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ORIGINAL ARTICLE

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. However, not all initiatives are equally effective and many struggle to reach scale. In this article, I review some of the earlier services that generally targeted farmers with price information to reduce search costs and increase their bargaining power vis-a-vis traders. I reflect on the reasons why these initiatives often led to disappointing results and provide examples of (complementary) interventions that look more promising. Furthermore, I highlight some of the dangers of relying too much on ICT-mediated information, such as exclusionary networks, bias in crowdsourced data, and "fake news." Finally, I explore why ICT applications that address information inefficiencies seem to be less successful than innovations that address other barriers to efficient and inclusive food supply chain development, such as risk or credit constraints.

KEYWORDS
agricultural extension, asymmetric information, Information and Communication Technologies, market efficiency

JEL CLASSIFICATION
O13, O33, D83

1 | 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. Information asymmetries are cultivated and protected to create an advantage for one party. Information gaps are complemented with heuristics prone to stereotyping and suffer from cognitive biases. Consequently, as is the case with other incomplete or missing markets, information inefficiencies arising from incomplete or missing information markets often lead to suboptimal 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 the 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 (ICTs). For instance, Jeffrey Sachs, director of the Earth Institute at Columbia University, has called the cell phone the single most transformative technology for development (Voigt, 2011). The last few decades have 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 are. 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 article, I highlight some of the ICT applications to provide insight on what works and what not, and why. I then point to some ongoing initiatives that look promising, and reflect on future projects that build on what we have learned. The focus of the article will be mostly on the usefulness of ICTs to increase market efficiency and inclusiveness, and facilitate information flows within agricultural value chains. Another area where ICTs are expected to be particularly useful is in the delivery of agricultural advisory services. The literature on the use ICTs for agricultural extension is somewhat more developed, and so the interested reader is referred to existing review papers (e.g., Aker, 2011; Fabregas et al., 2019; Spielman et al., 2021).

After a brief section that highlights the primary characteristics of ICTs, I describe how ICTs have been used to increase market efficiency in the past. I note that many of the earlier initiatives were somewhat unidirectional, targeting farmers with price information. I reflect on reasons why these initiatives often provided disappointing results, and argue that complementary interventions may be needed and/or the flow of information may need to be reversed. I also discuss more advanced applications designed to reduce asymmetric information in input supply chains. In a next section, I highlight some of the dangers of relying on ICTs for information transmission in agricultural value chains, and argue that crowdsourcing and network effects may lead to exclusion and introduce bias. The last section concludes by comparing ICTs that reduce information inefficiencies with ICT-mediated interventions that focus on other barriers in the sector.

2 | 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).

However, ICTs these days are capable of much more than just passing on information. ICTs often have processors, allowing them to aggregate and process large amounts of data. As such, networked devices are becoming more and more common as decision support tools throughout the value chain. Below, I hypothesize that 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 (Klemperer, 2016). 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 value chain development (Fafchamps & Minten, 2001). However, as we will see below, they can also lead to exclusion, and add noise to information.

3 | ICTS TO INCREASE MARKET EFFICIENCY AND VALUE CHAIN PERFORMANCE

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

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

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 lead to fragmented markets with excessively high prices in one location and low prices in other areas (Van Campenhout, 2007).

In a seminal article, 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 sea 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 relying on simple technologies such as 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 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 threat 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 & Minten, 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 themselves. Aker et al. (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 et al. (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 & 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 crowdsourcing 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 (or about USD30), which could be redeemed for farm inputs at a selected farm input outlet. The data obtained through this crowdsourcing 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

[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, an so forth.

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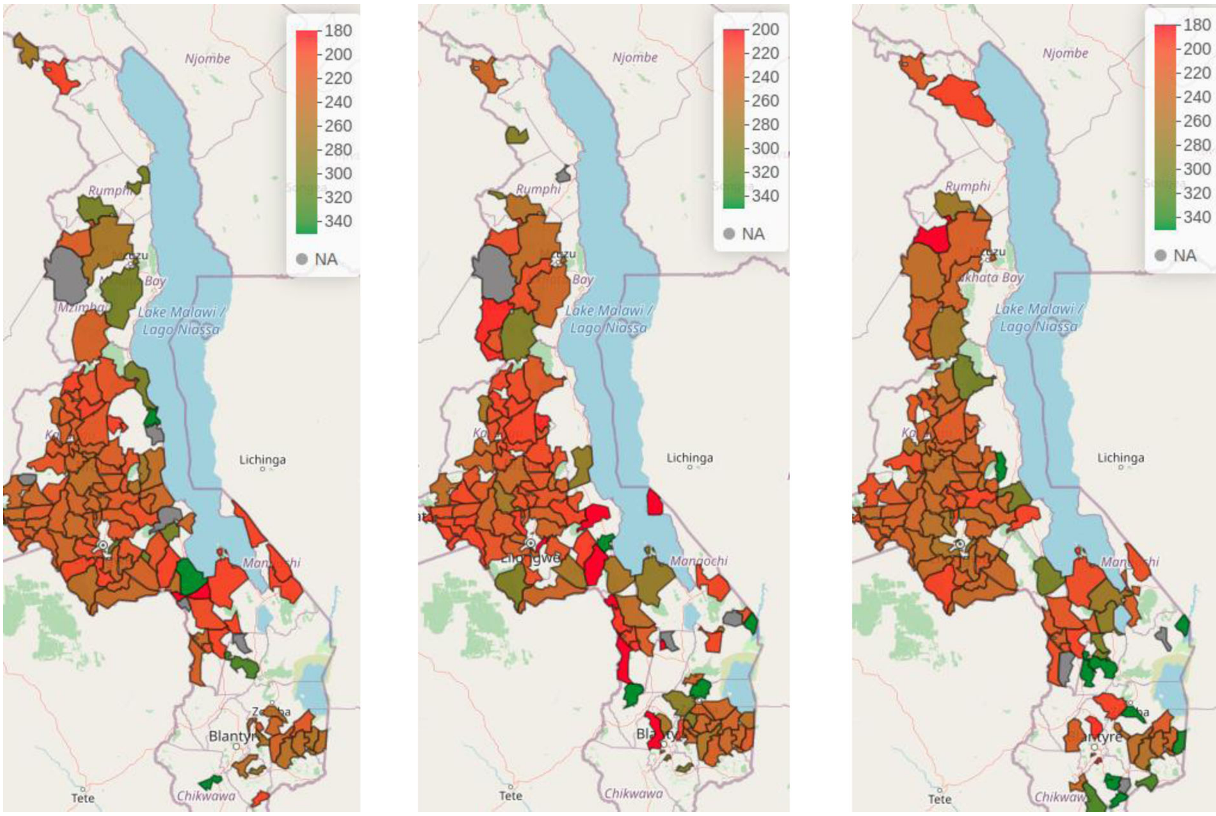

FIGURE 1 Farmgate prices (in Malawian Kwatcha) in May, June, and July

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 traders with detailed information on time- and location-sensitive arbitrage opportunities. Crowdsourced 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 are also a powerful means to address the asymmetric information that may exist within supply chains. An important example of the existence and consequences of asymmetric information is the case of agro-inputs in Uganda (Bold et al., 2017). Agricultural inputs are often experience goods, as it is difficult to assess quality by simply examining these goods in the agro-input shop. Bold et al. (2017) found that agricultural yields are noisy and farmers' ability to learn about the quality of inputs is limited. This leads to a situation where high-quality inputs are driven out of the market. ICTs can be used to help farmers discover input quality and reduce information asymmetry.

One hypothesis is that agro-input dealers engage in widespread counterfeiting. In Uganda, Gilligan et al. (2019) evaluated an e-verification intervention, which involves labeling agricultural inputs with an authentication code that can be used to confirm that the labeled product is genuine through 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 the potential to foster technology adoption. No effects were found on yield or net income, but the data are noisy.

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, an information clearing house to reduce asymmetric information in the market for veterinary services was piloted (Hasanain et al., 2017). 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% 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.

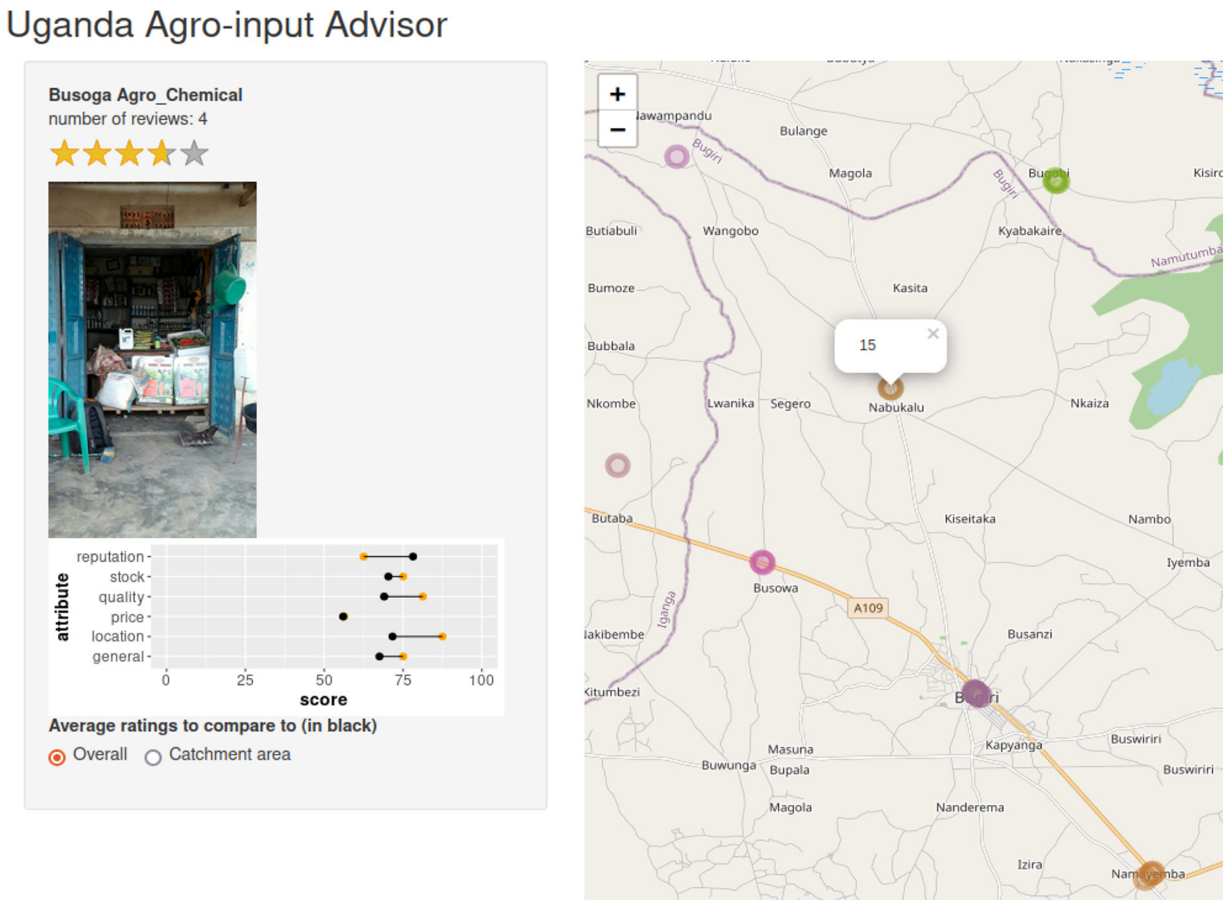

FIGURE 2 Agro-input advisor

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

4 | DANGERS AND DRAWBACKS OF RELYING ON ICT TO INCREASE INFORMATION FLOWS

Even though ICTs—and mobile phones in particular—have been hailed for their potential to integrate poor smallholders and informal value chains into the wider economy, there is often inherent selection bias as a result of differential access to the technology. Furthermore, 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.

More importantly, in addition to the issue of low excludability and nonrivalry, 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. The more (often conflicting) information becomes available, the more difficult it becomes to filter out good information from "fake news." Especially when networks are leveraged or crowdsourced information is used, misleading or even false information may start to dominate. This problem is often compounded by the low cost of information transfer through ICTs, resulting in a lot of unsolicited content and robocalls, up to the point where it renders the ICT unusable.

There are also reasons to be wary about information clearing mechanisms based on crowdsourced data. If crowdsourced data are thin, outliers may drive the information that is fed back into the system. Public review platforms are prone to manipulation (Mayzlin et al., 2014).

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But even if sufficient data are available from crowdsourcing, implicit bias may lead to unfair competition. Research in other areas has shown, for example, that female instructors are evaluated less favorably than their male counterparts in teaching evaluations (Mitchell & Martin, 2018). If these evaluations are then used to inform decisions on promotion or hiring, this could lead to discrimination. Van Campenhout and De (2021) test for systematic differences in the crowdsourced 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.

By now, there is ample evidence that farmers rely on their social networks to learn about new agricultural inputs and technologies (Bandiera & Rasul, 2006; Conley & 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. Social networks have also been found important for commodity movement within the value chain. For example, Fafchamps and Minten (2001) show that in areas with weak institutions where it is hard to enforce contracts, social networks are important to facilitate trade relationships. Networked technologies that allow for frequent contact and easy sharing of experiences with particular traders (such as through Facebook or WhatsApp groups) are likely to strengthen social ties and increase networks.

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 & Dillon, 2018). Social networks that are divided between traders along ethnic lines may lead to barriers to entry for other traders (Fafchamps, 2003).

5 | BOTTOM-UP VERSUS TOP-DOWN DEVELOPMENT OF ICT APPLICATIONS

The reason why many of the ICT-mediated projects and initiatives fail may also be 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 & 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 prepaid 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 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 relatives or neighbors for phone use. The bottom-up nature means that there was a real demand for the product that was created. The demand-driven nature of mobile money 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 nonrival good such as information at the farm level may be low. For ICT applications to become more successful in agriculture, a different business model may be needed, for instance by bundling information services to other services.

That said, more recently and partly in response to the COVID-19 pandemic, small-scale traders in cities and towns seem to have started adopting online food ordering and delivery platform such as Uber Eats. This suggests that informal traders are open to the adoption of fairly complex ICT applications and willing to pay for it if they see the need.

6 | CONCLUSIONS

This article reflects on the role of ICT in smallholder marketing and value chain development more in general. It notes that early studies on the impact of mobile phones on price transmission between value chain actors prompted a range of initiatives that attempted to empower smallholder farmers with price information. The initial excitement about these initiatives was perhaps somewhat overblown as there is only mixed evidence on the impact (Aker & Ksoll, 2016). Many of the apps developed by startups to empower farmers with information seem to struggle to reach scale. Building on these early initiatives, I discuss some initiatives and ideas that seem more promising. These include initiatives aimed at making the price information more actionable for farmer, and a pilot project that targets traders as opposed to farmers. I also point out a few promising studies that use ICTs to reduce information asymmetries within the value chain.

However, despite the excitement, there are also clear dangers related to relying on ICTs for information transfer within value chains. I discuss how cheaper communication can easily lead to too much information, and that crowdsourced information and the networked nature of ICTs are prone to "fake news." I further warn that the networked nature of ICTs can be a strength in some respects, but may also exacerbate inequalities.

I also argue that, despite the mixed evidence, ICTs remain 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 from ICTs 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 (Aker, 2010; Jensen, 2007; Svensson & Yanagizawa, 2009) or fixed effects (Muto & Yamano, 2009; Sekabira & 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.

From this, I conclude that 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 the 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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REFERENCES

Aker, J. C. (2010). Information from markets near and far: Mobile phones and agricultural markets in Niger. *American Economic Journal: Applied Economics*, *2*(3), 46–59. https://doi.org/10.1257/app.2.3.46

Aker, J. C. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics*, *42*(6), 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Aker, J. C., Blumenstock, J. E., & Dillon, B. (2020). *How important is the yellow pages?* Experimental evidence from Tanzania. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3560296

Aker, J. C., & Ksoll, C. (2016). Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. *Food Policy*, *60*, 44–51. https://doi.org/10.1016/j.foodpol.2015.03.006

Bagamba, F., Van Campenhout, B., Ntakyo, P. R., Sparrow, R., Otim, G., Spielman, D. J., & Miehe, C. (2021). Demand and supply factors constraining the emergence and sustainability of an efficient seed system—three experiments in Uganda [Unpublished manuscript]. AEA RCT Registry. https://doi.org/10.1257/rct.6361

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption in northern Mozambique. *The Economic Journal*, *116*(514), 869–902. https://doi.org/10.1111/j.1468-0297.2006.01115.x

Beaman, L., & Dillon, A. (2018). Diffusion of agricultural information within social networks: Evidence on gender inequalities from Mali. *Journal of Development Economics*, *133*, 147–161. https://doi.org/10.1016/j.jdeveco.2018.01.009

Bold, T., Kaizzi, K. C., Svensson, J., & Yanagizawa-Drott, D. (2017). Lemon technologies and adoption: Measurement, theory and evidence from agricultural markets in Uganda. *The Quarterly Journal of Economics*, *132*(3), 1055–1100. https://doi.org/10.1093/qje/qjx009

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review*, *100*(1), 35–69. https://doi.org/10.1257/aer.100.1.35

Fabregas, R., Kremer, M., & Schilbach, F. (2019). Realizing the potential of digital development: The case of agricultural advice. *Science*, *366*(6471), eaay3038. https://doi.org/10.1126/science.aay3038

Fafchamps, M. (2003). Ethnicity and networks in African trade. *Contributions in Economic Analysis & Policy*, *2*(1), 1–51. https://doi.org/10.2202/1538-0645.1227

Fafchamps, M., & Minten, B. (2001). Social capital and agricultural trade. *American Journal of Agricultural Economics*, *83*(3), 680–685.

Fafchamps, M., & Minten, B. (2012). Impact of SMS-based agricultural information on Indian farmers. *The World Bank Economic Review*, *26*(3), 383–414. https://doi.org/10.1093/wber/lhr056

Gilligan, D. O., Karachiwalla, N., & Thai, G. (2019). *An evaluation of the impact of e-verification on counterfeit agricultural inputs and technology adoption in Uganda* (Endline report). United States Agency for International Development. https://pdf.usaid.gov/pdf_docs/PA00WDZR.pdf

Goyal, A. (2010). Information, direct access to farmers, and rural market performance in central India. *American Economic Journal: Applied Economics*, *2*(3), 22–45. https://doi.org/10.1257/app.2.3.22

Hasanain, A., Khan, Y., & Rezaee, A. (2017). *No bulls: Crowdsourcing away asymmetric information in the market for artificial insemination in Pakistan*. J-PAL. https://www.povertyactionlab.org/sites/default/files/research-paper/No-bulls_AI-in-Pakistan_Hasanain-Kahn-Rezaee_October2017.pdf

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the south Indian fisheries sector. *The Quarterly Journal of Economics*, *122*(3), 879–924. https://doi.org/10.1162/qjec.122.3.879

Klemperer, P. (2016). Network goods (Theory). In M. Vernengo, E. P. Caldentey, & B. J. Rosser Jr. (Eds.), *The new Palgrave dictionary of economics* (Living ed.). Palgrave Macmillan. https://doi.org/10.1057/978-1-349-95121-5_2178-1

Mayzlin, D., Dover, Y., & Chevalier, J. (2014). Promotional reviews: An empirical investigation of online review manipulation. *American Economic Review*, *104*(8), 2421–2455. https://doi.org/10.1257/aer.104.8.2421

Mitchell, K. M., & Martin, J. (2018). Gender bias in student evaluations. *PS: Political Science & Politics*, *51*(3), 648–652. https://doi.org/10.1017/S104909651800001X

Muto, M., & Yamano, T. (2009). The impact of mobile phone coverage expansion on market participation: Panel data evidence from Uganda. *World Development*, *37*(12), 1887–1896. https://doi.org/10.1016/j.worlddev.2009.05.004

Ochieng, D. O., & Baulch, B. (2020). *Report on a study to crowdsource farmgate prices for maize and soybeans in Malawi*. International Food Policy Research Institute. https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/134039/filename/134249.pdf

Sekabira, H., & Qaim, M. (2017). Can mobile phones improve gender equality and nutrition? Panel data evidence from farm households in Uganda. *Food Policy*, *73*, 95–103. https://doi.org/10.1016/j.foodpol.2017.10.004

Sitko, N. J., & Jayne, T. S. (2014). Exploitative briefcase businessmen, parasites, and other myths and legends: Assembly traders and the performance of maize markets in eastern and southern Africa. *World Development*, *54*, 56–67. https://doi.org/10.1016/j.worlddev.2013.07.008

Spielman, D., Lecoutere, E., Makhija, S., & Van Campenhout, B. (2021). Information and Communications Technology (ICT) and agricultural extension in developing countries. *Annual Review of Resource Economics*, *13*, 177–201. https://doi.org/10.1146/annurev-resource-101520-080657

Suri, T., & Jack, W. (2016). The long-run poverty and gender impacts of mobile money. *Science*, *354*(6317), 1288–1292. https://doi.org/10.1126/science.aah5309

Svensson, J., & Yanagizawa, D. (2009). Getting prices right: The impact of the market information service in Uganda. *Journal of the European Economic Association*, *7*(2–3), 435–445. https://doi.org/10.1162/JEEA.2009.7.2-3.435

Van Campenhout, B. (2007). Modelling trends in food market integration: Method and an application to Tanzanian maize markets. *Food Policy*, *32*(1), 112–127. https://doi.org/10.1016/j.foodpol.2006.03.011

Van Campenhout, B., & De, A. (2021). Gendered perceptions in maize supply chains: Evidence from Uganda. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3956680

Voigt, K. (2011). Mobile phone: Weapon against global poverty. *CNN*. https://edition.cnn.com/2011/10/09/tech/mobile/mobile-phone-poverty/index.html

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