A Framework for Analyzing the Role of ICT on Agricultural Commercialization and Household Food Security

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Abstract

Lack of agricultural information has been attributed to the inability of smallholder farmers to transition from subsistence to commercial agriculture. Recent efforts to improve smallholder access to agricultural information have seen increased application of ICT technologies in developing agriculture. These efforts use ICT-based market information to reduce transaction costs of smallholder participation in markets, promote commercialization, and improve household food security. Emerging studies document the benefits of such ICT-based applications in agriculture, including increased incomes and improved performance of agricultural markets. Unfortunately these studies have been context specific and the link between provision of ICT-based market information, smallholder commercialization and household security remains unclear. This paper develops a framework that can be used to analyze the link between ICT application in smallholder agriculture, household commercialization, and food security. The paper generates testable hypotheses relating ICT application in agriculture and reduction in transactions costs, smallholder farmer commercialization, and household food security. It then provides illustrative cases where ICT application in agriculture has benefited smallholder production and improved market performance. However, more research must be done to test the generated hypotheses. The paper discusses the implications of the framework for practitioners.

Keywords: Commercialization; Developing Country Agriculture; Food Security; ICT; Smallholder Farmers; Transaction Costs

1.0 Introduction

One of the constraints on smallholder farmers' access to markets is lack, or asymmetry, of information (Barrett, 2008) about product, input and credit markets. Farmers rely on friends, relatives and extension agents for market information. However the usefulness of information from these sources is usually limited because the information is either unreliable or not timely.

The consequences of information asymmetry are problems of moral hazard, and opportunistic behaviour by traders and money lenders towards smallholder farmers. Studies in several African countries indicate that under such circumstances, input and output markets are thin and exchange is personalized, requiring physical presence of parties and commodities (Fafchamps & Hill, 2005; Doward et al., 2005; Fafchamps & Gabre-Madhin, 2006). The high transactions costs of such exchange process impede access to better-paying markets and entrench poverty (Barrett, 2008) because when and if they participate in markets, smallholders are often obliged to accept low prices for their produce (Shiferaw et al., 2007). Furthermore, poor roads and telecommunication networks, increase transactions costs and risks (Poulton et al., 2006) and tends to limit access of smallholder farmers, especially those in remote areas, to efficient and competitive markets.

Lack of market information exacerbates the problem of low-level equilibrium poverty trap that locks smallholder producers into subsistence production and imperfect markets where they typically trade in low volumes. Farmers may thus be unwilling to diversify out of "low value" staples into higher value crops if markets for the latter are too costly or too risky to rely on for food purchases (Fafchamps, 1992; Jayne, 1994).

The problem of farmer access to market information is an old one. Smallholder farmers were not the focus of colonial governments in many developing countries. After independence, many governments still pursued extension methods that focused on larger progressive farmers. While large-farmer bias has to some extent reduced, public agricultural extension systems in most developing countries lack the financial and human capacity to reach the large numbers of geographically dispersed smallholder farmers.

Recent attempts to resolve the problem of poor access to information by smallholder farmers have focused on promoting information transfer through ICT-based innovations (Tollens, 2006; Aker, 2008). Munyua (2007) and de Silva (2008) document the use of several ICT-based interventions in agriculture in Africa and Asia respectively. In Kenya alone, for instance, there were 34 projects that used ICT as a platform for disseminating agricultural information in 2008 (Okello & Jakinda, 2008). South Africa, Kenya, Tanzania, Uganda, Malawi, Madagascar and the whole of West African belt have ICT applications targeting the transfer of information to smallholder farmers.

Evidence of the benefits and impacts of ICT-based interventions in improving smallholder access to markets remains anecdotal. A few studies have attempted to investigate the effects of ICT-based interventions on smallholder and market performance. Examples include use of internet-based technology to link horticultural farmers to input and output markets in Kenya (Ashraf et al., 2007); use of mobile phones to obtain real-time prices of fish in India (Jensen, 2007), synchronize production practices with export market requirements in Colombo (de Silva, 2008), and by grain traders in Niger to obtain price information in other markets (Aker, 2008). None of the past studies systematically examines the effectiveness of ICT-based market information

systems on smallholder market linkage in a broader context that encompasses, among others, the different cultures, commodities, and farmer types. Therefore findings on the impact of interventions are patchy and context-specific.

This paper develops a framework that can be used to analyze the role of ICT interventions in agriculture on household commercialization and food security. It develops a set of hypotheses that can be tested empirically but uses illustrative cases to provide a flavour that there exists evidence, albeit context specific, that the hypothesized relationships might actually exist. These illustrative cases do not in any way mean that the hypothesized relations *do* exist. Such proof will require more robust studies.

1.1. The Context

The debate on how best to provide smallholder farmers with agricultural (production and market) information has occupied academic and development practitioners and policy forums for many years (Shepherd, 1997; Eicher & Staatz, 1998). It has led to search for the best model for reaching farmers with agricultural information over the years. Early examples include the public extension model which was based on the personal contact between a trained extension agent and the farmer. There are several variants of this approach including the progressive farmer approach that targeted the better-off farmers and hoped that messages passed on to these farmers would trickle down to the rest of the farmers. However, this model had the shortcoming that the messages were not always relevant and appropriate, besides being a top down approach.

In many countries, the T&V's model of personal contacts with farmers has been modified and the training component removed. At the same time, the fortnightly visits have been removed and non-scheduled visits are made instead. In other countries, other models of communicating agricultural information are being tried namely the field day approach, on-farm trials and demonstrations, and the residential training through farmer/agricultural training schools. The farmer and community based organizations approach has also been tried, where the organization acts as an information hub. The extension officers use the organization to pass necessary agricultural information to members who are then expected to pass it one to neighbors. The effectiveness of these models of communicating agricultural information is however unknown. Nonetheless, they tend to be cheaper.

In most developing countries, agricultural extension models, such as the Training and Visit (T&V) have traditionally been supplemented by traditional mass media channels such as the radio and television. However, the messages transmitted through these channels have tended to be dated because the information gathering, processing and release takes time. Timing of delivery of information through radio and television is also a problem as most of the programmes tend to be aired when farmers are out in the fields or busy with other domestic chores (Okello et al., in press; Munyua, 2000). Governments have also attempted to address the market

information gap through the provision of price information either on radio or in print media (Mangisoni, 2006)[2]. The rationale for the price information programmes is that traders would respond to significant price differentials and move commodities between low price and high price areas. However the impact of this market information initiative has been limited because it relies on limited channels of disseminating the information and the weekly dissemination of the information is too low a frequency to be of value to both farmers and traders.

The more recent applications of ICTs in smallholder market linkage projects are the mobile SMS, web/internet-based resources and telecenters. Radio and television are also used often interactively with mobile phones. The increased focus on modern ICT-based methods of information provision comes from the realization that they can be used to i) communicate knowledge and information to rural farmers on time, ii) deliver training modules to farmers at low cost, iii) improve farmers' access to markets and agricultural credit, iv) empower farmers to negotiate prices better, and v) facilitate and strengthening networking among smallholder farmers.

Proponents of the use of ICT in providing farmers with agricultural information also argue that it can greatly improve the productivity of smallholder farmers resulting in smallholder commercialization and the exit from the low equilibrium poverty trap (Barrett, 2008). Smallholder commercialization has the benefit of improving the food security status of such households. Consequently case studies are emerging that attempt to test the usefulness of ICT in smallholder farmer commercialization[3]. However, such analyses have been based on different and often uncoordinated approaches. We provide a unifying framework in which analysis of the role of ICT in stimulating smallholder commercialization can be analyzed.

The rest of this paper is organized as follows. Section 2 lays out the proposed framework. Section 3 provides some illustrative cases of ICT application in agriculture and the outcomes. Section 4 concludes and presents implications for policy and further research.

2.1 Transaction Costs and the Smallholder Farmer

Lack of agricultural information impedes smallholder commercialization by raising their transaction costs of participating in input and output markets. Transaction cost can loosely be defined as cost of doing business or cost of exchange between two trading partners, in our case farmers and buyers. The theory has been widely used in studying agricultural markets in developing countries (Jaffee, 1995, Jaffee, 2003; Fafchamps, 2004; Fafchamp & Hill, 2005; Okello & Swinton, 2007). It posits that difficulties in economic exchange between two partners arise because of three exchange related problems namely, asymmetric information, bounded rationality and opportunism.

In small farm situation, asymmetric information arises when either the farmer or buyer lacks essential information relating to the exchange. The more informed parties therefore take

advantage of the exclusively available information to benefit themselves, a situation referred to as opportunism and which has been defined by Williamson (1985, p. 45) as "self-interest seeking with guile" (Miller, 2005). In agricultural marketing in Africa, the small farmers tend to be less informed than traders/buyers. Buyers and traders therefore use the exclusively available information (about price, supply condition, or quality) to their benefit. Uncertainty of future outcomes means that the buyers, even with a priori agreement on terms of exchange can take advantage of the smallholder farmers by engaging in actions that are contrary to the specifications of the agreement (i.e. abuse the spirit of the contract), a condition known as moral hazard. Alternatively, the buyer may claim ability to meet the terms of the agreement (e.g., buy the entire commodity from the farmer) only to fail to do so due to changes in the market, a situation called adverse selection. These conditions prevail in many rural farming environments in which agricultural information is generally unavailable (Mangisoni, 2006) and has been one of the factors behind the push for ICT-based projects.

Lack of information between the seller (farmer) and the buyer makes trade more costly (Furubotn & Richter, 1997; Furubotn, 2001; Williamson, 2004). Farmers who need to sell some produce must search for buyers and screen-off unreliable or opportunistic ones thus incurring search and screening costs (Coase, 1937). Once the buyer is identified, the farmer has to negotiate the terms of sale (i.e., price, quantity, quality, time of sale, frequency of sale, etc). The farmer thus incurs costs relating to time spent and financial outlays in negotiating the terms of exchange. A farmer may then have to monitor the buyer to ensure that the latter meets the terms of exchange, and incurs monitoring costs in the process. The farmer may also have to spend time and resources getting the buyer to honor the terms of agreement and thereby incurs enforcement costs. Lastly, in long-term agreements, changes in production and market condition may dictate adjustments in the terms of exchange such as the sales volume, quality, price, and frequency or time of sale. The farmer may thus incur monetary or time costs (i.e., mal-adaptation costs) during the re-negotiation of the terms of exchange.

The four categories of transaction costs above are prevalent in both input and output markets in developing countries. Poulton et al. (2006), Fafchamps (2004), and Fafchamps and Gabre-Madhin (2006) for instance highlight some of these costs in relation to African farmers and traders. ICT-based information services reduce these transactions costs by reducing the asymmetry of information and uncertainty related to trade.

In sum, lack of market information increases the costs of exchange between the smallholder farmer and buyer. Smallholder farmers due to their geographic dispersion incur higher variable transaction costs of accessing inputs and selling their produce. The higher costs emanate from the costs of searching for and screening of exchange partners, negotiating the sale of output or purchase of inputs, monitoring and enforcing the terms of exchange and also adjusting to changes in market environment. Farmer access to market information helps to reduce these costs of doing business and allows the farmers to increase net income. The increased income is in turn expected to provide greater incentives to smallholder farmers to participate in the market. We therefore hypothesize that:

H1: Smallholder farmer access to market information through ICT-intervention reduces the costs of doing business.

2.2 Transaction Costs and Performance of Spatially and Temporally Separated Markets

Studies on the performance of spatially and temporally separated markets focus mainly on the efficiency with which prices are transmitted between such markets which in turn is partly driven by the availability of and farmer/trader access to market information. Such studies have a long history dating back to von Thunen (1926) and build on studies by Samuelson (1952) and Takayama and Judge (1964). They measure the tendency for prices in two spatially or temporally separated markets to move together (i.e., integration) or of price shocks in one market to be transmitted into another (Moser et al., 2005). Recent studies of price transmission focus on the nature of relationship between price series at different levels of the value chain or at spatially separated markets (Abdulahi, 2007). Such studies use time series methods and, in some cases, use lag structures on prices to analyze the relationship between prices in spatially separated markets (see Fackler and Godwin (2001) for a review of such time series-based studies).

The speed and degree of price transmission between markets can signal presence of market failures arising from high transfer costs and the lack of market information (Abdulahi, 2007). The extent of adjustment and the speed with which price information is transmitted among various actors in the market reflects the behaviour of actors. Slow transmission of price information following a shock may be indicative of the high marketing margins, large price spreads and mark-ups and unfavourable pricing practices (i.e., opportunistic behaviour). However previous studies suggest that lack of investment in market infrastructure (especially transport and communication) can exacerbate the problem of high transfer costs and hence impede efficient transmission of prices between spatially separated markets. Good transport infrastructure is needed to lower the cost of obtaining and disseminating information in circumstances where farmers have to travel to spatially or temporally separated markets to obtain and pass information to other markets (Aker, 2008). On the other hand, good communication systems, including electronic ones, can ease the information search costs and improve the performance of spatially separated markets (Jensen, 2007).

Efficient transmission of price information between markets is important for the meso-level (i.e., inter-village/ interregional) trade to occur. Given the limiting effect of lack of information on the performance of markets, provision of such information benefits smallholder farmers by, among others, i) improving their access to markets and hence improving the price obtained, ii) improving the speed and efficiency of price adjustment between spatially separated markets through arbitrage, iii) making response to market shocks more rapid and complete and iv) making price discovery process by farmers, traders and consumers more efficient and rapid. Based on the foregoing we hypothesize that:

H2: The provision of price information using ICT increases the efficiency or performance of spatially and temporally separated markets.

2.3. Transaction Cost, Marketing Margins and Market Participation

The effect of information asymmetry and transaction costs at the micro and meso levels can be understood by looking at simple stylized models relating the household and market price and prices between two markets. Following Minot (1999), Larson (2006) and Barrett (2008) we argue that transaction cost at the micro level causes a wedge between the exogenous market price and the price the household receives for its produce. Transaction cost is affected by the state of infrastructure especially the condition of the roads and distances to input and output markets. In addition, we argue that smallholder farmers' cost of doing business is affected by farmer/household asset endowment including possession of physical assets such as radio, TV, mobile phone; human capital assets such as skills and experience and; social capital assets that can be in form of membership to a farmer organization. High transaction costs caused by difficulties in accessing input and/or output markets increase input costs and reduce the net price earned by farmer/household thereby depressing the household's desire to participate in input and output markets. This in turn causes the household to produce only what is enough for its subsistence needs (i.e., become subsistence oriented). Such households stay out of the market (Barrett, 2008). Similarly, poor state of infrastructure, lack of market information services and lack of needed assets can increase the costs of inter-village/inter-regional trade thus reducing or eliminating opportunities for trade between local and regional markets. The high costs of inter-regional trade can in turn cause different regions to focus on meeting food needs rather than pursuing trade.

The importance of farmer access to information is in reducing the transaction costs of exchange. ICT-based projects usually seek to provide access to agricultural information hence the presence of an ICT-based project in an area is expected to provide farmers with an easy access to market information. However, for farmers in an area with ICT-based project to benefit from the agriculture information service provided by the project, they need to be aware of the presence of the project and use the services provided by it. Undoubtedly, farmers will use the services from the project if they find it profitable to so. The use of any technology entails a cost. In the case of ICT-based market information services, the cost may include the expenses on mobile phone calls to the project center to acquire information, the cost of buying a mobile phone handset, the fees levied on internet browsing, etc. The benefits of using market information services provided by an ICT-based project, on the other hand, include reduced cost of: finding and selecting a trading/exchange partner (i.e., search and screening costs), negotiating and monitoring the terms of exchange and, adjusting the terms of exchange. The reduction in these costs increase the margins earned by farmers and hence the revenues/income from participating in the output market. The increase in income can also be due to increase in the volume of produce sold which in turn may be caused by reduction in costs. Access to market information through ICT-based

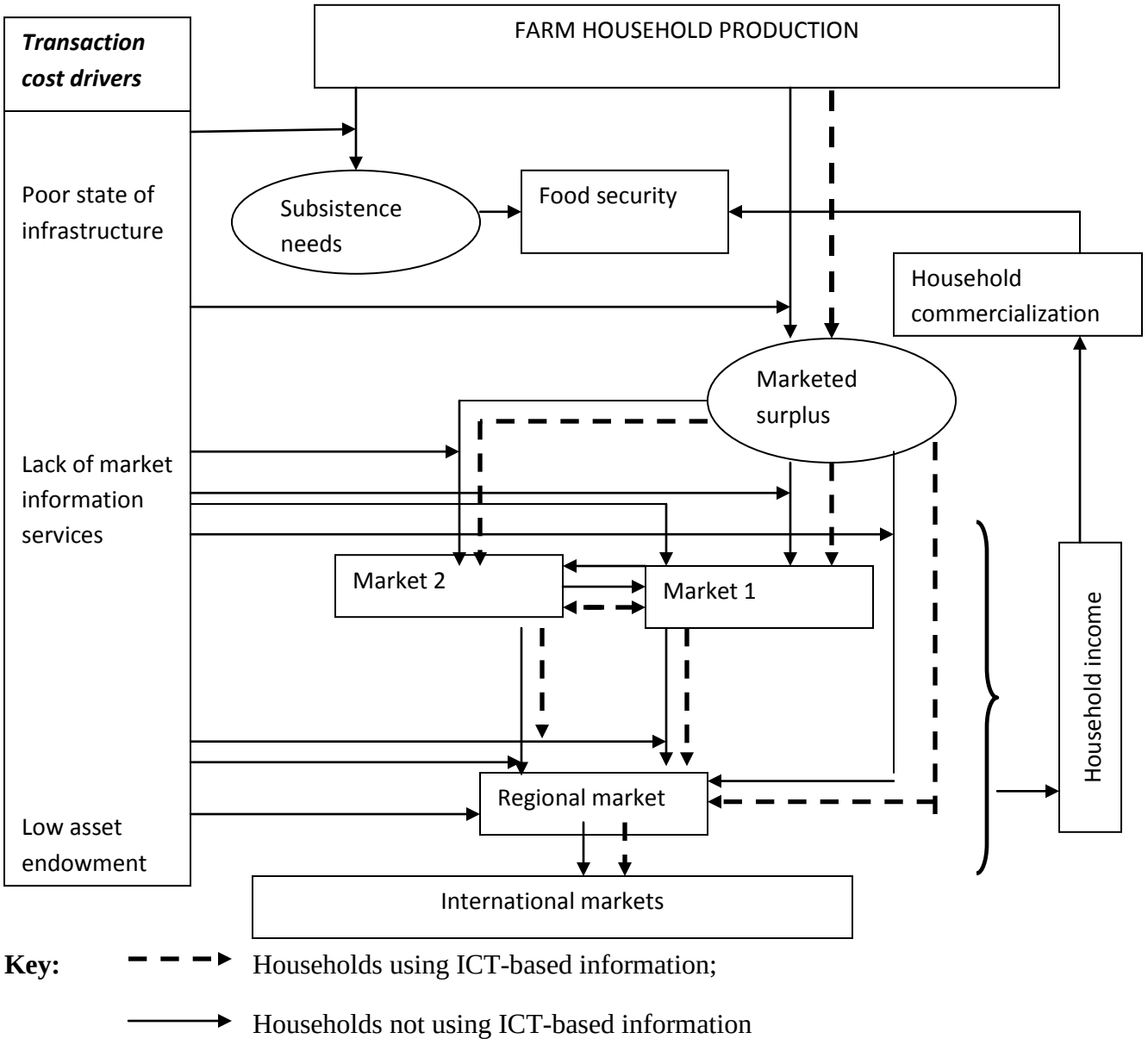
project is also expected to reduce the costs of acquiring credit and other inputs by lowering search, negotiation and monitoring costs thus increasing the margins and revenues assuming constant output price.

Theoretically, households that use market information services provided by ICT-based projects are expected to face lower production and marketing transaction costs. Such farmers are therefore expected to earn higher margins (see paper by Okello et al, in this issue that presents evidence on this). The increased revenue earned by such households is expected to spur investment in agriculture. This leads us to hypothesize that:

H3: The use of ICT-based market information will promote commercialization of smallholder agriculture.

We use Figure 1 to illustrate the pathways by which ICT-based market information will bring about commercialization of smallholder agriculture. As shown, we anticipate that households that increase production out of use of ICT-based market information services will participate in the market through sale of surplus production to village Market 1, Market 2 or to regional markets. Trade would then occur between village markets, between village and regional markets, between regional markets (e.g., between market in two districts but one country) or between regional and international markets. We assume that households that do not use the services of ICT-based project have no or very little access to market information. Consequently, such households face higher costs of doing business both in the input and output markets. Such households therefore either stay out of the market (are purely subsistence-oriented) or sell little surplus, hence the small arrows. On the other hand, farmers/households that use ICT-based market information services produce more marketable surplus hence sell more. Increased volume of sales increases household income which spurs commercialization. Such households, represented by the bigger broken arrows in Figure 1, engage in commercial farming compared to counterparts who are constrained by high costs of doing business.

Figure 1. The effect of transaction on market participation



Commercialization of smallholder agriculture is further expected generate and/or strengthen backward linkages with input sector. In particular, it is expected to generate greater demand for services that will further increase agricultural productivity including ICT-mediated agricultural information. Increased revenue will also increase the demand for other agricultural inputs (e.g., in the form of increased use of such inputs as fertilizers, improved seed) and also bring about in the medium-term investments in productive assets including human, physical, financial and natural assets. The increased revenue earned by households with access to market information is also spent on meeting households needs (especially food) besides re-investment in agriculture. Indeed, most households often meet their food needs first before meeting the input needs. The

increased income, by increasing the disposable income that households can spend food needs, thus contributes to the welfare of the household. Thus we hypothesize[4] that:

H4: Access to ICT-based market information increases the food security status of household that use such information

We illustrate in Figure 1 the pathways by which household commercialization could improve the food security status. We assume that as households commercialize, they would use the more incomes earned from sale of produce to purchase food needs. However household food security is also affected by the volume of home production for subsistence needs.

Some existing ICT-based projects provide more than just the market information services. A number of them provide the infrastructure needed to facilitate access to such information while also building capacity of farmers to produce marketed surplus. Background studies indicate that a number of ICT-based project in Africa create the necessary infrastructure needed by farmers to access market information (see Munyua, 2007). These include creation of information kiosks, internet shops, or tele-centers and also the strategic location of such infrastructure in closer to farmers, thereby increasing access. At the same time the background studies find that a number of ICT-based projects in Africa build the capacity of farmers to more effectively use the services they provide through training and/or provision of basic assets especially the mobile phone handsets on interlinked credit arrangement. Other projects mount television sets or information billboards at strategic points in the market places for use by farmers. Provision of such infrastructure and assets enhances access to market information, reduces transaction costs facing the household by reducing search, screening, negotiation and monitoring costs, and increases price earned by the household from market participation hence revenues. It also increases reigning price in spatially separated markets linked through trade. In both cases reduction in transaction costs enhances the likelihood of participation in the market due to increased margin. In deed poor state of infrastructure and lack of assets (often referred to as asset poverty) are the major causes of poor access to market information (Barrett, 2008). Nonetheless, households face differential effects of the transaction costs (Omamo, 1998b; Key et al., 2000; Renkow et al., 2004). At the same time differences in costs of commerce may make geographic or spatially separated markets be differentially integrated (Godwin & Fackler, 2001; Barrett, 2008).

3. Illustrative Case Studies

In this section we provide case studies that appear to lend support to some of the hypotheses generated in this paper. As intimated earlier, we do not attempt to provide proof of the hypotheses above using these cases because the cases are too context specific. At the same time studies in this field are still too few to allow careful synthesis and triangulation of evidence to test the hypotheses. Doing this would require a more carefully designed study that covers general contexts. The examples we present are from two continents (Asia and Africa) and were designed

to address the problem of poor access to market information and the ensuing high transaction costs of doing business. Both examples use mobile phones as platforms for agricultural information provision. However, while the Asia case focuses at the micro-level, the African case focuses at the meso-level.

3.1 Importance of ICT in Resolving Farm-level Information Problems: The Sri Lanka Case

The Sri Lanka case is drawn from studies by Harsha de Silva (2008) in Sri Lanka. The case is based a study of a number of smallholder vegetable farmers producing and selling vegetables in Sri Lanka wholesale market called Dambulla Dedicated Economic Centre (DDEC). The farmers also plant maize, cowpea, mungbean, chilli, onion and rice hence have to decide which crop to plant during each season. Landholdings are typically very small averaging 0.25 hectares. As majority of the smallholder farmers, these farmers encounter a number of information problems at the production (micro-level). To produce a crop and eventually market it, they need information of what to plant, when to plant, where to obtain agricultural inputs (including seeds, fertilizer, pesticides and labor), when to harvest (in order seize good prices in the market), when to sell, and where to sell. Searching for these different types of information entail both time and financial outlays and hence involve transaction costs related to search for information, screening potential input sellers and produce buyers, travelling to the information source, negotiating with the seller and follow-up (i.e., monitoring) the seller for payment in case the payment comes after delivery. The case study farmers therefore encountered two broad categories of information costs namely, the search transaction costs and the transportation transaction costs.

The farmers had two options for obtaining the production and marketing information namely, walk to the information source or use a mobile phone or electronic/computerized information stalls in the DDEC wholesale market. Walking to the information source involves paying visits to various stores, input sellers/markets, and traders and entails both financial and time costs. The mobile phones could instead be used to obtain information on input availability and prices and also on the timing of planting and sale of produce at the cost of airtime, usually less than the costs of travelling to the information source. The DDEC information stalls, on the other hand, provide information on selling prices only. Overall, 11% of the costs of doing business is associated with the costs of searching for information on input availability and prices. Some extra 4% of the costs of doing business resulted from transportation costs. Hence transaction costs accounted for 15% of the costs. The search costs contributed to 70% of the total transactions costs incurred by the farmers.

The study finds that most of the farmers travel to the information source to obtain needed information. A farmer makes on average 24 trips over the production season to a market and incurs on average USD 1.8 per trip giving a total of USD 52. So how would the use of mobile phone change the situation? The study estimates that if just half of the trips are replaced by a phone call, the costs of information search would drop to USD 35 over the production season. This represents 33% drop in the information search costs. These results seem to agree with our

expectations as outlined in hypotheses *H1*. It proposed that the saving on information search costs will increase the net incomes earned by households that opt to use mobile phones rather travel to the market. This case study did not assess the effect of this reduction on information search costs on household incomes. However, another study conducted in Sri Lanka (Soysa, 2007) finds that use of mobile phones to obtain information on how to reduce wastage significantly increased farmers' income. Lack of income is often attributed to the failure of smallholder farmers to shift from subsistence to commercial farmers. Hence the results of these case studies suggest that the use of mobile phones can facilitate the commercialization of smallholder agriculture as hypothesized in *H3*.

3.2 ICT and Performance of Spatially Separated Markets: The Niger Case

This case study draws from studies of grain markets by Jenny Aker (see Aker, 2008 for a complete treatment of this case) focusing on the role that ICT plays in determining price transmission in spatially separated grain markets in Niger. Hence unlike the Sri Lanka case, this case is a meso-level study of how different regional markets perform. The study focuses on grain markets because of the way prices and traders behave especially during periods of short grain supply.

Grains in Niger are bought and sold through a system of traditional markets separated by distances ranging between 10km to 900km. Grain traders typically searched for price by travelling to the markets, which sometimes took several days. Traders thus incurred travelling and time costs. For instance a trader travelling from Bakin Birgi market (to the east of Niger) to Zinder (in central region) spent on average USD 20.00. The costs of information search escalated with distance to the destination. Consequently many traders simply traded in the principal markets where they know the price (usually home markets) with limited interregional trade occurring between markets. As a result prices differed greatly between markets, especially during times of grain scarcity, with low prices co-existing in different markets, even in the same region, with high prices. The prices reigning in one market did not, in many instances, differ from the prices in another by the amount of the transfer costs as suggested by the "law of one price". Famines exacerbated the price spread between some markets as speculation and hoarding occurred.

Between 2001 and 2006, mobile phone towers were introduced in most (76%) of the grain markets throughout Niger. Rather than travel to distant and other markets, traders could now simply call their contacts in such markets and get information on prices. How did this affect the performance of such markets?

Aker uses unique panel dataset comprising 395 traders in 35 markets across Niger to investigate the effect of mobile phone roll-out on grain markets. The data was collected over the period 2005-2007 and subjected to various econometric analyses. In line with our hypothesis *H2*, her

study finds statistically significant association between mobile phone roll-out and the reduction in grain price dispersion in markets connected by mobile phone by 6.5-22%. In other words, mobile phone roll-out improved the performance of grain markets in Niger. How did this happen? Rather than travel to market, traders were able to obtain price information in other and distant markets using phone call for as low as USD 2.00. At the same time, unlike the pre-mobile phone era, traders in markets with mobile phones are also able to search for better prices in 26% more markets than before. Thus mobile phone roll-out increased the number of trading partners traders knew and could source price information from.

The reduction in price spread between markets had welfare implications as well. It implied that consumers paid lower prices than they would without the phones. At the same time traders secured higher profits. These findings suggest, in line with our hypothesis *H4*, that ICT can improve household food security situation. The study however does not assess the welfare gains from mobile phone roll-out on farmers and consumers.

4. Conclusion and Implications for Development Practioners

The application of ICT in agriculture has gained popularity because of the expectation that it can resolve the constraints facing smallholder farmers, increase their participation in markets and contribute to higher investments and food security of farm households. Hence the number of ICT applications targeting smallholder agriculture has increased. A number of studies have recently emerged that attempt to assess the impact of these ICT applications in agriculture. These studies have generated interesting findings. However, they have mainly been context-specific. At the same time the analyses have usually focused on one area (i.e., farm or market) of the continuum of farm household which typically encompasses both production and marketing.

We have presented a framework for analysing the effects of ICT interventions on farm households. The channels of these effects include improved efficiency of input and output markets, improved benefits to farmers in terms of reduced costs of marketing (transactions costs) which then serve as further incentives for investment and commercialisation. Increased production arising from higher investments improves food self-sufficiency, an important step towards food security of farm households. The channels by which ICT interventions lead to commercialisation and food security are however conditional on factors such as quality of infrastructure and household asset endowment. Therefore these factors must be examined in any analysis of the benefits of improved information from ICT-based interventions. Finally, the reach of ICT-based interventions determines the level of impact they can make. Therefore factors that affect that reach, such as awareness and willingness of farmers to participate in an intervention need to be a part of any assessment of effectiveness of interventions.

The major implication to be drawn from this paper is that while there has been increased attention on the use of ICT-based projects to provide smallholder farmers with market

information, conditions such as asset poverty can dampen their incentives to adopt services rendered by such projects. Asset poverty, which encompasses poor infrastructure and the lack of human, financial, social and/or physical capital, is prevalent in smallholder production system. Hence providing market information services through ICT technologies alone is not sufficient in spurring commercialization of smallholder agriculture. Investment in physical infrastructure and in providing access to inputs/assets that such farmers need to facilitate the use of such services is equally important. Indeed, evidence from the DrumNet project in Kenya (presented elsewhere in this special issue) indicate that smallholder farmers are more likely to benefit from ICT-based market information projects if such a project resolves the other idiosyncratic market failures they face.

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[2] Although Mangisoni described the system in Malawi, the same system has operated in Ghana.

[3] Agricultural commercialization describes the transition by farmers from subsistence farming to market oriented farming and is usually measured by the volume of household production that is marketed (Wambugu, 2008).

[4] While H4 may be far reaching we hypothesize, *ceteris parbus*, that households that have access to ICT-mediated agricultural information are likely to be better off than those that don't.