Chapter 9
Digital Trading and Market Platforms: Ghana Case Study

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1 Development Challenge

In many poor nations and areas, the lack of markets is a major constraint to economic development. We will focus in this paper on smallholder agriculture, primarily in sub-Saharan Africa. In these areas, farmers would want to increase their outputs but worry that they will not find buyers for their crops at a good price. Buyers and traders similarly often have needs for agricultural goods and often cannot find farmers to supply those goods at the right quality and consistency over time. Potential agricultural food processing industrialists would want to set up their factories but also fear that they will not be able to reliably and consistently obtain the inputs for their goods.

In other words, in many poor nations, the lack of adequate markets is a big constraint on economic progress and growth. In economics, we normally refer to a market failure as a problem within economies which prevents Adam Smith's invisible hand to guide a nation or society to the optimum. Market failures are often defined as situations where there are gains from trade among different economic agents but where the markets are either nonexistent or have problems which prevent those gains from trade from being realized. These are situations in which if the market failure could be addressed there could be gains or benefits to the different market participants collectively.

This paper makes the case for the role of technology in addressing issues related to the lack of markets or the poor functioning of markets. We study how technology

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could help engineer improvements in markets or the creation of markets where none existed before. As we mentioned earlier, we focus on sub-Saharan agricultural markets primarily, and that will be where we draw most of our examples. We believe, however, that the work presented here also applies to many other smallholder-dominated farming areas in developing countries.

So, in what precise forms does the inadequacy of markets take in our context of small holder farmers? In what ways is the "market failure" manifested? We will list a few of these now. The technological innovations we discuss in this chapter will address many of these failures.

This chapter is of course not the place to provide a lengthy description of agricultural markets in rural sub-Saharan Africa and similar emerging countries. For what we study though, there are two main economic agents we will identify. The first is the smallholder farmer. This farmer typically uses little machinery outside of his or her cutlass and produces on small tracks of land typically one or two acres. The other market participant is the trader or buyer. Most traders are small and travel to a limited number of villages to look for farmers with crops to sell and negotiate a price with them. The trader then takes the crops to bigger markets to sell. Sometimes, there are slightly larger buyers working on behalf of agro-processors or larger poultry companies who purchase crops from farmers in a manner similar to the traders but with slightly higher volumes. Due to poor road infrastructure, transportation by traders to farmers' farms or villages is relatively expensive and time-consuming for the trader.

With this brief picture of the context of the agricultural market structure we study, we now list some of the precise development challenges inherent in this system.

1.1 Matching Supply and Demand

In many rural areas, farmers wait on their farms (technically their "farm gates") with their crops waiting for traders to pass by and negotiate terms for a sale (see, e.g., Aker & Ksoll, 2016; Svensson & Yanagizawa, 2009; Drott & Svensson, 2010). Alternatively, they may send their goods to very small nearby villages or small-town markets again waiting for traders to show up. The traders in turn may live in bigger towns or cities. There are a large number of different villages each trader could visit to purchase crops. They may make the trek to one village, incurring the transport cost, only to find that there is very little good quality crop to be picked up there. There may be another village that the trader could have gone to with good crops at a good price; however, the trader did not have that information and so did not travel to that village. There is therefore a missing market or trades that should have taken place but did not (see Fafchamps & Minten, 2012; Demise et al., 2017; Ssekibuule et al., 2013). The farmer with the good crops and the trader with the need for those crops could not meet and trade because they did not know each other existed on that particular trading day. Some aspects of this interaction have been modeled as a search process (see, e.g., Nyarko & Pellegrina, 2020) – farmers are searching for traders and traders are searching for farmers, and many times each may fail to find the other. The lack of information on the existence or whereabouts of the farmer and trader is a major source of the market failure in this case. That is, when the farmer and trader do not succeed in finding each other, a "market" cannot be formed for them to trade. The farmer would then be stuck with his/her unsold produce ("postharvest losses"), and the trader may have incurred travel costs to a village and will have to return empty-handed. This is a "market failure."

In the literature, there is debate about the source of the market failure and even the existence of the market failure (i.e., where the market fails to function properly and enable people who want to trade to be able to find each other and be able to trade). For instance, Dillon and Dambro (2017) suggest that in these agricultural settings, there is no market failure and that the evidence has focused on measuring market integration (prices being set correctly) rather than market failure per se. They argue that there may be hidden risks or costs borne by traders which may cause markets to appear inefficient with less than optimal trading but that they are efficient if these risks and costs are factored into the analysis. For example, traders may have to factor into their calculations the risk of losing their goods when trucks break down on bad roads or if their goods are stolen. However, there is vast evidence that shows otherwise – smallholder farmers face constraints on both the supply side (inputs needed by farmers like fertilizers, seeds, and tractor services are in limited supply) and the demand side (buyers of their farm produce do not show up or provide good prices). On the supply side, some of the well-studied constraints faced by farmers include credit access (Banerjee, 2013; Harrison & Rodríguez-Clare, 2009) and lack of quality inputs (Bai, 2018). On the demand side, some of the constraining factors studied in the literature include access to high-income and high-price markets (Atkin et al., 2017; Verhoogen, 2008).

1.2 Price Information

There is a second aspect of lack of good markets which applies to smallholder farming. Typically, one side of the market does not have full information to make the appropriate economic decisions (see, e.g., Goyal, 2010; Allen, 2014; Startz, 2016). In our case of smallholder agriculture, it is usually the farmer who is stuck on his or her farm in a small village and has less information than the trader. The trader in contrast is the one who is often in a bigger town or else travels to many markets and so is up to date on the general trading conditions. When a trader goes to the farmer's farm to negotiate a trade, the trader usually has better information than the farmer. This often means that the trader will be able to offer the farmer unreasonably low prices because the farmer does not know that there are other markets where prices are higher. The price of a crop could be commanding high prices in a city. The trader who comes to visit the farmer may offer the farmer low prices for the farmer's goods. The farmer, not knowing that prices have recently risen in the cities, would accept the lower price offered by the trader. If the farmer had known of the better prices,

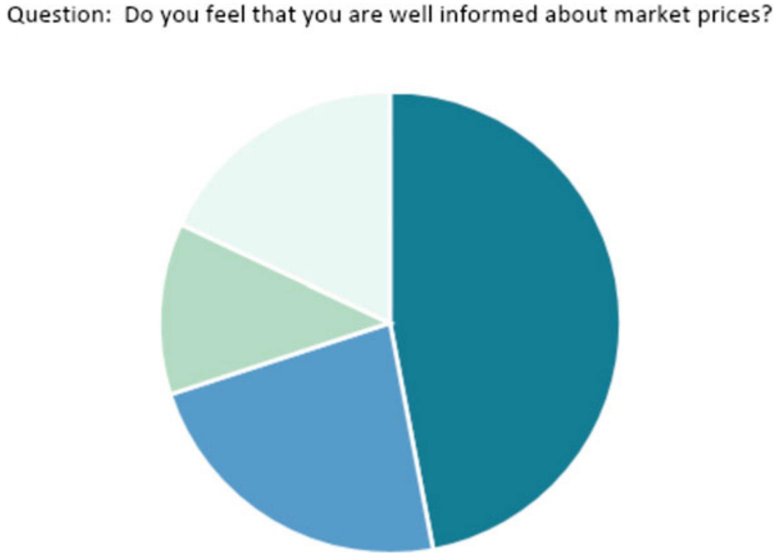

Fig. 9.1 Results of a survey of farmers on the question of knowledge of prices

the farmer would have bargained for a better price. Figure 9.1 shows the result of a survey of farmers on the question of knowledge of prices from Hildebrandt et al. (2020).

One could argue that, since both the farmer and the trader are poor, this is not a major problem because all this means is that traders can get a better price relative to farmers. In other words, what is the relative distribution of the gains from trade among these two market participants? Of course, to us as researchers, there are two responses to this. The first is that if the farmers could be guaranteed higher and more consistent prices, then the farmers would respond by increasing their output and perhaps investing more in their farms. That is, the lack of information on prices could be introducing risk and uncertainty to farmers making them unwilling to expand the scale of their operations. The second response is that we do often place more weight on the welfare of farmers than on traders. The farmers are usually poorer and have fewer alternative options for work in comparison with the traders and buyers of produce. So, both government policy and researchers often seek ways of improving the lot of farmers relative to the traders and buyers.

An important role of markets is what is often called "price discovery." It is meant to convey the belief that the markets communicate the "true" price of the commodity – that which will clear the market so farmers sell all they want and buyers buy all they want at the prevailing prices. In poorer communities and in particular in many smallholder agricultural communities, the trading processes do not result in the appropriate price discovery. The markets, to the extent that they exist, do not perform adequately their price discovery function. Markets do not inform the farmers of the potential true value of their crops, so they can make correct economic decisions. There could be high demand for a farmer's goods in a city (high prices), but nobody shows up to the farmer's farm in the village to ask for his/her goods. Alternatively, there could be abundant surpluses of a crop in one area or village (low prices), which is needed in a town, but the trader does not know of this so does not go to that area. The prices in the different areas are not transparent to (or known by) the farmers and traders. Or, technically, there is little "price discovery."

1.3 Information on the Quality of Crops

In many of the rural economies we study, there are typically complaints on both sides of the market exchange, farmers and buyers, about quality issues. On the one hand, buyers and traders complain that they do not get from farmers the quality of goods that they would desire. They say that the farmers are always trying to cheat them with inferior-quality goods. The prices traders pay to farmers, therefore, have to take into account the possible low quality of the goods they receive. On the other hand, many farmers do not believe that traders are honest in the assessment of the quality of their produce. Many farmers, because of this, do not believe that they receive the full benefits from improving the quality of their goods (Bagwell, 2007; Bai, 2018). Consider the example of smallholder transactions in maize (corn). Traders or buyers would want dry and clean maize free of pests and diseases like aflatoxins (a mold-like disease). Visual inspection of the maize is not always sufficient to check for disease and pests, especially in large bags. Farmers in turn do not believe that they will get better prices if they go through the work of properly drying the maize and fully clearing it of dirt and pests. Even if they believe there is some reward to this activity, they are not fully conversant with the price gradient – how much additional money they receive for the additional increase in the quality of their grains. Again, this is a failure of the market to adequately provide the price signals, in this case, the price gradient for quality (see Saenger et al., 2014; Bernard et al., 2017).

This market failure has important effects on the rural economy. Farmers often complain that they are not getting enough for their crops. They often say that they would put in more effort in their farming if they could be assured of a return on that investment. If the markets could create the price gradient in quality, the farmers would "climb" that gradient by producing better-quality goods, thereby increasing the return from their efforts and their crops. Traders and buyers too would benefit from the higher-quality goods. For example, many agro-processing industries cannot function without the reliable supply of consistently high-quality grains. In short, the economic development and transformation of the rural economies may be stymied by the market failure in pricing for quality of the crops.

1.4 Storage and Credit Market Failures

In rural economies, there is also often the failure of credit markets (World Food Program, 2010; Svensson & Yanagizawa, 2009). One way in which this happens and where there is the clearest manifestation of the market failure is in postharvest credit (Kaminski & Christiaensen, 2014). This is the situation where a farmer has successfully harvested the crop and has the crop bagged and ready to be sold. The crop, however, is being harvested at a time when most of the other farmers are storing their goods. If the crop is sold right after harvest, the farmer receives a low price for their crop. Indeed, a lot of the crop may go unsold if traders, inundated with many farmers all trying to sell their maize at the same time, do not come to their farm gates to purchase the maize. Agro-industries may similarly not need the produce of the farmers when there is a glut of crops in the market. Instead, they would most probably prefer the smoothing of the availability of crops across the year and seasons.

Both the farmers and the buyers would, therefore, wish for there to be a mechanism for sale of the crops at a future date. For this to work though, credit may be essential for the farmer. The farmer may need cash upfront to pay for unavoidable bills. The farmer will have household expenses and school fees for children, and they will need money to start planting for the next season. If the sale of the newly harvested grain is to be postponed, the farmer will have a demand for credit. Banks would want to supply that credit and to offer loans to such farmers. Banks, however, need to get collateral from the farmer without which the farmer may decide to default. There is the produce of the farmer which could be used as collateral. However, there is no way of easily and cheaply verifying the quality and hence value of the corn and also to verify that the corn will still be with the farmer when it is time to repay the loan. The farmer could always decide not to repay the loan, that is, to default. This is a classic credit market failure as both sides would want to trade if there could be credible certification and collateralization of the farmer's produce. In a well-functioning market, the farmer would want to take a loan from the bank, and the bank would want to offer the loan. However, the market will fail to be formed.

A consequence of lack of storage and credit facilities is that when there is a harvest, there may be a glut of food crops upon harvest which may not be sold and go to waste. This is a part of the postharvest losses which plague these markets. FAO (2019, page 32) estimates that in sub-Saharan Africa, 14% of food is lost between postharvest and retail distribution along the supply chain.

2 The Ideation

One may ask how we, the researchers, noticed these issues faced by farmers and came up with the idea of using technology to fix these problems. The answer of course is straightforward. The farmers in the communities told us their problems and explained their concerns to us. Many years ago, one of the authors of this chapter and his PhD students visited farmers in Ghana. Many of the farmers complained about how they were being cheated by the traders who gave them low prices for their goods. They spoke about not knowing what the prices in the big cities for their goods were. They mentioned that they engage in one-on-one bargaining with a trader who comes to their farm gate after they have completed harvesting or just before. The farmers said that they are in a weak negotiating position at that time as they have a perishable good, in addition to being the weaker informational position. Similar evidence was found by Eggleston et al. (2002), Aker and Fafchamps (2015), and Nakasone (2013).

All of that got our research team thinking about what is the best way of solving these development challenges faced by these poor and rural smallholder farmers. The team then started conversations with an African agricultural food services company with a strong technology focus, Esoko. This chapter discusses a lot of the initial work with Esoko on mobile phone-based price alerts. The chapter also discusses our work on commodity exchanges which was inspired by the initial work on price alerts. This chapter will not delve into the technological details per se. Instead, we will describe the impacts of the technology on the smallholder farmers and the lessons learned from various interventions, by the authors and many others.

3 Implementation Context

The research reported in this chapter took place primarily in Ghana although a lot of the early work and insights came from Ethiopia (see Minten et al., 2014). As mentioned earlier, the knowledge of the development challenges and the appreciation of their importance came from the farmers and traders in these countries when we undertook research visits to those nations over a number of years.

The first formal research conducted was with the company Esoko which provided price alerts to farmers in Ghana (see Hildebrandt et al., 2020). Our team was very bullish on the importance of the mobile phone in overcoming development challenges in our research communities. The mobile phone is ubiquitous in rural areas. Even in very small villages, we find farmers with mobile phones. When their own villages have no electricity or cellular network signals, the farmers go to the next small town near theirs on a regular basis to charge their phone or even make the calls. The national governments are committed to increasing mobile phone signal reception, so over time, access to mobile phones was expected to increase. By the end of 2018, sub-Saharan Africa had a mobile subscriber penetration rate of 44%, and 23% of the population used mobile Internet on a regular basis (GSMA Mobile, 2018). That explained our initial focus on mobile phones as a vehicle for addressing some of the development challenges.

In both Ghana and Ethiopia, the government and policy leaders were all keenly interested in improving the lot of the farmers in their countries. It was therefore easy to get the attention and the support at the highest levels for our research activities.

Our early research on mobile phones taught us the potential of technology could be high in our communities. As we moved to working on commodity exchanges, the personnel at the exchanges were enormously helpful to us. We had the support of the leader of the Ethiopian Commodity Exchange (ECX), first with the inaugural Chief Executive Officer (CEO) Eleni Gabre-Madhin through subsequent CEOs Anteneh Assefa and Ermias Eshetu and their teams. In Ghana, we had the support of the Ghana government (Ministry of Finance and Ministry of Trade and Industry), as well as the initial project staff and current leadership of the Ghana Commodity Exchange's (GCX), CEO Dr. Kadri Alfah, Chief Operating Officer Robert Owoo, and their teams.

4 Innovation

We divide our discussion on innovations into three sections: Sect. 4.1 Price Alerts Services, Sect. 4.2 Mobile Phone-Based Trading Platforms, and Sect. 4.3 Commodity Exchanges. Here, we will discuss the innovations themselves. In subsequent sections, we will discuss the implementation and evaluation of these interventions. An even later section will describe the results and lessons learned.

4.1 Price Alerts Services

One of the earliest innovations we were engaged in and an early area of interest in the academic literature is in mobile phone-based price alerts (see Hildebrandt et al., 2020; and the literature mentioned there). We mentioned in the development challenge in Sect. 1.2 that in many situations, smallholder farmers are at a price disadvantage when it comes to knowledge of prices of their commodities. Traders and buyers have more immediate knowledge of prices of foodstuff and crops across a nation, while the farmer, holed up on his farm, does not. Many researchers were therefore of the belief that mobile phone-based price alerts could either solve or lessen the impact of this problem.

Esoko is an agricultural services company in Africa. They provide farmers the prices of their commodities in different district, regional, and national markets (see Fig. 9.2). The company was started in 2009 based on the belief that there are gaps in the information flow for farmers, in particular on farmers getting access to price information. It was a startup with individuals recognizing this market failure, who formed a company to provide the information services. The Esoko business model, at least at the time of this research, was as follows. Market surveyors in the various district, regional, and national markets would collect on a weekly basis (or more frequently as needed) the market prices of all of the major food crops. Farmers who subscribe to the Esoko service would receive the prices of the crops they were interested in from the markets they are interested in. For example, a farmer would

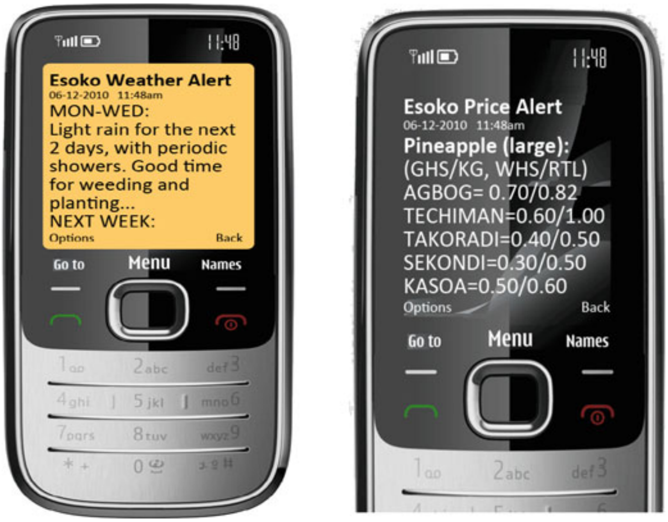

Fig. 9.2 Left: Esoko text message weather alert. Right: Esoko text message price alert (Reproduced from Esoko, 2019)

tell Esoko that they are interested in the price of maize in both the regional market and in the national capital. The farmer would want that information so as to be in a better bargaining position when the traders show up on their farm gates or at the local markets to purchase their crops.

After the farmer has subscribed to the service, Esoko would then text the farmer the prices of the requested crops in the requested market on a monthly basis. They are able to see these prices and presumably use this information when bargaining with traders for their crops.

In the section on evaluation, we indicate how we evaluated this Esoko intervention. In Sect. 6, we review the results of the intervention and also indicate the results obtained from other researchers on other related price alert interventions for similar populations.

4.2 Mobile Phone-Based Trading Platforms

The next step in complexity but still using the mobile phone as the base is the use of the mobile phone in trading. We mentioned in our development challenge in Sect. 1.1 that matching supply and demand is a big problem in smallholder agricultural communities. Farmers often cannot find traders, and traders often cannot find farmers with the right good of the right quality and quantity. Another innovation in this space is the use of the mobile phone as a trading platform.

These platforms connect buyers and sellers in rather geographically fragmented markets and usually focus on a major cash crop of the selected region. In contrast to the traditional markets, these structured platforms allow farmers, traders, processors, and financial institutions to enter legally formalized trading and financial arrangements (Ochieng et al., 2020). They operate by digitizing and automating these price discovery mechanisms, which include detecting and declaring winners in auctions, disseminating price information, and garnering farmers to access alternative electronic markets. Consequently, these interventions and platforms have the ability to inform farmers about prevailing market prices, increase market competition, and enable transparency of the price search process. By rapidly connecting disparate market agents, they reduce information costs at various stages of the agricultural chain. This allows farmers to take advantage of previously untapped trade opportunities and to learn about previously unknown innovative practices. In consequence, the cost reductions yield welfare and income gains (Nakasone et al., 2014).

An example of this is Kudu, an electronic market platform for agricultural trade in Uganda (Newman et al., 2018). In this model, the farmers place their requests to either buy or sell goods in a centralized national database; then, the app processes to identify profitable traders, and the two sides are informed about it. Rather than allowing the buyers and sellers to browse through a list of potential trading partners, Kudu's matching algorithm connects bids based on maximizing the gains from trade that the platform can offer.

There are several features that make Kudu attractive to farmers. First, users not only place the desired price and quantity of their bid but also are able to narrow the options of their desired trade: this includes features of the grains such as shelled versus unshelled grains and wet versus cleaned maize. Second, the platform allows users to trade with anyone across the country, and the app's algorithm will take travel costs into account when proposing matches. The Kudu platform provides users with in-village support service and a call center, which enhance its reliability. Furthermore, Kudu does not charge for transactions, and while the creators have considered monetization options such as charging commissions for each transaction, they recognize that such changes are nontrivial. Finally, users can trade through the Kudu platform in four different ways: through short message service (SMS), using an Unstructured Supplementary Service Data (USSD) application, through a website, or speaking through the call center. All of these options provide its customers with the same features: buy, sell, and quote/request price information (see Fig. 9.3) (see Ssekibuule et al., 2013; Reda et al., 2010; for other mobile-based trading platforms in the context of development).

There are other mobile apps across sub-Saharan Africa that apply the same principle: provide a virtual market where farmers and buyers can trade their agricultural goods. Among those are M-Farm; DrumNet; and, more recently, Twiga Foods in Kenya (Baumüller, 2013; Mire, 2019) and Agro-Hub in Cameroon (Balashova & Sharipova, 2018). A variety of studies have confirmed the benefits, as well as the limitations of mobile trading apps. A survey of M-Farm users confirmed that receiving price information can help them plan for production; however, the

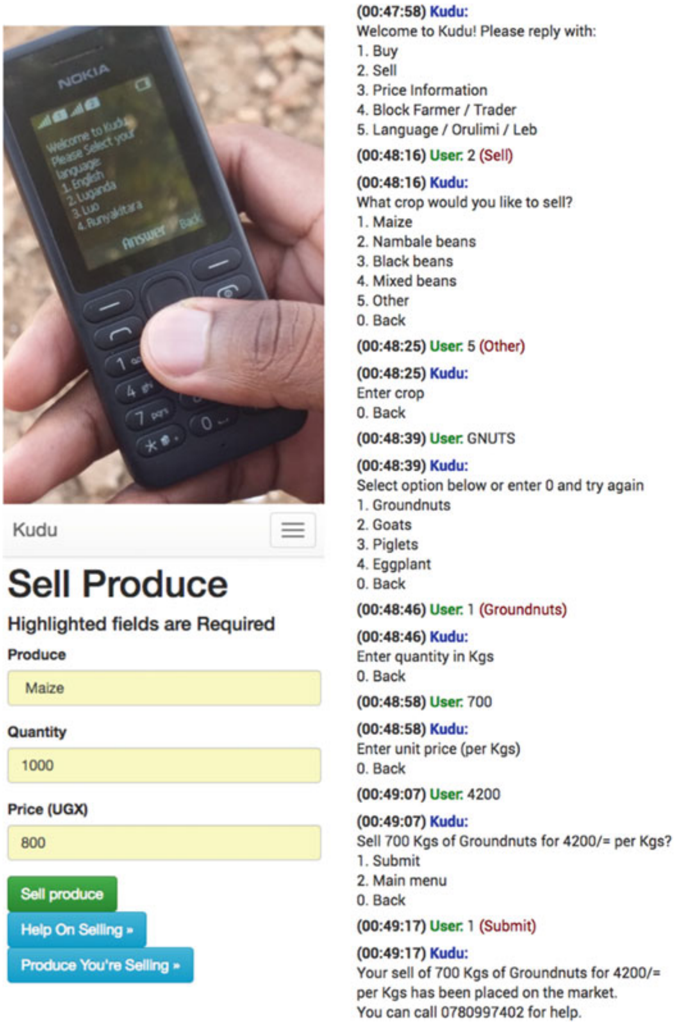

Fig. 9.3 Top left: Kudu's USSD interface running on a phone. Right: Sample USSD interaction for selling groundnuts. Bottom left: A user placing an ask on Kudu's web interface (Reproduced from Newman et al. 2018)

survey also revealed that there was a limited impact on expanding market linkages. This was driven by the fact that M-Farm could only provide single bilateral contracts between a farmer and a buyer, rather than establishing a full network that allowed for multiple connections (see Baumüller, 2013), where Agro-Hub is an agency that connects smallholder farmers with sustainable markets. More than 700 farmers reported an increase in productivity and income (Balashova & Sharipova, 2018). Twiga Foods is a mobile-based food distribution platform for small- and mediumsize fruit and vegetable farmers. After both farmers and vendors sign up through the online and phone platform, the platform acts as a bridge between sellers (i.e., farmers) and buyers. It guarantees farmers a consistent market with higher prices, and similarly, through its food safety standards, it ensures a reliable and high-quality supply to vendors. It currently operates on a national scale and is the largest seller of bananas in Kenya. As of 2020, the company sources 245 tons of bananas each week from over 3000 farmers, which are distributed to over 14,000 vendors.

4.3 Commodity Exchanges

Ramping up the complexity of technological innovation, we move from the price alerts in Sect. 4.1, through the mobile phone-based platforms in Sect. 4.2, to arrive at the commodity exchange platforms. The commodity exchanges are usually national government–run institutions. They serve as national centralized markets for crops.

Commodity exchanges have existed for many years in many countries. The commodity exchanges in Africa and many areas with smallholder farmers are very recent, and many countries still do not have them. The improved technology in existence today has made modern commodity exchanges much easier to establish and is now within the reach of many poor nations. While big telephone and mainframe computer infrastructure would have been necessary in the past, today, relatively lower footprint technologies and cloud-based systems are able to run the exchanges in poorer nations at a fraction of the former cost.

The commodity exchanges work as follows. Farmers upon harvesting their crops send them to a warehouse close to their farms. The warehouse then inspects the grains and assigns a grade to them. The farmer then receives a receipt for the crops (called a Grain Receipt Note and/or, in the more advanced version to be described later, a warehouse receipt). The warehouses are usually owned or operated by the commodity exchange. Each farmer chooses a broker or is assigned one. The farmer gives instructions to the broker on when to sell their crops and at what price.

The buyers of grains also use brokers to purchase grains. The buyers and sellers of grains make offers on the commodity market. In some exchanges, this is at a set time during the day, while in others, it can occur at any time. Brokers look at the offers, and at some point, a buy-side and a sell-side broker will decide to trade. The price at which the broker trades will be entered onto the GCX platform for all to see. The buyer then picks up the grain at the warehouse that the buyer's broker has just purchased. On the other side of the market, the seller will receive cash through the seller's broker who has just sold the grains to the buyer's broker.

The commodity exchange is really nothing other than technology plus rules of trading, plus government-backed standards and warehouses. Software engineers write code that accepts bids from different market participants on their platform. When two sides of the market agree to trade, then the trading engine software matches them. Prior to the match, farmers would have deposited their produce at the warehouse, and this would be recorded by the software. Farmers would have sell-side brokers who seek to sell their commodities on their behalf. On the other side of the market are buyers working through buy-side brokers. All brokers are registered on the software and are screened and licensed.

Just as with the mobile phone-based trading platforms, the commodity exchange allows buyers and sellers to find each other. It therefore addresses the development challenge set out earlier, by enhancing the matching of buyers and sellers. In many of the commodity exchanges, rural farmers are able to access the commodity exchange through their mobile phones or through calls on the mobile phone to their brokers.

Since prices traded on the commodity exchange are made public, there is price information, so in principle, the problem described in Sect. 1.2 is solved, especially when the farmer has access to the prices either through price alerts issued by the exchange or through a direct phone call the farmers make to their brokers. Furthermore, the commodity exchange is a way of matching buyers and sellers. Any farmer, for example, looking for buyers simply needs to be in touch with his or her broker. The broker in turn has access to all the buyers on the exchange platform. Similarly, a buyer looking for farmers with grains simply needs to contact their broker who has access to all the farmers on the platform through the brokers representing the farmers.

In addressing the development challenges, the commodity exchange is like the price alerts and the mobile phone platforms. Where the commodity exchange has a unique advantage is in addressing the development challenges explained in Sects. 1.3 and 1.4.

The commodity exchange grades the commodity when the farmer brings the commodity into the exchange warehouse. The grading process ensures the grain is free of diseases and pests. It ensures the moisture level of the grain meets a minimum threshold, and as is, for example, maize, the drier grains receive a higher grade (the maximum allowed moisture content is 14%, and 12% moisture content can help get a grade I as opposed to a grade II or III or IV designation). The commodity exchange sales, or contracts as they are called, are all based on the grade. For example, there will be a price and trading day for grade I white maize contracts and a different price and trading day for the grade II white maize contract. In this manner, a market for different grades of the crop is created.

There will be a price gradient for quality, and farmers will know that when they invest their effort in producing better higher-grade maize, they will be rewarded for their effort. Traders will similarly know what the quality of their grain is and will know that they can pay more for better-quality grain. They will appreciate having the price gradient for different grades, so they can choose what grade to purchase rather than paying one price and not knowing the grade and therefore having the price according to a perceived average of many possible grades.

Finally, the commodity market is unique in its ability to address the market failure issues in Sect. 1.4 – storage and in particular credit market failures. The storage is straightforward – being a larger and national institution, the exchange is able to establish warehouses at strategic locations across the country. More importantly, the warehouse receipts the farmers receive upon depositing their grain at the warehouse can be used as collateral at a bank to obtain a loan. This will address the potential credit crunch that farmers face when they harvest their crops and prices fall with the glut of food in the market. The farmers are able to store their crops at the exchange warehouses to await a time when the prices improve. They are able to do that because they are able to take a loan from banks, collateralized by the warehouse receipts. Banks are willing to offer the loans because the warehouse receipt states the quality of the goods, as certified by the exchange, and there is a ready market for that collateral at the exchange. Historical prices give some indication of the value of the collateral. Höllinger et al. (2009) provide a description of the mechanics and structures required for a warehouse receipt system (WRS) with an emphasis on emerging and transition economies of Eastern Europe. Other studies on WRS include Miranda et al. (2019), Adjognon et al. (2019), and Katunze et al. (2017).

5 Evaluation

Most of the technological innovations mentioned in this chapter are evaluated using randomized control trial methodologies (Duflo et al., 2007). The basic idea can be illustrated in the intervention described by Hildebrandt et al. (2020) which we use here as our principal example. A number of communities were chosen, approximately 100. Through randomization, one-half of them, in this case 50, would be treatment communities with the other half (50) being the control communities. Farmers will be chosen as subjects in each of the 100 communities. The farmers in the randomly chosen treatment communities will be given the technology to be evaluated. In the work of Hildebrandt et al. (2020), it is the price alerts. In the current research of the authors of this chapter with other co-authors, it will be access to the services of a commodity exchange. Outcomes of interest of the subjects in all communities will be measured. These would be things like prices obtained for farmers' goods, production levels, and sales. Statistical techniques will then be used to determine whether there are observable differences in the treatment communities relative to the control communities. If there is, then we would have evaluated the technology and will record an impact.

Of course, what is described above is the very simple skeletal structure for the evaluation. In many of the experiments, there are two principal problems that need to be addressed. The first is spillover effects. For example, if there is a mobile phone price alert that is being evaluated, there need to be safeguards against one subject in a treatment community showing the price information to a subject in a control community. This problem of spillovers is typically addressed by clustering communities so that, for example, those which are geographically close to each other, other those with many farmers who are friends across communities, are pooled together and considered as one larger community. Again, one can see work of Hildebrandt et al. (2020) for ways of creating a connectivity measure between communities which was used to cluster those communities that were too close to each other by this metric.

The second big problem that comes up is one of balance. Since the communities are chosen randomly, it is possible that most of the treatment communities by chance happen to be in, say, the more prosperous part of the wider study area. In this example, the effects of the technology may be hard to disentangle from the effects of being in a more prosperous region. This problem of balance is solved using stratification. The wider area is divided into strata where issues like wealth levels and other characteristics are held fixed, and within those fixed areas, the randomization takes place. As an example, in the Hildebrandt et al. (2020) paper, there was concern that geography could play a role (you could be in one of four quadrants of our area, each with different climate and suitability to agriculture), and you could also be in a yam- or non-yam-producing area (yam being the major cash crop in the area). So instead of simply dividing the 100 communities into 50 treatment and 50 control, eight strata were created (each being in one of four geographic quadrants and being in majority yam or not majority yam community). Each of the strata would have approximately 100 communities divided by eight strata so 100/ε or 1/2 or so communities. The randomization into approximately 50% treatment and 50% control would then take place within each strata. Each strata would then have, by construction, a similar number of treatment and control communities. We show the treatment and control villages in our Esoko price alert intervention in Fig. 9.4. The cluster and strata formation is shown in Fig. 9.5.

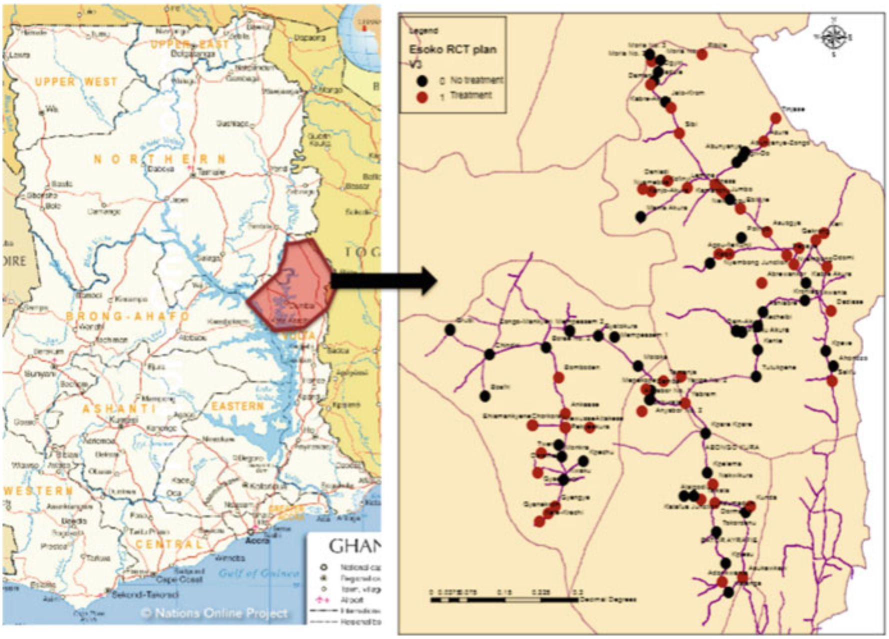

Fig. 9.4 Treatment and control villages in the Esoko price alert intervention

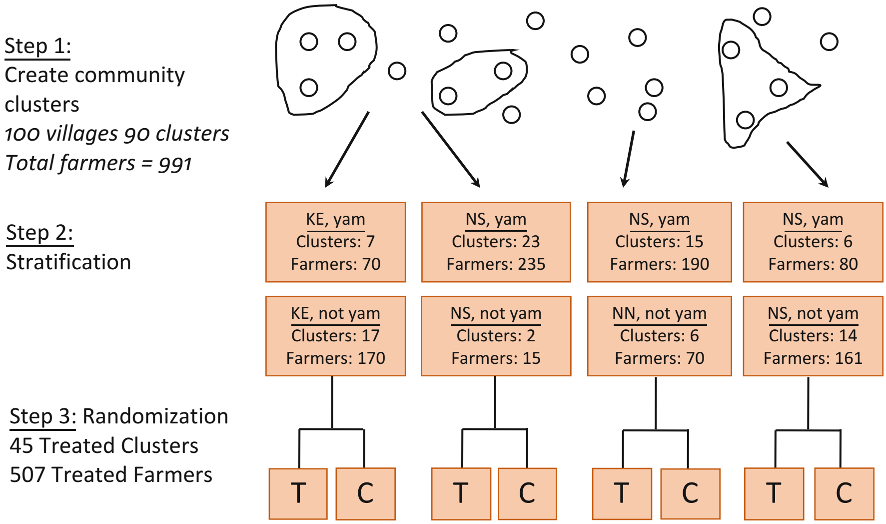

Fig. 9.5 Formation of clusters and strata

The basic econometric model is easily explained as below:

$$p_{iit} = \lambda + \kappa T_i + \psi X'_{ii} + \omega_k + \omega_t + e_{iit} \tag{9.1}$$

In this equation, here, p_{iit} represents the variable of interest (here, the producer price outcome for farmer λ living in community λ selling in month t). The variable T_i is the treatment size indicator (one if treatment and zero if control), X'_{ii} denotes a set of additional covariates, and ω_i and ω_t denote randomization strata fixed effects (whether or not it is in the kth strata) and time period fixed effects, respectively. (The λ and e_{iit} are of course the constant and the error terms.)

Equation 9.1 measures the price alert intervention. One can imagine similar evaluation techniques being used for both the mobile phone trading platforms and the commodity exchange platforms (innovations in Sect. 4.2 and 4.3). For example, in rural areas, some communities could be exposed to the commodity exchange services where others would not be. Assuming lack of communication between the communities (the spillover problem) and either general lack of knowledge of the existence of the commodity exchange or difficulty in accessing it, it would be possible to target the services of the commodity exchange to some communities and not others. The randomized control techniques just described for the price alerts could then be applied to the commodity exchange intervention.[1]

[1] The authors, with co-researchers Chris Udry, Lauren Bergquist-Falcao, and Lorenzo Casaburi, are engaged in one such evaluation.

6 Results and Lessons

6.1 Price Alerts Services

Hildebrandt et al. (2020) show that Esoko price alerts had a positive effect on yam prices received by farmers in their study. The initial results of the paper show that there was an increase of 8.73 Ghana cedis (GH₵) per 100 tubers of yam relative to those farmers who had received no Esoko price alerts. This was equivalent to a 5% increase in prices. This initial peak declines steadily over time, making the effect small in magnitude and statistically insignificant; there was a price decline of 0.01 GH₵ per 100 tubers of yam, leading to a 0.8% decrease. This decline is due to a mechanism the paper called "bargaining spillover." In such a landscape, middlemen cannot distinguish between those farmers with price knowledge and those without. So, the whole pool of farmers ends up adjusting their bargaining strategies. Similarly, the traders have to decide if each farmer is an informed or uninformed one. Since traders know that informed farmers will reject low prices, they have to estimate how high they can push the offer without getting a rejection. Therefore, the trader's strategy depends both on the farmer's actual price knowledge but also on how well the trader assesses this. As such, providing information has positive effects even on farmers that did not access price information directly. Prior to the price alert intervention, maize prices were homogenous because bargaining was less prevalent and farmers had a reference "market price." In other words, this study finds positive price effects – obvious effects in the short run and more subtle effects (because all farmers benefit) in the long run. Such results are supported by a similar study by Courtois and Subervie (2015) who found that Ghanaian farmers received about 10% higher prices for maize and groundnuts when they had access to the market information system (MIS). Furthermore, this is consistent with previous evidence which shows that the introduction of information and communication technologies (ICT) reduced price dispersion as agents were able to bargain for better prices, Jensen (2007) being one of the first and classic papers in this recent line of literature and also of Aker (2008). This is further supported by a more recent study on maize farmers in Mozambique, for whom the introduction of mobile phones led them to experience a statistically significant decrease in maize price differentials of 10–13% (Zant, 2019).

The Hildebrandt et al. (2020) paper shows that there could be a big difference between short-run and long-run effects. In the short run, some market participants adjust their behavior (farmers in that paper), while others (traders) adjust their behavior only in the long run. In the long run, all market participants get to adjust their behavior upon introduction of an innovation, which could change the outcomes relative to the short-run effects.

The long-term implications of better access to market price data are not fully clear. Mitra et al. (2018) use an asymmetric bargaining model to study a market price information intervention among potato farmers in West Bengal, India. The authors concluded that access to better price information does not necessarily benefit farmers in their negotiations with middlemen because they don't have access to alternative markets. In Karnataka, India, Levi et al. (2020) evaluated the implementation of the Unified Market Platform (UMP) on market prices and farmers' profitability. They found that the UMP had generated a greater benefit for farmers with high-quality produce, increasing, on average, the prices of maize, groundnuts, and paddy by 5.1%, 3.6%, and 3.5%, respectively. The provision of price information alone might not be enough to facilitate trade among small farmers. While such interventions reduce information asymmetries between traders and farmers, if the market agents do not have outside options for their sales, information will do little to improve their marketing outcomes. On the other hand, if farmers have access to larger markets and have increased bargaining power, more information may represent potential gains, as farmers could potentially access the traders who are ready to pay the higher prices.

While most studies that evaluate the impact of ICT diffusion in the agricultural sector find significant results, a few of them find no evidence of an effect. Futch and McIntosh (2009) investigated the introduction of village phones in Rwanda and found that while the technology did increase the proportion of farmers arranging their own transport to markets, there was no significant increase in the commodity prices that those farmers received. Similarly, Fafchamps and Minten (2012) evaluated the impact of Reuters Market Light (RML), a service that provided farmers with agricultural information through mobile phones in Maharashtra, India. Ultimately, the authors found no differences in average prices for farmers with RML subscriptions. Aker and Fafchamps (2015) analyze the expansion of mobile phones in Niger and find no evidence of increases in farm gate prices as well.

When farmers' knowledge of prices increases, the research has found an effect on both the farmers' production and postharvest decisions. Hildebrandt et al. (2020) show that there is a significant impact on produce prices and production decisions in Ghana. The authors notice that by providing price information of a certain crop, farmers are incentivized to produce more of a particular crop (in this case, yam). They find farmers report growing a new crop or growing more of an existing crop. In addition, price alerts also caused fewer farmers to sell in the local markets and induced them to sell at the farm gate.

In similar studies, Baulch et al. (2018) argue that some price discovery mechanisms might target large traders who are able to sell in large volumes. Thus, only a few small farmers can access these market options through their farming associations. In Central Malawi, Ochieng et al. (2020) find that greater efforts are needed to sensitize the farmers and traders on the quality and quantity requirements of such structured markets, which could result in an increase in the farmer's level of commercialization in such markets. Mitchell (2017) in a study conducted in Gujarat, India, shows that there is an implicit increase in producer prices, leading to an increase in the amount of crops produced.

Additionally, market information systems allow farmers to decrease their postharvest losses. Jensen (2007) finds that the introduction of phones in fisheries in Kerala reduces waste by 4.8%. Fafchamps and Minten (2012) argue that for Indian farmers in the Maharashtra state, the price improvement generated through the price alerts leads them to better agricultural practices and postharvest handling. Finally, Dixie and Jayaraman (2011) show that to avoid postharvest losses, farmers in Zambia used SMS text messages to coordinate among local truckers and enhance product transportation.

6.2 Commodity Exchanges

While price alerts and mobile phone-based trading provide farmers with a market, these solutions present some constraints. Even though farmers are informed about prices – which earns them bargaining power, this does not necessarily translate into better bids: middlemen still have direct access to the markets that the farmers, many times, do not (see Mitra et al., 2018; Mitchell, 2017). Furthermore, most mobile applications for trading, if not all, do not include an algorithm that can account for the difference in crop quality that is offered and demanded by farmers. Including this within the mobile app will present two challenges: comprehensive enforcement and inconsistency in the farmers' ability to grade crops correctly and effectively (see Newman et al., 2018; Levi et al., 2020). Lastly, many of the studies on mobile applications notice that few farmers have smartphones and that many are illiterate, forcing these projects to rely on human interaction (see Aker et al., 2016). As we will see below, a commodity exchange addresses and overcomes these problems by altering the agricultural landscape in multiple fronts: bargaining dynamics, production decisions, and household dynamics.

Commodity exchanges are modern marketing systems based on warehouse receipts, allowing small farmers to store their surplus safely while they wait for prices to increase. Furthermore, these stored commodities serve as a collateral to secure loans to finance household consumption and investment in the meantime (see Miranda et al., 2019). The effects of using warehouses go beyond the immediate storage facilities and financing opportunities for farmers. For instance, ECX reduced price dispersion between export prices and retail prices and facilitated the tendency of prices of the same commodity to move together (see Andersson et al., 2017). It also led to an increase in the quantity of coffee exported; Minten et al. (2014) showed that exported quantities from Ethiopia were 50% higher in 2012 than 10 years earlier.

Exchanges have the potential to change farmers' production decisions, as grading systems reveal high- and low-quality grains. Prior to a commodity exchange, almost all crops from the production areas are physically transported to a regional or national central market, usually outdoors, for auction. Without formal regulation, a significant volume of the crops can be adulterated by mixing high-quality grains with low-quality ones. This, in addition to information friction and scattered markets, leads to under-provision of quality crops (Bai, 2018). A commodity exchange allows differentiating between a crop's quality, usually through sorting and inspecting grains, and consequently, the transactions cover every class of the grading given by the commodity exchange warehouses, otherwise a limitation that most mobile trading applications face (Demise et al., 2017). This, in consequence, has the potential to encourage farmers to produce higher-quality products.

7 Conclusion

In this chapter, we have described a development problem facing smallholder farmers in places like sub-Saharan Africa and other similar regions. The problem can be summarized as a lack of effective markets for their goods. We described innovations which have the potential to address parts of this problem. We discussed three innovations, which, in order of increasing complexity, are the mobile phone-based price alerts, electronic trading platforms, and national commodity markets. The three are all similar in the sense that at their core, they are technologies which allow the transmission of information to farmers and those who trade with farmers. We described briefly these innovations and sketched the basic randomized control trial methodology for their evaluation. We indicated the results and lessons learned from these evaluations – both from the authors' own work and from work in the academic literature.

Discussion Questions

Are experiments needed to rigorously test some of the conjectures of this chapter?

There are a number of discussion questions this chapter suggests. The first set of questions have to do with formally proving a number of the conjectures of this chapter. Although there is some current ongoing research, the impacts and benefits attributed to commodity exchanges in the earlier section need to be verified with rigorous field experiments. Designing a nationwide experiment for the commodity exchange intervention has a number of difficulties, which of course are not surmountable.

Could the innovation be harmful? Is price information potentially harmful to farmers?

We need to be mindful of whether the new technologies introduced could inadvertently harm those the innovation is meant to help. One can imagine a situation where the introduction of price information to some farmers could actually hurt those farmers. It is possible that when traders realize that some farmers have superior information, they will shun those farmers and go to other farmers. The farmers with the superior information may then find themselves in the situation where they no longer have any (or as many) traders coming to their farms to trade. In the extreme case where they have no traders coming to them, they may therefore be much worse off than if they did not have the price alerts. So, general equilibrium effects could cause farmers to be hurt. In the Hildebrandt et al. (2020) paper, the authors find that the farmers are not hurt. This potential for harm is not realized in that case. There are, however, at least conceivable situations where technology could be harmful to the intended recipients of that technology.

Can technology cause increased inequality among farmers?

Next, even as we introduce innovations to help farmers, those innovations may increase inequality among the farmers. If the price alerts or the commodity exchange innovations are more likely to help the farmers who are already better off, then inequality may increase among the farmers. In the work of Hildebrandt et al. (2020), for example, it is found that the price alerts benefit primarily those who produce the cash crop yam. If those farmers are also those who are richer to begin with, as it is reasonable to suppose, then the innovation would help the better-off farmers more than the less well-off farmers. It is an open question how much of a concern that should be to us. On the one hand, all of the farmers are poor, so helping some of them via technology, even if only the relatively better-off ones, should be a good thing. On the other hand, our intent may be to help the poorest of the poor, so we may be worried if those farmers are not reached by our technological innovation. This question of course requires more data and more study. We also mentioned earlier the commodity market innovation. One could similarly imagine that the better-off farmers are the ones more likely to engage with the commodity exchange. In that case again, the introduction of the innovation could lead to increased inequality. With all technological innovations, this leads to a pair of discussion questions: will the innovation result in more inequality, and is that inequality harmful (e.g., it does not help those we really care about, like the poorest of the poor), or is it benign (e.g., enough of the farmers benefit that the inequality is unimportant relative to the wider gains the technology enables)?

Building Capacity Through Research

With both the price alert intervention with Esoko and the commodity exchange intervention with GCX, the researchers worked extremely closely with host institutions. After the research, both institutions emerge stronger with greater capacity. With Esoko, insights from the field were transmitted immediately. In one example, researchers noticed that farmers on the Esoko app preferred using local traditional units (bowls or what is called locally "Olonka") rather than the standardized units, which was duly and immediately communicated to Esoko for action. With GCX, our earlier work with farmers encouraged the government to make the final steps in the establishment of the exchange. The earlier work gave the researchers credibility in front of the government when pushing for the exchange.

Mitigating Climate Change

One can think of two reasons why the innovations in technology discussed here would be essential as climate change begins to take its toll and agricultural systems begin to change:

I. As climate changes, supply will inevitably change in unpredictable ways. The need for speedy price discovery and extensive knowledge of prices would therefore be needed for farmers to react to the changes. Markets would become more and not less important in these more volatile climate change-induced environments.

II. As evidenced by the responses to the Covid-19 lockdowns, technology may be important for staying connected and working when there are difficult environmental conditions in existence. There is a slight advantage in not having to travel so much to find market partners when there are environmental challenges. The technological innovations mentioned here enable markets to form with much less physical movement of people.

Role of Gender in Agriculture Markets

While women account for almost 50% of the agricultural labor force in sub-Saharan Africa, they are often constrained in their access to markets and price information, especially where engagement in markets involves travel and searching for customers in faraway villages, often with the risk of crime. Hence, if women themselves were able to access market knowledge through mobile phones and commodity exchanges, they would possibly benefit even more than men would. Hildebrandt et al. (2020), Aker and Ksoll (2016), and Gomez and Vossenberg (2018) focus on gender and show positive impacts on women, for the reasons just mentioned. There are also factors related to within-household bargaining and dynamics which yield benefits to women from technology. One can imagine more peace in the household as the price alerts provide proof of the sales one household member is able to obtain at the market from the household farm. Indeed, some farmers in the Hildebrandt et al. (2020) study mentioned that the Esoko price alerts were useful because with it, they said, "my wife will not cheat me." This was probably a situation where the man worked on the farm, the women did the selling, and there was little trust between the two. As a second example, after the integration of the Agricultural Commodity Exchange for Africa (ACE) in Malawi, 75% of the women interviewed by Gomez and Vossenberg (2018) started keeping books and carrying out some financial planning or budgeting. The warehouse receipt system allowed women to earn more bargaining power, which then benefited their farming opportunities. One of the quotes from that paper is as follows: "ACE helps me to make informed business decisions which are atypical for a woman."

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