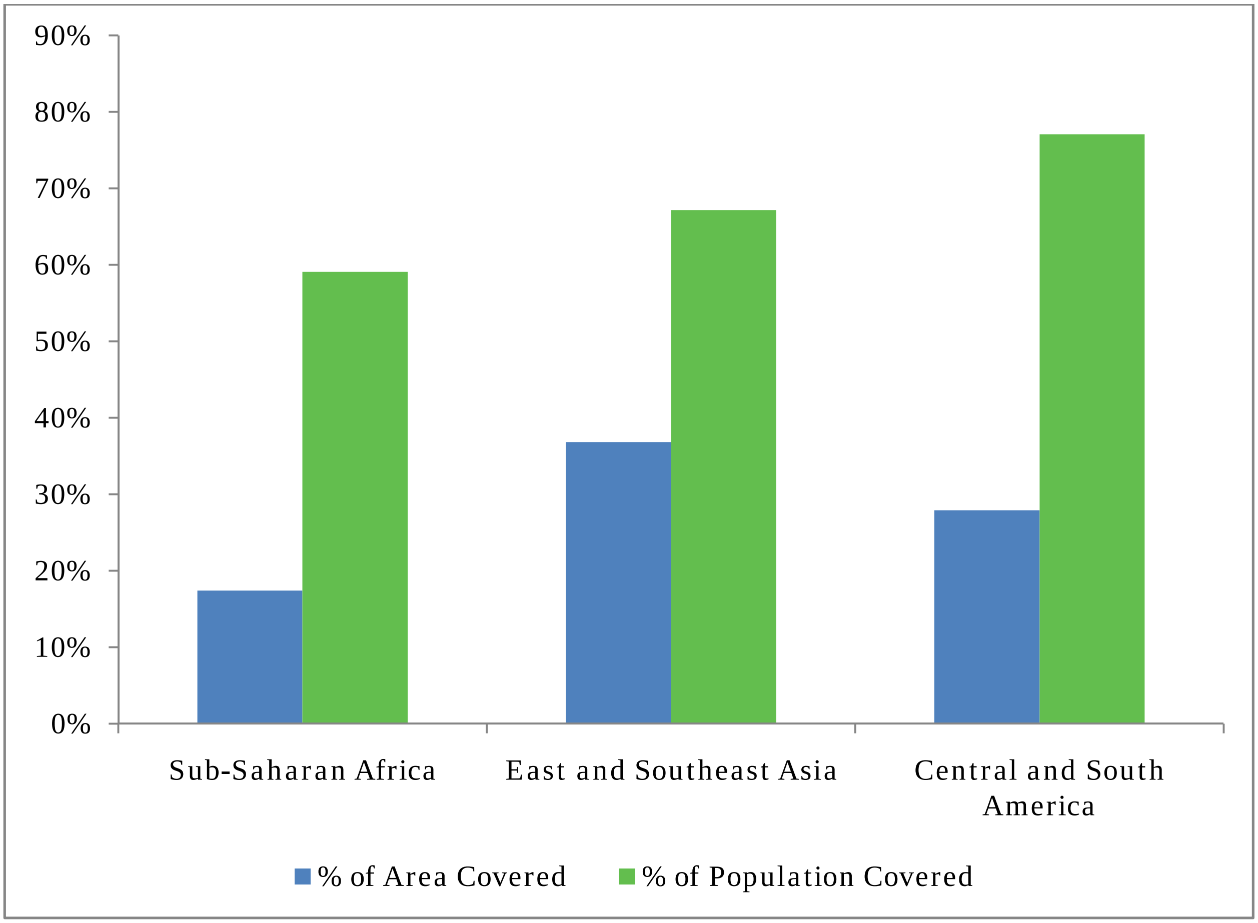
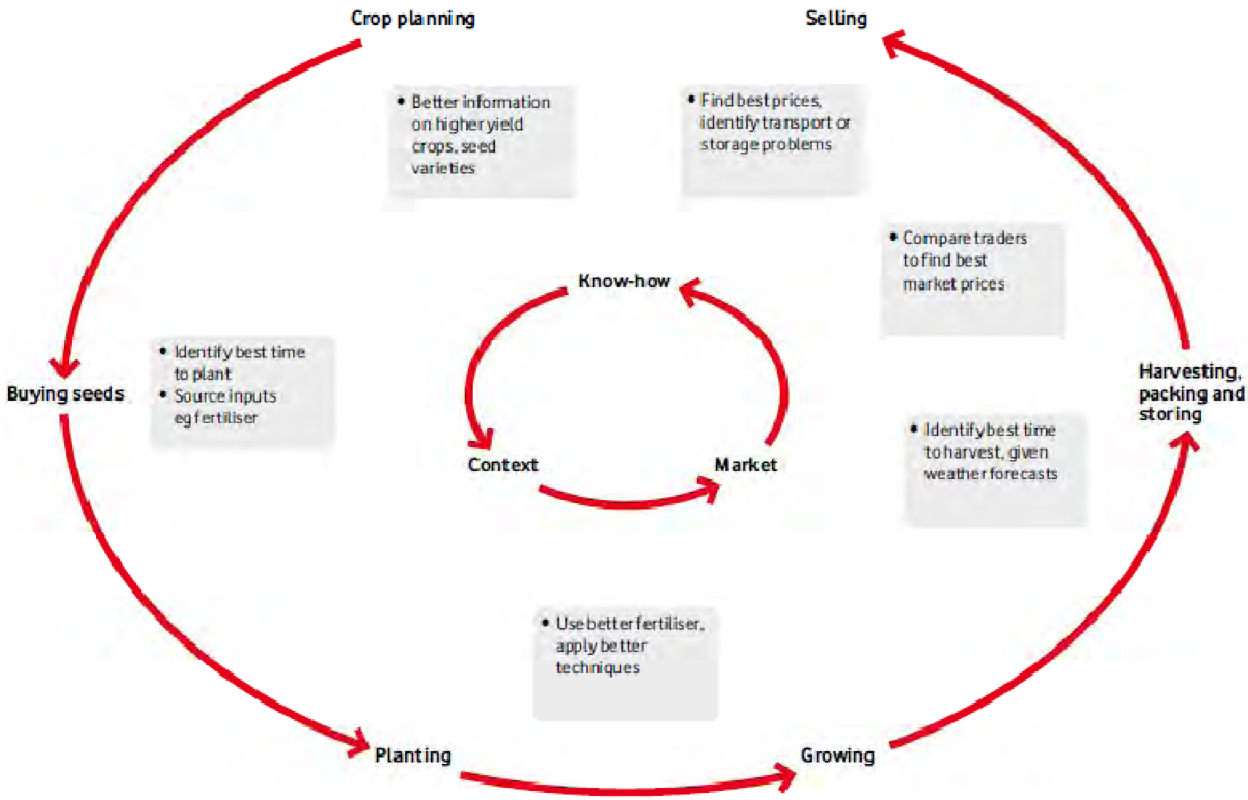


Figure 5. Stages of the Agricultural Production Process and Information Needs



Source: Figure 3, Ghandi, Mittel and Tripathi, 2009.

Figure 6. Cost of Searching of Information (per search) in Niger

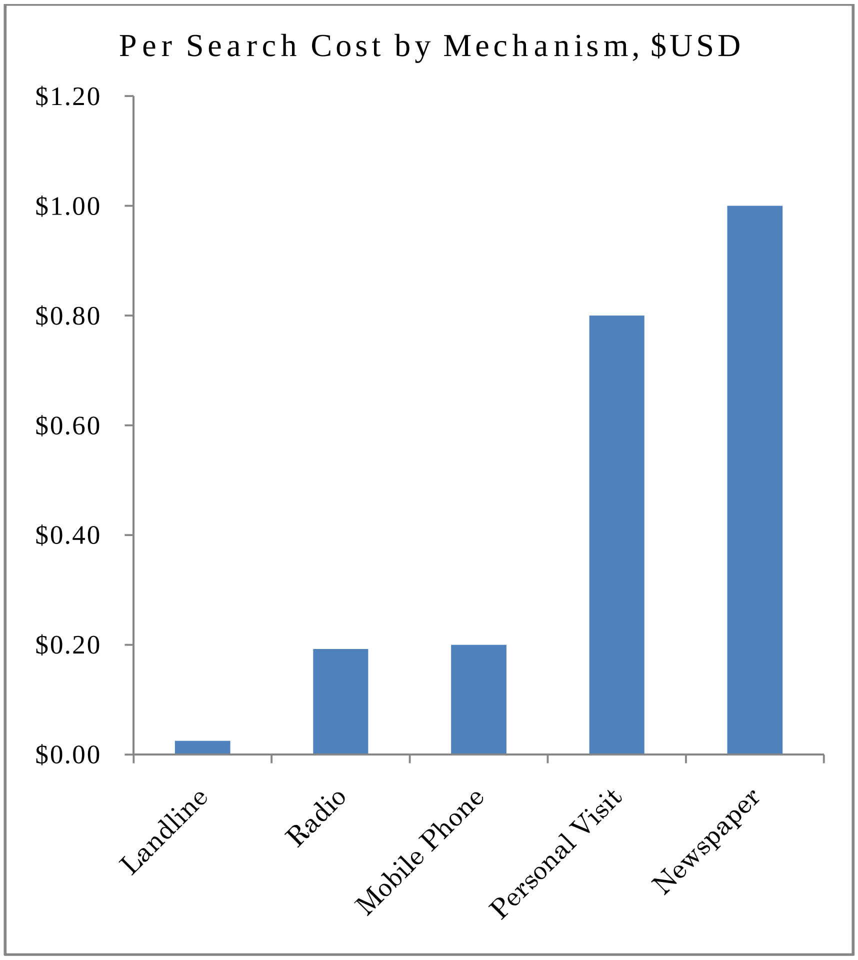


Figure 7.

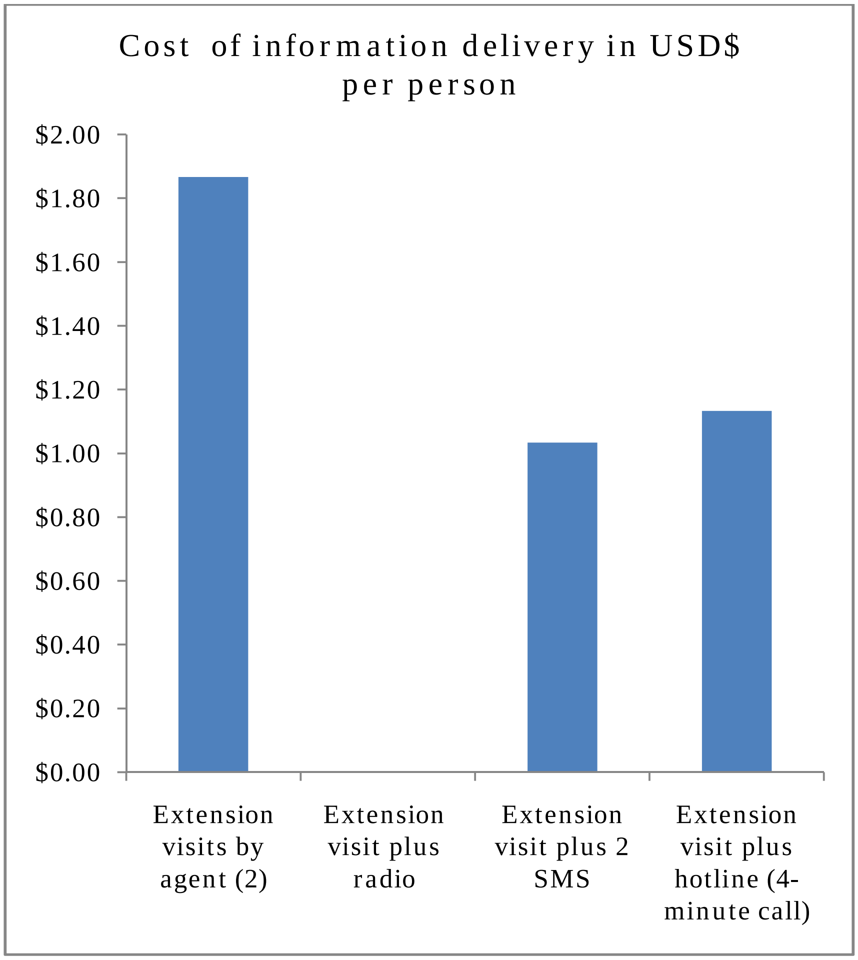

Cost of information delivery in USD$ per person
$2.00
$1.80
$1.60
$1.40
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
Extension visits by agent (2)
Extension visit plus radio
Extension visit plus 2 SMS
Extension visit plus hotline (4-minute call)

Figure 8. Field Experiment Setup for a SMS-Based Market Information Program

Table 1. Information Provided by Agricultural Extension Services and Types of Good

By types of goods	**Use rules**:	
	Rival (disappears with use by one)	***Non-rival*** (use by one does not prevent use by others)
Access rules: ***Excludable***	Private good	Club Good
	Information for private inputs or client-specific information or advice)	Time sensitive information
Non-excludable	Common pool	Public good
	Information for locally available resources or inputs	Mass media, time-insensitive information

Source: Anderson and Feder (2007).

Table 2.

Type of Extension	Study	Outcome Variable	Country
Farmer Field Schools			
	Feder, Murgai and Quizon, 2004	Productivity and yields	Indonesia
	Weir and Knight, 2004	Adoption and diffusion	Ethiopia
	Tripp, Wijeratne and Piyadasa, 2005	Adoption and diffusion	Sri Lanka
	2008	Adoption and diffusion	India
	Godtland, Sadoulet, de Janvry, Murgai and Ortiz, 2004	Knowledge, Productivity	Peru
	World Bank, 2005.	Livelihoods	Mozambique
	Van den Berg and Jiggins, 2007	General	
	Braun, Jiggins, Röling, van den Berg and Snijders, 2006	General	
Training and Visit			
	Evenson and Mwabu, 2001.	Productivity	Kenya
	Cerdán-Infantes, Maffioli and Ubfal	Productivity	Argentina
	Owens, Hoddinott and Kinsey, 2003	Productivity	Zimbabwe
	Feder and Slade 1986, Feder, Law and Slade 1987	Productivity	Pakistan
	Hussain, Byerlee and Heisey (1994)	Productivity	Pakistan
	Gautam 2001.	Productivity	Kenya
	Bindlish and Evenson, 1997.	Productivity	Kenya,
	Martin and Taylor, 1995.	Adoption and diffusion	Honduras
	Evenson and SiegelSource, 1999.	Adoption and diffusion	Burkina Faso
Farmer to Farmer			
	Alenea and Manyong, 2006	Productivity	Nigeria
Social networks			
	Foster and Rosenzweig, 1995.	Adoption and diffusion	India
	Bandiera and Rasul, 2006	Adoption and diffusion	Mozambique
	Conley and Udry, 2009.	Adoption and diffusion	Ghana
General extension			
	Romani, 2003.	Productivity	Ivory Coast
	Birkhaeuser, Evenson and Feder, 1991.	General	
	Anderson and Feder, 2007.	General	
	Davis, 2008.	General	
	Feder, Just and Zilberman, 1985.	General	
	Evenson, 2001.	General	

Table 3. Review of Mobile Phone-Based Agricultural Extension Programs

Name of Project	Type of Information (Prices, Techniques, Inputs, Buyers/Sellers, General)	Country	Mechanism (Voice, SMS, Internet)	Public (NGO, Government, UN) or Private	Free or Fee for Service	Website
Voice						
Agricultural Commodity Trade Platform	Prices, buyers, sellers	Pakistan	Voice	Both		
Allo Ingenier	General	Cameroon	Voice			http://www.irinnews.org/Report.aspx?ReportId=78408
Bangalink	Techniques	Bangladesh	Voice		Fee	
Banana Information Line	Techniques (bananas)	Kenya	Text-to-speach			http://www.comminit.com
China Mobile - 12582	Prices, techniques	China	Voice, SMS	Private	Fee	
Southern Africa Development Q&A Service	General	South Africa	Voice	Public		
National Farmer's Information Service (NAFIS)	General	Kenya	Voice	Government		http://www.nafis.go.ke/termcond
T2M (Time to Market)	Prices, supply	Senegal	Voice, SMS, Internet			http://t2m.manobi.sn/
Millennium Information Centers and Community Parliaments	General	Kenya	Voice, SMS			
Question and Answer Service (QAS) Voucher System	General	Uganda	Voice (ask question), radio, internet	Government, NGO		
IKSL Agri Hotline	Techniques	India	Voice and SMS	Both	Fee	
KRIBHCO Reliance Kisan Limited	General	India	Voice, SMS, internet	Both	Fee	
Kenya Farmer's Helpline	Market prices, weather	Kenya	Voice	Both		
Radio Dial-Up						
African Farm Radio Research Initiative (AFRRI)	General	Ghana; Malawi; Mali; Tanzania; Uganda	Radio			http://www.farmradio.org

Family Alliance for Development and Cooperation (FADECO)	General	Tanzania	Radio, SMS	NGO	http://www.hedon.info/FADECOTanzania
Freedom Fone	General	Zimbabwe	Voice, SMS, Internet		http://www.kubatana.net
Infonet Biovision Farmer Information Platform	Techniques	Kenya	Radio	NGO	
Information Network in Mande	Techniques	Mali	Radio	NGO	
Jekafo Guelekan System for Farmers in Sikasso	General	Mali	Radio	NGO	
The Organic Farmer	Techniques	Kenya	Radio, internet, magazine		www.organicfarmermagazine.org
Strengthening the Agricultural Information Flow and Dissemination System	General	Zambia	Radio	Government	
SMS-Based Extension and Price Information Services					
Agricultural Marketing and Information System for Malawi (MIS-Malawi)	Prices, Buyers, Sellers	Malawi	SMS, internet, radio	Government, NGOs	http://www.ideaamis.com
Agricultural Market Information for Farmers	Prices	Bangladesh	SMS		
Agricultural Marketing Systems Development Programme (AMSDP)	Prices	Tanzania	SMS	Government	http://www.ifad.org/english/operations/pf/tza/i575tz/i
Agricultural Research Extension Network (ARENET)	General	Uganda	Internet	Government/UN	http://www.arenet.or.ug
Apps for Africa	Techniques, weather, buyers, sellers	Uganda	SMS	Public (Grameen), private (google, MTN)	
CELAC	Techniques, weather, buyers, sellers	Uganda	SMS	Public	
Dialog	Prices, buyers, sellers	Sri Lanka		Public and private	
Esoko (formerly Tradenet)	Prices, buyers, sellers	Benin; Burkina Faso; Côte d'Ivoire; Ghana; Madagascar; Mali;	SMS, internet	Private	http://www.esoko.com

		Mozambique; Nigeria; Tanzania; Uganda; Cameroon; Afghanistan				
Farmers Information Communication Management (FICOM)	Prices, buyers, sellers	Uganda	Voice, SMS, internet, radio	NGO		http://www.syngentafoundation.org
Gyandoot	General	India	Internet			
ICT Support for Agricultural Literacy	Market prices	Ghana	SMS	Public		
ICT for Improving Agriculture in Rwanda	General	Rwanda	SMS			http://www.spidercenter.org
Informations sur les Marches Agricoles par Cellulaire (IMAC)	Prices	Niger	SMS	NGO, university		http://sites.tufts.edu/projectabc
InfoPrix Benin	Prices	Benin	SMS	Government		http://www.onasa.org/
Infotrade Uganda	Prices	Uganda	SMS, internet	Private		
Kenya Agricultural Commodities Exchange (KACE) MIS Project	Prices, buyers, sellers	Kenya	Voice, SMS, internet		Fee	http://www.kacekenya.com/
Livestock Information Network and Knowledge System (LINKS)	Prices, buyers, sellers	Kenya, Ethiopia, and Tanzania	SMS, internet			Kenya (www.lmiske.net), Ethiopia (www.lmiset.net), an Tanzania (www.lmistz.net)
Manobi	Prices	Senegal	SMS	Private, public		http://www.manobi.net
Makuleke Project	Prices, buyers, sellers	South Africa	SMS	Private		http://www1.alcatellucent.com
mKrishi	General	India	SMS and Voice SMS	Private		
Network of Market Information Systems and Traders' Organizations of West Africa (MISTOWA)	Prices, buyers, sellers	ECOWAS countries	Internet, radio, email, SMS	Private/Public		www.mistowa.org, www.wa-agritrade.net
Nokia Life Tools	Prices, weather, techniques	India, Indonesia	SMS and user interface	Private		
Regional Agricultural Trade Information Network (RATIN)	Buyers and Sellers	East Africa	Internet, voice	Government/NGO		www.ratin.net

Reuters Market Light	Prices, weather, techniques	India	SMS	Private	Fee	
Vodacom Tanzania	Prices	Tanzania	SMS	Private	Fee	
SMS Information Service	Prices, buyers, sellers	Zambia; Democratic Republic of Congo	SMS, internet	NGO		http://www.farmprices.co.zm/
Système d'Information des Marchés Agricoles (SIMA)	Prices	Niger	SMS	Government		http://ictupdate.cta.int
Trade at Hand	Prices	Burkina Faso; Mali; Senegal; Mozambique; Liberia	SMS	UN	Fee	http://www.intracen.org/trade-at-hand/
West African Agricultural Market Information System Network (RESIMAO/WAMIS-Net)	Prices, buyers, sellers	Benin; Burkina Faso; Côte d'Ivoire; Guinea; Niger; Mali; Senegal; Togo; Nigeria	Internet, radio, email, SMS			http://www.resimao.org/html/en
Women of Uganda Network (WOUGNET)	Prices	Uganda	SMS	Public	Free	
Xam Marsé	Prices, buyers, sellers	Senegal	SMS, internet		Free	http://www.manobi.sn
Mobile Phone Data Collection						
Integrating ICT for Quality Assurance and Marketing	Production quality, buyers	Zambia	Handheld computers	Public		
Research on Expectations about Agricultural Production (REAP)	Weather, pests	Tanzania	Voice	Public	Free	
E-Learning						
Agriculture Research and Rural Information Network (ARRIN) Ndere Troupe	General	Uganda	Internet			http://www.iicd.org/projects/uganda-arrin
Agrovision	Techniques	Nigeria	Internet	NGO/Government		http://www.eagriculture.org
Agricultural Sector Development Programme (ASDP)	General	Tanzania	Internet, SMS	UN		http://www.ifad.org/operations/pipeline/pf/tan.htm
Collecting and Exchanging of Local Agricultural Content (CELAC)	General	Uganda	Internet, radio, email, SMS	NGO		http://celac.or.ug

CROMABU (Crops Marketing Bureau) Project	Prices/Buyers/Sellers	Tanzania	Telecenter (computers)	NGO		http://www.iicd.org/projects/tanzania-abis-cromabu
DrumNet (Solution)	Prices/Buyers/Sellers	Kenya, Uganda	Internet			http://www.drumnet.org/
Eastern Corridor Agro-market Information Centre (ECAMIC)	Prices	Ghana	Email, mobile phones	NGO		http://www.sendfoundation.org
E-commerce for Non-traditional Exports	Buyers, sellers	Ghana	Internet		Fee	http://www.iicd.org/projects/ghana-ecommerce/
E-commerce for women	Buyers, sellers	Ghana	Internet	Government		
Enhancing Access to Agricultural Information using ICT in Apac District (EAAI)	Techniques	Uganda	Radio, mobile phones	NGO		http://www.comminit.com
Farmers' Internet Café	Buyers, sellers, general	Zambia	Internet	NGO		http://www.iicd.org/articles/iicdnews.2005-09-06.1315
First Mile Project	Buyers, sellers	Tanzania	Internet	Government		http://www.firstmiletanzania.net/
Fruiléma	Buyers, sellers	Mali	Internet, mobile phones	Private		http://www.fruilema.com/ http://www.iicd.org/projects/mali-quality-fruilema
Ghana Agricultural Information network System (GAINS)	General	Ghana	Radio			http://www.gains.org.gh/
Gyandoot	General	India	Internet			
ICT for Shea Butter Producers	General	Mali	Computers	Public		
iKisan	General	India	Internet (kiosks)			
Miproka	General	Burkina Faso	Internet (computers)	Public		
Sene Kunafoni Bulon	Buyers, sellers	Mali	Internet (computers)	Public		
Sissili Vala Kori	General	Burkina Faso	Internet (computers)			
TV Koodo: Market price information using web and national TV	Market prices	Burkina Faso	Internet, TV	Public		
Virtual extension and research communication network	General	Egypt	Internet	Government		
Warana	General	India	Internet (kiosks)			
Input Provision						
Mobile Transactions Zambia	Cashless input voucher system	Zambia	Mobile scratchcards	Private, WFP		http://www.mtzl.net<http://www.mtzl.net/default.asp

Bibliography

Alenea, Arega D. and V. M. Manyong. 2006. “Farmer-to-farmer technology diffusion and yield variation among adopters: The case of improved cowpea in northern Nigeria.” *Agricultural Economics*. 35: 203-211.

Anderson, Jock R. and Gershon Feder. 2007. “Handbook of Agricultural Economics.” *Agricultural Extension*. 3: 2343-2378.

Bindlish, Vishva and Robert E. Evenson. 1997. “The Impact of T&V Extension in Africa: The Experience of Kenya and Burkina Faso.” *The World Bank Research Observer*. 2(2): 183-201.

Birkhaeuser, Dean, Robert E. Evenson and Gershon Feder. 1991. “The Economic Impact of Agricultural Extension: A Review.” *Economic Development and Cultural Change*. 39(3): 607-650.

Braun, Arnoud, Janice Jiggins, Niels Röling, Henk van den Berg and Paul Snijders. 2006. “A Global Survey and Review of Farmer Field School Experiences.” *International Livestock Research Institute (ILRI) Final Report*.

Cerdán-Infantes, Pedro, Alessandro Maffioli and Diego Ubfal. 2008. “The Impact of Agricultural Extension Services: The Case of Grape Production in Argentina.” *Working Paper prepared by the Inter-American Development Bank*.

Conley, Timothy G. and Christopher R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review*. 100(1), 35-69.

Davis, K. 2008. “Extension in Sub-Saharan Africa: Overview and Assessment of Past and Current Models and Future Prospects.” *Journal of International Agricultural and Extension Education*. 15(3): 15—28.

Dercon, Stefan and Luc Christianson. 2008. “Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia.” *WEF Working Paper 0035, ESRC*. World Economy and Finance Research Programme, University of London.

Duflo, Esther, Michael Kremer and Jonathon Robinson. 2009. “Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya.” *Poverty Action Lab*.

Duflo, Esther, Rema Hanna and Stephen Ryan. 2007. “Monitoring Works: Getting Teachers to Come to School.” *BREAD Working Paper No. 103*.

Evenson, R.E. and G. Mwabu. 2001. “The Effect of Agricultural Extension on Farm Yields in Kenya.” *African Development Review*. 13: 1-23.

R.E. Evenson and D. Gollin, 2003. *Crop Variety Improvement and its Effect on Productivity*. Cambridge, MA: CABI.

Evenson, R. E. and Michele Siegel. 1999. “Gender and Agricultural Extension in Burkina Faso.” *Africa Today*. 46(1): 75-92.

Foster, Andrew and Mark Rosenzweig. 1995.

Foster, Andrew and Mark Rosenzweig. 2010. "Microeconomics of Technology Adoption." *Annual Review of Economics*. 2: 395-424.

Feder, Gershon, Rinku Murgai, and Jamie B. Quizon. 2004. "Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia." *Review of Agricultural Economics*. 26(1): 45-62.

Gakuru, Mucemi, Kristen Winters and Francois Stepman. 2009. "Inventory of Innovative Farmer Advisory Services using ICTs." *Prepared for The Forum for Agricultural Research in Africa.*

Gautam, Madhur. 2000. "Agricultural Extension: The Kenya Experience, An Impact Evaluation." *The World Bank.*

Ghandi, S., Mittal, S. & Tripathi, G. 2009. "The Impact of Mobiles on Agricultural Productivity." *Paper prepared for Vodaphone,* Indian Council for Research on International Economic Relations (ICRIER), New Delhi.

Godtland, Erin M., Elisabeth Sadoulet, Alain de Janvry, Rinku Murgai and Oscar Ortiz. 2004. "The Impact of Farmer Field Schools on Knowledge and Productivity: A Study of Potato Farmers in the Peruvian Andes." *Economic Development and Cultural Change.* 53(1): 63-92.

Herberich, David H., Steven D. Levittt and John A. List. 2009. "Can Field Experiments Return Agricultural Economics to the Glory Days?" *American Journal of Agricultural Economics*. 91(5): 1259-1265.

Holloway, Garth John and Simeon K. Ehui. 2001. "Demand, Supply and Willingness-to-Pay for Extension Services in an Emerging-Market Setting." *American Journal of Agricultural Economics*. 83(3): 764-768.

Jensen, Robert T. Forthcoming. "Information, Efficiency and Welfare in Agricultural Markets." *Agricultural Economics.*

Mancini, Francesca, Aad J. Termorshuizen, Janice L.S. Jiggins and Ariena H.C. van Bruggen. 2008. "Increasing the environmental and social sustainability of cotton farming through farmer education in Andhra Pradesh, India." *Agricultural Systems*. 96(1-3): 16-25.

Martin, Michael J. and Timothy G. Taylor. 1995. "Evaluation of a Multimedia Extension Program in Honduras." *Economic Development and Cultural Change.* 43(4): 821-834.

Munshi, Kaivan. 2004. "Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution." *Journal of Development Economics*. 73(1): 185-215.

Owens, Trudy, John Hoddinott and Bill Kinsey. 2003. “The Impact of Agricultural Extension on Farm Production in Resettlement Areas of Zimbabwe.” *Economic Development and Cultural Change*, 51(2): 337-357.

Romani, Mattia. 2003. “The impact of extension services in times of crisis: Côte d'Ivoire (1997-2000).” *CSAE Working Paper*.

Suri, Tavneet. 2009. “Selection and Comparatie Advantage in Technology Adoption.” Mimeo, MIT Sloan School.

Tripp, Robert, Mahinda Wijeratne and V. Hiroshini Piyadasa. 2005. “What Should We Expect from Farmer Field Schools? A Sri Lanka Case Study.” *World Development*. 33(10): 1705–1720.

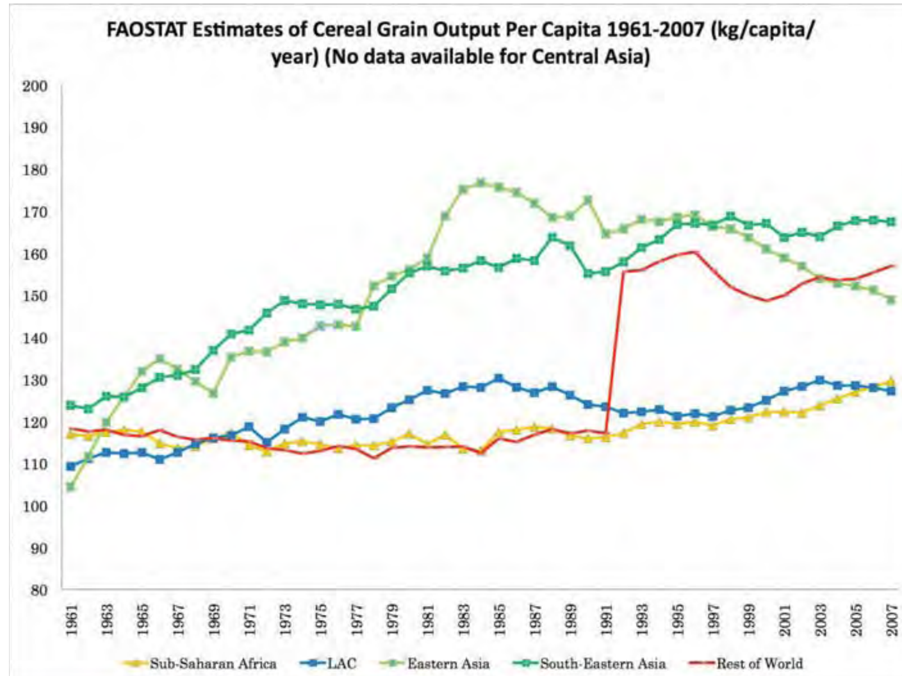
Van Den Berg, Henk and Janice Jiggins. 2007. “Investing in Farmers – The Impacts of Farmer Field Schools in Relation to Integrated Pest Management.” *World Development*. 35(4): 663–686.

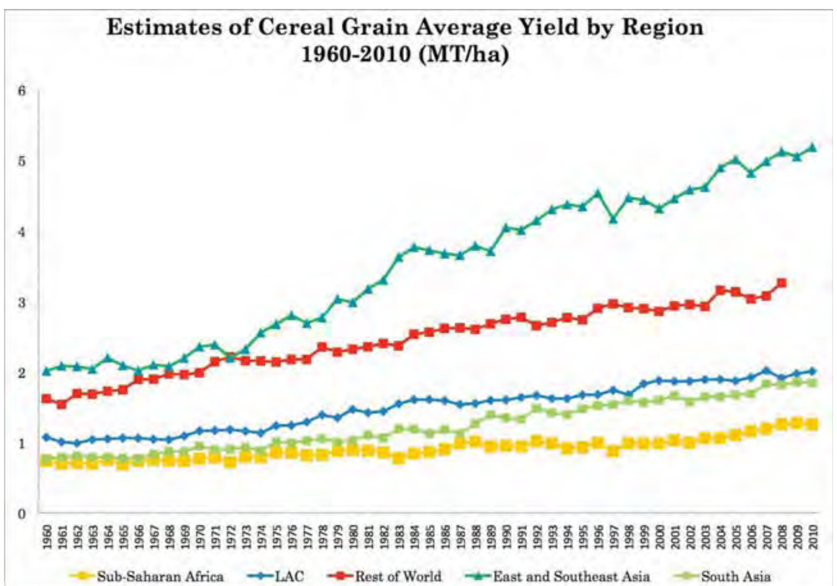
Weir, Sharada and John Knight. 2004. “Externality Effects of Education: Dynamics of the Adoption and Diffusion of an Innovation in Rural Ethiopia.” *Economic Development and Cultural Change*. 53(1): 93-113.

World Bank. 2005. “Impacts of extension services in rural Mozambique: Rural livelihoods enhanced by extension activities in Mozambique.” *ECON, Report no. 2005-015, Project no. 42860.*

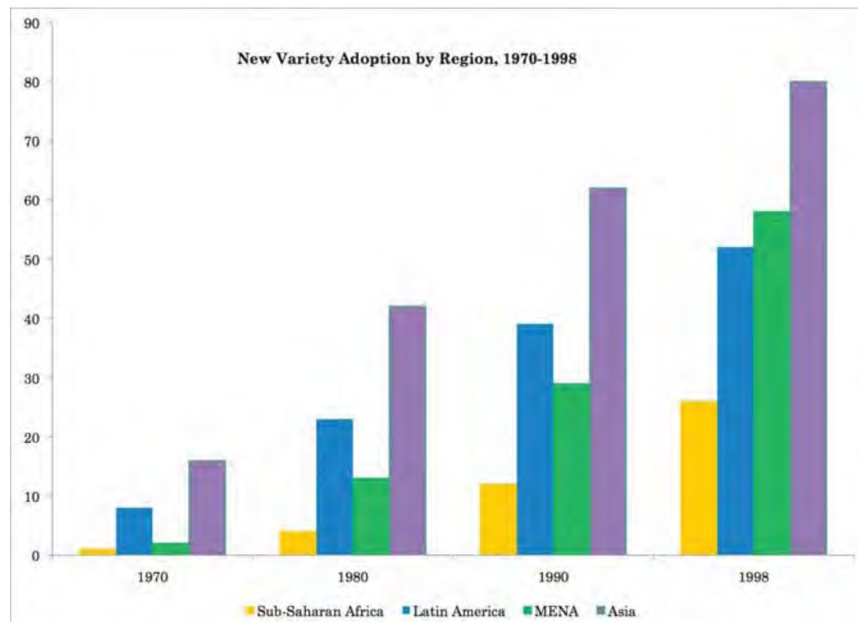
Dial "A" for Agriculture: Using ICTs for Agricultural Extension

Jenny C. Aker, Tufts University
A Paper Prepared for the Conference on Agriculture and Development
University of California-Berkeley
October 1, 2010



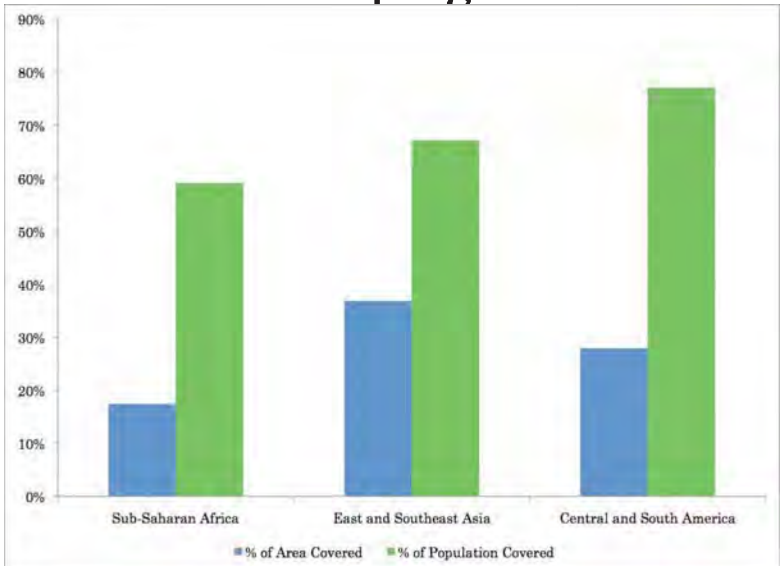


Source: Author's calculations based upon USDA data; modification of graph presented in Masters (2010).



Improvement and its Effect on Productivity. Cambridge, MA: CABI. Figure adapted from Masters (2010).

ICTs in Developing Countries



Author's calculations based upon GSMA data.

ICTs in Developing Countries

Table 1
Mobile phone subscriptions in the developing world

	Mobile Phones				Landlines	
	Number of subscriptions (millions)		Subscriptions/100 people		Number of subscriptions (millions)	Subscriptions/100 people
	2003	2008	2003	2008	2008	2008
Africa	53	364	6	39	32	3
Asia	482	1,791	13	46	580	15
Latin America	127	460	23	78	105	18

Source: ITU World Telecommunication/ICT Indicators Database 2008. Asia includes the Middle East and excludes Hong Kong, Japan, and Macao.

Source: Jensen, forthcoming, *Agricultural Economics*.

This Paper

- Review the rationale for and impact of agricultural extension programs in developing countries
- Identify the potential mechanisms through which mobile phones could improve agricultural extension and increase adoption
- Survey existing ICT-based agricultural extension programs
- Identify issues of measuring impact and future research questions

Overview

- Technology adoption, agricultural production and welfare
- Determinants of Technology Adoption
- The Role of Agricultural Extension and Adoption
- ICTs in Agriculture
- Examples of ICT in Agriculture Programs
- How can we measure impact?

Agriculture and Development

- GDP growth generated in agriculture is particularly effective in benefitting the poor (Ligon and Sadoulet 2007, Bravo-Ortega and Lederman 2005, Byerlee, de Janvry and Sadoulet 2010)

Technology adoption, agriculture and growth

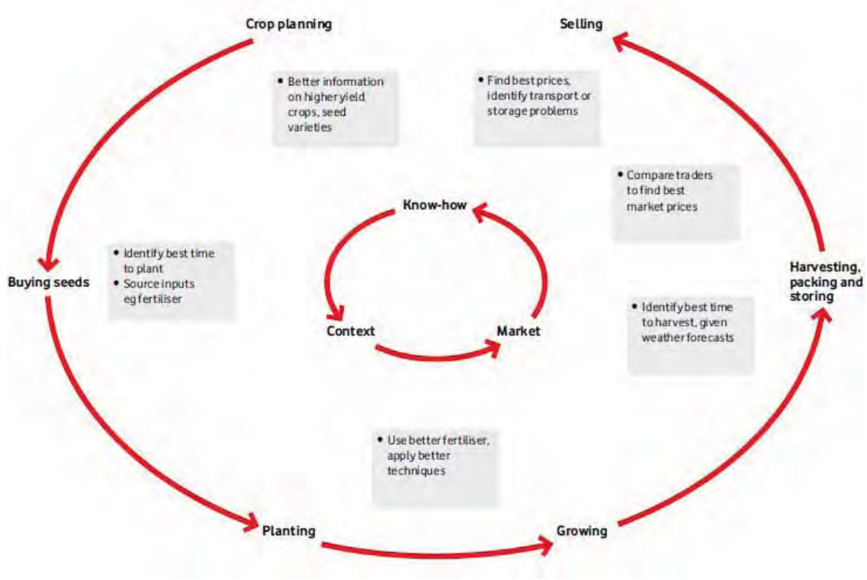
- Technology is the relationship between inputs and outputs (Foster and Rosenzweig 2010)
- The set of tools both hardware (physical) and software (algorithms, techniques) that help us act and think better.
- Hardware includes improved cultivars, fertilizers and pesticides
- Software includes practices such as inter-cropping, mulching and IPM

Who Adopts and Why?

- Determinants of agricultural technology adoption (Feder, Just and Zilberman 1985, Foster and Rosenzweig 1995, Sunding and Zilberman 2001, Suri 2009, Conley and Udry 2009, Duflo, Kremer and Robinson 2010)
- Microeconomics of adoption (Foster and Rosenzweig, 2010)

Who Adopts and Why?

- Education
- Wealth
- Access to information (learning, social networks)
- Risk
- Expected returns (benefits and costs)
- Tastes and tradition



Source: Figure 3, Ghandi, Mittel and Tripathi, 2009.

What is agricultural extension?

- The delivery of information inputs to farmers (Anderson and Feder 2007)
- Agricultural extension seeks to transfer knowledge and advice from researchers to farmers
- Extension seeks to reduce the differential between potential and actual yields in farmers' fields by accelerating the technology transfer and help farmers become better managers
- It can also provide a feedback loop to researchers to better adapt a technology to a local context

What is agricultural extension?

- Training and Visit (T&V)
- Decentralized T&V
- Fee for service
- Farmer field schools (FFS)

- This involves more than information dissemination and communication – it requires being able to understand the situation, diagnose the problem and share information

What is "effective" agricultural extension?

- Adequate and timely access by farmers to relevant advice
- Potential non-linear effects over time – more useful at the early stages of dissemination, less useful as more farmers are aware
- An effective system depends upon the type of information and the type of farmer

Agricultural Information: Public or Private Good?

By types of goods	Use rules: Rival (disappears with use by one)	Use rules: Non-rival (use by one does not prevent use by others)
Access rules: Excludable	Private good Information for private inputs or client-specific information or advice)	Club Good Time sensitive information
Non-excludable	Common pool Information for locally available resources or inputs	Public good Mass media, time-insensitive information

Based on Umali and Schwartz 1994, Figure 3.2.

Agricultural Information: Public or Private Good?

- General, non-excludable information (market information, cropping patterns) tends to be public
- Specialized, excludable information (fertilizer recommendations for a specific farm) tends to be a toll good (Umali-Deininger 1996)

Does Agricultural Extension Work?

- Value of information provided
- Value of the delivery system for supplying information
- Alternative suppliers of information (friends, neighbors, firms, media)
- Measuring the outcome variables

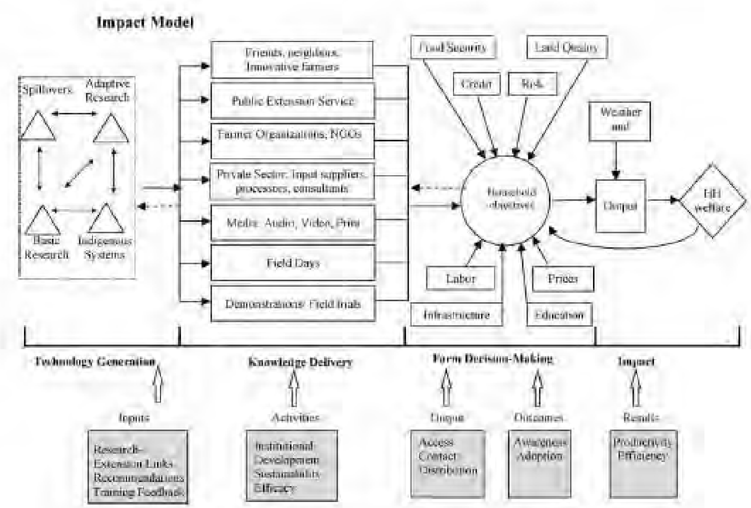


Figure 1. Scheme for an impact evaluation of extension [Gautam (2000)].

Does Agricultural Extension Work?

Outcome Variables

- Knowledge
- Adoption
- Yields
- Rates of return
- Welfare

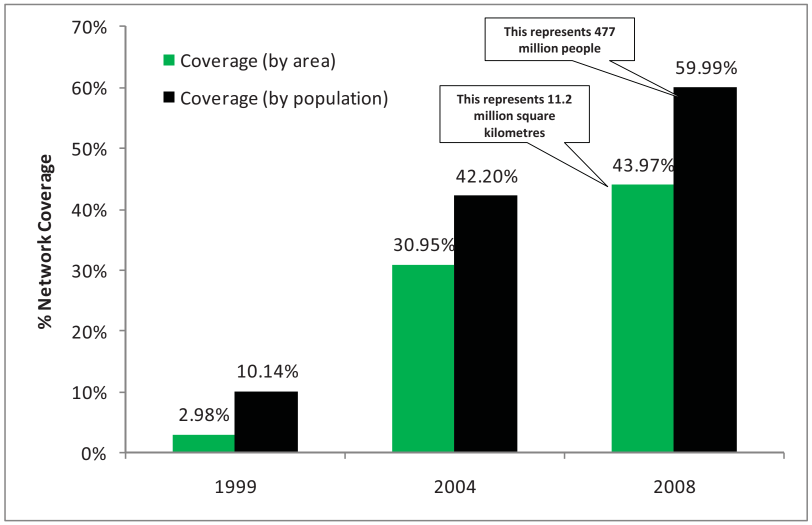
Constraints

- Measurement error
  - Returns to technology adoption
  - Optimal input use
  - Obtaining cost data
- Endogeneity

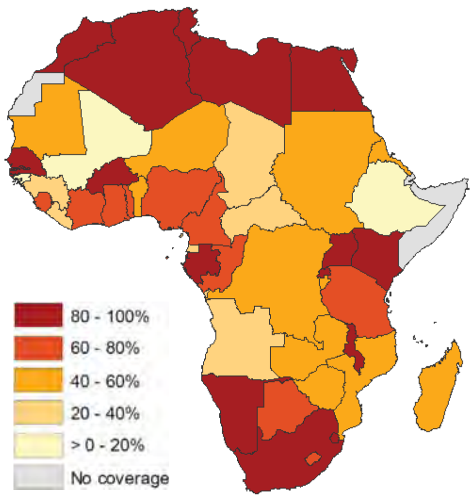
Do Agricultural Extension Systems Function?

- Scale and sustainability
- Policy environment
- Limited links with research centers and universities
- Sparse rigorous evidence on the impact of agricultural extension
- Limited accountability of field staff

477 million people covered by mobile

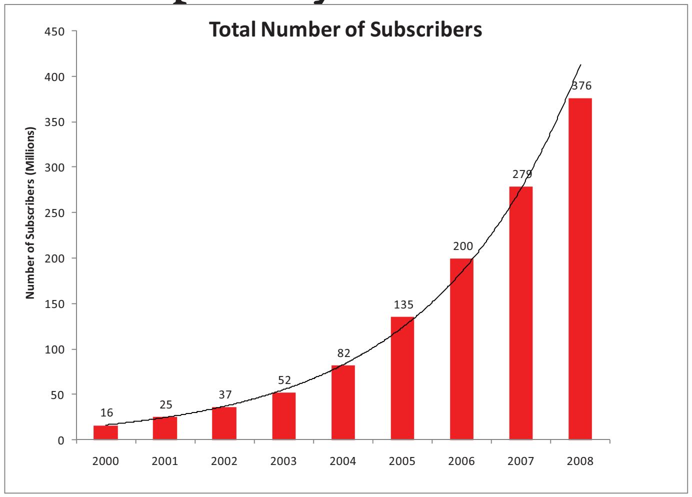


Source: GSMA 2009



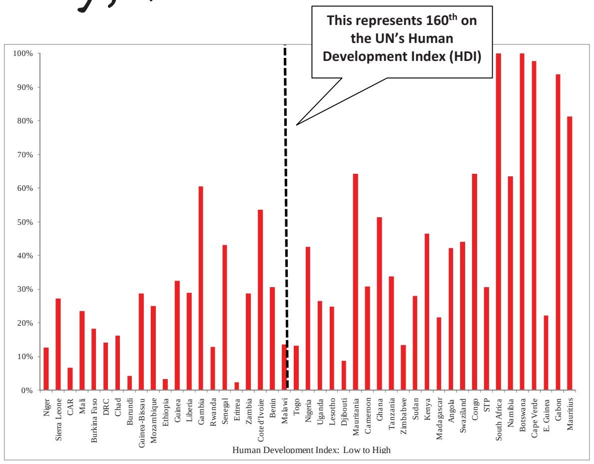
Source: Author's calculations based upon GSMA data.

Mobile Phone “Adoption” on Less than US1$ per day



Source: Wireless Intelligence

Mobile Phone “Adoption” by Country, 2008



Source: Wireless Intelligence

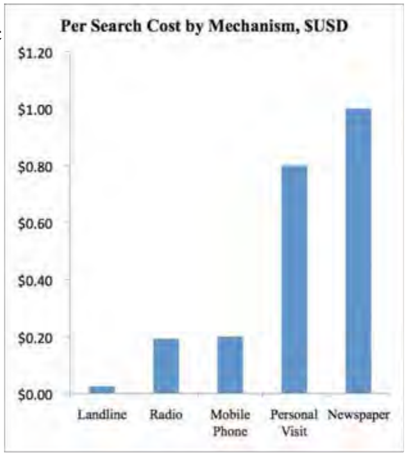
HDI=74 HDI=179

How can Mobile Phones Improve Agricultural Extension?

- Increase access to private information
  - Increase access to information about the technology and its benefits and reduce risks via improved communication among social networks
- Increase access to public information
  - Reduce costs of extension services and improve information quality
- Improve farmers’ management of input and output supply chains
- Facilitate service delivery (insurance, credit)
- Improve accountability via data collection
- Strengthen links with research systems

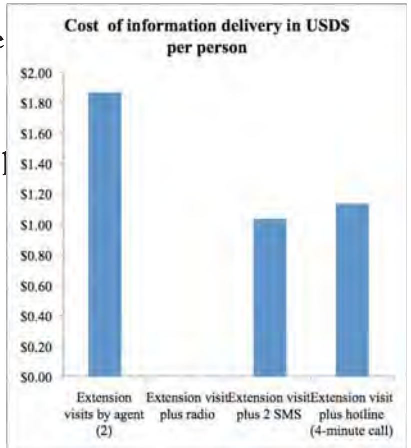
Increase Access to Public and Private Information

- Mobile phones reduce the costs of obtaining information as compared with traditional mechanisms (landlines, radio, newspaper, personal travel)
- This can reduce search (observational) costs, increase contact with social networks and expand those networks



Increase Access to Public and Private Information

- Mobile phones reduce the costs of providing extension services as compared with traditional in-person services
- This can increase scale and sustainability
- This can improve information quality by providing more timely and context-specific information



Improve Farmers' Management of Input and Output Supply Chains

- Identify potential buyers and increasing potential benefits of technology adoption
- Can allow farmers to order inputs, thereby avoiding costly stock-outs

How can Mobile Phones Improve Agricultural Extension?

- Increase access to private information
  - o Increase access to information about the technology and its benefits and reduce risks via improved communication among social networks
- Increase access to public information
  - o Reduce costs of extension services and improve information quality
- Improve farmers' management of input and output supply chains
- Facilitate service delivery (insurance, credit)
- Improve accountability via data collection
- Strengthen links with research systems

Types of ICT/Agricultural Extension Projects

Means of Dissemination

- Voice information delivery services
- Radio dial-up and broadcasts
- SMS-based extension and monitoring services
- E-learning for basic skills and agricultural education

Type of Information

- Market prices
- Weather
- Technical advice on agricultural practices, inputs and prices
- Supply and buyers at a local market

Potential (Technical) Challenges

- ICT-based agricultural extension are highly dependent upon the type of information: market prices, weather, new agricultural technologies and practices, and local and context-specific advice
- SMS holds limited information and requires some literacy
- Voice-based solutions are complicated to develop and can require machines to produce natural speech
- Most ICT-based solutions will require public-private (mobile phone company) partnerships
- Requires inter-operational platforms
- Needs rigorous impact evaluations

Measuring the Impact of ICT-Based Agricultural Extension

- What is the impact of ICT-based agricultural extension services on farmers' knowledge, adoption and welfare?
- What are the causal mechanisms behind this effect?
- Do these effects differ according to the type of information provided or the type of individual?
- Is ICT a complement or substitute to existing agricultural extension systems?
- Is an ICT-based approach more cost-effective (and sustainable) than the traditional approach?

Measuring the Impact of ICT-Based Agricultural Extension

$$Y_{it} = \alpha + \beta d_{it} + X'_{it}\gamma + \theta_t + \theta_v + \theta_i + u_{it} + \varepsilon_{vt}$$

- Y_{it} is use of the service, knowledge, adoption, yields or welfare
- d_{it} is an indicator variable for the ICT agricultural extension program
- X_{it} is vector of farmer-level characteristics, some of which are time-varying
- θ_t is a time trend
- θ_v is a village-level fixed effects
- u_{it} is unobserved farmer ability, ε_{vt} is common village-level error component
- Can also have θ_{it} as an interaction between farmer fixed

Threats to Measuring Impact

- Measurement error in the dependent variable
- Identifying the causal impact and mechanisms of ICT-based agricultural extension
- Serial correlation
- Disentangling the other benefits of mobile phones from ICT-based agricultural extension
- Disentangling the mobile phone adoption decision from the agricultural adoption decision (ie, technological spillovers)
- Spillover effects (within and across villages)

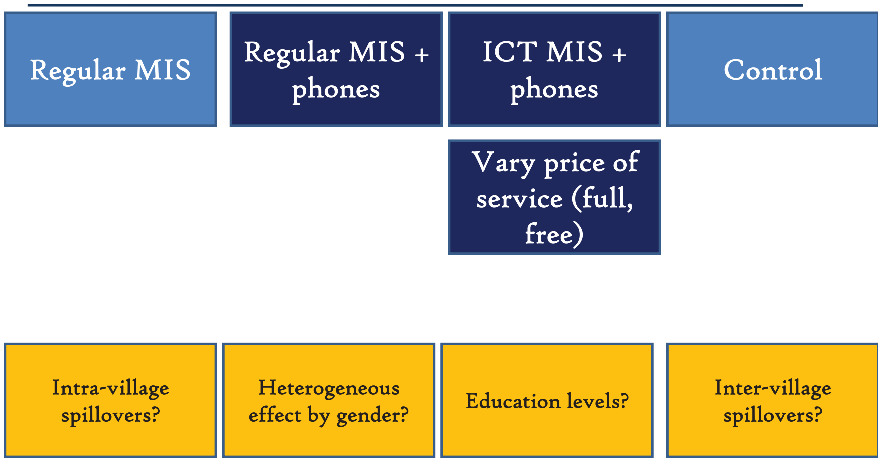
General Approaches to Identifying Impact

- Track usage data and monitor the quality of the technical advice provided
- Ensure a group with "placebo" phones
- Collect social network data and baseline data
- Collect GIS data to control for spillover effects
- Assign treatment at the village level (given spillover effects)

Field Experiment: SMS-Based Market Information

- We set up an agricultural market information system that provides market prices to farmers via SMS.
- We can (simply) compare farmers' outcomes in villages with SMS-based MIS to those with access to "regular" MIS villages and no MIS.
- But:
  - o What about mobile phone non-information benefits?
  - o What about the cost of the service?
  - o What about literacy?

Field Experiment: SMS-Based Market Information



Field Experiment: Agricultural Hotline

- Suppose that we set up an agricultural hotline in Mozambique that allows farmers to call in to ask technical questions
- In general, we will need to focus on a specific type of technical information and a specific agricultural extension model (FFS, T&V) and compare this with the hotline-based approach

Field Experiments? An Example

Hotline + Phones	FFS + Hotline+ Phones	FFS + Phones	FFS
Vary price of service (full, free)	Vary price of service (full, free)		

Future Research Questions

- Will ICT-based agricultural extension serve as substitutes or complements to **existing extension systems**? In other words, do they need to be implemented in collaboration with in-person systems?
- Does the impact of the program depend upon the type and value of information?
- What is the **demand for such information**? Will this allows the systems to be sustainable without subsidies?
- Are these systems **cost-effective**?
- Will such systems be useful only for **certain types of technologies** (ie simpler) or information?