Mobile Devices and Their Role in Agricultural Markets in sub-Saharan Africa: A Microeconomic Analysis of Mobile Phone Incorporation into the Farm Household Behavior Model

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Abstract

This thesis will examine the role of the mobile phone on production and consumption decisions for five farm household models. The first section will give a review of the literature concerning mobile phone penetration in developing countries; the second section will present the five farm household models; the third section will provide a theoretical analysis of the affect the introduction of the mobile phone has on each household; the final section will provide concluding remarks concerning the implications mobile phones have for economic and agricultural development.

I. Introduction

There is a huge population in the world that is often forgotten in the age of globalization and technological advancement. Less developed countries (LDCs) in the world account for 1.6 billion people, nearly one-fourth of the world's total population (World Bank, 2007). However, since this population is largely extremely poor and their country's economic growth is slow or non-existent, they are often underestimated as drivers of economic growth. Within the LDC population, according to de Janvry and Sadoulet (20214) there are some 400 million smallholder farm households. These smallholder farmers have the potential to play a crucial role as engines of growth in both national and global agricultural production.

In sub-Saharan Africa alone, 85% of the population is rural and actively engaged in agriculture (Bryceson, 1996). Due to poor infrastructure, political instability, rampant poverty, low technological advancement, and small individual production size, these farmers are often left behind in a rapidly developing Western-dominated global economy (Bryceson, 1996). This thesis will evaluate the effects that mobile phones can have on the behavior of farmers as both consumers and producers. The analysis will incorporate five farm household models developed by de Janvry and Sadoulet. It will then examine how a mobile phone as a search tool, information tool, and monitoring tool affects the income constraint side and the consumption side of each farm household. The mobile phone will have different uses, capabilities, and effects on each category of farm household, depending on their labor, technology, and land endowment characteristics. Furthermore, this thesis will answer the underlying question of whether there is a farm household that the mobile phone affects the most in terms of their behavior model. In terms of the wider international agricultural development sector, the questions addressed in this thesis have relevant policy implications.

II. Review of Recent Literature

This subject of study is relevant because smallholder farmers are potential drivers of agricultural growth[1]. This is especially the case in developing countries that are heavily populated with a dominant agricultural economic sector. According to recent World Bank estimates, around 17 percent, or over one billion people, in the developing world live on less than $1.25/day (World Bank, 2014). Most of this population is located in Africa, and is dominated by subsistence farmers living in rural villages. Improved production decisions could increase their revenues and economic stability.

To improve production decisions and behavior of farmers, information can make a significant difference. Markets often fail because there is insufficient or incomplete information that causes the cost of a transaction through a market exchange to be too high (Janvry, Fafchamps, and Sadoulet, 1991). This results in market failures that make all parties worse off and lead to inefficiency and waste. Efficient market outcomes assume that agents have all needed price information when engaging in trade or arbitrage. This lends relevancy to the use of mobile phones by farmers participating as producers in these rural agricultural markets.

This thesis focuses on the farm household, of which there are five categories. A farm household, according to de Janvry and Sadoulet, can be defined by Ellis' six conditions from his book *Peasant Economics* (Ellis, 1994). The characteristics of a farm household are:

1. Income derived mainly from agriculture, including pastoralism, forestry, and fishing.

[1] Smallholder farmer is defined as a small rural household that derives the bulk of their income from agricultural products that they are the producers of (Jayne et al., 2003).

2. Use mainly family labor in production.

3. Are partially integrated into markets where they engage in multiple transactions, but they also have a certain degree of self-sufficiency in consumption and the self-provision of outputs

4. They participate in markets that are notably imperfect, with high transactions costs, imperfect and asymmetrical information, and lack of competitiveness.

5. Are members of communities that give them access to Common Property Resources, mutual insurance, land and labor contracts, interlinked transactions, patron-client relations, the provision of local public goods, and voice in political affairs.

6. The farm households are part of a larger non-peasant society where they are dominated by other social classes.

These six conditions, when satisfied, result in a specific behavior model that defines the farm household. This particular behavior model explains the production and consumption decisions of the smallholder farmer as a social class (de Janvry and Sadoulet, 2014).

In sub-Saharan Africa, the agricultural markets that farmers participate in are seen by many development economists to be in need of revitalization.[2] Problems facing agricultural development in Africa include too much state intervention, not enough private sector activity, poor infrastructure and public investment, poorly implemented market liberalization, missing or unreliable markets for agricultural inputs and outputs, and high transaction costs and risks in agricultural marketing (Poulton, Kydd, and Dorward, 2006).

Structural constraints in particular are what Delgado (1999) argues prevent smallholder farmers in Africa from maximizing their revenue and increasing production. He posits that these

[2] Like Esther Duflo (Abhijit and Duflo, 2011), Roger Thurow (Thurow, 2009), William Easterly (Easterly, 2002), and Elisabeth Sadoulet, Derek Byerlee, and Alain De Janvry (Byerlee, De Janvry, and Sadoulet, 2009).

structural constraints manifest themselves in high and oftentimes prohibitive transaction costs. High transaction costs mean that key markets for agriculture, both inputs and outputs, are inefficient or missing. Small and large farm households do not have access to information, technology, or other resources (Delgado, 2006). This translates to farmers diversifying instead of specializing to reduce risk. This can lead to the rise of absolute poverty levels (World Bank, 1992) and to farmers becoming more resource poor (Eicher, 1992).

Overcoming or decreasing transaction costs is the most effective strategy for increasing farmer access to markets as both producers and consumers (Delgado, 2006). A fundamental component to any strategy to overcome transaction costs is information. Access to information for farmers will alleviate the principal-agent problems that exist in agricultural markets. This thesis identifies how mobile phones change the production and consumption decisions of farmers who must cope with these transaction costs while operating within these agricultural markets.

Mobile phone adoption rates are rapidly rising throughout Africa. By 2008, over 65 percent of Africa had access to mobile phone coverage. Mobile phone subscriptions on the continent have increased from 16 million in 2000 to over 376 million in 2008. In North Africa 93 percent and in sub-Saharan Africa 60 percent of the population has access to mobile phones (Aker, 2010). Gale Business Insights estimates that Kenya alone has nearly 18.5 million cellular customers. Mobile phones have surpassed the adoption rate of landlines, particularly in sub-Saharan Africa where there is a quickly growing network of mobile phone base stations that are powered by diesel generators (Aker, 2010).

There are four categories in which mobile phones can provide solutions to food and agricultural market failures: improving access to financial services, providing agricultural

information, improving data visibility for supply chain efficiency, and enhancing access to markets. Within these categories, a recent study published by Oxfam (2011) in association with GSE indicates 12 opportunities within these categories that mobile phones can impact the lives of smallholder farmers:

1. Mobile payment system: A way to cheaply and rapidly transfer money to other individuals, transfer to savings, or purchase agricultural inputs

2. Micro-insurance system: A way to buy micro-insurance against crop failure

3. Micro-lending platform: Opportunity to secure loans for inputs or connect with distant investors to buy capital to increase output

4. Mobile information platform: Farmers can receive text messages with news and information that can improve their productivity. These updates, like on local weather patterns, can help farmers decide on the best timings to plant, irrigate, and harvest

5. Farmer helpline: Farmers can use a helpline to call and receive high quality information from a variety of agents that range from experts and researchers to traders

6. Smart logistics: Using mobile phones to collect data on a location and use it to increase speed and route of distribution

7. Traceability and tracking system: Using mobile phones to record movements of items through the agricultural supply chain

8. Mobile management of supplier networks: In which agricultural field agents visit farms and use mobile phones to record data on farm conditions and expected yields

9. Mobile management of distribution networks: Retailers can use mobile phones to keep records of sales of agricultural inputs, like seeds, fertilizer, and chemicals

10. Agricultural trading platform: An online marketplace for farmers to trade directly with buyers through the use of their mobile phones

11. Agricultural tendering platform: A mobile platform that allows agricultural customers and suppliers to post and respond to tenders for work and agree on labor contracts

12. Agricultural bartering platform: A platform that enables community members to exchange goods and services with each other for agricultural production, processing, and consumption

However, there is debate on how useful mobile phones actually are as information and search tools. There is controversy as to the extent to which they can improve farmer income and access to information, and how well their usefulness is in real agricultural markets instead of theoretical ones. Jenny Aker (2010) uses Niger as a case study and examines how mobile phones reduce dispersion of grain prices across agricultural markets. Mobile phones were phased-in throughout Niger between 2001 and 2006. Before this, grain traders travelled to markets to obtain price information for agricultural products.

Aker finds with mobile phone use inter-market price dispersion declined by an average of 3.5 CFA[3]/kilogram (Ibid). Mobile phone adoption by grain traders results in a 10 to 16 percent reduction in price dispersion between markets relative to market pairs without mobile phones. She concludes that the most beneficial aspect of mobile phones is their impact on search costs, which is captured in the amount of price dispersion between grain markets. The introduction of mobile phones results in a decrease in price dispersion between different grain markets by 3.5CFA/kilogram (Ibid).

Jensen (2007) finds evidence that mobile phones and other information technologies increase earnings for south Indian fishermen. If a market economy has goods that are more highly valued on the margin in one market than another. Access to complete information will signal profit-seeking suppliers and traders to reallocate goods until the price differences disappear (Jensen,

[3] Stands for Communauté Financière d'Afrique. The CFA is the currency of eight West African states that are part of a monetary union with their currencies pegged to the French franc.

2007). Jensen studies mobile phone introduction in fifteen beach markets in northern Kerala. He divides the sample into four time periods that compare the changes in price dispersion, waste, and welfare. He finds a 35 percent increase in the proportion of fishermen who travelled beyond their usual markets to sell fish for a higher price and thus better profit. In addition, consumer surplus from the purchase of sardines increased by 6 percent per person per day (Ibid).

Other studies cast a more critical eye on the capabilities of mobile phones as information tools in rural agricultural markets. Molony (2008) studies fifteen tomato and potato farmers from the Iringa region in Tanzania, five Dar es Salaam-based wholesalers, and a small number of wholesalers from the municipal market in Kariakoo. Molony's chain of wholesalers, middlemen, and rural farmers make up the typical production side of agricultural markets throughout sub-Saharan Africa.

Molony builds the model of a market for perishable foodstuffs, arguing that it is the most pertinent of agricultural sub-sectors to study. This is due to the time-sensitivity of these products, which requires prompt and complete communication and information. In production and distribution of a perishable agricultural product, there are three agents: the small-scale farmer, the middlemen, and the wholesaler. The small-scale farmer is often barely above subsistence level and is extremely risk averse. The middlemen buy the crops from the small-scale farmer and either sell the crops locally or send them to a larger city market. The wholesaler is simply a broker that buys from many of these middlemen and has multiple selling channels so as to be able to operate in economically risky environments (Ibid).

Molony's model of the production side in Tanzanian agricultural markets assumes that farmers sell to local or semi-local middlemen. Farmers have formed a personal relationship with

these brokers, who have the resources to act as reliable intermediaries and sell the perishable goods to larger wholesalers. Resource-strapped small-scale farmers are unable to sell directly to these wholesalers. This is due to high transaction costs like transportation, proper storage facilities, and marketing resources. Molony argues that small-scale farmers chose to sell to a particular middleman based on how much social capital this middleman has. This social capital is a composite of list of contacts, charisma, and popularity (Ibid).

Molony's research finds that mobile phones are only used by smallholder farmers that can afford their initial fixed cost and the cost of credit. He also finds that for those smallholder farmers that can afford this piece of capital, they use the mobile phones to convey supply and demand information for the buying and selling of their crops to middlemen at a distance. This cuts down the high transport cost that is often incurred on one or both parties, and it is this aspect of mobile phones that Molony argues holds the most potential in the supply chain of agricultural markets. Mobile phones are most successful at ensuring that relevant information is exchanged in time between the smallholder farmers and the middlemen. He further contends through interviews with traders and farmers that though the mobile phone can be effectively used to decrease transport costs between the smallholder farmers and middlemen, the distance and marginality of these farmers makes it difficult for them to use the mobile phone to sell directly to the wholesalers (Ibid).

Mobile phones are beneficial for improving information about supply and demand between farmers, and other levels of the production chain. They are also effective in decreasing transaction costs. Molony argues that the role of mobile phones is to improve information exchanged between already existing smallholder farmers and brokers that they have chosen to sell to. This indirectly increases farmer revenue by lowering the transaction costs of

communication and travel. This conclusion differs from Aker's and Jensen's research. Both Aker and Jensen prove that mobile phones can be used as information tools to allow producers to move to markets that offer a higher price for their products. This directly increases farmer revenues.

This is an important distinction and indicates that the role of the mobile phone varies depending on farmer characteristics and the design of the production chain. Depending on the structure and nature of the production chain, mobile phones have different capabilities in agricultural markets. This thesis will add to the existing body of research by explaining the way that the mobile phone affects production decisions and consumption decisions of farm households. This thesis examines the capabilities that the mobile phone has depending on what type of farm household uses it.

III. Conceptual Framework: Farm household behavior models

The economic model of this thesis is tailored from five farm household models. These households are distinguished from each other based on their labor, land, and technology endowment. This section provides a brief account of the characteristics and assumptions for each household. These farm household behavior models are based on typical microeconomic production and consumption functions.

There are five households that have the labor choice of cultivating their own land or joining the labor market. This categorizes them as the social class "family farmers," different from other rural household types. The optimal labor strategy for each of these households depends on its asset endowment and a price band model where there are transactions costs in the

labor market (Sadoulet and de Janvry, 1995). The five households are labelled as follows: Consumer-worker household, Sub-family farm, Pure family farm, Small commercial farm, and Pure producer.

In the local labor market a wage w is offered. There are transaction costs involved in participating in the labor market, both for a household hiring labor and a household selling labor. Transaction costs are high enough that farmers are unwilling to move between nearby labor markets, such as in neighboring villages. All wages that the households receive are net wages. Each household is paid a market wage for each hour of work, but the wage received is the market wage less the transaction costs to participate in the labor market. The wage received when selling labor is w-TC, where TC is transaction cost involved in reallocating labor away from the farm to the labor market. For simplification purposes, the net wage that the household receives for selling labor in the labor market after subtracting TC is denoted W_1. So if a farm household has labor that is not being used on the farm, then W_1 is the wage that the household member who enters the labor market receives. TC includes but is not limited to the following: transportation costs, information costs, search costs, and failed attempts to find a job.

If a farm household has too much land for the members of the household alone to maximize production, it will want to hire labor from the labor market. This cost of hiring labor is the wage paid to workers plus additional transaction costs. That wage is adjusted for the transaction costs involved in looking for and employing the labor. The wage paid to an individual when hiring labor is w+TCh. The h is the transaction costs for hiring labor that the employer incurs, different from the transaction costs that employees incur.

So the wage that the household pays to hire workers for its farm is a net wage, and for simplification purposes will be denoted as W_2. All these households face high enough transaction costs that if they want to hire labor the wage paid is higher than wage paid in perfectly competitive labor markets where non-farm employers do not have high transaction costs. Transaction costs that farm households must pay to hire labor include but are not necessarily limited to the following: monitoring of workers, mitigating labor and production conflicts, paying for transportation, and the interviewing and search costs for hiring workers. Transaction costs play a crucial role in the choices that each household makes for production, consumption, and time allocation decisions. The wage that the farm would get if selling labor is the same paid if the farm is hiring labor, and the only distinction is how the transaction costs are distributed. If the farm is selling labor, the transaction costs incurred by the farm reduce the net wage rate it received. If the farm is buying labor, then the cost of labor is the wage they pay to hire labor plus the transaction costs.

These five farm households are defined by the amounts of their land endowment and labor endowment. The small farm household is the smallest of the household categories and has no land endowment. The sub-family farm household has a small land endowment but it is small enough that some members of the household need to work on the labor market. The pure family farmer household has a large enough land endowment to work on the farm only. The small commercial farm household has a large enough land endowment that it can chose to hire additional workers to maximize their land productivity, and the entire household works on the farm. For the pure commercial farm household, the household has a land endowment large enough that the household only hires labor to work on it. Each household demands an amount of labor based on their land endowment given their production function.

The labor that the small commercial and the pure commercial farm households buy is only for cultivating land for whatever agricultural good these households are producing. All hired labor is people working on the land endowments of these households. Households that sell their labor in the labor market may or may not work in the agricultural sector, but this distinction is irrelevant for this model. The labor quantity demanded for farm production increases with a farm's land endowment. A household will work on their farm until the marginal productivity of working on the farm equals the wage that members of the household can earn in the labor market. If the labor market wage is higher than the marginal productivity of working on the farm, the farm household will reallocate some or all of its labor to the labor market. The amount reallocated is contingent on the land amount of the household. There will be some minimum amount of labor allocated to the farm for each land amount. In the consumer-worker household, which doesn't have any land to farm, no labor will be allocated to farm work. The other farm households must supply this minimum amount of labor to their land or else they would have no economic benefit in owning it.

In the following behavioral models, the farm household is an economic unit that is built on theory of the firm when explaining labor allocation decisions, along with the theory of consumer behavior in explaining how the household decides to spend time on work or leisure. Both theories are necessary as each farm household must make both production and consumption decisions. Each household makes choices to maximize a utility maximization of the form $U(Y, T_Z)$ where Y income and T_Z is leisure time. Income, Y, is from labor market earnings and revenue from selling crops as producers. The income is then used either for consumption or saved. There are three types of goods that are consumed: durables, semi-durables, and nondurables. The consumption function for each farm household is based on finding the optimal

amount of durables (D), semidurables (D_s), and nondurables (D_n). Each household will use all their income to buy a combination of durables, semidurables, and nondurables. Each household also has the option of saving some portion of its income. The portion a household saves is invested in capital like roofs, cows, goats, and other capital items that are safer than keeping cash around the house.

The fixed land endowment is expressed as $\bar{A}$ and the total time that devoted to either work or leisure T_z. The time worked is further divided into time worked on the farm T_F and time worked on the labor market T_w. Work on the farm can also be supplemented by hired labor, expressed as L_{IN}. The production function $Q(L, \overline{A})$ is used to indicate the amount of crop(s) produced on the farm. This is a function of technology, labor, and land endowment. The total labor input on the farm, denoted L, is either solely family labor or complemented by hired labor. Labor is the primary input because of the high cost of other inputs like fertilizer, irrigation systems, and better quality soil. The nature of each of these farm households means that it does not have access to large amounts of other inputs. This is why its production function is the amount of crops produced given the productivity of labor and its land endowment. The quantity of hired labor is expressed asL_{IN}. Each farm household will be further deconstructed in the following five economic models.

i. Consumer-worker household

Assumptions: This household has no or very little land endowment. The choices of the household correspond to the theory of consumer behavior. The household allocates all its family labor to the labor market, and has an income equation based on time worked on the labor market and wage received for that time. This income constraint will determine the optimal bundle of

goods the household consumes. The conditions of not having enough of a land endowment relative to family labor make it worthwhile to only work off-farm on the labor market.

The following is the behavioral model for the consumer-worker household to maximize utility subject to income constraint.

$$\max_{T_z} U^{cw}(D, D_S, D_N, T_z) \qquad (1.1)$$

Subject to:

$$T_w + T_z = \bar{T}\ time\ constraint$$

$$Y = W_1 T_w, income\ equation$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$W_1 T_w = p_D D + p_{DN} D_N + p_{DS} D_S$$

ii. Sub-family farm

Assumptions: This household has a large number of working age members but a proportionally small land endowment relative to the number of household members. Household members work both on and off the farm depending on wage rates and prices of goods they can produce on the farm with their fixed land endowment and family labor amount. The surplus farm labor will be apportioned to the labor market shown in this behavioral model. The farm household uses all income to consume a combination of durables, semidurables, and nondurables.

$$\max_{T_z} U^{S}(D, D_S, D_N, T_Z) \qquad (2.1)$$

Subject to:

$$Q = Q(T_F, \bar{A}), production\ function$$

$$Y = pQ + W_1 T_w, income\ function$$

$$T_F + T_w + T_z = \bar{T}, time\ constraint$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$pQ + W_1 T_w = p_D D + p_{DN} D_N + p_{DS} D_S$$

iii. Pure family farmer

Assumptions: This household is assumed to be self-sufficient in labor. This situation occurs when a family farm has no labor market or they are within the price band for a labor market but transaction costs prohibit their use. The household has a high enough land endowment that the opportunity cost w_s of going to the labor market is less than the marginal productivity of labor on the farm. However, the marginal productivity of labor on the farm is not high enough as the cost w_H of hiring labor for farm production. The household also uses up all its income buying a combination of durables, semidurables, and nondurables.

$$\max_{T_z} U^P(D, D_S, D_N, T_z) \qquad (3.1)$$

Subject to:

$$Q = Q(T_F, \bar{A}), production\ function$$

$$Y = pQ, income\ equation$$

$$T_F + T_z = \bar{T}, time\ constraint$$

$$W_1 < MPL_F < W_2$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$pQ = p_D D + p_{DN} D_N + p_{DS} D_S$$

iv. Small commercial farm

Assumptions: The household has a large land endowment relative to number of working age household members. All the household members work on the farm and hired labor with be used as well. Hired labor amount will be proportionally less than number of working age members of the household.

$$\max_{T_z} U^{SC}(D, D_S, D_N, T_z) \qquad (4.1)$$

Subject to:

$$Q = Q(L, \bar{A}), production\ function$$

$$Y = pQ - W_2 L_{IN}, income\ function$$

$$L = T_F + L_{IN}, total\ farm\ labor\ use$$

$$T_F + T_Z = \bar{T}, time\ constraint$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$pQ - W_2 L_{IN} = p_D D + p_{DN} D_N + p_{DS} D_S$$

v. Pure producer

Assumptions: This household model corresponds to the theory of the firm. The household hires more labor than it uses family labor. Family labor is increasingly indirectly involved in farm

labor, usually taking on a supervisory role. The model for this farm household assumes that only hired labor is used. Family labor is concentrated to leisure or other activities. Maximizing utility is comparable to maximizing profit. The pure producer household has a consumption function the same as the other household models.

$$max_L \Pi = pQ - W_2 L$$

$$max_Y U^{PP}(D, D_s, D_n) \tag{5.1}$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$pQ - W_2 L = p_D D + p_{DN} D_N + p_{DS} D_S$$

Subject to:

$$Q = Q(L, \bar{A}), production\ function$$

IV. Economic Analysis: The Role of the Mobile Phone Device

This section will incorporate the mobile phone into each household behavior model. An economic analysis will be given on how mobile phones affect each model, the variables that are influenced, and in what way they are influenced given certain conditions. These conditions will also be defined in this analysis section. The mobile phone variable will be denoted m. Its capabilities can be put into three main categories: an information tool, a search tool, and a monitoring tool. Each household model operates under the assumption that the mobile phone is used because the fixed cost of buying the initial phone and the variable cost of paying for the operating service are both lower than the opportunity cost of not having the mobile phone as an additional piece of capital for the household. When the total cost of the mobile phone (the fixed

and variable costs together) is larger than the opportunity cost of not having the device, then it will not be used. The following models are based on the assumption that the total costs of the mobile phone are less than the opportunity cost, and are within the consumption budget constraint of each household.

i. Consumer-worker household

The behavioral model for the consumer-worker household:

$$\max_{T_z} U^{cw}(D, D_S, D_N, T_z, m) \tag{1.2}$$

Subject to:

$$T_w + T_z = \bar{T}, time\ constraint$$

$$Y = W_{m1}T_w, income\ equation$$

$$W_{m1} = mW_1 + W_1, wage\ rate\ equation$$

$$Y = p_D D + p_{DN}D_N + p_{DS}D_S, income\ constraint\ for\ consumption$$

$$W_{m1}T_w = p_D D + p_{DN}D_N + p_{DS}D_S$$

The mobile phone variable is used as a search tool for the members in the household to find comparatively better wages for work. Since the consumer-worker household has no land endowment, the household's income is entirely based on the wage rate for work on the labor market. With a mobile phone, members of the household can search for higher wages and better information about jobs. The mobile phone variable is expressed as a percentage, multiplied by the old wage rate and then added to it to create the new wage rate. This is because with the mobile phone the household will not get worse information concerning wages. The mobile phone

variable may be zero, in the case where there is no better wages even after having better information and search abilities. Then the wage that the family members earned before the mobile phone is used would still be available and the best option.

The mobile phone is expected to increase the household's wage rate because it will lower the transaction costs involved in finding work. The household will be more competitive in its work options. For example, household members will be able to cut down on transportation costs by applying online, conducting phone interviews, and complete other processes in the job search. The household would be able to choose from jobs that previously without the mobile phone would incur too high of transaction costs.

The time constraint for the consumer-worker household would also change. The amount of total time devoted to work and leisure is fixed, but the slope of the level of the constraint changes. This is due to the wage amount changing. With more information about work choices and less search costs involved in finding work, the time allocated to work and to leisure will change. This is due to the ability to get a higher net wage or lower transaction costs even if the wage is the same. The allocation will be determined based on whether the income effect or the substitution effect is stronger for the household. These effects are contingent on how sensitive to price the household is. If the household is fairly sensitive to changes in price, then an increase in the wage rate will increase the demand for work by a proportionally larger amount.

If the income effect is stronger for the household, then the amount of time devoted to leisure or other activities besides working on the labor market will increase. If the substitution effect is stronger for the household, then the amount of time working on the labor market will increase at the expense of time devoted to leisure. Either way, the incorporation of the mobile

phone will not change the total time constraint. This will remain fixed in the short run, with only the amount of time allocated to leisure or labor within this constraint shifting.

ii. Sub-family farm

The behavior model for the sub-family farm:

$$\max_{T_z} U^S(D, D_S, D_N, T_Z, m) \quad (2.2)$$

Subject to:

$$Q = Q(T_F, \bar{A}, m), production\ function$$

$$Y = p_m Q + W_{m1} T_w, income\ function$$

$$T_F + T_w + T_z = \bar{T}, time\ constraint$$

$$p_m = mp + p, market\ price\ equation$$

$$W_{m1} = mW_1 + W_1, wage\ rate\ equation$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$p_m Q + W_{m1} T_w = p_D D + p_{DN} D_N + p_{DS} D_S$$

For the sub-family farm, the effects of mobile phone use are seen in terms of price, wage, and time allocation. Wage will be affected the same way that wage is affected for the consumer-worker household. Due to abilities to search between agricultural markets, have lower transaction costs, and gain price information, the price p_m will be higher with the use of the mobile phone than the original price. This will be the case unless there is no arbitrage in the price the farm household was able to find for their crops before the mobile phone or after. In that case,

m will be equal to zero and p_m will be identical to p. It is likely that p_m will be larger than p because a mobile phone will lower the transaction costs involved in travelling between markets. This will allow farmers to take advantage of arbitrage, and find higher prices for their crops on the edges of markets in the short term.

The time constraint will remain fixed in the short run, but the slope of the time constraint, which shows time allocated to farm work, work on the labor market, and leisure will change. This is due to the change in the price of labor both on and off the farm, along with the price the household can get for selling its crops. The time allocated to leisure will be contingent on whether the income or substitution effect is stronger for the farm household. Again, the price sensitivity of the household will determine whether the substitution or income effect is stronger. Since the household is also a producer, if it is sensitive to price changes in terms of production decisions then an increase in the price the household can get for selling its crop will signal an increase in quantity produced. If the substitution effect is larger than the income effect, time worked on either the farm or the labor market will increase as time previously devoted to leisure is reallocated. If the income effect is more powerful than the substitution effect, then time allocated to leisure will increase at the expense of time spent working.

A further word on the effect of the mobile phone on the time constraint is needed. If time worked increases at the expense of hours previously devoted to leisure, it can either go into more household members joining the labor force or more members working on the farm. This choice will depend on whether the wage increase is larger than the price increase the farm household can get for their crops. If so, the household members will benefit more from participating in the labor force over working on the farm. Due to their land endowment, unless the new wage the household can get using mobile phones is higher than the opportunity cost of

the marginal product of labor on the farm, the household will not reallocate all labor to the labor market. It will only do this until the marginal product of labor on the farm is equal to the marginal product of labor working on the labor market.

In addition, since quantity produced is a function of the farm household's land endowment and time allocated to working on the farm, quantity of crop produced would increase if the farm household allocated more time to working on the farm. This is contingent to the household getting a better sale price for crops than wage increase on the labor market. If the quantity produced does increase, it will only increase to the point of maximizing the amount of land endowment the household has.

iii. Pure Family Farmer

The behavior model for a pure family farm household:

$$\max_{T_z} U^P(D, D_S, D_N, T_z, m) \tag{3.2}$$

Subject to:

$$Q = Q(T_F, \overline{A}, m), production\ function$$

$$Y = p_m Q, income\ equation$$

$$p_m = mp + p, market\ price\ function$$

$$T_F + T_z = \bar{T}, time\ constraint$$

$$W_{m1} < MPL < W_{m2}$$

$$W_{m1} = mW_1 + W_1$$

$$W_{m2} = mW_2 + W_2$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$p_m Q = p_D D + p_{DN} D_N + p_{DS} D_S$$

One of the main characteristics of the pure family farmer is that the marginal productivity of family labor on the farm is above the opportunity cost of going on the labor market but below the cost of hiring workers. This price band changes the way the mobile phone influences the behavior of the pure farm household. The mobile phone will either cause the farm household to continue to not participate in the labor market or participate by either joining the labor force or hiring additional farm workers.

This decision is determined in part by the allocation of time with the addition of the mobile phone. Like in previous models, as an information and search tool the mobile phone reduces transaction costs for the household. The household can search for a higher price for produce, a lower price for hired work, and a higher wage for joining the labor market. Either way, the slope of the time constraint will change. Time allocated to labor or leisure with the addition of the mobile phone will change because either the household can get a better price for labor and crops it produces, or lower transaction costs even with the same wage and price of crops. Depending on whether the income or substitution effect is stronger, the mobile phone will cause the household to either allocate more time to working on the farm or leisure. If the substitution effect is stronger than the income effect, the household will allocate more time to work. In allocating more time to work, the household will not reallocate labor to the labor market, even if they can find higher wages using the mobile phone as a search tool. This is due to two main reasons:

1. The household has a high enough land endowment that taking away labor from working on the farm and reallocating it to the labor market would result in less output from the farm. This would not be the most beneficial choice for the farm household in terms of increasing their income, because it would cancel out any increase in wage that would tempt the farm household to change their labor choice.
2. With the mobile phone the household can receive a better price for the crops they are producing on the farm. This will increase their marginal product of labor and their revenue, disincentivizing the household further from using entering the labor market.

So the pure farm household will not participate in the labor market with the introduction of the mobile phone. The household will either continue to be self-sufficient or they will chose to hire labor. There are three factors that will enable the farm household to hire labor:

1. The extent to which the mobile phone allows the household to search and find cheaper labor. If W_2decreases enough, then the farm household will hire labor.
2. The size of land endowment. If land endowment is large enough that the only reason the household didn't hire labor before the mobile phone tool was due to high transaction costs and too high W_2as a result of these, then the household will hire labor.
3. If the new p_m and increase in $T_f$is enough to signal the household to increase Q produced, the household will then need to hire additional labor from the labor market.

For the pure family farm household, the use of the mobile phone will increase their income by allowing the household to find a higher selling price for crops. Depending on how the household reallocates time, the mobile phone also has the ability to decrease the price band that the household is restricted by, allowing them to hire labor and increase output. Price sensitivity is

also a factor that determines the time allocation of the household. The farm household will become more sensitive to prices for their output with the introduction of the mobile phone because transaction costs that previously prevented them from getting a better price for their crops will be lower. This will further signal the household to produce more of their crops. The mobile phone has the potential to transform the pure farm household into a small commercial farm.

iv. Small commercial farm

The behavior model for a small commercial farm:

$$\max_{T_z} U^{SC}(D, D_S, D_N, T_z, m) \tag{4.2}$$

Subject to:

$$Q = Q(L, \bar{A}, m), production\ function$$

$$Y = p_m Q - W_{m2} L_{IN}, income\ function$$

$$p_m = pm + p, market\ price\ fuction$$

$$W_{m2} = W_2 m + W_2$$

$$L = T_F + L_{IN}, total\ farm\ labor\ use$$

$$T_F + T_Z = \bar{T}, time\ constraint$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$p_m Q - W_{m2} L_{IN} = p_D D + p_{DN} D_N + p_{DS} D_S$$

For a small commercial farm, the farm household has enough land to work entirely on the farm. The household does not have enough workers to fully maximize production, so the household also hires labor. With the use of the mobile phone, the farm household will be able to hire additional workers due to decreased transaction costs and information about cheaper wages. The household will also be able to get a higher market price for their crops, both of which result in increase in household income.

As with the other models, the slope of the time constraint for the household will change with the introduction on the mobile phone. How the slope of the time constraint changes is determined by the changes in price of crops and the price of hired labor. The amount of time allocated to either labor or leisure will depend on the strength of the income or substitution effect. The strength of these effects is affected by the price sensitivity of the household, as with the previous models. Time allocation also depends on whether the household decides to hire additional workers compared to before mobile phone use. If the household hires more workers because they can find cheaper labor and the transaction costs are lowered enough, the productivity of the hired labor will determine whether the farm household allocates more time to leisure. This determines whether the household will hire enough labor to become a pure producer.

v. Pure producer

The behavior model for a pure producer:

$$max_L \Pi = p_m Q - W_{m2} L$$

$$p_m = pm + p$$

$$W_{m2} = W_2 m + W_2$$

$$max_Y U^{PP}(D, D_s, D_n, m) \quad (5.2)$$

$$Y = p_D D + p_{DN} D_N + p_{DS} D_S, income\ constraint\ for\ consumption$$

$$p_m Q - W_{m2} L = p_D D + p_{DN} D_N + p_{DS} D_S$$

Subject to:

$$Q = Q(L, \bar{A}, m), production\ function$$

The pure producer is a household that hires workers to do all the labor on the farm. The time function of the pure producer household is the combination of time spent overseeing labor and the general production of crops, and leisure time. The behavior model for the producer farm household is simply the profit maximizing function of a firm. With the addition of the mobile phone, the household will be able decrease transaction costs like monitoring, screening, and search costs for labor. The household will be able to search for cheaper labor and higher prices for their production. How sensitive the household is to price changes will determine how much additional labor the household employs. If the household is sensitive to changes in price of the goods they are producing, then a higher selling price for crops will signal the household to increase production. Additionally, since the household can find better information about the labor market and search for cheaper labor, price sensitivity will signal them to demand more hired labor for their farm.

V. Implications and Concluding Remarks

This thesis built a theoretical model to examine the effects of mobile phones on five types of farm households. This inclusion of the mobile phone variable into each household model had significant implications for household production and consumption decisions. Specifically, for each household the use of the mobile phone leads to a decrease in transaction and search costs. This means that the households who have family members participating in the labor market, they can search more easily and quickly for better wages. For households that are hiring labor, they can search for cheaper and more efficient farm labor. And for the households that are producing crops for sale, they can find a more competitive price for their crops, decreasing price dispersion between markets. Overall, the benefits of farm households using mobile phones will be seen in increases in income for each household type.

These results have policy implications. If the mobile phone is beneficial for households both producing crops and participating in the labor market, then there should be incentives in place to lower the opportunity costs involved in buying and using mobile phones. According to Banerjee and Duflo (2011), between 25 percent and 98 percent of the rural poor are households running farms. The income that these farm households are generating has a large impact on their decision to buy and use a mobile phone, even if the mobile phone will increase their income by lowering transaction and search costs.

There is a need for a set of policies that make it easier for these farm households to buy and use mobile phones. Much of the time, households will not invest in new technology because the risk is too high (Banerjee and Duflo, 2011). Banerjee and Duflo (2011) give the example of farmers who know that there is a more productive variety of their main crop but they actively

chose not to adopt it. Even though the better crop variety seeds would repay the investment with one good harvest season, the risk that the crop will fail is enough that the farmers refuse to buy it. Due to the amount of risk that these farm households have to deal with, there should be policies in place to manage this risk.

In terms of specific policy recommendations, governments should decide between two policies. The first one is subsidizing mobile phones, so it is less expensive for farm households to acquire and use them. A subsidy of some kind is also needed to mitigate the fixed costs of installing cell towers and other electrification infrastructure. However, a second policy that could be effective in increasing mobile phone uptake by farm households is the implementation of a voucher system. For the households that do depend on the amount of output their land produces for a portion of their income, implementing a voucher scheme could be helpful in mitigating the risk of buying a mobile phone.

For example, there could be vouchers for year-long mobile phone contracts available at a discounted price right after harvest time. Depending on how price elastic the mobile phone market is, if year-long contracts are offered at a discount price after harvest season, when the farm household has more income to spend, then the farm households might be more inclined to purchase a mobile phone. Also, the increase in demand for mobile phones at this discounted price would make up for the losses that the mobile phone companies incur in selling at a discounted price. However, this would be dependent on the level of price elasticity.

The benefit of making a year-long contract available at a discounted price right after harvest is that these farm households would be more inclined to buy it due to their relative increase in income from the harvest. In addition, they would be paying for a mobile phone plan

for an entire year, so it would be a lump sum that they wouldn't have to worry about paying for when their income is relatively smaller right before harvest time. These are just two policy recommendations that could ease the risk that a farm household faces in their decision to buy and use mobile phones.

This thesis has developed a theoretical model to show that mobile phones have the potential to decrease transaction costs, information costs, and search costs. In doing so, the device has the potential to increase the income of a farm household, whether or not they are hiring labor or members of the household are entering the labor market themselves. It is important for governments and international organizations to incentivize the use of mobile phones, because they have the potential to generate increases in income and more efficient production decisions.

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