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A text message away: ICTs as a tool to improve food security

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Abstract

The growing use of ICTs around the world, particularly cellular phone technology, provides a significant development opportunity. Under certain situations, ICTs can improve rural households' agricultural production, farm profitability, job opportunities, adoption of healthier practices, and risk management. All these effects have the potential to increase wellbeing and food security in rural areas of developing countries. Several challenges to effectively scaling up the use of ICTs for development remain, however. Taking advantage of the opportunities provided by ICTs depends on increased *connectivity* of marginalized population groups, the *content* and usefulness of the information provided through ICTs, and the *capacity* of households in rural areas to understand and act on the information that they receive. We need innovative ways to bring together the public and private sectors to ensure that the three *C*s (connectivity, content, and capacity) are addressed as a whole.

JEL classifications: D83, O13, Q18, O32

Keywords: Information and Communication Technologies; Mobile phones; Agricultural Extension; Market Price Information

A South African chief was asked what he would want for his village if he could choose among a telephone line, a school, and a clinic. He replied, "The telephone line, so that I can lobby ministers in the capital about the school and the clinic."

Roughly three-quarters of the world's poor live in rural areas of developing countries (Ravallion et al., 2007; World Bank, 2008). Therefore, addressing global poverty requires paying special attention to rural populations, especially smallholders. Rural population represents more than half of the total population in South Asia, Sub-Saharan Africa, and East Asia & the Pacific. These three regions account for around 1.1 billion poor people (living on less than the international poverty line of $1.25 a day)—roughly 90% of the world's poor (World Bank, 2010, 2013).

The major challenges faced by rural populations include lack of access to both physical products and information related to new opportunities, technologies, and ideas. This lack of access may limit income opportunities and impede improvements in health and education outcomes. It could arguably also increase environmental degradation through unsustainable agricultural practices and resource use. A growing body of evidence suggests that information and communication technologies (ICTs), specifically cellular phones, can help address these problems in many (though not all) circumstances by increasing access to both information and capacity-building opportunities for rural populations in developing countries.

ICTs have expanded considerably in the developing world since the early 2000s. The ICT champion has clearly been the exponential adoption of cellular phones. The massive adoption of cellular phones has reduced the digital divide between developed and developing countries (see Fig. 1). In fact, several developing countries currently have higher rates of penetration than developed countries. By 2012, there were already more mobile connections than people in Europe and Central Asia and in Latin America and the Caribbean. By 2013, the number of cellular phone subscriptions has approached global population figures (see Fig. 2). Even in poorer regions such as Sub-Saharan Africa, phone subscriptions have also increased dramatically.

The availability of other forms of ICTs—such as the internet—has also increased in the last decade in the developing world.[1] However, internet access is still far from extensive: only 27% of the population in developing countries uses this

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[1] In our analysis, we abstract from other forms of ICTs. For example, we do not analyze the impact of fixed phone lines, which developing countries (for

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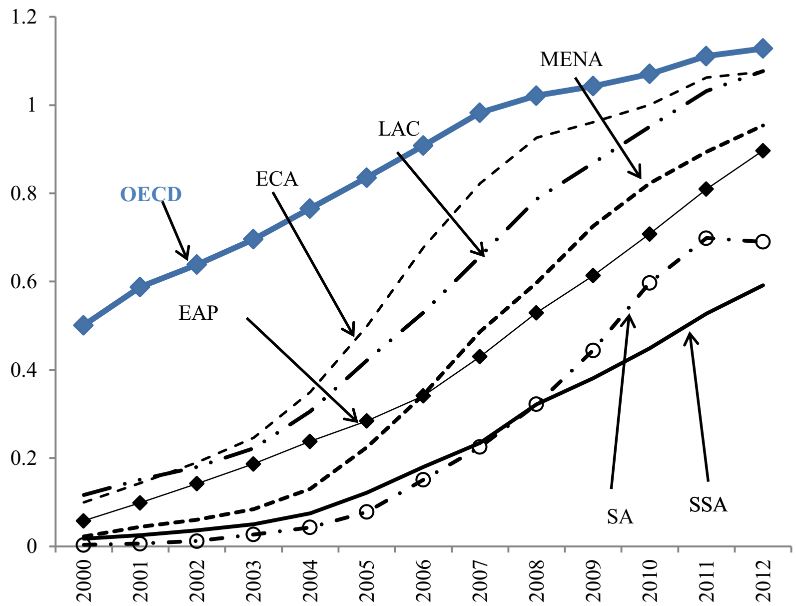


Source: Mobile phone subscriptions are from the International Telecommunication Union (ITU) and country categories are from the World Bank. Modified from Figure 1 of Nakasone et al. (2013).

Fig. 1. Ratio of mobile phones subscriptions to population by region.*
*EAP = East Asia and Pacific; ECA = Europe and Central Asia; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA = South Asia; SSA = Sub-Saharan Africa. High-Income (OECD countries only).

technology, and there are only 0.05 broadband subscriptions per inhabitant (see Figure 3). In contrast, by 2012, there were 0.82 mobile phone subscriptions per capita in the same group of nations, many of which have more subscriptions than people.

The aim of this article is to provide an overview of the impact of ICTs (with an emphasis on cellular phones) on food security in developing countries. We highlight findings in the available literature to provide suggestive insights of the conditions under which ICT projects can make a difference in livelihoods in rural areas. We also highlight three challenges (or the three C's) to effectively upscale ICT applications for development: *connectivity* to services, *content* of the information, and the *capacity* of farmers to use the information that they receive.

1. How can ICTS help smallholders and improve food security?

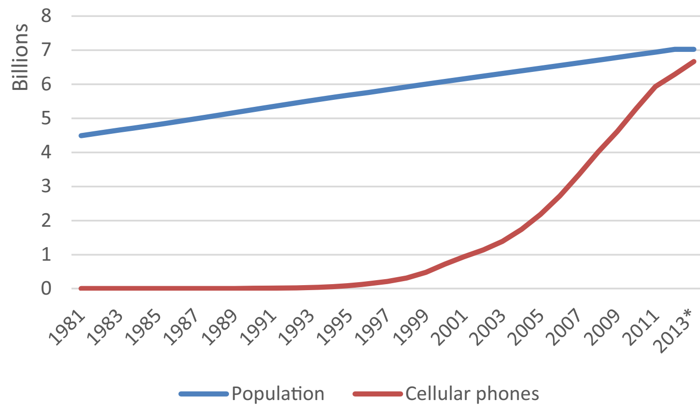
ICTs can improve food security and improve livelihoods in rural areas through different channels. First, ICTs can constitute potential vehicles to inform farmers about new technologies, improved input management, and better farming techniques. Second, famers can become aware of better sales opportunities for their crops. Third, ICTs can enhance the efficiency of agricultural markets, reduce price volatility in agricultural markets, and improve the food availability. Fourth, they can enrich health practices and allow households to assess the safety and nutritional value of their food. Finally, they can impact households' food security through other effects, such as increased access to nonfarm labor opportunities, financial inclusion through mobile money, and access to remittances.

the most part) leapfrogged in favor of cellular phones. As a result, as of 2012, there were only 0.11 fixed lines per inhabitant in the developing world.

2. ICTS and improved farm management

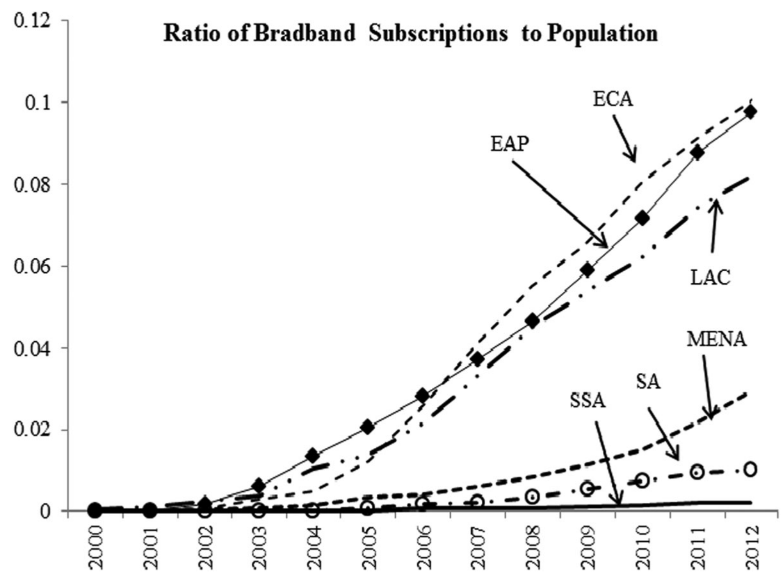
Governments have actively pursued increases in agricultural productivity through the dissemination of new and improved farm management practices. This has led to the implementation and expansion of agricultural extension services in mostly every country. Despite considerable investments, we know very little about their actual impact on farmers' agricultural productivity and extension programs have been subjected to several criticisms (Feder et al., 1999; Gautam, 2000; Swanson and Rajalahti, 2010).

Traditional extension services usually rely on itinerant government workers, who visit rural villages, and provide farmers with advice. There are three main criticisms about this system. First, poor infrastructure in developing countries makes visits to remote areas harder and more costly. Second, traditional extension programs usually provide only one-time information to farmers. This lack of follow-up information and feedback can restrict the information's long-term benefits. Finally, extension workers are subject to little (or no) accountability: it is hard to monitor their levels of effort in delivering advice or to



Source: Mobile phone subscriptions are from the International Telecommunication Union (ITU) and total populations are from World Bank estimates

Fig. 2. Mobile cellular subscriptions and population.



Source: International Telecommunication Union (ITU) (mobile phone subscriptions); World Bank country categories. Obtained from Nakasone et al. (2013).

Fig. 3. Ratio of broadband subscriptions to population in the developing world.
*EAP = East Asia and Pacific; ECA = Europe and Central Asia; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA = South Asia; SSA = Sub-Saharan Africa. High-Income (OECD and non-OECD) are excluded from the sample.

even know if they have visited the remote villages they were assigned to.

In this spirit, ICTs can contribute to overcoming these problems (Cole and Fernando, 2012). Governments can easily access remote areas through ICTs, eliminating high transportation costs and enabling more frequent two-way communication between farmers and agents. ICTs also allow more accountability by providing more effective platforms to monitor extension workers' delivery of advice. Aker (2011) also claims that, in addition to reducing the cost of public information provided through extension services, ICTs can also allow farmers to better access private information and farming advice through their own social networks.

There is some available evidence on whether cellular phones can be used as an effective tool to boost agricultural extension.[2] Fafchamps and Minten (2012) investigate a program that provided crop advisory tips and local weather forecasts to farmers in India through an SMS-based "push" (i.e., information sent in a predetermined moment, and not necessarily when requested

[2] Note that this review is limited to cellular phones and agricultural extension. Alternative technologies can be used to improve the dissemination of improved agricultural practices. For example, Gandhi et al. (2009) analyze the impact of participatory videos in India. Nakasone and Torero (2016) investigate a pilot project in Peru that provided agricultural extension through internet to high school students, and assess whether teenagers subsequently transmitted this information to their parents.

by the user) delivery system. The authors find no impacts on cultivation practices or harvest losses. However, Casaburi et al. (2014) analyze a program in which sugar cane growers in Kenya received SMS farmers advising them to complete certain tasks on their fields. The SMS were sent at individualized moments, based on each farmer's harvest cycle and the age of their cane. The authors find that this program increased yields by 11.5%. Larochelle et al. (2016) explore the impact of a program that trained smallholders through a farmer field day in Ecuador, and complemented this traditional training with SMS reminders about agricultural practices. The authors find that a positive *additional* impact of these reminders on farmers' adoption of new practices.

Due to its simplicity and low costs, SMS has been a popular mechanism to provide farmers with agricultural extension advice. However, there are a few studies that have analyzed alternative strategies. For example, Cole and Fernando (2012) conduct an impact evaluation of the Avaaj Otalo (AO) program among cotton farmers in Gujarat, India, which delivered information through voice messages. This system provided both push content (weekly information on weather and crop conditions) and pull content (a hotline for specific advice). Farmers' calls to the hotline were processed by agronomists and answered via voice message. In their evaluation, Cole and Fernando randomly select a group of households who received access to the toll-free AO service. Their results suggest that households who benefited from AO shift their pesticides from hazardous to safer ones. Their results also suggest that beneficiaries are more likely to harvest cumin, a high-value cash crop. These findings suggest that the content provided through the voice messages was useful for the farmers and was adopted more willingly.

Similarly Fu and Akter (2012) investigate the impact of a program called "Knowledge Help Extension Technology Initiative" (KHETI) in Madhya Pradesh, India. KHETI operates through agricultural specialists who travel across villages with special mobile phones. These mobile phones are able to record Short Dialogue Strips (SDSs), short videos that depict a particular problem faced by a farmer. These SDSs are sent to scientists, who determine solutions for each case. These solutions are then passed back to the farmers. Using difference-in-differences estimations, Fu and Akter argue that those in the KHETI group[3] increased their awareness and knowledge of extension services compared to a control group. The authors also provide before-and-after comparison of perceptions of beneficiaries, indicating that farmers perceive KHETI to be more useful, faster, and of better quality than other services. However, it should be noted that no clear impacts are identified.

These studies highlight the heterogeneity of extension projects: one-way vs. two-way communication between farmers and agricultural specialists, SMS vs. voice transmission[4] of advice, and oral description of problems vs. visual representations. However, there is still not a lot of evidence regarding which projects work and which do not, as the majority of agricultural extension work being conducted through ICTs is fairly recent.

3. ICTS and farmers' sales

Access to cellular phones should enable farmers to make better sales decisions: by increasing their access to information, farmers would become more aware of prevailing market prices. When sales take place at farm gate, this information should improve their bargaining power against visiting middlemen. Alternatively, if farmers decide to sell their harvests in local markets, the information should inform them about the most profitable market to travel to.

Though far from conclusive or uniform, some studies have provided a range of estimates for some of the hypothesized effects of ICT information flows on smallholders' sale prices and profits. For example, Svensson and Yanagizawa (2009) investigate the impact of price dissemination via radio and find large increases in farm-gate prices for maize (around 15%) in Uganda. Similarly large effects are suggested by preliminary research in Peru (Beuerrmann, 2015; Chong et al., 2005) and the Philippines (Labonne and Chase, 2009). Others find much smaller (Goyal, 2010) or no effects (Fafchamps and Minten, 2012; Mitra et al., 2011). A more thorough list of such studies is presented in Table 1.

There is also anecdotal evidence suggesting that ICTs might help farmers to improve their sales outcomes by reducing transportation costs. A farmer in India states: "I was in process of transporting my produce of (approximately 1,000 boxes in two trucks) to Delhi when I got an SMS through RML (Reuters Market Light, a service that provides several types of agricultural information through text messages on cellular phones) that the freight rate from Kotgarh to Delhi is Rs. 41.07 per box. I showed this message to the truck operator, who till then was citing a rate of Rs. 44 per box. Following this, I was able to settle the transporting deal at Rs. 41.07, finally saving around 3,000 rupees (Reuters, 2012)."

4. Role of ICTS in agricultural market efficiency and arbitrage

There are many reasons to believe that ICTs may have a large impact on the outcomes of agricultural markets. ICTs can allow different market agents to communicate more efficiently, thus enhancing information flows. This can be critically important

[3] All households in the KHETI group were previously part of an association of poor and marginalized farmers in Madhya Pradesh. Given that the treatment and control groups may have had different characteristics to begin with, these results should be interpreted with caution.

[4] Mittal et al. (2013) argue that voice messages can come at unpredictable times during the day, so SMS might be more convenient. However, if there is a substantial proportion of illiterate population, voice messages can be a better dissemination tool.

Table 1
Review of studies on the impact of ICTs on farmers' income

Technology	Location/product	Effect (and outcome)	Study
Latin America			
Public pay phones	Peru/various crops	+16% on prices	Beuermann (2011)
Public phones	Peru/various enterprises	+13% on farm income	Chong et al. (2005)
Cell phones	Peru/various crops	+11% household consumption	Beuermann et al. (2012)
Cell phones	Peru/various crops	+11–14% on average prices	Nakasone (2016)
SMS	Colombia/various crops	No significant effect	Camacho and Conover (2011)
Africa			
Radio	Uganda/maize	+15% on prices	Svensson and Yanagizawa (2009)
Mobile phone coverage	Uganda/banana and maize	Somewhat positive relationship, but depends on distance to district center No effect for maize	Muto and Yamano (2009)
Grameen/MTN village phones	Rwanda/various products	No significant effect	Futch and McIntosh (2009)
Cell phones	Niger/cowpeas	No significant effect	Aker and Fafchamps (2010)
SMS	Ghana/maize and groundnuts	Price increases for maize (12.7%) and groundnuts (9.7%)	Courtois and Subervie (2015)
SMS	Ghana/various crops	7% price increase for yams. No effect for maize, cassava, and gari	Nyarko et al. (2013)
Asia			
Cell phones	Philippines/various crops	+11–17% on the growth rate of per capita consumption	Labonne and Chase (2009)
Cell phones	Kerala, India/fisheries	+8% in fishers' profits	Jensen (2010)
eChoupal	Madhya Pradesh, India/soybeans	+1–3% (average: 1.6%) on prices	Goyal (2010)
SMS	West Bengal, India/potatoes	No significant effect	Mitra et al. (2011)
SMS	Maharashtra, India/various products	No significant effect	Fafchamps and Minten (2012)

Source: References.

for rural areas in developing countries, where markets tend to be less integrated due to inadequate infrastructure.

Jensen (2010) discusses some of the main potential gains from information use in agricultural markets. Most importantly, information can improve market efficiency. Prices, in essence, signal profitable opportunities for producers, consumers, and traders: opportunities where excess demand creates more profitable opportunities to sell or where excess supply leads to cheaper deals to buy. In a context of little information—and thus limited arbitrage—prices tend to vary based on the current local supply. However, as information flows improve, more opportunities for arbitrage emerge, effectively limiting the influence of local fluctuations and more closely relating market prices to (less volatile) aggregate supply.

Jensen (2007) investigated the introduction of mobile phones among fishermen in Kerala, India. Fish prices were volatile in coastal markets prior to the introduction of cellular coverage. The author finds that, when fishermen could use cellular phones to inquire about alternative prices in markets, prices in the region converged (i.e., followed the law of one price) and waste was eliminated.[5] Information allowed for a better allocation of fishermen's catch across markets, and led to increases in both consumers' and producers' surplus.

In a similar fashion, Aker (2010) analyzes the introduction of cellular phones among grain traders in Niger. She finds that phones allow traders to search for price information over larger areas and sell grains in more markets. The increased ability of traders to arbitrage across markets led to a reduction of 10–16% in grain price dispersion. Aker's study took place in a period of food crises and increases in grain price in some locations of Niger (Aker, 2008). In this spirit, it is likely that better allocation of grains across markets increased food availability in more severely affected areas. Aker and Fafchamps (2010) find that the introduction of mobile phones among farmers in Niger led to a reduction in the dispersion of farm gate sales prices for cowpeas. Importantly, the authors also find that the introduction of cellular phones led to a decrease in the intra-annual coefficient of variation of sales prices. This suggests that access to better information is also associated with lower price risk among farmers.

Because market prices signal more profitable opportunities, access to cellular phones can also inform farmers how much to plant in each season and what type of investments could be profitable based on demand and supply fundamentals. Goyal (2010) investigates a program in India that provided soybean farmers with market price information in India through internet kiosks (called *e-choupals*). The intervention allowed farmers to get higher prices and led to an increase of 19% in farmers' land allocated to soybean cultivation.

5. ICTS and health practices

Cellular phones can increase households' welfare by enhancing their ability to gauge the nutritional value of their food and promote healthier behavior. For example, Krishna and Boren

[5] Abraham (2007) finds similar evidence for fishermen in Kerala.

(2008) review 18 studies that provided various tips for self-management of diabetes (e.g., diet, exercise, monitoring advice, weight management, etc.) through text messages. Their meta-analysis suggests a positive effect of this information on diabetic patients' behavior, learning, or clinical outcomes. Hall et al. (2015) investigate the impact of text messaging in other medical applications such as encouragement of physical activity, smoking cessation, and medical adherence for antiretroviral therapy. The authors find general positive effect of SMS on these applications.

These examples illustrate the potential impact of ICTs to encourage the adoption of healthier practices and medical advice. However, more research is required to understand how ICTs can effectively change diet patterns and inform about food quality in developing countries.

6. Other impacts

There are other indirect effects through which cellular phones can increase food security. For example, mobile phones may not only enhance farm opportunities for rural households, but can also create nonfarm employment. Based on the rollout of cellular coverage in South Africa, Klonner and Nolen (2010) find increases in employment opportunities among women in localities that benefited from cellular coverage. The authors also find that employment opportunities shift away from agricultural activities in favor of nonfarm employment.

Additionally, cellular phones can increase participation in the financial system through mobile banking. Mobile money platforms have emerged in Africa, Asia, and Latin America. With about 14 million users[6] in Kenya, M-Pesa is probably the most prominent example of mobile banking in the developing world.[7] In theory, these platforms can increase formal savings and allow delivering basic banking services to poorer households with less access to financial vehicles (Mas and Kumar, 2008; Mas and Mayer, 2016). Based on this premise, mobile banking can affect households' food security by enabling them to save resources that can be used during times of decreased economic activity. However, it is not clear whether mobile banking can increase households' savings. Demombynes and Thegeya (2012) find larger savings among M-Pesa users. However, Mbiti and Weil (2011) find that most M-Pesa users access this platform for transfers and not necessarily to store wealth. Blumenstock et al. (2015) investigate a program that shifted workers' in-cash salary payments to mobile money in Afghanistan. The authors find that the program increased savings through mobile money. However, these increases came at the expense of reduced savings though other mechanisms and led to no overall increases in total savings.

While there is no clear consensus about the impact of mobile banking on households' savings, there is evidence that these platforms can facilitate transfers during times of distress. In Kenya, Jack and Suri (2014) find that households that used M-Pesa are better able to mitigate negative shocks than those who did not. In Rwanda, Blumenstock et al. (2016) find that cellular phones allowed money transfers to households that experienced unexpected shocks. In this spirit, cellular phones seem to provide a mechanism to cope with shocks by reducing the transaction cost of money transfers between households.

7. Major constraints: the three c's

ICTs' use for development is constrained in three major areas: connectivity, content, and capacity.

7.1. Connectivity

Regarding connectivity, penetration rates may exaggerate true access to mobile phones. Most statistics on cellular phone adoption (such as the ones in Figs. 1 and 2) are based on penetration rates (i.e., the ratio of mobile phone subscriptions to population). However, many cellular phone users in developing countries have more than one SIM card for their phones. Users change their SIM cards based on the person they call to avoid out-of-network charges. Using detailed household surveys from 25 developing countries, Nakasone et al. (2013) find that *actual* mobile phone ownership is much lower than the levels suggested by penetration rates.

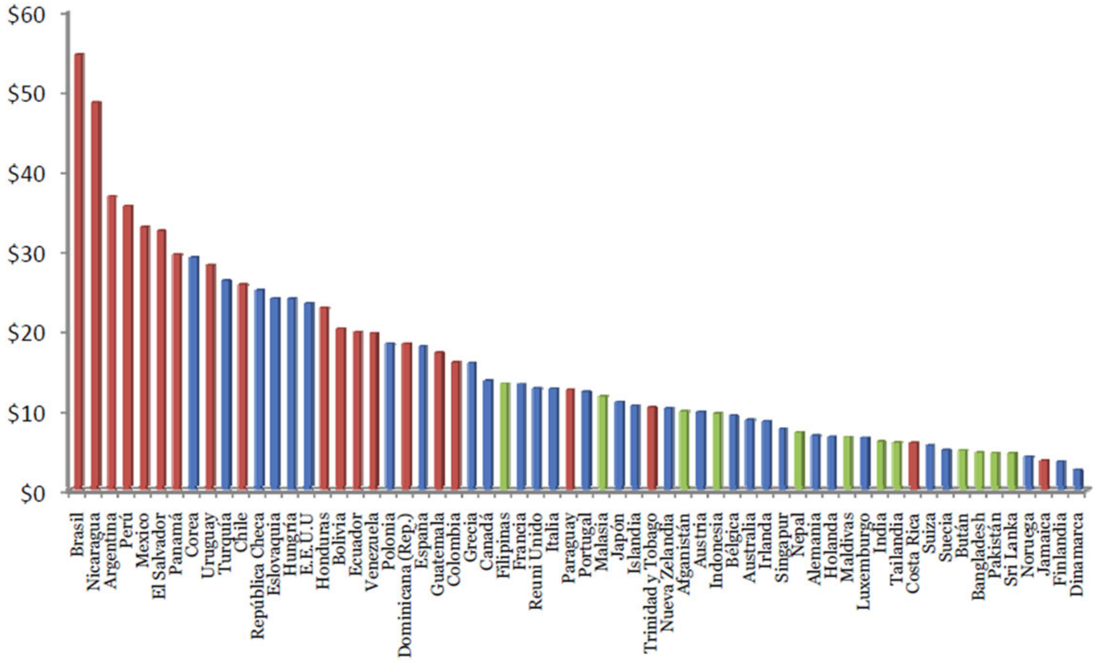
Second, aggregate data tend to mask considerable differences in cellular phone adoption within countries. Looking at detailed data from different household surveys in developing countries, we find significant differences between rural and urban access. For example, in Brazil, the share of rural households who own a cellular phone is 53.2% in rural areas and 83.3% in urban areas. Rural and urban access rates to cellular phones are 18.7% and 77.6% in Bolivia, 51.2% and 76% in India, 32.3% and 72.7% in Malawi, and 29.6% and 63.5% in Ghana, respectively.[8] Clearly, access to mobile phones varies considerably between countries, and there are still wide gaps in rural connectivity in many developing countries.

One potential explanation for the variation in access between countries and for the access gap in rural areas is directly related to the cost of mobile phone service. As shown in Fig. 4, for a low-volume basket, typical of a prepaid phone in a rural area, the costs are still significantly high. While the cost of this low-volume basket varies significantly, it can be higher

[6] This refers to 30-day active customers. See: http://www.safaricom.co.ke/annualreport_2015/strategic-priorities.html .

[7] Jack and Suri (2011) describe the profile of the adopters of M-Pesa and the purposes for which they use this platform.

[8] The sources of the data are: (a) for Brazil and Bolivia, the data were taken from OSILAC (http://www.eclac.org/tic/flash/), and are based on different household surveys; (b) for India, the data were taken from Census of India: http://tinyurl.com/kej98a8; for Malawi, the data were taken from the Demographic and Health Survey 2010; and for Ghana, the data were taken from Percentage of the population 12 years or older possessing mobile phones. 2010 Population and Housing Census.



Source: Galperin (2009). "Tarifas y brecha de asequibilidad de los servicios de telefonía móvil en América Latina y el Caribe." Buenos Aires, Argentina: Universidad de San Andrés.

Fig. 4. International comparison of the costs of a low-volume basket of mobile traffic in 2009 US$ PPP.*
*Charges include taxes. The cost of the equipment and connection costs are not included. The low-volume basket includes 30 outgoing call and 33 SMS per month. The following structures of calls are assumed: local to fix phones (15%), national (7%), mobile *on-net* (48%), mobile *off-net* (22%), and voice box (8%). The estimations assume that 48% are done during peak times, 25% during off-peak times, and 27% during the weekends. The following duration of the calls is assumed (in minutes) by destiny: 1.5 for local and national, 1.6 for mobile *on-net*, 1.4 for mobile *off-net,* and 0.8 for voice box. The tariffs are prorated according to the market shares of each operating company.

than $30 in countries such as Brazil, Nicaragua, Argentina, Peru, and Mexico. To illustrate how the high cost of cellular phone service can affect poorer household, we can plot the curve of accessibility taking into account the difference between the cost of the basket of low-volume mode prepaid and 5% of the income of the potential users in each income decile (this threshold of expenditure on telecommunications services is widely used in the literature; e.g., Milne (2006) as well as by multilateral bodies and regulators). As an example, we report estimates from Galperin (2009) for Brazil. The results show that the high level of fees results in a wide gap between the considered basket and the payment capacity of the potential users. In this case, 90% of the population must spend more than 5% of their income to buy the basket of mobile services (the horizontal line represents the cost of the basket). The high costs seen in some developing countries may stem from the lack of significant competition among cellular service providers and the lack of appropriate regulation. Network industries like telephony are subject to strong economies of scale due to significant initial investments needed to establish operations. To avoid excessive charges, governments need strong regulatory authorities to allow that existing infrastructure (normally under monopoly or oligopolistic power) be made available to all competitors at reasonable access charges ("access pricing").

7.2. Content

The second constraint faced by ICTs relates to the relevance of the information provided. If the content provided does not march farmers' information needs, they may be less likely to utilize these technologies. We discuss the relevance of contents provided to farmers in developing countries based on two popular types of agricultural information provided through mobile phones (discussed above): (a) market price information and (b) agricultural extension advice.

Fig. 6 presents a graphic account of the evidence available for the impact of market price information systems (description of the studies in Table 1). We focus on four dimensions to classify the available studies: (a) the level of penetration in the country at the time of the implementation of the interventions; (b) the specific characteristic of the commodity in terms of its value in the markets; (c) the specificity or quality of the content being provided to the farmers (i.e., general price information or information specific to the commodity and the markets relevant for the farmer); and (d) the statistical significance of the impacts (red meaning not significant and blue meaning significant).

Although the synthesis presented in Fig. 6 cannot be conclusive given the small number of existing studies and the preliminary nature of several of them, we find some important

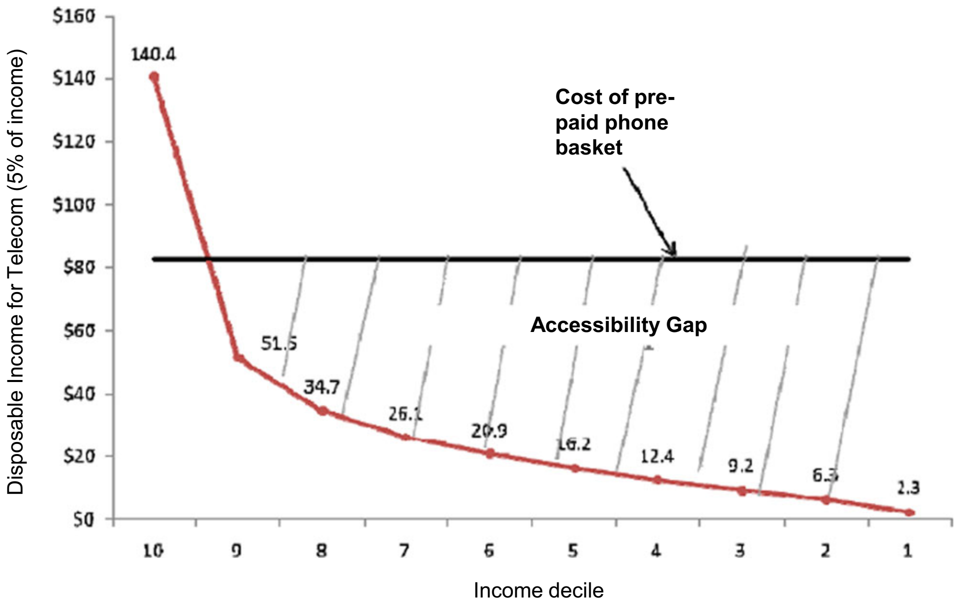


Fig. 5. Brazil: Disposable income (in R$) for telecommunications (5% of income), by income deciles. From: Galperin (2009).

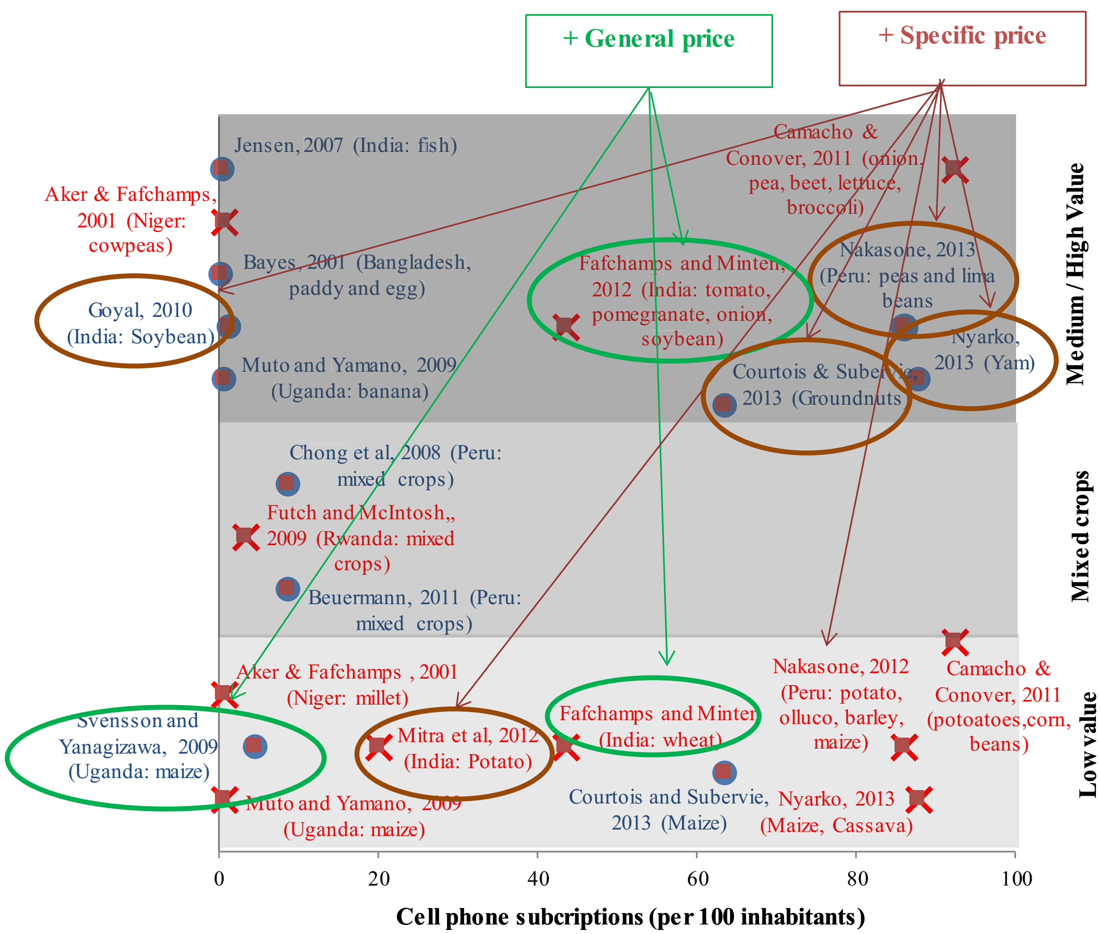
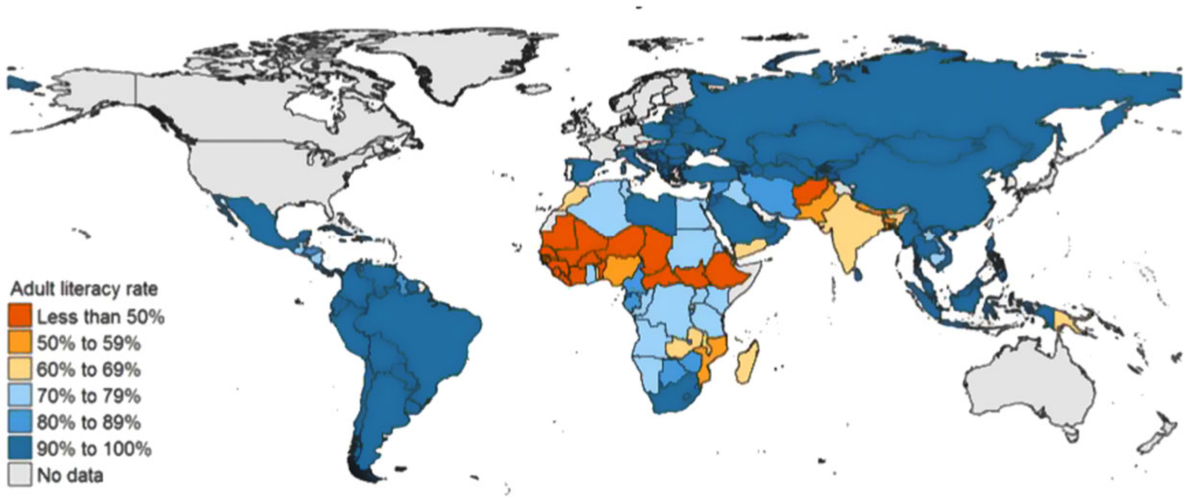


Fig. 6. Summarizing impact of ICT by penetration, type of commodity and content of information provided.



Source: UNESCO Institute for Statistics (2015)

Fig. 7. Adult literacy rates in 2013.

patterns that suggest hypotheses for further research. First, we find that the lower the penetration at the time of implementation, the more significant the studies' impact, especially for medium- and high-value commodities. This result can be partially explained by the fact that low penetration can be directly related to a significant difference in knowledge about prices (or information asymmetry) between agents. As ICT penetration increases, all agents might be better able to access the same price information. Second, as penetration and access to information increase, the specific content of the information comes to matter significantly (i.e., quality of the information responding to the specific needs of the farmer). In fact, we find that the impact of information only seems significant when that information provides specific price information regarding high-value commodities. Fafchamps and Minten (2012), who assessed the impact of information in regions of India where cellular phone penetration was higher than 40% but which only provided generic information, do not show any significant results stemming from that information. On the other hand, Nakasone (2016), Courtois and Subervie (2015), and Nyarko et al. (2013) show significant results when the information provided was customized to the specific high-value commodities and varieties produced by the farmers studied. Nakasone (2016) also suggests that increased information, no matter how specific the content, is not significant for low-value and less perishable commodities.

The relevance of the information provided through mobile phones can also be critical for agricultural extension. As discussed above, there is a large heterogeneity in the impact of farming advice provided through mobile phones. Fafchamps and Minten (2012) find no impact of agricultural information based on a "push" scheme through SMS. While there are many possible reasons for this, three strong possibilities are that: (a) the advice was not provided at appropriate times, (b) push contents did not address farmers' specific farming concerns, or (c) farmers were unable to understand the advice based on short messages. Casaburi et al.'s (2014) study reinforces the idea that timing might be crucial in the delivery of agricultural advice. Cole and Fernando's (2012) "pull" content (based on farmers' demands) might have been more effective to help beneficiaries better manage their farms. Larochelle et al.'s (2016) suggest that—while text messages might not be an initial good vehicle to expose farmers to new techniques—SMS-based campaigns might be effective reinforcing concepts that have been previously taught to farmers.

7.3. Capacity

ICTs can constitute a cost-effective tool to disseminate important information among households. However, their effectiveness might be hindered by farmers' capacity to use new technologies.

While SMS can be a cheap and quick way to reach rural areas in developing countries, low literacy levels can prevent the implementation of large-scale information campaigns in some areas. Fig. 7 shows the average adult literacy rates by country in 2013. While literacy rates are relatively high in most of East Asia, South–East Asia, Central Asia, and Latin America; they are considerably lower in South Asia and Sub-Saharan Africa. UNESCO (2015) finds that there are still 14 countries where more than half of the adult population is illiterate (and 13 of these are in Sub-Saharan Africa).[9]

However, the implementation of ICT campaigns might be difficult even in countries with relatively high levels of literacy. Older adults are the ones who make most of the decisions within

[9] Adult literacy rates were below 50% in the following 13 countries of Sub-Saharan Africa: Benin, Burkina Faso, Central African Republic, Chad, Côte d'Ivoire, Ethiopia, Guinea, Haiti, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone, and South Sudan. The other country with a literacy rate below 50% is Afghanistan.

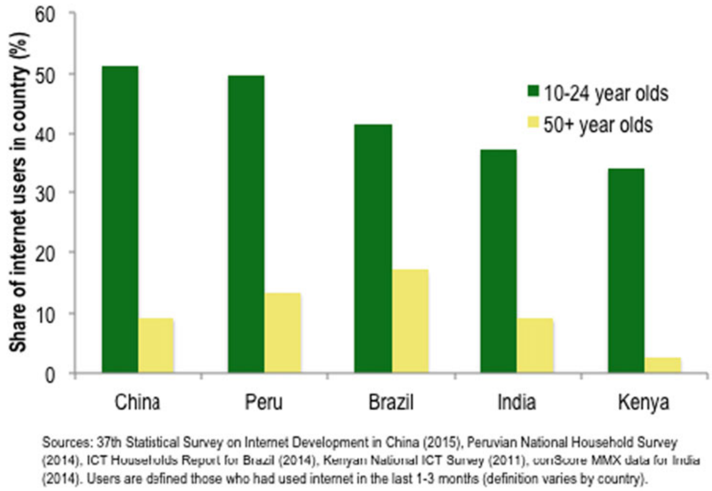


Fig. 8. Share of internet users by age group, circa 2014.

their households. However, they are harder to reach through ICTs. Not surprisingly, most ICT users in developing countries are teenagers and younger adults, who tend to be earlier technology adopters. While mobile phones might be increasingly more accessible among older adult populations, it is still difficult to deliver information through new technologies—such as the internet—among large groups of the population. Fig. 8 shows the share of internet users by age group in some selected developing countries in Africa, Asia, and Latin America circa 2014. The share of internet users between 10 and 24 years old in these countries is consistently above 35%. The number of internet users in this age group is 3.7–12.6 times than their counterparts who are 50 years or older. Because projects can potentially exclude large groups in developing countries, literacy (and ICT-literacy) should be an important component of how to better use ICT strategies as a development tool.

8. Conclusions

The accelerating adoption of ICTs all over the world provides a great opportunity. The penetration of cellular phone technology has significantly increased in developing countries although still there is an important gap between access in urban and rural areas, as well as significant costs. Under certain situations, ICTs can improve rural households' agricultural production, farm profitability, job opportunities, adoption of healthier practices, and risk management. All these effects have the potential to increase wellbeing and food security in rural areas of developing countries.

Taking advantage of these opportunities, however, depends crucially on the three C's: connectivity, content, and capacity. Despite the fact that the cost of ICTs is falling rapidly, there is still a need to continue improving access and use of new technologies in the poorest areas, given the significant difference in costs that are still present in many developing countries. In response to this problem, a number of subsidy mechanisms have been implemented aiming to improve access among rural households and to ensure that poor people pay no more than their wealthier urban counterparts for access to telecommunications. The economic rationale for subsidies is based on the existence of consumption and production externalities, network externalities, and scale economies. The main problem with such schemes, however, is sustainability and best practices should be explored.

Content is also crucial, especially when cellular phone penetration is high. The existing evidence, although limited to a small number of cases, suggests the importance of content quality to ICTs' use for development; there is a clear need to continue assessing the impact of good quality information. In addition, many aspects of agricultural information constitute a public good, and governments need to invest in providing the best possible information regarding prices for different markets, produce varieties, and produce quality, as well as information regarding production technologies and other agronomic information. If these investments are not made, ICTs' potential impact could be limited, especially for high-value commodities and markets.

Finally, development projects should consider the capacity of farmers to understand and take advantage of information through ICTs. A better understanding of the local conditions and farmers' ability to internalize advice is required to make better use of ICTs as a development tool. In some cases, the projects might want to consider alternative technologies (e.g., voice-based systems instead of SMS) or might want to rely altogether on traditional methods to provide information.

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