ICTs to address information inefficiencies in food supply chains

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Abstract

In developing countries, incomplete and/or asymmetric information contributes to inefficiencies in food supply chains. Various products and services have emerged that rely on Information and Communication Technologies (ICTs) to facilitate information flows between agro-input providers, farmers, traders, and consumers. Examples include crowdsourced price information and market intelligence services, ICT mediated agricultural advisory services, and user-experience rating-based quality assurance. However, not all initiatives are equally effective and many struggle to reach scale. I focus on some of the design features that characterize successful ICT enabled agricultural information initiatives, such as the technology used or the content disseminated. I further explore why ICT applications that address information inefficiencies seem to have less impact than innovations that address other barriers to efficient and inclusive food supply chains, such as risk or credit constraints. I point out the dangers of bypassing vulnerable groups and shown how inclusiveness can be increased. I also discuss how social networks can be leveraged to accelerate information dissemination.

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Introduction

Economic agents acting independently on the basis of full and relevant information is one of the cornerstones of neoclassical economic theory. However, reality is characterized by information inefficiencies. Fake news is often harder to debunk than to spread. Information asymmetries are cultivated and protected to create an advantage for one party. Information gaps are complemented with heuristics prone to sterotyping and suffer from cognitive biases. Consequently, as is the case with other incomplete or missing markets, information inefficiencies often lead to sub-optimal outcomes.

In food supply chains, information flows related to the quality and quantities of commodities are central to supply chain efficiency. Farmers need to know what standards they should meet and what they can expect in return for delivering. Processors need to know how much of the raw inputs they can source to consistently deliver a quality end product to consumers. Traders need information to predict storage capacity and conditions. Input providers need to know what inputs and services they should provide to best support farmers, traders, and processors.

In many poor countries, agricultural value chains remain important for food security. Furthermore, a large share of the population is directly or indirectly employed in food supply chains. Increasing information flows to increase efficiency and inclusiveness of value chains can thus have a tremendous impact. As a result, much is expected from Information and Communication Technologies (ICT). For instance, Jeffrey Sachs, director of the Earth Institute at Columbia University, has called the cell phone the single most transformative technology for development (Voight, 2011). The last few decades has seen the birth (and often failure) of a plethora of ICT mediated projects that promise to solve information inefficiencies. Today, some of the world's leading economists are trying to find out just how effective all these initiatives can be. For instance, Michael Kremer co-founded an NGO with the primary aim of testing ICT application in the field (Precision Agriculture for Development).

In this paper, I highlight some of the ICT applications that provided insight, point to ongoing initiatives that look promising, and reflect on future projects that build on what we have learned. After a brief section that highlights the primary aims of ICTs, I discuss the usefulness of ICT to match demand and supply of commodities, thereby increasing market efficiency. Research on market efficiency, which is rooted in the theory of the role of price information in spatial arbitrage, naturally led to projects that aimed to empower smallholder farmers with price information to strengthen their bargaining power vis-a-vis middlemen. The potential of ICT to reach farmers in remote areas also led to a multitude of projects that focus on agricultural extension. I then turn to more advanced applications to reduce asymmetric information in input supply chains. After a brief interlude on the role of social networks, I then review some of the dangers of relying on ICTs for information transmission in agricultural value chains. The last section concludes by comparing ICTs that reduce information inefficiencies with ICT mediated interventions that focus on other barriers in the sector.

Characteristics of ICTs

One of the primary aims of ICTs is facilitating the flow of information. Technology reduces the cost of information transfer, which makes it cheaper to disseminate information. For instance, by using a commercial cloud communication platform, it is possible to send Short Message Services (SMS) messages with customized information to 1000 farmers in Uganda for about US$60.[1] But it also becomes cheaper to obtain information, affecting search cost in the context of agricultural transactions: A farmer can now simply call a trader in the market to check on the price instead of having to go there in person (Aker, 2010).

ICTs are also often able to aggregate and process large amounts of data. This makes it possible to generate customized information and provide tailored advice. Such decision support systems have been shown to be more effective than one-size-fits-all advice that is typically provided by agricultural extension agents (Arouna et al., 2021).

However, applications that combine increased efficiency in the collection and dissemination of large amounts of data with processing power are likely to generate the most impact. Such applications hold the potential to reduce asymmetric information and increase coordination between actors in the value chain.

ICTs are also networked technologies, which become more useful as more people use them. These virtual networks partly overlap with the social networks of the users. As with social networks, the networked nature of ICTs may also be important for agriculture.

[1] https://telnyx.com/pricing/messaging/ug

ICTs to increase market efficiency

Early research on the impact of ICTs on commodity supply chains focused on how ICTs affect search costs when producers decide where to sell or traders and processors decide where to buy. In the theory of spatial arbitrage, the "law of one price" states that the difference in the price of an identical commodity in two locations cannot exceed the transaction cost.[2] In rural settings with poor infrastructure, search costs related to finding where commodities are cheapest or where demand is highest can be substantial. This high cost could leading to fragmented markets with excessively high prices in one location and extremely low prices in other areas (Van Campenhout, 2007).

In a seminal paper, Jensen (2007) found that fishermen used mobile phones to engage in spatial arbitrage. In Kerala, India, while still at sea, fishermen used mobile phones to inquire about the market conditions in various markets within reach and set sail to the most promising market. Jensen showed that this process greatly reduced price variability and effectively eliminated situations where fish has to be thrown back into the see because no buyers could be found. The effect of ICT on market performance has also been found in other contexts. For instance, Aker (2010) found that in Niger, mobile phones significantly reduced the price margin between markets, particularly between markets with high transaction costs.

The power of ICT to improve outcomes for producers, as illustrated in the above landmark studies, resulted in a large number of initiatives, often delivered through SMS. Many of these initiatives aimed to empower farmers with market price information. In areas characterized by semi-subsistence farming, farmers often sell at the farmgate to small-scale itinerant traders who then aggregate agricultural commodities and sell further downstream to large-scale traders or processors. The assumption underlying these initiatives is that traders exploit an informational advantage as they have a much better idea of the prevailing prices in different markets. Providing farmers with timely price information in nearby markets should enable farmers to better evaluate the trader's offer price, and the farmer can exploit this information in the form of a credible treat to take his produce to the market himself. However, the evidence that these initiatives can actually increase farmer bargaining power vis-a-vis middlemen seems mixed (Fafchamps and Minten,

[2] The transaction cost is the total cost of moving the product from the low price area to the high price area. Transport cost is only a part of this cost. Transaction cost will also include search cost, a risk premium, etc.

2012).

One reason that sending prices to farmers may have less impact than expected is that complementary information may be necessary to make the price information useful. Knowing the price in some remote market may not, in itself, affect the bargaining power of a farmer with a single trader, especially in remote areas where there is little competition between traders and the farmer has no means to transport the commodity him or herself. Aker, Blumenstock, and Dillon (2020) note that the expansion of landlines came with additional information in the form of telephone directories. While mobile phone users in developed countries use the internet to look up new contacts, this may be less straightforward in a developing country context, as small scale traders and processors may not have a presence on the web. Aker, Blumenstock, and Dillon (2020) tested an intervention on the production and distribution of a ”Yellow Pages” phone directory with contact information for local enterprises. They find a range of effects and also indications that farmers sell crops for somewhat higher prices. This suggests that a complementary intervention that provides farmers with the contact details of traders may make price information more actionable. This result is in line with Goyal's (2010) finding that dissemination of wholesale price information through internet kiosks combined with access to an alternative marketing channel led to a significant increase in the price of soybeans in the central Indian state of Madhya Pradesh.

Most projects that aim to improve welfare by increasing market efficiency target smallholder farmers as the main project beneficiaries. However, to increase prices that farmers receive for commodities sold at the farmgate, it may be more effective to increase competition between itinerant traders. Unfortunately, in most interventions, these "middlemen" are often overlooked, vilified as exploitative, and branded as parasites by farmers and policymakers alike (Sitko and Jayne, 2014). Worse, many development interventions explicitly aim to cut out the middleman. An alternative view would consider middlemen to be the grease that keeps the value chain running. In this view, the problems are created by too few middlemen, rather than too many. In such a case, more impact may be possible if the direction of the price information flow is reversed: Instead of collecting data at markets and pushing this to individual farmers, it may make more sense to collect data from farmers at the farmgate and signal areas of potential excess supply to traders.

Ochieng and Baulch (2020) report on a proof of concept to use crowd-sourcing to obtain maize and soybean farmgate prices in Malawi. In collaboration with Farm Radio Trust (FRT), farmers were encouraged to report the prices they received via SMS or by calling a toll-free number whenever they made a sale during the marketing season. To get sufficient farmers to call in, targeted SMS messages were sent by FRT to their customers and local radio stations (Mzati FM, Gaka FM, and Angaliba TV and FM) aired radio jingles in local dialects throughout the study period. To further encourage farmer participation, calls and text messages were entered into a weekly raffle, in which the winners received a coupon worth MWK25,000, which could be redeemed for farm inputs at selected farm input outlet. The data obtained though this crowd-sourcing exercise can be used to investigate price variation (and underlying differences in demand and supply) over time and space. The results of such an analysis can then be visualized in dynamic maps that are accessible through a portal to traders and policymakers, allowing them to identify areas of excess supply and demand and start moving products from low price areas to high demand locations (Figure 1).

However, a more proactive approach would target farmers with detailed information on time- and location-sensitive arbitrage opportunities. Crowd-sourced price data could be combined with data obtained from satellites, hyper-local weather stations, and market intelligence in a real-time decision support system designed to forecast arbitrage opportunities. Information about these opportunities could then be sent to registered traders depending on their proximity to where arbitrage opportunities emerge. Nudging traders to exploit arbitrage opportunities at such local levels would increase competition at the farmgate, leading to higher farmgate prices.

ICTs and agricultural advisory

ICT also shows potential to be useful for agricultural extension. Agricultural advisory services provide information about the availability and use of quality inputs such as improved seed varieties or inorganic fertilizer. They are also used to promote good agronomic practices such as row planting and irrigation. As agricultural extension information is assumed to be a public non-rival good, extension services are generally organized by the government. However, there are many challenges, including failure to reach farmers in remote places, motivation of extension agents, and monitoring more generally. ICTs have been hailed as a technology that can solve most if not all of these

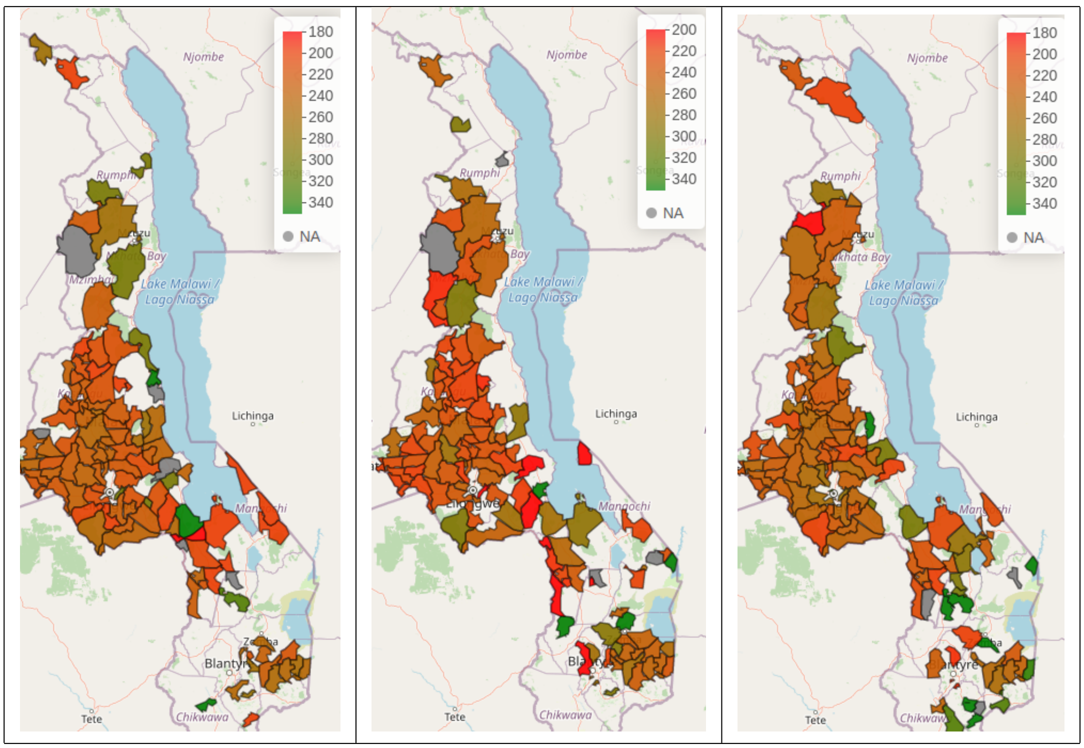

Figure 1: Farmgate prices (in Malawian Kwatcha) in May, June, and July

problems (Spielman et al., 2021).

A range of applications and technologies are used to facilitate agricultural extension provision. I will discuss approaches that have been studied most, including SMS messaging, Iterative Voice Response systems and related call-centers, and video based interventions. I then review more holistic interventions that bundle a range of services and/or rely on various technologies.

SMS is probably one of the cheapest ways to deliver personalized information.[3] While SMS is rather top-down and probably too short to provide new information, research in various areas found it may be useful for providing reminders or making particular information more salient (Lester et al., 2010; Karlan et al., 2016). As a result, various projects and initiatives use SMS to encourage farmers to adopt a particular technology or practice, or to remind farmers about important practices at particular points in time. Fabregas and colleagues (2019) report on six field experiments in Kenya and Rwanda, where farmers were targeted with SMS messages to encourage them to use agricultural lime to mitigate acidic soil conditions. The found a 20 percent increase in the adoption of the recommendation, but the messages needed to be resent every season. Van Campenhout, Spielman, and Lecoutere (2021) find no additional effect of sending SMS messages to maize farmers in Uganda at targeted points in time to remind them about important agronomic practices such as fertilizer application and weeding, over and above the effect found of showing a short video demonstrating a range of important practices.

More complex setups than simple SMS messages include demand-driven interactive services that allow farmers to indicate what information they require. Such setups could be text based, for instance through Unstructured Supplementary Service Data (USSD) code-based menus. Because farmers may be illiterate, however, Interactive Voice Response (IVR) systems or hotlines have been used as alternatives. For example, Cole and Fernando (2020) evaluated Avaaj Otalo, a mobile phone-based technology service geared towards cotton farmers that allowed users to call a hotline, ask questions, and receive pre-recorded responses from agricultural scientists and local exten-

[3] It is fairly straightforward to send customized messages to individual subscribers through a commercial SMS Application Programming Interface (API) platform. For example, as part of an information clearinghouse set up to test asymmetric information about seed quality between small agro-input dealers and farmers, Sparrow et al. (2021) sent out almost 30,000 messages to farmers informing them about how customers rate seed dealers in their vicinity.

sion workers. The intervention significantly increased the adoption of recommended agricultural inputs for cotton cultivation. Effects on yield and profits are positive, but the data seemed too noisy to draw conclusions. Van Campenhout, Spielman, and Lecoutere (2021) also added an IVR treatment to their short video that provides information on a range of important agronomic practices to maize farmers in Uganda, but found no incremental effect, perhaps because uptake is extremely low.

Alternative models of ICT mediated extension rely on audiovisual information. Video is used in many formats and settings. They can be shown privately to individuals, much like YouTube videos (Vandevelde, Campenhout, and Walukano, 2021), or they can be used in Farmer Field School-type mediated video-based trainings, projected using battery-powered pico projectors (Vasilaky et al., 2015). Video-based approaches can be formal recordings of authoritative figures (such as an extension officer) sharing technical information, or a model farmer recounting a success story that other farmers can relate to, as farmers appear to learn more from those with whom they identify (BenYishay and Mobarak, 2018).

The main intervention in Van Campenhout, Spielman, and Lecoutere (2021) consisted of a short and engaging video in which farmers explain what they did to become successful farmers. The video includes technical information such as optimal timing for planting, instructions for row planting and optimal seed rate, and frequency of weeding. It also recommends the use of improved seed varieties and inorganic fertilizers. The video also explains some simple inter-temporal cost-benefit calculations, driving home the point that farmers have to invest now to get more in the future. The study uncovers a range of positive effects along the causal impact chain, including a significant increase in maize yields.

A particularly powerful feature of audiovisual content is the potential to challenge norms and increase aspirations through the use of role models (Bernard et al., 2015). This could be particularly useful for making agricultural extension systems more gender inclusive. Female role models have been shown to encourage other women to enter male-dominated sectors (Porter and Serra, 2020). Role models featured in movies, television series, and videos seem to affect aspirations and subsequent behviour (Riley et al., 2017; La Ferrara, Chong, and Duryea, 2012). In Lecoutere, Spielman, and Van Campenhout (2020), we assess the impact of agricultural extension videos featuring a female role model. We find some support that female role models in the extension videos challenge men's beliefs and stereotypes about women's roles in agriculture, and encourage the adoption of recommended practices by women.

SMS, IVR, and video are probably the most common simple technologies used for agricultural extension. But over time, developers have started combining approaches to develop complete decision support systems that integrate and process data from various sources. An early example comes from Uganda, where the Grameen Foundation experimented with Community Knowledge Workers (CKW). Modeled after a project that successfully equipped community health workers with mobile phone–based tools in India (Flaming et al., 2015), the CKW project equipped resident community members with an Android smartphone pre-loaded with an in-house developed mobile application. CKWs can then use this application to look up information requested by farmers about farming and crop marketing, including location-specific weather forecasts or price information in nearby markets. Despite initial excitement and evidence that the intervention increased market orientation of farmers, the project was discontinued (Van Campenhout, 2017).

Currently, various startups offer cloud-based platforms that involve complete digitization of farms and data-driven decision-making supported by artificial intelligence and machine learning. Examples include CropIn's SmartFarm platform that promises complete farm management solutions including satellite and weather-input based advisory. As these platforms combine various components, it is hard to learn about the underlying mechanisms and impact pathways using impact evaluations. Furthermore, as these are often private for-profit initiatives, independent and credible impact evaluations are often not available.

ICTs have not only been used to get information to farmers more efficiently, but also to motivate extension agents and monitor performance. Equipping extension agents with fancy smart-phones or tablet computes may increase motivation in itself. Namyenya et al. (2021) report on the development of electronic diaries with the primary aim of increasing monitoring. Other ICT mediated applications to increase extension agent monitoring include the use of geolocation to determine whether extension workers visited certain locations (Dal Bó et al., 2021) and the use of video to allow extension workers to document their efforts (Duflo, Hanna, and Ryan, 2012).

ICTs to reduce asymmetric information

ICTs are also a powerful means to address the asymmetric information prevalent in agricultural service delivery and agro-input provision. Agricultural inputs are often "experience" goods, as it is difficult to assess quality by simply examining these goods in the agro-input shop. In Uganda, Bold et al. (2017) found that agricultural yields are noisy and farmers' ability to learn about quality of inputs is limited, leading to the marketing of low quality inputs. ICTs can be used to help farmers learn about inputs and technologies, thus reducing poor quality inputs.

One hypothesis is that agro-input dealers engage in widespread counterfeiting. In Uganda, Gilligan, Karachiwalla, and Thai (2019) evaluated an e-verification intervention, which involves labeling agricultural inputs with an authentication code that can be used to confirm the labeled product is genuine though a message or phone call. They find that the verification program caused a broad increase in the adoption of high-quality agricultural inputs, thereby showing that such a verification scheme has potential to foster technology adoption. No effects were found on yield or net income, but the data is noisy.

ICTs can potentially solve coordination problems between farmers and traders by obtaining large quantities of data through crowd-sourcing, aggregating this data, and then providing it back to users. ICTs provide a powerful way to reduce information asymmetry at the input- or service provider-farmer-link in the value chain by collecting, processing, and disseminating information in near real-time.

In Pakistan, Hasanain, Khan, and Rezaee (2017) implemented an information clearing house to reduce asymmetric information in the market for veterinary services. To do so, they crowdsourced success rates for artificial insemination of livestock, as well as prices charged by vets, and this information is aggregated and fed back to farmers. They find that the intervention leads to 37 percent higher artificial insemination success rate. Interestingly, they find that this effect should be attributed to increased effort by the vets, as few farmers seem to switch to other vets. The study illustrates how clearing house mechanisms can be used to address problems of motivation of extension services and increase accountability also mentioned in the previous section.

In Van Campenhout et al. (2021), a sample of farmers were asked to rate the quality of maize seed that agro-input shops in their vicinity sell. This

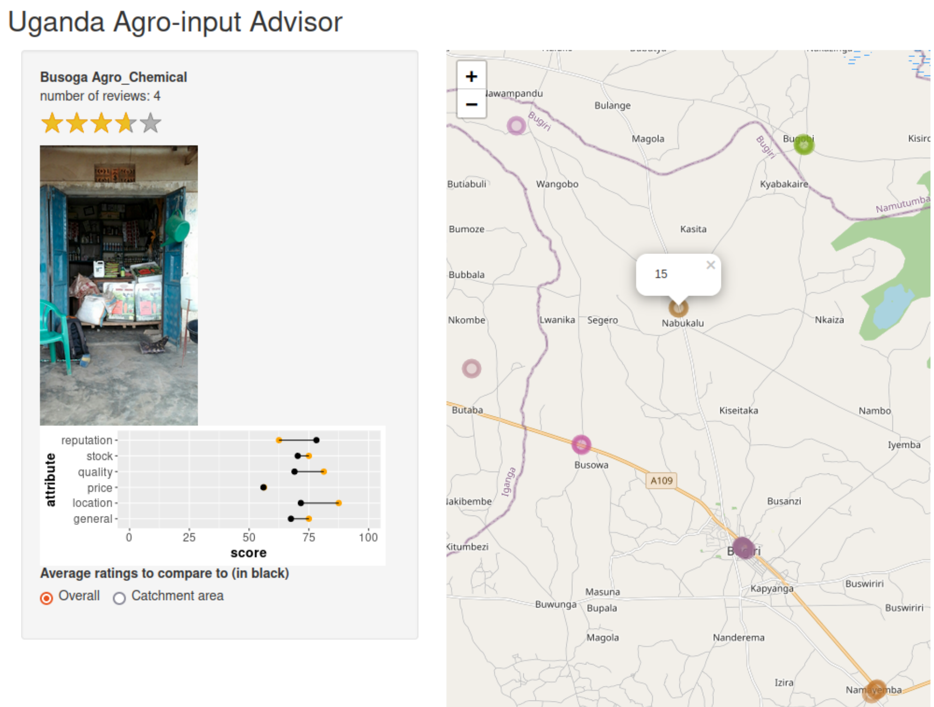

Figure 2: Agro-input Advisor

information was used to assign scores to agro-input dealers, which were then provided back to both the farmers and the agro-input dealers (Figure 2). Farmers received scores for each input dealer in their neighborhood. Input dealers received a slightly more elaborate report with their own score, which compared their score to the average scores of all agro-input dealers in their immediate neighborhood. The report that input-dealers received also doubles as a certificate that agro-input dealers can advertise in their shops if they choose to do so. Midline data collection is scheduled for the beginning of 2022 and endline data will be collected after two full agricultural seasons in the second half of that year.

Networks and ICT

By now, there is ample evidence that farmers rely on their social networks to learn about new agricultural inputs and technologies (Bandiera and Rasul, 2006; Conley and Udry, 2010). As a result, researchers have started to explore ways to leverage existing social networks to make agricultural advisory systems more effective and inclusive. The networked nature of ICTs provides a natural way to further exploit these network effects.

In developed countries, the dissemination of information through virtual social networks such as Facebook or Instagram, where people can follow, like, and share, has become very important. Drawing on the model of these social networks, Digital Green encourages farmers to showcase farming techniques in short YouTube-like videos, in the hope that the most promising farmers develop into influencers (Toyama et al., 2009). While initiatives at this scale are rare, farmers do often use virtual networks, albeit at a modest scale, such as WhatsApp groups for farmer cooperative members. In this way, content can be discussed among peers to make it more salient. Being able to discuss content with peers may be particularly important to uncover returns to investment in a new technology (Van Campenhout, 2021).

The effectiveness of using social networks to increase agricultural technology adoption also depends on the network's structure. Targeting central nodes in the network has been found to lead to better results than just randomly disseminating information (Beaman et al., 2021). User data obtained from virtual social networks may be useful to learn about network structure and identify optimal nodes to insert information into the network.

Social networks are also important for commodity movement within the value chain. In the previously discussed study by Aker, Blumenstock, and Dillon (2020), farmers were able to increased their network of potential buyers through telephone directories. However, in areas with weak institutions that cannot enforce contracts, social networks are also important to facilitate trade relationships (Fafchamps and Minten, 2001). Networked technologies that allow for frequent contact and easy sharing of experiences with particular traders (such as through Facebook groups) are likely to strengthen social ties and increase networks.

Pitfalls and dangers

Even though ICTs—and mobile phones in particular—have been hailed as the solution to reach the last mile in for example agricultural extension, there is often inherent selection bias as a result of differential access to the technology. Indeed, the poorest in society, who are likely to benefit most from a particular ICT mediated intervention, may not have access to mobile phones. And even if they have a phone, it is likely to be a very simple phone which is only used for receiving phone calls. It is thus important to develop ICT tools that can be used with the technologies accessible to the target group. Examples include IVR or interventions that send SMS or use USSD codes for basic user input, and hybrid extension models in which extension workers visit and share videos on their devices, among others. Access to mobile phones and technology more generally may be unequally distributed among particular groups. For instance, Aker, Ghosh, and Burrell (2016) note that ICT mediated information exchange platforms should be designed with the gendered digital divide in mind.

In addition to selection bias, there are still vast areas that lack cellular coverage, or if coverage is available, connectivity is spotty and data transfer is slow, which has implications for the effectiveness of ICTs. One of the key comparative advantages of ICTs is the ability to customize advice with, for instance, time sensitive feedback and hyper local information, but this feature is likely to suffer due to limited cellular access. Second best solutions include offline applications that are able to perform basic analysis on devices locally instead of through an Application Programming Interface (API) and distributed solutions where data is stored locally and automatically synchronized once connectivity is established.

In addition to the issue of low excludability and non-rivalry, information as a commodity is also difficult to evaluate. Indeed, one generally acquires information because of a lack of knowledge. As a result, it is often difficult to assess the quality of the information itself. Interestingly, it seems the more information becomes available, the more difficult it becomes to filter out good information from "fake news."

There are also many reasons to be wary about information clearing mechanisms based on crowdsourced data. If crowdsourced data is thin, outliers may drive the information that is fed back into the system. Public review platforms are prone to manipulation (Mayzlin, Dover, and Chevalier, 2014). But even if sufficient data is available from crowd-sourcing, implicit bias may lead to unfair competition. Research in other areas has shown, for example, that female academics are evaluated less favorably than their male counterparts. If these evaluations are then used to inform decisions on promotion or hiring, this could lead to discrimination (Mitchell and Martin, 2018). In De, Miehe, and Campenhout (2021), we test for systematic difference in the crowd sourced rating of agro-input dealers and find that female agro-input dealers receive significantly lower scores than male agro-input dealers. To avoid creating unfair competition, this bias should be corrected when scores are fed back.

Walter et al. (2020) identify problems with IVR through a thorough analysis of the call logs. One of the main problems that IVR systems need to overcome is user impatience. IVR systems typically rely on two-way information exchange, and the IVR system needs to collect a minimum level of information about farmers. This often means lengthy registration processes that users have to go through on their first call, leading many farmers to drop the call. Therefore, it is better to ask only the most important data upfront and ask for additional input as users navigate further through the menu. The low cost of dissemination means that there may also be a lot of unsolicited content and robocalls, up to the point where it renders the ICT unusable.

Unfortunately, relying on social networks to disseminate information can also lead to the exclusion of certain groups of people. When these networks are gender-specific and gender-segregated, problems associated with asymmetric information persist (Beaman and Dillon, 2018). Social networks that are divided between traders along ethnic lines may lead to barriers to entry for other traders (Fafchamps, 2003). Furthermore, leveraging virtual social networks may also result in ineffective or even harmful information about agricultural inputs or technologies being amplified, and it is well known that social media is a particularly fertile breeding ground for fake news.

Conclusion

This paper provided an overview of the most informative studies to date on the effectiveness of ICTs to tackle information inefficiencies in agricultural value chains. It also highlighted some ongoing studies that explore new directions in this area. The paper uses the existing research to highlight some of the typical pitfalls that need to be considered when developing ICT mediated solutions to information inefficiencies in agricultural value chains. The initial excitement was perhaps somewhat overblown: While we have witnessed many mobile phone-based interventions in the agricultural sector over the past two decades, there is mixed evidence on the impact (Aker and Ksoll, 2016). Many of the apps developed by startups to empower farmers with information seem to struggle to reach scale.

However, despite the mixed evidence, I would still argue that ICTs are a powerful means to increase information transmission and to reduce asymmetries in information between actors in the agricultural value chain. But the way in which farmers, traders, processors, and input providers benefit seems much more informal and bottom-up. For example, instead of subscribing to daily price updates delivered through a price dissemination app on a smartphone, farmers seem to use their mobile phone to call relatives in urban areas to get an idea of current prices. Or, instead of using artificial-intelligence powered decision support systems to give customized advice, coffee farmers may form a WhatsApp group of cooperative members to share experiences and best practices on coffee farming. The informal use of ICTs may also explain why studies that rely on quasi-experimental methods such as difference-in-difference (Svensson and Yanagizawa, 2009; Jensen, 2007; Aker, 2010) or fixed effects (Muto and Yamano, 2009; Sekabira and Qaim, 2017) generally seem to find a significant impact, while case studies and experimental studies that focus on a particular application seem to be less successful in detecting effects.

The reason why many of the ICT mediated projects and initiatives fail may also partly related to the mindset of people and organizations involved in ICT for development. Many organizations often think too much like startups from California and develop complex apps that require a constant broadband internet connection and fast smartphones with geo-location capabilities. In light of this, it may be instructive to compare ICTs in agriculture to innovations in mobile phone-based money transfer, payments, and micro-financing services, where initiatives such as M-pesa seem to be much more successful in generating broad impact (Suri and Jack, 2016).

I see two key differences between the use of ICTs to address information inefficiencies and the use of ICTs to provide financial services. First, mobile money evolved in a very bottom-up way, where network operators attempted to formalize and expand how pre-paid customers used the scratch card system to transfer money in the form of phone credit. For example, a person can buy a scratch card in one place and use it to put a mobile phone credit on the phone of someone in a different location. The other person would then often convert the phone credit back to money by charging relative or neighbors for phone use. The bottom-up nature means that there was real demand for the product that was created.[4] The demand-driven nature of mobile money

[4]Again, information as a commodity is special as people will generally not realize or

also resulted in a solution that acknowledged the limits of technology, preferring USSD- and SMS-based technologies that are also accessible with cheap cell phones instead of applications that require smartphones. A second key difference is that financial mediation can be priced much easier than information provision. ICT applications that provide information often rely on subscription-based business models. However, the ability and/or willingness to pay for a non-rival good such as information at the farm level may be low. For ICT applications to become more successful in agriculture, particularly in the area of agricultural advisory services, a different business model may be needed.

The most promising applications of ICT for development are those that solve complex coordination problems and reduce asymmetric information. In rich countries, the use of such applications requires access to a smartphone or a computer. The challenge will be to develop applications that are able to solve these complex information problems by using technology available to and accessible by the poor. This will likely involve some combination of simple technologies (SMS, IVR, USSD) and human mediation where community members or government agents facilitate the interface between technologies and users.

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admit that they lack information.

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