Dial "A" for Agriculture

A Review of Information and Communication Technologies for Agricultural Extension in Developing Countries

Jenny C. Aker

Abstract

Agriculture can serve as an important engine for economic growth in developing countries, yet yields in these countries have lagged far behind those in developed countries for decades. One potential mechanism for increasing yields is the use of improved agricultural technologies, such as fertilizers, seeds and cropping techniques. Public-sector programs have attempted to overcome information-related barriers to technological adoption by providing agricultural extension services. While such programs have been widely criticized for their limited scale, sustainability and impact, the rapid spread of mobile phone coverage in developing countries provides a unique opportunity to facilitate technological adoption via information and communication technology (ICT)-based extension programs. This article outlines the potential mechanisms through which ICT could facilitate agricultural adoption and the provision of extension services in developing countries. It then reviews existing programs using ICT for agriculture, categorized by the mechanism (voice, text, internet and mobile money transfers) and the type of services provided. Finally, we identify potential constraints to such programs in terms of design and implementation, and conclude with some recommendations for implementing field-based research on the impact of these programs on farmers' knowledge, technological adoption and welfare.

JEL Codes: D1, I2, O1, O3
Keywords: Agriculture; agricultural extension; information technology; program evaluation

Center for Global Development
www.cgdev.org

Working Paper 269
September 2011

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

Jenny C. Aker

This paper is forthcoming in *Agricultural Economics*.

Jenny C. Aker is a non-resident fellow at the Center for Global Development and assistant professor of economics at Tufts University, Economics Department and Fletcher School, 160 Packard Avenue, Medford, MA 02155. Jenny.Aker@tufts.edu. She would like to thank Tanguy Bernard, Alain de Janvry, Jean-Jacques Dethier, Travis J. Lybbert, Jeremy Magruder, Isaac Mbiti, Elisabeth Sadoulet, Muzhe Yang, an anonymous referee and participants at the Agriculture for Development Conference at the University of California-Berkeley for helpful comments and suggestions. All errors are her own.

CGD is grateful for support of this work from its funders and board of directors.

Jenny C. Aker. "Dial "A" for Agriculture: A Review of Information and Communication Technologies for Agricultural Extension in Developing Countries." CGD Working Paper 269. Washington, D.C.: Center for Global Development.
http://www.cgdev.org/content/publications/detail/1425497

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

202.416.4000
(f) 202.416.4050

www.cgdev.org

1. Introduction

The potential role of agriculture as an engine for economic growth has long been recognized (Byerlee, de Janvry and Sadoulet 2009). Yet despite the importance of agriculture for development, agricultural production and yields have lagged far behind those in developed countries over the past few decades. One potential explanation for this stagnating growth in yields is the underutilization of improved agricultural technologies, which has remained relatively low in developing countries since the 1970s (Figure 1).[1]

Numerous economic studies have identified the determinants of technology adoption and the 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, common factors identified in the theoretical and empirical literature include education, wealth, tastes, risk preferences, complementary inputs and access to information and learning. Of these, the role of asymmetric and costly information has received particular attention.

Governments and international organizations have attempted to overcome some of the perceived information failures related to technology adoption via agricultural extension services, generally defined as the delivery of information inputs to farmers (Anderson and Feder 2007). There were approximately 500,000 agricultural extension personnel worldwide in 2005, with 95 per cent of these working in public agricultural extension systems (Anderson and Feder 2007). Yet despite decades of investment in and experience with public extension programs, evidence of their impact upon agricultural knowledge, adoption and productivity remains limited. Furthermore, the systems themselves have been criticized for high costs, problems of scale and low levels of accountability (Anderson and Feder 2007).

The rapid spread of information and communication technologies (ICT) in developing countries 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: over sixty percent of the population of sub-Saharan Africa, Asia and Latin America had access to mobile phone coverage in 2009. Coinciding with this increase in mobile phone coverage has been an increase in mobile phone adoption: As of

[1]Low levels of adoption do not necessarily indicate under-adoption, 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).

2008, there were approximately 4 billion mobile phone subscribers worldwide, with 374 million subscriptions in Africa, 1.79 million in Asia and 460 million in Latin America (ITU 2009). While initial adoption was primarily by wealthier, urban and more educated residents, in recent years, mobile phones have been adopted by rural and urban populations in some of the world's poorest countries (Aker and Mbiti 2010).

Mobile phones significantly reduce communication and information costs for the rural poor. 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 services. 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), radio 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, empirical evidence on their impact remains limited. In order to measure the impact of such services on farmers' knowledge, adoption and welfare, as well as their cost-effectiveness, 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. 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 a framework for measuring the causal impact of ICT-based agriculture programs. 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 of 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 have 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).

Despite the importance of agriculture for economic development, agriculture is yet to perform as an engine of growth in many developing countries – especially in 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 advances in agricultural innovations during that time (Masters 2009).[2] In addition, data on the adoption of improved agricultural technologies paint a picture of low levels of adoption in developing countries, particularly sub-Saharan Africa.[3]

The low rates of adoption in developing countries have been well-documented, and there is widespread theoretical and empirical literature identifying the determinants of agricultural technology adoption in different contexts (Feder, Just and Zilberman 1985, Foster and Rosenzweig 1995, Suri forthcoming, Conley and Udry 2010, Duflo, Kremer and Robinson forthcoming).[4] While the findings differ according to the technology and context, numerous studies have identified the importance information and learning for the adoption process.[5]

2.2. Information, Agricultural Extension and Technology Adoption

The agricultural production function implies that farmers need information on a variety of topics, at a variety of stages, before adopting a new technology. Figure 2 provides a stylized representation of the agricultural production function, including distinct yet nested adoption decisions (de Silva and Ratnadiwakara 2008, Mittal, Gandhi and Tripathi 2010).[6] Farmers have different types of information needs during each stage of the process, ranging from weather forecasts, pest attacks, inputs, cultivation practices, pest and disease management and prices.

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[2] Masters (2009) notes that national estimates of crop productivity suggests that cereal grain output per capita in sub-Saharan Africa now equals that of South Asia.

[3]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. 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).

[4]Duflo, Kremer and Robinson (forthcoming) find that the returns to fertilizer are high in Kenya and suggest that fertilizer is under-utilized. Suri (forthcoming) suggests that some farmers with high returns to adopting hybrid seeds do not adopt, and attributes this in part to poor infrastructure.

[5]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 an individual to obtain information about how to optimally manage the new technology.

[6]The simplified model identifies six stages: The "pre-planting" stage, whereby farmers decide on the crops and the allocation of land to each crop; the "seeding" stage, whereby farmers decide whether to purchase seeds or use their own; the "preparing and planting" stage, whereby farmers prepare the land using own or hired labor or land preparation machinery; the "growing" stage, which requires decisions about the application of water, fertilizer and pesticides; the "harvesting, packing and storage" stage, which requires decisions about labor for harvesting and storage; and the "marketing" stage, whereby farmers must decide whether, when and where to sell the commodity (de Silva and Ratnadiwakara 2008, Mittal, Gandhi and Tripathi 2010).

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 information is costless, information is rarely symmetric or costless in developing countries. This is partly due to the high cost of obtaining information via traditional means, such as travel, radio or newspaper. As a result, information asymmetries can be an important barrier to agricultural technology adoption in developing countries.

Since the 1960s, agricultural extension has been put forth as a means of reducing the information asymmetries related to technology adoption in both developed and developing countries. Broadly speaking, agricultural extension is the "delivery of information inputs to farmers" (Anderson and Feder 2007). The general extension approach uses specialists to provide a range of services to farmers, from technology transfers to advisory services and human resource development. [7] In some cases it has also sought to connect researchers directly to the farmer in order to ensure that new technologies are better targeted to the specific conditions of agricultural communities.

Agricultural extension models can take several forms.[8] 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 are able to train others. T&V was promoted by the World Bank and applied in more than 70 countries between 1975 and 1995 (Anderson, Feder and Ganguly 2006).[9] Farmer field schools (FFS) were specifically designed to diffuse integrated pest management (IPM) methods in Asia. FFS also utilize contact farmers, relying on participatory training methods that build farmer capacities. Fee-for-service extension comprises both public and private initiatives with some public funding. In these programs, farmer groups contract extension agents with specific information and service requests.[10]

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

[8]Agricultural extension has expanded in developing countries since the 1960s with significant public sector financing. There are approximately 500,000 agricultural extension workers worldwide, and 80 percent of these are publicly funded and delivered by civil servants (Anderson and Feder 2007).

[9] The decentralized T&V approach is similar to the T&V approach, but the responsibility for delivery is given to local governments (Crowder and Anderson 2002).

[10]While agricultural extension services are primarily financed and implemented by the public sector, the information provided via such systems is not always a public good. Table 1 shows the different types of information provided via extension systems and their classification as either private, public, club or common pool goods (Anderson and Feder 2007).

2.3. Does Agricultural Extension Work?

Despite decades of investment in agricultural extension systems, there are surprisingly few rigorous impact evaluations of these services in developing countries. Table 2 provides an overview of these studies, based upon the type of agricultural extension system (T&V, FFS, fee for service and social networks) and the outcome variable of interest (knowledge, adoption, yields, rates of return and general livelihoods) (Evanson 2001, Anderson and Feder 2007). The results provide contradictory evidence of the impact of agricultural extension programs.[11]

Do these results suggest that agricultural extension does not work? There are two potential explanations for the mixed results in Table 2. First, there are several challenges to identifying a causal relationship between agricultural extension and development outcomes. Measuring the outcome variables of interest in such studies (e.g., adoption, production and returns) is notoriously difficult, thereby introducing measurement error in the dependent variable. While this will not introduce attenuation bias (the bias toward zero), it can reduce precision, thereby making it more difficult to detect a statistically significant effect. Furthermore, observable and unobservable characteristics that are simultaneously correlated with extension programs and the outcomes of interest will very likely differ across extension and non-extension communities, as well as across users and non-users, which makes the participation status of extension programs endogenous. And finally, given the different types of agricultural extension models (T&V, fee for service, FFW) and the wide range of information provided via these models, cross-country comparisons of agricultural extensions programs are meaningless.

Beyond problems of measurement error and endogeneity, another potential reason for the seemingly weak impacts of these programs could simply be the quality of the agricultural systems themselves. A worldwide review of public extension systems by Rivera, Qamar and Crowder (2001) found that many agricultural extension systems were barely functioning, related to the following factors:

- **Limited scale and sustainability**: In countries where the farm sector is comprised of small-scale farmers, extension clients often live in geographically dispersed areas. This can result in high costs, limited geographic coverage and unsustainable services (Anderson and Feder 2007).

- **Policy environments that reduce the value of information provided via extension services,** mainly due to terms of trade that are tilted against agriculture, poor infrastructure and inadequate input supplies.

[11] 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).

- **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 may not be the case in developing countries. Consequently, the incentives of these institutes are not aligned with agricultural priorities in the country (Purcell and Anderson 1997) and technologies are not always locally adapted.

- **Low motivation and accountability of extension field staff.** As is the case with all public servants, monitoring the presence and motivation of extension staff is difficult. This is particularly problematic in the case of 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, motivation and the availability of appropriate technologies.

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

3. How ICTs Could Affect Agricultural Adoption and Extension in Developing Countries[12]

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 with limited access to other sources of information (landlines, newspapers and radios). While infrastructure investments still remain low in many developing countries, one of the most dramatic changes over the past decade has been an increase in mobile phone coverage and adoption. In sub-Saharan Africa, for example, less than 10 percent of the population had mobile phone coverage in 1999, increasing to over 60 percent of the population in 2008 (Aker and Mbiti 2010).

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

Coinciding with this growth in coverage has been an increase mobile phone adoption and usage, even in some of the world's poorest countries. There were 16 million subscribers in sub-Saharan Africa 2000, growing to 376 million in 2008. Similar rates of mobile phone adoption have been observed in Latin America and Asia (Figure 3).[13] The number of mobile phones per 100 people in developing countries often exceeds access to other information technologies, such as landlines (Jensen 2010), newspapers and radios (Aker and Mbiti 2010).

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

The rapid growth of mobile telephony in developing countries 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 and offer only one-way communication (Demographic and Health Surveys, various countries). Newspapers are primarily concentrated in urban areas, are expensive 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 (DHS surveys, various countries). Landline coverage has been limited, with less than one landline subscriber per 100 people in 2008 (ITU 2009). Access to other search mechanisms, such as fax machines, e-mail, and internet, is similarly low. And finally, personal travel to different locations to obtain information not only requires the cost of transport, but also the opportunity cost of an individual's time.

Aker and Mbiti (2010) provide an overview of the mechanisms through which mobile phone telephony can affect economic development in sub-Saharan Africa, including improved access to market information and coordination among agents; increased job creation; improved communication among social networks; and the development of new services, such as mobile banking. In that vein, this paper identifies six potential mechanisms through which mobile phones could potentially improve farmers' access to information about agricultural technologies and adoption in general, as well as access to and use of agricultural extension services in particular.

How Mobile Phones can Improve Access to (Private) Information

Mobile phones can improve access to and use of information about agricultural technologies, potentially improving farmers' learning. As Figure 2 shows, farmers require information on a variety of topics at each stage of the agricultural production process. In many developing countries, such information has traditionally been provided via personal exchanges, radio and perhaps landlines and newspapers. Compared with these mechanisms,

[13]The number of subscribers 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).

mobile phones can significantly reduce the costs of obtaining agricultural information. Figure 4 shows the per-search cost of price information for different types of search mechanisms. Mobile phones are significantly less expensive than the equivalent per-search cost of personal travel or a newspaper, yet more expensive than landlines or radio. Nevertheless, landlines are not readily available in most regions of the country, and radio only provides price information for specific products and markets on a weekly basis.

The reduction in search costs associated with mobile phones could increase farmers' access to information via their private sources, such as members of their social network (Baye, Morgan and Scholten 2007, Aker 2010, Aker and Mbiti 2010). 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.[14] While this could potentially increase the rate of technology adoption, it could also reduce the rate of adoption in the presence of learning externalities (Foster and Rosenzweig 1995, Foster and Rosenzweig 2010).[15]

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 to public information such as those provided via agricultural extension services. Figure 5 shows the marginal cost (borne by the extension system) of providing agricultural price information, either via extension agent's visits, short message service (SMS) or a call-in hotline, based upon data from a SMS-based market information service in Niger. The marginal cost of providing market information via SMS is cheaper than providing the same information via an additional extension visit, and is equivalent to providing the same information via radio.[16] Reducing the costs of disseminating information could increase the extension system's geographic scope and scale, as well as facilitate more frequent and timely communications between extension agents and farmers. This could, in turn, improve the

[14]In addition to the impact of mobile phones on obtaining information on a technology, mobile phones could speed up information flows within a social network, thereby increasing access to informal credit, savings and insurance and thereby affecting a farmer's adoption decision (Aker and Mbiti 2010).

[15]Increased access to information – either via learning by doing or learning from others – will not necessarily lead to higher rates of adoption, as learning that a new technology is not efficacious will reduce adoption in the next period (Foster and Rosenzweig 2010). There are also two potential opposing effects of social networks on the adoption decision: an individual farmer's incentive to adopt increases as the number of members in his or her social network using the new technology increases; yet this also creates an incentive to delay adoption due to free-riding behavior and information spillovers (Foster and Rosenzweig 1996).

[16]While the fixed costs for constructing radio towers and mobile phone base stations differ by location and country, within a given country or location, the fixed costs of constructing a radio tower are similar to those of a mobile phone base station. In many cases, however, the costs of constructing the radio tower are borne by the public sector. 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.

quality (or value) of the information services provided. Yet the impact of these reduced costs on farmers' adoption decisions will depend upon the ability of such information to serve as substitute for in-person mechanisms.

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

Several studies have highlighted the importance of risk and supply-side constraints as barriers to agricultural technology adoption (e.g., Suri forthcoming). By reducing communication costs, mobile phones could assist risk-averse farmers in identifying potential buyers for their products over larger geographic areas and at crucial moments, thereby reducing price risk and potentially increasing the net benefits of the technology. Similarly, improved communication between farmers and traders could also facilitate the provision of inputs to rural areas, potentially reducing their cost.

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. The most prominent of these is mobile money transfers (known as m-money), a system whereby money can be transferred to different users via a mobile phone. M-money applications can facilitate the delivery of complementary services to farmers (such as access to credit or savings, or agriculture and health insurance), thereby helping to address some of the "missing markets" that can 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 (Dillon 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. In addition, mobile phones can be used to verify agents' visits, similar to what has been done with cameras in Indian schools (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

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 price and quality (Goyal 2010). In some countries, national ministries of agriculture have attempted to integrate ICTs into information delivery services, specifically by establishing district information centers (FARA 2009). With the growth of mobile phone coverage, many of these initiatives have moved away from "traditional" ICTs to mobile telephony, including voice, SMS and internet-based services. Table 3 provides a survey of these projects, categorized by the mechanism of dissemination (voice, radio, SMS and internet) and their primary purpose (FARA 2009).

- **Voice-based information delivery services** primarily include telephone-based information delivery services that provide advice on farming methods and market access. Some of these services use call-in centers or hotlines for agricultural extension support. The mechanisms range from the use of a simple telephone – such as landlines or mobile phones – to more complicated technology and computing applications (FARA 2009).

- **Radio dial-up and broadcasts** include regular radio broadcasts that provide market prices or other agricultural information, as well as dial-up radio that feature a series of short segment audio programs (FARA 2009). The radio system often features a regularly updated 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 (FARA 2009).

- **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 information (on market prices or agricultural production) and receiving the response via SMS; and receiving mass SMS on agricultural topics (FARA 2009).

- **E-learning programs** typically include telecenters and internet kiosks that allow farmers to access computers and the internet for agriculture-related information.

The information provided via these different mechanisms includes market prices, weather, technical advice and suppliers and buyers in local markets. A majority of these services focus on market prices, weather and transport costs, most likely because this information is easy to collect and disseminate, objective and less prone to measurement error (albeit quickly outdated and constantly changing). Projects that provide information on agricultural practices and inputs are relatively rare, possibly because such information is more nuanced and difficult to convey.

While all of these mechanisms offer potential alternatives to traditional means of disseminating information, there are challenges to using ICT in agricultural extension systems. First, the use of ICT-based agricultural extension is highly dependent upon the type of information provided. For example, while information on market prices and weather might be easily disseminated via mobile phones and therefore replace traditional extension mechanisms, more nuanced information on agricultural practices and inputs might be complements. Second, SMS-based platforms – which are often the easiest to establish – can only hold limited information and require that users have some literacy skills and technological knowledge. Such services can be useful in providing simple or standardized information but are as easily adaptable for more complex information exchanges. Third, while voice-based Q&A services overcome the limitations of text-based platforms and can provide more nuanced information, they can be complicated to develop or require machines to produce natural speech. Some early initiatives have made audio files accessible to farmers through the use of mobile phones (Kenya, Uganda and Zimbabwe). Finally, since many of these applications and services have been developed and managed by the private sector, the use of these initiatives for agricultural extension will most likely require some sort of public-private partnership. All of these factors suggest that ICT-based extension services could fundamentally change the way in which agricultural information is provided in developing countries, and highlights the need for evaluating whether such 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. Identifying the Impact of ICT-Based Agricultural Extension

Mobile phones are one tool among many for disseminating and collecting information on agricultural technologies, yields and prices in developing countries. Before scaling up such interventions, it is necessary to evaluate the impact of existing ICT-based approaches. Such evaluations should seek to address the following questions:

1. **What is the impact of ICT-based agricultural programs on farmers' knowledge, agricultural adoption and welfare?** In other words, are changes in outcomes observed before and after the intervention due to the ICT-based intervention or other factors? This requires identifying a *causal effect* of the program, either the average treatment effect (ATE), the average treatment effect on the treated (ATT) or the intention to treat (ITT).

2. **Are the observed changes in outcomes due to the ICT project or access to the mobile phone?** In some cases, ICT-based projects provide participants with access to mobile phones. Since mobile phones can affect farmers' access to information and services through different channels, it is necessary to disentangle the impact of the ICT-based *service* from the impact of mobile phone usage.

3. **What are the mechanisms behind the treatment effect?** In other words, how (or through what pathway) does the ICT-based agricultural extension service change farmers' access to information, learning and adoption?

4. **How does the estimate of the treatment effect differ by farmer type and the type of information provided?** Beyond the average effect of the program, assessing the heterogeneity of the treatment effects among different groups can provide important information for scale-up.

5. **What are the potential spillovers of the ICT-based program, both on other project participants and non-participants?** An advantage of mobile phone technology is that it can be shared among many users, thereby allowing non-users to potentially benefit from the service. While such spillovers can complicate the identification of the treatment effect, incorporating their impact into the treatment effect is necessary in order to understand the dynamics of the technology and technology adoption.

6. **Is the ICT-based approach cost effective as compared with traditional mechanisms?** Is it a substitute or complement for traditional approaches?

7. **Are the results externally valid?** In other words, are they applicable to other regions within the same country, other populations or other countries? If so, under what conditions?

These questions provide a potential framework for designing impact evaluations of ICT-based agriculture and agricultural extension programs. The next sections will discuss some of the specific challenges to identifying the impact of these programs and offer some recommendations for conducting such evaluations

5.2. Threats to Identifying Impact of an ICT-Based Agricultural Program

A simple two-period econometric model of the impact of the ICT-based program might take the following form:

$$Y_{it} = \delta + ad_{it} + X'_{it}\gamma + Z'_{v}\pi + \theta_t + \theta_v + \theta_i + u_{it} + \varepsilon_{vt} \quad (1)$$

where Y_{it} is outcome variable of interest, such as farmers' agricultural knowledge, technology adoption, yields, farm-gate prices or welfare; d_{it} is an indicator variable for assignment of individual i into the ICT-based agricultural extension program at time t; X_{it} is vector of farmer-level characteristics; Z_v is a vector of village-level baseline characteristics; and θ_t, θ_v, and θ_i are time-, village- and individual-level fixed effects, respectively.[17] u_{it} is unobserved

[17]Time-varying farmer-level characteristics (X'_{it}) may be preferred to baseline characteristics, which would be removed by fixed effects or first-differences estimators.

farmer ability or idiosyncratic shocks and ε_{vt} is a common village-level error component. Equation (1) is a difference-in-differences (DD) specification, comparing the group means of the treatment and control group between the pre- and post period. The model could be modified in a variety of ways, including controlling for θ_{it} (an interaction between farmer fixed effects and season fixed effects) or learning (by including the number of adopters in a farmer's social network) (Foster and Rosenzweig 2010).

There are numerous challenges to identifying the treatment effect, *a*.[18] While some of these threats are common to all impact evaluations, some are specific to ICT-based agricultural extension programs. These include:

- **Identifying the appropriate counterfactual for the treatment group**. Assuming that the potential outcomes are (conditionally) independent of the treatment status (d_{it}), then a will measure the treatment effect of d_{it} on Y_{it}. Nevertheless, this requires controlling for potential differences in observable or unobservable characteristics by establishing a proper counterfactual group (de Janvry, Dustan and Sadoulet 2010).

- **Ensuring common types of information across treatment groups.** Most impact evaluations represent the program by a binary indicator variable (d_{it}). In the case of ICT-based agricultural extension programs, however, there can be multiple treatments, depending upon the mechanism used for disseminating the information (e.g., SMS, voice, in-person visits, SMS and in-person visits). While this is easily resolved econometrically by including different indicator variables, the primary challenge is in the *interpretation* of the treatment effect; each treatment may not only differ in the *mechanism of dissemination* but also the *type* (*or quality*) *of information provided*. For example, voice-based services permit farmers to ask questions and receive more detailed information, whereas in-person visits can allow extension agents to demonstrate a new technique. This implies that the treatment effect will capture the impact of both the *mechanism* and the *information conveyed*.[19]

- **Disentangling the effects of the mobile phone from impact of the ICT-based extension.** If the ICT-based agriculture program facilitates participants' access to a mobile phone, mobile phone ownership or usage might have a wealth effect, thereby decreasing the relative costs of an agricultural technology or

[18] The interpretation of *a* will depend upon the design of the program. For example, in programs where the ICT-based extension service is randomly assigned at the community-level, there may not be a one-to-one relationship between assignment to the extension service and a household or farmer's decision to *use* the service. In this case there is imperfect compliance, and standard average treatment effects may not be estimated. Rather, an Intention to Treat (ITT) or Local Average Treatment Effect (LATE) will be estimated for compliers (Imbens and Angrist 1994, Angrist and Imbens 1995).

[19] Using an indicator variable for impact evaluations also does not take into account the intensity of treatment, which is potentially endogenous.

increasing the benefits associated with that technology. This can therefore make it difficult to disentangle the benefit of the mobile phone from the benefit of the ICT-based agricultural extension program.

- **Separating out the mobile phone adoption decision from the agricultural adoption decision.** In most traditional agricultural extension programs, accessing information only requires the opportunity costs of the farmer's time. In the case of ICT-based agricultural extension, obtaining that same information also requires how to use the new mobile phone technology. This dual adoption decision can affect a participant's decision to use the ICT-based agriculture system.

- **Controlling for spillover effects**. Spillover effects *within* villages are common for traditional agricultural extension programs. Yet such programs usually have minimal spillover effects *between* villages, unless extension agents or farmers in treated villages share information with those in control villages. With access to mobile phones, farmers are able to contact members of their social networks more easily, thereby increasing the likelihood of inter-village spillovers. This can also lead to broader general equilibrium effects, especially if farmers change production patterns or marketing behavior and are concentrated within a specific geographic location.

5.3. Potential Field Experiments in ICT-Based Agricultural Extension

A variety of econometric methodologies can be used to estimate equation (1) and address the potential threats to validity identified in Section 5.2. These include natural experiments or randomized controlled trials (RCTs); regression discontinuity design (RDD); matching; difference-in-differences; and instrumental variables. Each approach has relative strengths and weaknesses in terms of internal and external validity (de Janvry, Dustan and Sadoulet 2010) and practical implementation. This section proposes some general principles for conducting evaluations of ICT-based extension programs, and provides two examples of setting up field experiments to estimate the impact of ICT-based agriculture programs.

There are some general principles that can be used to estimate the effect of ICT-based agricultural extension programs. These include focusing on *microeconometric impact analysis*, which allows for a more careful identification of the appropriate counterfactual (de Janvry, Dustan and Sadoulet, 2010); *collecting pre- and post data for treatment and comparison groups*, so that DD can be used to control for time-varying unobservables on the basis of the common trend assumption; *assigning treatments at the village level* (rather than the individual, household or plot level) to minimize potential spillovers on the comparison group[20]; *collecting data on social*

[20] Nevertheless, in some cases, observing the social dynamics of learning could be of interest. In this case, while treatment could be at the village or cooperative level, different strategies could be used to target opinion leaders or decision-makers to better understand how this affects information-sharing and adoption.

networks within villages, in order to identify potential learning across individuals; *assigning one group to receive "placebo" phones* (i.e., phones that are provided without access to the ICT-based extension service), in order to identify the impact of the ICT-based service from mobile phone usage; and *using random assignment, randomized phase-in or clear-cut criteria* to assign units into the treatment and control groups, so that selection bias can be controlled for more explicitly. More specific examples of potential experimental setups are provided below.

Example #1. A SMS-Based Market Information System (MIS) Experiment

Over 35 percent of the ICT-based programs in Table 3 provide market information to farmers, either via radio, SMS or internet. Traditional evaluations of these programs compare farmers' outcomes (e.g., prices and sales) before and after the program, or compare the outcomes of farmers with access to the program to those without access. Yet simple pre-post or contemporaneous comparisons will not control for potential selection bias and do not address some of the key questions and threats outlined in Sections 5.1 and 5.2.

A potential experimental design for estimating the effect of an ICT-based MIS program could include three treatments and one control:

- *T1*: Regular market information system offered
- *T2*: Regular market information system offered and "placebo" phones distributed
- *T3:* SMS-based market information system offered and mobile phones distributed
- *Comparison:* No market information or mobile phones

If these treatments are randomly assigned across different groups, then this would ensure independence between the treatment status and the potential outcomes, thereby allowing us to have a causal interpretation of the treatment effect.[21] Furthermore, since individuals in T2 would receive mobile phones but not access to the SMS-based MIS, we would be able to disentangle the wealth effect of the mobile phone from the impact of the ICT-based information system (e.g., comparing T2 with T3). We could further estimate the *demand* for such services by varying the price of the service in T3, potentially by offering the service at full cost, a subsidized cost or free. And finally, by assigning treatment at the village level, this would minimize the potential spillover effects across villages.[22]

[21] Since there may be imperfect take-up of the MIS system – in other words, farmers may be assigned to treatment but not choose to use the service – then we could measure either the ITT or the LATE. For a discussion of the assumptions required for LATE in infrastructure programs, see Bernard and Torero (2011).

[22] We could also modify the field experiment to estimate the treatment effect for specific sub-groups (e.g., women or men, different educational levels), or by targeting particular individuals or opinion leaders within the group.

Despite the improvements of this approach as compared with a simple first difference analysis, there are several weaknesses to this experimental design. First, even a "basic" field experiment with three treatment groups and one control group would require a sample size of between 200-300 villages, depending upon the power calculations. This problem could be exacerbated if there is weak compliance among those assigned to the program, especially if information via the extension service is shared between users and non-users.[23] Second, the design does not address the potential general equilibrium effects of the program. If farmers start buying and selling in new markets due to the MIS, then this will affect local demand (supply) on those markets and potentially affect producers and consumers from comparison villages. For this reason, this design will only estimate the partial equilibrium effect. And finally, random assignment might not be feasible in every context, implying that an alternative method of assigning units to treatment and control groups might be required.[24]

Example #2. An Agricultural Hotline Experiment

An alternative type of ICT-based agricultural program is the call-in hotline, whereby farmers can call a technical expert and ask specific questions. While these programs are more flexible than SMS-based services, the type of information provided – and hence the impact evaluation -- is more complex. A key challenge to estimating the impact of this program is harmonizing the type of information provided and the type of extension program offered (T&V, FFS, fee for service), so that it is possible to disentangle the impact of the information provided from the extension model. In addition, it is important to determine whether the hotline is a complement or substitute for in-person extension services.

A potential experimental design for estimating the effect of an ICT-based hotline might include four treatments and one control:

- *T1:* Caller hotline + phones
- *T2*: Caller hotline + in-person extension visit + phones

The intervention could also be modified to remove the provision of mobile phones, thereby reducing the number of treatment groups.

[23] Such within-village spillovers would also violate the Stable Unit Treatment Value Assumption (SUTVA), thereby biasing the treatment effect downward (in the case of positive spillovers) or upward (in the case of negative spillovers).

[24]An alternative to randomization could be RDD, whereby villages that meet certain criteria (such as those located more than *X* km from a market) would be assigned to treatment, and those less than X km would be in the control group. However, this approach would raise additional challenges, as it might be difficult to find villages that are "arbitrarily close: to the cutoff point, which is necessary for a RDD design. Alternatively, a DD approach could be used, whereby villages are assigned to treatment or control group based upon some specific and observable criteria that could be included as control variables in the regression.

- *T3:* In-person extension visit + placebo phones
- *T4:* In-person extension visit only
- *Comparison group:* No phones, no visits, no hotline

If units are randomly assigned to different treatments, then this would ensure independence between the treatment indicator and the potential outcomes, and therefore allow us to identify the treatment effect. Since individuals in T3 would receive mobile phones but would not have access to the hotline, we would be able to disentangle with wealth effect of the phone from the mechanism for providing information (e.g., comparing T3 with T4, and T1 with T3). We could further estimate the *demand* for such services by varying the price of the hotline in T1 and T2. And finally, by including T2 (a group with access to the hotline, visits and phones), this would enable us to determine the extent to which the hotline is a complement or substitute for in-person extension visits.[25]

Despite the improvements of this approach as compared with traditional approaches, the key challenge with this impact evaluation is the (unobserved) differences in information provided via each mechanism. For example, in-person visits might allow extension agents to show farmers how to use a new technology or technique, and different types of information will be provided during visits and discussions. Controlling for these differences is difficult if not impossible, unless the technical information and technology is very narrowly defined. And while hotlines might be more useful for time-sensitive and technically simple inputs or techniques, they would be less useful for technologies that are more difficult to learn or use.

6. 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 sub-Saharan 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 bested suited for these programs; calculate the demand for such services and hence their potential sustainability; and calculate their cost effectiveness.

[25] The evaluation design could be further modified by varying the intensity of treatment; e.g., varying the frequency of visits or calls.

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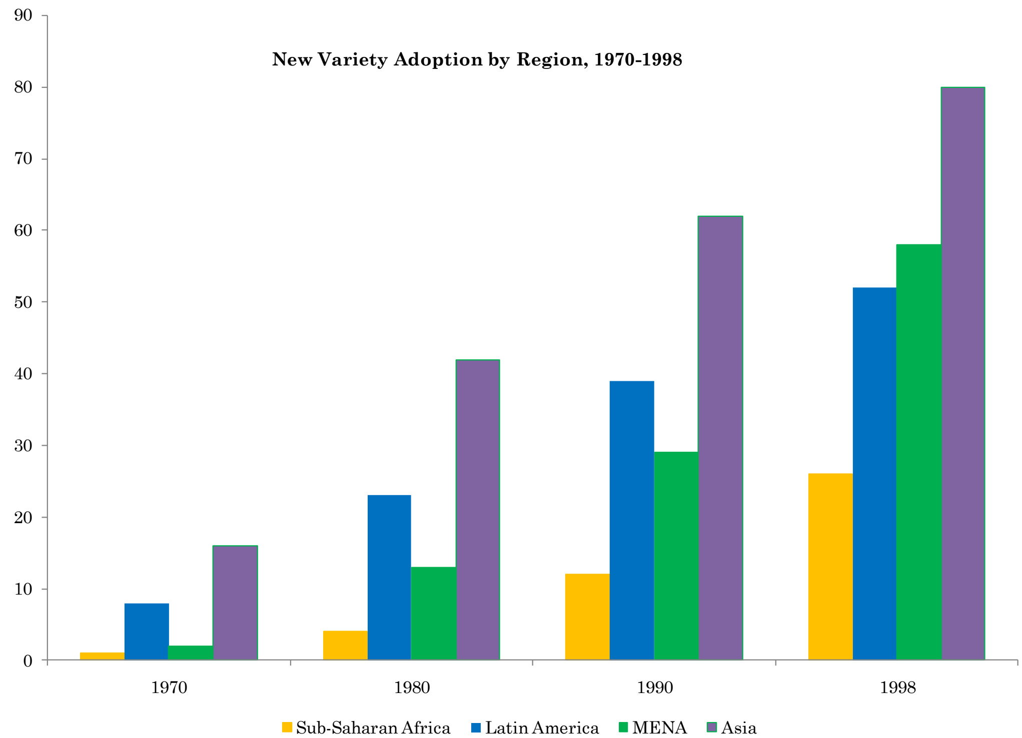
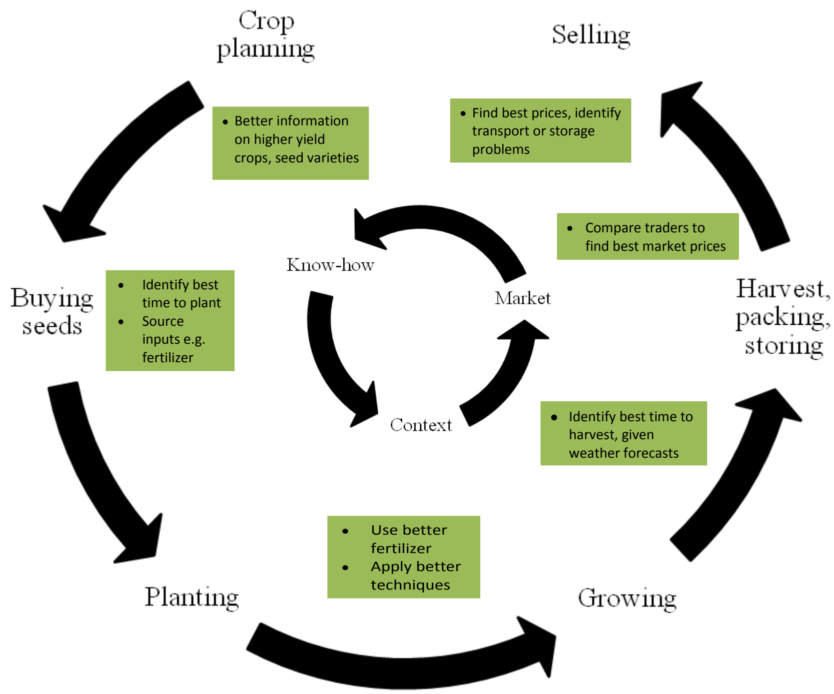
Figure 1. New Variety Adoption by Region, 1970-1998



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 (2009).

Figure 2. Stages of the Agricultural Production Process and Information Needs



Notes: Figure reproduced from Mittal, Gandhi and Tripathi. 2010. 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.

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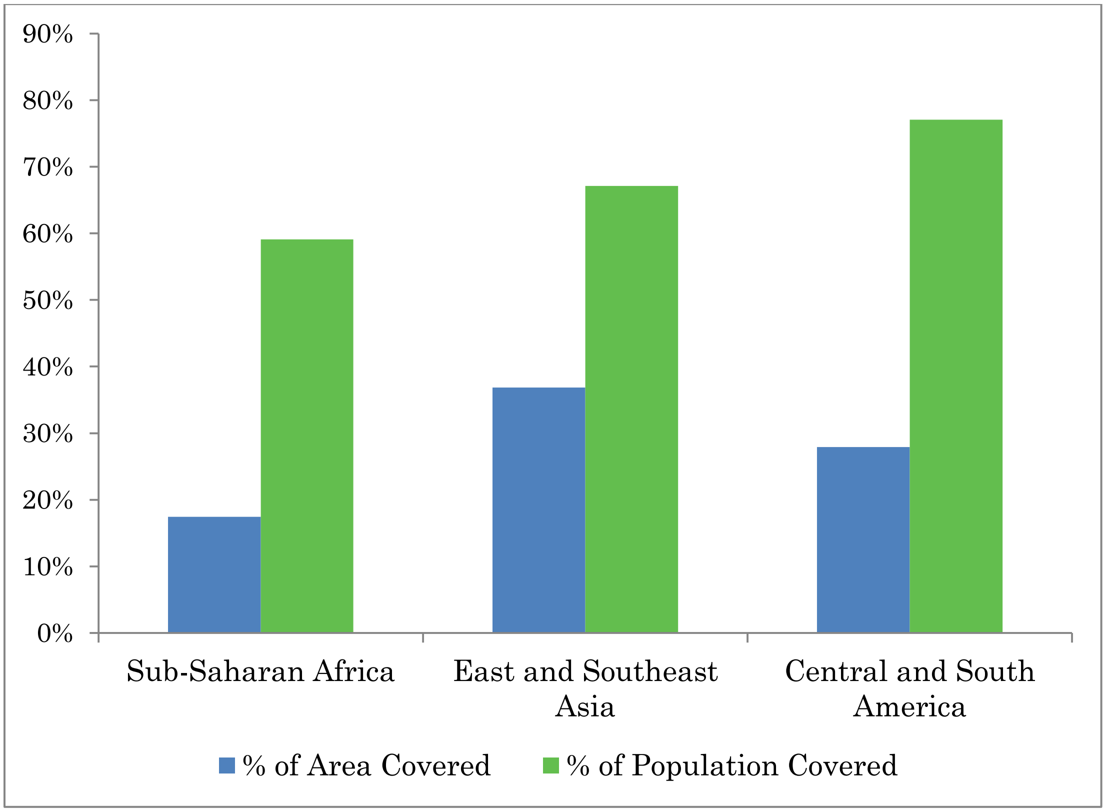
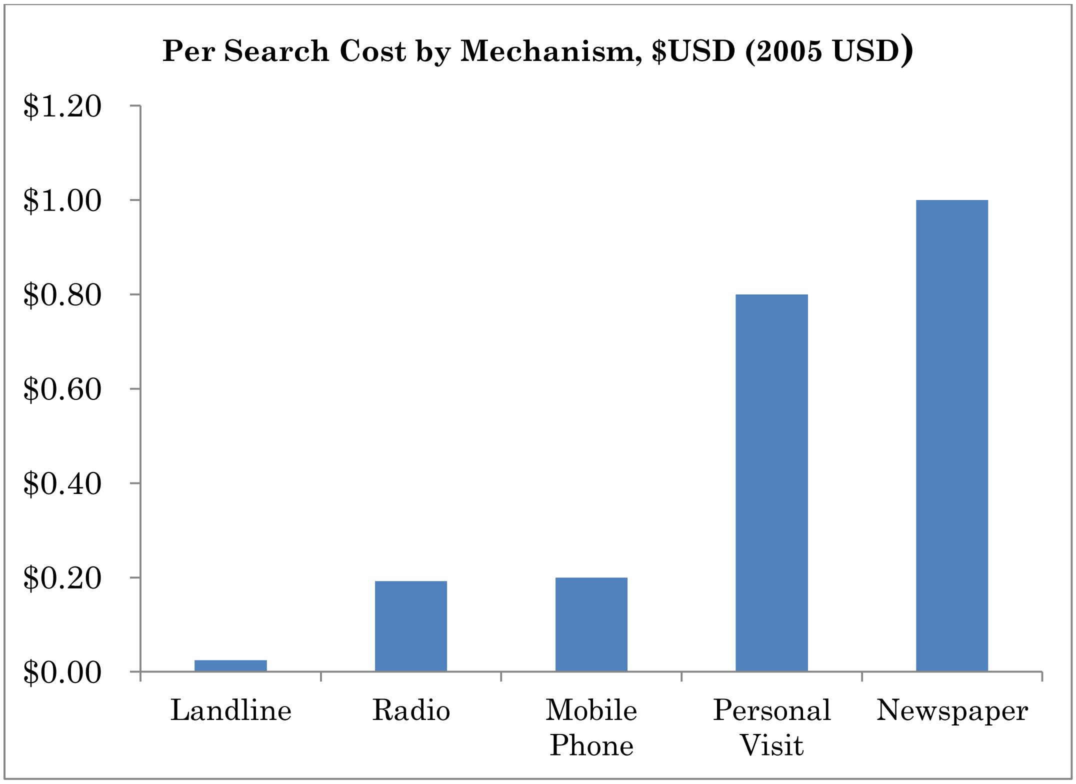
Figure 3. Area and Population with Mobile Phone Coverage in 2009, by Region



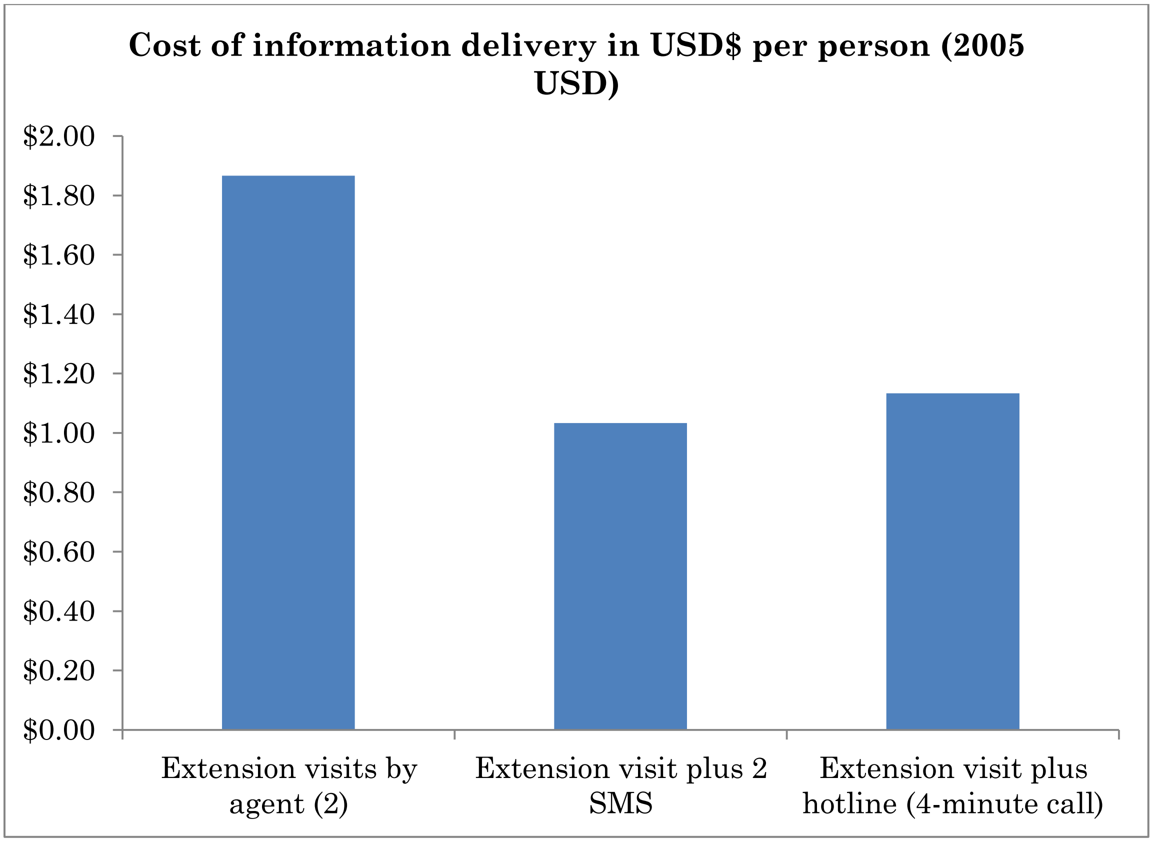
Source: Authors' calculations based upon mobile phone coverage data from the GSMA in 2010.

Figure 4. Marginal (per Search) Cost of Price Information in Niger, 2010



Notes: Based upon the authors' calculations from data collected in Niger between 2005 and 2010.

Figure 5. Marginal Cost of Information Delivery in Niger, 2010



Notes: Based upon the authors' calculations from data collected in Niger between 2005 and 2010.

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

Notes: The original version of this table was provided in Anderson and Feder (2007).

Table 2. Review of Economic Studies of Agricultural Extension Programs

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
	Bruggen, 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	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	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
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	

Notes: Research studies compiled from Anderson and Feder (2007) and other sources.

Table 3 Survey of ICT-Based Agricultural Extension Programs

Mechanism/Project	Type of Information (Prices, Techniques, Inputs, Buyers/Sellers, General)	Country	Mechanisms (Voice, SMS, Internet)	Website
Voice				
Agricultural Commodity Trade Platform	Prices, buyers, sellers	Pakistan	Voice	
Allo Ingenier	General	Cameroon	Voice	http://www.irinnews.org/Report.aspx?ReportId=78408
Bangalink	Techniques	Bangladesh	Voice	
Banana Information Line	Techniques (bananas)	Kenya	Text-to-speech	http://www.comminit.com
China Mobile – 12582	Prices, techniques	China	Voice, SMS	
Southern Africa Development Q&A Service	General	South Africa	Voice	
National Farmer's Information Service (NAFIS)	General	Kenya	Voice	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	
IKSL Agri Hotline	Techniques	India	Voice and SMS	
KRIBHCO Reliance Kisan Limited	General	India	Voice, SMS, internet	
Kenya Farmer's Helpline	Market prices, weather	Kenya	Voice	

Mechanism/Project	Type of Information (Prices, Techniques, Inputs, Buyers/Sellers, General)	Country	Mechanisms (Voice, SMS, Internet)	Website
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	http://www.hedon.info/FADECOTanzania
Freedom Fone	General	Zimbabwe	Voice, SMS, Internet	http://www.kubatana.net
Infonet Biovision Farmer Information Platform	Techniques	Kenya	Radio	
Information Network in Mande	Techniques	Mali	Radio	
Jekafo Guelekan System for Farmers in Sikasso	General	Mali	Radio	
The Organic Farmer	Techniques	Kenya	Radio, internet, magazine	www.organicfarmermagazine.org
Strengthening the Agricultural Information Flow and Dissemination System	General	Zambia	Radio	

Mechanism/Project	Type of Information (Prices, Techniques, Inputs, Buyers/Sellers, General)	Country	Mechanisms (Voice, SMS, Internet)	Website
Internet				
Agriculture Research and Rural Information Network (ARRIN) Ndere Troupe	General	Uganda	Internet	http://www.iicd.org/projects/uganda-arrin
Agrovision	Techniques	Nigeria	Internet	http://www.eagriculture.org
Agricultural Sector Development Programme (ASDP)	General	Tanzania	Internet, SMS	http://www.ifad.org/operations/pipeline/pf/tan.htm
Collecting and Exchanging of Local Agricultural Content (CELAC)	General	Uganda	Internet, radio, email, SMS	http://celac.or.ug
CROMABU (Crops Marketing Bureau) Project	Prices/Buyers/Sellers	Tanzania	Telecenter (computers)	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	http://www.sendfoundation.org
E-commerce for Non-traditional Exports	Buyers, sellers	Ghana	Internet	http://www.iicd.org/projects/ghana-ecommerce/
E-commerce for women	Buyers, sellers	Ghana	Internet	
Enhancing Access to Agricultural Information using ICT in Apac District (EAAI)	Techniques	Uganda	Radio, mobile phones	http://www.comminit.com
Farmers' Internet Café	Buyers, sellers, general	Zambia	Internet	http://www.iicd.org/articles/iicdnews.2005-09-06.1315910878/
First Mile Project	Buyers, sellers	Tanzania	Internet	http://www.firstmiletanzania.net/
Fruiléma	Buyers, sellers	Mali	Internet, mobile phones	http://www.fruilema.com/ http://www.iicd.org/projects/mali-quality-fruilema
Gyandoot	General	India	Internet	
ICT for Shea Butter Producers	General	Mali	Computers	
iKisan	General	India	Internet (kiosks)	
Miproka	General	Burkina Faso	Internet (computers)	

Sene Kunafoni Bulon	Buyers, sellers	Mali	Internet (computers)
Sissili Vala Kori	General	Burkina Faso	Internet (computers)
TV Koodo: Market price information using web and national TV	Market prices	Burkina Faso	Internet, TV
Virtual extension and research communication network	General	Egypt	Internet
Warana	General	India	Internet (kiosks)

Mechanism/Project	Type of Information (Prices, Techniques, Inputs, Buyers/Sellers, General)	Country	Mechanisms (Voice, SMS, Internet)	Website
Mobile Money Transfers (SMS)				
Mobile Transactions Zambia	Cashless input voucher system	Zambia	Mobile scratchcards	http://www.mtzl.net<http://www.mtzl.net/default.asp?id=18
Mobile Phone Data Collection				
Integrating ICT for Quality Assurance and Marketing	Production quality, buyers	Zambia	Handheld computers	
Research on Expectations about Agricultural Production (REAP)	Weather, pests	Tanzania	Voice	

Mechanism/Project	Type of Information (Prices, Techniques, Inputs, Buyers/Sellers, General)	Country	Mechanisms (Voice, SMS, Internet)	Website
SMS-Based Extension and Price Information Services				
Agricultural Marketing and Information System for Malawi (MIS-Malawi)	Prices, Buyers, Sellers	Malawi	SMS, internet, radio	http://www.ideaamis.com
Agricultural Market Information for Farmers	Prices	Bangladesh	SMS	
Agricultural Marketing Systems Development Programme (AMSDP)	Prices	Tanzania	SMS	http://www.ifad.org/english/operations/pf/tza/i575tz/index.htm
Agricultural Research Extension Network (ARENET)	General	Uganda	Internet	http://www.arenet.or.ug
Apps for Africa	Techniques, weather, buyers, sellers	Uganda	SMS	
CELAC	Techniques, weather, buyers, sellers	Uganda	SMS	
Dialog	Prices, buyers, sellers	Sri Lanka		
Esoko (formerly Tradenet)	Prices, buyers, sellers	Benin; Burkina Faso; Côte d'Ivoire; Ghana; Madagascar; Mali; Mozambique; Nigeria; Tanzania; Uganda; Cameroon; Afghanistan	SMS, internet	http://www.esoko.com
Farmers Information Communication Management (FICOM)	Prices, buyers, sellers	Uganda	Voice, SMS, internet, radio	http://www.syngentafoundation.org
Gyandoot	General	India	Internet	
ICT Support for Agricultural Literacy	Market prices	Ghana	SMS	
ICT for Improving Agriculture in Rwanda	General	Rwanda	SMS	http://www.spidercenter.org

Informations sur les Marches Agricoles par Cellulaire (IMAC)	Prices	Niger	SMS	http://sites.tufts.edu/projectabc
InfoPrix Benin	Prices	Benin	SMS	http://www.onasa.org/
Infotrade Uganda	Prices	Uganda	SMS, internet	
Kenya Agricultural Commodities Exchange (KACE) MIS Project	Prices, buyers, sellers	Kenya	Voice, SMS, internet	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), and Tanzania (www.lmistz.net)
Manobi	Prices	Senegal	SMS	http://www.manobi.net
Makuleke Project	Prices, buyers, sellers	South Africa	SMS	http://www1.alcatellucent.com
mKrishi	General	India	SMS, Voice	
Network of Market Information Systems and Traders' Organizations of West Africa (MISTOWA)	Prices, buyers, sellers	ECOWAS countries	Internet, radio, email, SMS	www.mistowa.org, www.wa-agritrade.net
Nokia Life Tools	Prices, weather, techniques	India, Indonesia	SMS and user interface	
Regional Agricultural Trade Information Network (RATIN)	Buyers and Sellers	East Africa	Voice, internet	www.ratin.net
Reuters Market Light	Prices, weather, techniques	India	SMS	
Vodacom Tanzania	Prices	Tanzania	SMS	
SMS Information Service	Prices, buyers, sellers	Zambia; Democratic Republic of Congo	SMS, internet	http://www.farmprices.co.zm/
Système d'Information des Marchés Agricoles (SIMA)	Prices	Niger	SMS	http://ictupdate.cta.int

Trade at Hand	Prices	Burkina Faso; Mali; Senegal; Mozambique; Liberia	SMS	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	
Xam Marsé	Prices, buyers, sellers	Senegal	SMS, internet	http://www.manobi.sn

Source: FARA (2009) and authors' data collection.