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► To cite this version:

Sabrina Bair. Assessing the impact of the use of information and communication technologies in the agricultural sector in Africa : the case of mobile telephony. Economics and Finance. Université Paris sciences et lettres, 2020. English. NNT : 2020UPSLM034 . tel-04368453

HAL Id: tel-04368453

<https://pastel.hal.science/tel-04368453>

Submitted on 1 Jan 2024

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THÈSE DE DOCTORAT
DE L'UNIVERSITÉ PSL

Préparée à MINES ParisTech

**Évaluation de l'impact de l'utilisation des technologies
d'information et de communication dans le secteur agricole
en Afrique: Cas de la téléphonie mobile**
**Assessing the impact of the use of information and
communication technologies in the agricultural sector in
Africa: the case of mobile telephony**

Soutenue par

Sabrina BAIR

Le 30 Septembre 2020

École doctorale n°543

**Sciences de la Décision,
des Organisations, de la
Société et de l'Échange**

Spécialité

Economie

Composition du jury :

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Part I

Summary

The objective of this thesis is to capture the potential of information and communication technologies (ICTs) , specifically mobile phones in Africa to alleviate the living conditions and empower households in rural areas, particularly in Sub-Sahara Africa through information dissemination, rent redistribution, and financial inclusiveness. As the last developed continent, Africa suffers from poverty, lack of essential infrastructure, famine problems, the highest illiteracy rates, and limited access to financial services, so International organizations such as the World Bank argues that the expansion of mobile telephony adoption represents an opportunity to overcome some of Africa's obstacles through innovative uses in the rural world, which suffers more from physical barriers.

We focus on assessing the impact of the innovative uses of mobile phone services in the agricultural sector where I will draw conclusions on mobile phone services' benefits, quantify them, and advise public and private authorities and organizations to set up suitable services to the populations' needs.

The first chapter analyses the impact of market information services via ICTs on cash crops' profits in a theoretical framework. This chapter explains the interactions between market agents and the farmer. This analysis concludes that the information dissemination design is essential to strengthen farmers' bargaining power. Furthermore, it is important not to neglect the farmers' know-how in marketing strategies accompanied by market information services.

The second chapter provides empirical results; it estimates the impact of the in-

formation received on farmers' incomes and profits. We conduct a randomized trial in Burkina Faso to assess the effect of market information services via mobile phones on the price and turnover received by sesame producers. Other aspects were analyzed, namely the dissemination of market price information on the one hand and its uses on the other. In our case of analysis, we show that information helps farmers to be strategic by being aware of price fluctuations and enhancing their bargaining power. According to our estimation, on average, the information received enables farmers to increase their prices by 4% regarding the treatment assignment. Besides, we report a heterogeneous effect between treated farmers that could limit the average impact using quantile treatment effects.

The third chapter addresses the issue of access to financial services, where ICTs are an opportunity to address their underdevelopment. Access to the financial sector in African countries is minimal - it does not exceed 10% of the population. One of the innovations of ICTs in this sector is mobile money. This chapter analyses the impact of ICTs on financial and banking services via mobile money, taking the example of Malagasy households. Through an empirical study of the 2015 Finscope survey in Madagascar, it is concluded that mobile money is a substitute for traditional, expensive, and sometimes risky money transfer services and allows to increase the frequency of the transfers and the transfers' amount. However, the services offered by mobile money are limited to money transfers or bill payments. The population needs bank services to finance their investments, savings accounts, and insurance services. Therefore, there is a need to develop mobile money ser-

vices further to evolve from a transfer or payment tool to a complete banking service allowing and sending money, credit and savings services, and insurance.

Résumé

Cette thèse a comme objectif de mettre l'accent sur le potentiel des technologies d'information et de communication TICs et précisément le téléphone mobile en Afrique subsaharienne afin d'améliorer les conditions de vie des ménages à travers la diffusion d'information, la redistribution des rentes et en favorisant l'inclusion financière. L'Afrique est le continent le moins développé, qui souffre de pauvreté, d'un manque d'infrastructure essentielle, des problèmes de famine, des taux les plus élevés d'analphabétisme et d'accès limité aux services financiers... Par ailleurs, des organismes internationaux tel que la banque mondiale estime que l'expansion de l'adoption de la téléphonie mobile représente une opportunité pour surmonter une partie de ses obstacles à travers des utilisations innovantes dans le monde rural qui souffre davantage de ces barrières physiques. L'objectif de cette thèse est d'évaluer l'impact de l'usage de ses services via le téléphone portable dans le secteur agricole. Afin de tirer des conclusions sur leurs bénéfices et pouvoir les quantifier, pour apporter des recommandations aux autorités publiques, privées et des organismes non gouvernementaux afin de les orienter vers des services adaptés aux besoins de la population.

Dans un premier temps, il est question d'analyser l'impact des services d'information marchés via les TICs sur les profits des cultures rentières dans un cadre théorique

qui rapporte et explique les interactions entre les agents du marché et l'agriculteur. On retient de ce modèle que la conception de l'information diffusée est importante pour ne pas affaiblir le pouvoir de négociation des fermiers. En outre, il est important de ne pas négliger le savoir-faire commerciale et marketing des fermiers qui pourrait être accompagné par ces services.

Le deuxième chapitre permet de tirer des résultats sur le plan empirique. En effet, il est question d'estimer l'impact de cette information reçue sur les revenus et les profits des agriculteurs. En conduisant une expérience randomisée contrôlée au Burkina Faso, afin de quantifier l'impact des services d'information marchande via le téléphone portable sur le prix, chiffre d'affaire reçus par les producteurs du sésame. D'autres aspects sont mis en jeu à savoir la diffusion de l'information d'une part et son utilisation d'autre part. En moyenne, l'information reçue permet aux agriculteurs d'augmenter leur prix de 4% en termes d'assignement au traitement. En plus de la conception d'information d'autres aspects se manifestent à savoir la compliance imparfaite, dont les principales causes sont l'analphabétisme, des problèmes d'insécurité et le besoin d'installations réseau adaptés pour profiter de ces services à grand échelle. En outre, nous avons reporté une distribution hétérogène de l'effet du traitement sur le prix et chiffre d'affaire reçu par les fermiers traités en utilisant une approche "Quantile treatment effect".

Le troisième chapitre aborde la question de l'accès aux services financiers sur lesquels les TICs constituent un enjeu primordiale pour remédier à leurs défaillance. L'accès à ses services dans les pays africains se limite à moins de 10% de la

population africaine. Une des innovations des TICs dans ce secteur est le mobile Money. Ce chapitre analyse l'impact des TICs sur les services financiers et bancaire via le mobile money, en prenant l'exemple des ménages malgaches. A travers l'analyse empirique des données de l'enquête FinScope Consumer au Madagascar au 2015, on conclue que le mobile money constitue un substitut des outils de transfert d'argent traditionnels, couteux et parfois risqués et permet d'augmenter les fréquences des transferts et les montants envoyés. Cependant, les services proposés par le mobile money se limitent au transfert d'argent ou les paiements de factures or la population africaine a besoin des services bancaiers pour financer leurs investissements, des comptes d'épargne et des services d'assurance. D'où le besoin d'un développement des services du mobile money et d'une transition d'un outil de transfert ou de paiement à un service bancaire complet.

Part II

Introduction

The world bank in 2012¹ underlined the importance of Information and Communication Technologies (ICTs) in terms of contributing to economic growth by stimulating the productivity of the poorest in developing countries. This optimistic view of the contribution of ICTs to economic growth was first revealed in developed countries, which consider investment in ICTs in innovative ways as a fundamental stimulus to productivity growth (see Romer (1986)Grossman & Helpman (1991)). ICTs are considered a special case of new technologies that serve as technologies leading to even further innovations. Primarily studies focus on developed countries at the firm, industry, vital sectors, and country level. The majority of studies show that the productivity effect of ICTs is positive and economically significant. This literature reviewed by Cardona *et al.* (2013), and Bloom *et al.* (2010) list a comprehensive set of studies applying different methodologies. Cardona *et al.* (2013) provide an overview of the empirical literature on ICTs and productivity and highlight the main results and methodological differences. The majority of studies indicate that the productivity effect of ICTs is indeed positive and significant despite the different analysis methodologies. Besides, Cardona *et al.* (2013) highlight that ICTs is a general propose technology (GPT) that allows innovations to build. Later on, in the introduction, we will also identify the innovative uses of ICTs in developing countries in several sectors

¹” Information and communication technologies (ICTs) have great promise to reduce poverty, increase productivity, boost economic growth, and improve accountability and governance.” <http://documents.worldbank.org/curated/en/105121468149370524/Information-and-Communication-Technology-ICT-for-greater-development-impact-World-Bank-Group-strategy-for-ICT>

of the economy.

However, in developing countries, empirical or theoretical research on the impact of ICTs use remains limited. This situation is explained on the one hand by the difficulty of finding large databases in developing countries and, on the other hand, by the late expansion of ICTs tools compared to developed countries. Because of the high cost of installing the necessary infrastructure, these countries are importers of these technologies.

Developing countries invest mainly in installing the internet and the mobile phone network and less in research and development because of the very limited financial and sometimes human capital capacity. However, the implementation of ICTs tools could promote economic growth by replacing traditional methods of increasing productivity. The additional productivity gains can be due to the reduction in transaction costs (as in agriculture De Silva & Ratnadiwakara (2008)). Therefore, investments in ICTs may decrease firms' administrative burden by introducing e-government applications, easier access to information, and acceleration of knowledge creation. ICTs could also be used for training and consulting services. It also enhances access to relevant information; a more straightforward tool for accessing financial services is through Mobile Money, an opportunity to explore the informal sector and boost it.

The expansion of ICT resources in Africa over the last two decades has made

it possible to use them innovatively, even (among the poorest 20 percent in sub-Saharan Africa, 82.4 percent (World Bank 2018) have access to mobile phones).

² According to the most recent report from GSMA, an association of mobile network operators worldwide, there are 764 million SIM connections in sub-Saharan Africa, which is more than the households who have access to sanitation or electricity in their homes. The source of these innovative ICTs initiatives is sometimes the result of people's daily needs. The source of inspiration and stimulation to develop these ICT services is to have the same facilities as in developed countries, try to do it with developing countries' resources, and overcome the delay or underdevelopment of key sectors such as education, health care, and agriculture in African countries.

The impact of using ICTs in several sectors, such as the agricultural, education, and health sector, is not well captured sometimes for the same reasons. In education, significant investments are being made in educational technologies (Kozma & Vota (2014)). Kozma & Vota (2014) reported several initiatives taken by governments of developing countries in Africa, Latin America, and the Middle East to provide students with the necessary digital equipment. To maintain the pace of economic digitization in developed countries, even though significant budget burden on some impoverished countries' finances. Independent research

²Available at <https://data.worldbank.org/indicator/IT.CEL.SETS.P2?locations=ZG> and last access on 14st of May 2020.

has concluded that providing each child with a computer fosters digital skills development (see Beuermann *et al.* (2013)). However, there is still no evidence to suggest that having access to a laptop improves learning in Math or Reading (see Beuermann *et al.* (2013)).

Besides, in the health sector, access to healthcare in developing countries is minimal, m-health and e-health represent an innovative technology to partially overcome the lack of specialist health personnel in the sub-region. Bervell & Al-Samarraie (2019) reviewed 66 articles to understand e-health and m-health³ use patterns across a spectrum of disease and health conditions in Sub-Saharan African countries. M-health is the main tool for providing adherence and remainder related services as in the agriculture sector. The main ICT technology used is the mobile phone, which is more accessible for the less educated and more valuable through the more widespread, less expensive network infrastructure. Some key challenges of using M-health in information provision and treatment were the infrastructure and the literacy level among patients or users of the device. The same challenges are in the agriculture sector. In the second chapter, we find that one of the first obstacles to introducing price information by text message to farmers was illiteracy. The farmers did not know whether they had received the information message or not because they could not read texts sent.

³e-Health and m-health consist of using the internet and mobile phone on medical issues, respectively.

In the agriculture sector, as in the health sector, ICTs can also overcome geographical distance challenges, especially in remote rural areas where the mobile phone is the main accessible ICT tools. Stimulating development and productivity via innovating in Africa's agricultural sector is essential. Firstly, one of the major problems that the African continent will face in the coming years is that Africa's agricultural production has not kept up with population growth. In the last 30 years, Africa's population has doubled, and its urban population has tripled, and internal agricultural production fails to meet 80% of the continent's food requirements. According to recent United Nations projections, the continent is expected to double its population by 2050, from one billion today to nearly 2.4 billion. So, the most direct consequence of this exponential population growth is that the continent now has more mouths to feed.

Secondly, the agricultural sector remains an important sector in most African economies and the principal source of revenue in rural households. The agricultural population in Sub-Saharan Africa stands at 645 million people.⁴ More than 60 percent of sub-Saharan Africa population is smallholder farmers dependent on family labor, with minimal machinery and several activities. In many countries in Sub-Saharan Africa, the average size is below 3 hectares, and a majority of farms, under 2 hectares, are essentially subsistence farmers. Furthermore, agriculture is

⁴Available at <https://data.worldbank.org/indicator/SP.RUR.TOTL?locations=ZG> and last access in 14th of May 2020.

the leading creator of jobs. The share of agriculture in total employment ranges between 20% and 50% for many countries, including the North of Africa, and could be as high or over 70% for others.

Thirdly, about 23 percent of sub-Saharan Africa's GDP comes from agriculture.⁵ The decline of agriculture's share in GDP in Africa follows the trend in economic development observed elsewhere. Also, the agricultural production in Sub-Saharan African countries is mainly based on increasing cultivated land and less on developing production tools (machinery, adequate seed, irrigation system, pesticides, fertilizers, and analysis ...). Indeed, agricultural production has more than tripled in the past 40 years. However, productivity is stagnating due to minimal improvement in production factors (labor and land), except in North Africa and, to a lesser extent, in West Africa. Agricultural growth in Africa is generally achieved by cultivating more land and mobilizing a larger agricultural labor force. Still, there has been minimal improvement in yields and barely any change in production techniques. Agriculture performance also depends on climate change. Drought is a significant risk faced by African agriculture since just 6% of cultivated land is irrigated. The agricultural balance of payments in Africa is negative, mostly because of rising agricultural imports.

⁵The share of agriculture in the gross domestic product (GDP) dipped from almost 40% in the early 1970s to less than 25% in 2015. The share averages 25% in Sub-Saharan Africa, but just 18% in North Africa.

Fourthly, several cash crops that generate foreign revenue, such as coffee, cocoa, peanut, cotton, palm oil, etc., are in crisis. These are products where government intervention in production and sales is very extensive and not subject to market laws and the wide variation in the specialization of export markets. Furthermore, we note that other cash crops have emerged, such as products with high value-added (such as processed fruits, some vegetables, sesame, etc.) or biological product sub-sectors and origin labeling. These sub-sectors provide significant opportunities for diversification and increasing revenues, as revealed by sesame producers in the second chapter.

Finally, the vast majority of producers are isolated and suffer from a total lack of public policies to support them during growing seasons and assist them in the modernization of their farms and commercializing their products. Regarding financial needs, fewer than 10% of producers have access to credit. Farmers operate in a very uncertain economic environment with high price volatility (see Barnett & Mahul (2007)). Risk is one of the main barriers to investing in agriculture: farmers avoid innovating and reduce their reliance on inputs, and financial institutions will not offer credit without insurance cover. Insurance for harvests and insurance against livestock deaths have been met with little success.

Therefore, small farmers face all these challenges, including limited access to physical infrastructure as reported before, and financial services, which increase research and transaction costs. This situation constrains farmers' optimal decision-

making strategies, not only for their initial production but also for the storage and the marketing decisions. In light of these challenges, do digital technologies represent rural households' opportunity to achieve various broader development goals? Could it make farming profitable and help small African farmers to earn more and increase their incomes? Could it allow farmers to buy modern inputs to facilitate the sales process and increase profits?

The role of ICTs is to provide information to farmers during the agriculture production cycle. Farmers need a precise set of information from the stage preceding cultivation to the harvest's marketing and sale (choice of crops, land, weather information, pest attacks, inputs price, cultivation practices, market information, and financial services). Mobile phones can contribute to productivity improvements by increasing farmers' access to knowledge and training programs. Thanks to these consulting production services via ICTs, the Farmer will no longer be limited to his sometimes less productive agricultural practices. Cole & Fernando (2016) show that demand for advice in rural India is high, and advice changes farmers' agricultural practices. Information provided via mobile phones to farmers increased their knowledge of available options for inputs such as seeds and fertilizers and choices of different crops leading to changes in their investment decisions and eventually to planting more profitable crops and increasing yields. Other information services from satellite imagery offer climatic information such as rainfall, temperature, evaporation. Analyzes of soil needs, of plague existence,

instantly adjust their production process (irrigation, fertilizer, pesticide ...). Other rather sophisticated precision farming systems use big data and artificial intelligence to increase big farms' yields and efficiency.

At the stage of selling the harvest, farmers need precise market information about prices in different local markets or contact potential buyers or advice about the marketing process. The usual information resources of farmers and other agricultural market agents are mainly their knowledge acquired through experiences, local social networks, namely the neighborhood of relatives and contacts, and in very remote areas, with deplorable infrastructure, and dispersed market. It is difficult to assume that market agents have all the information necessary to make optimal decisions. ICTs can rectify the market's irregularity and inefficiency caused by asymmetric information on prices of inputs and outputs and make connections between potential buyers and sellers.

Classic economic concepts can explain the potential impacts of more market efficiency by reducing market agents -as farmers and trackers - search costs when using ICTs. High search costs have tended to lower competition and create an inefficient allocation of goods across markets. In developing countries where markets are dispersed and infrastructure is lacking, farmers and traders face significant costs associated with acquiring that information (Bardhan (1989), Banerjee & Munshi (2004)). The reduction of information search costs via ICTs (Aker & Mbiti (2010), Aker & Fafchamps (2010), Aker & Fafchamps (2015), Nakasone *et al.* (2014)) makes it possible to reduce the time and the cost to access more precise

and extended geographic information. This spread of information allows them to benefit from the opportunities of space and time arbitration. These effects can be theatrical in rural developing countries, wherein in many places, mobile phones have represented the first modern telecommunications infrastructure of any kind. Jensen (2007) analyses the introduction of mobile phone coverage to estimate the impact of mobile phones on agricultural markets in developing countries. Examining mobile phones' effect on the fisheries sector in Kerala, India, Jensen finds that the expansion of mobile phone coverage leads to a significant reduction in the dispersion of fish prices across markets and a decline in waste. He shows that this leads to essential welfare improvements for fishermen and consumers; fishermen's profits increased by 8 percent, consumer prices declined by 4 percent, and consumer surplus increased by 6 percent. With improved access to information via mobile phones, fishermen can better take advantage of spatial arbitrage opportunities, thereby improving allocative efficiency. In the second chapter, we find that the informed sesame producer earns more (around 17%) by using temporal instead of spatial arbitrage as (Jensen (2007)).

Other researchers (citecourtois2014farmer and Fafchamps & Minten (2012)) examine another aspect, the impact of ICTs on the price or profit through the often less informed bargaining power Farmer and the better-informed tracker. The Farmer manages to negotiate his selling price better thanks to the market information momentarily received via ICTs. However, the reduction in transaction costs and bargaining power are closely linked. The Farmer does not have to seek

market information and can, at best, negotiate the sale price.

An element sometimes less taken into account is the ability to assimilate the information received. Thus, the information service design is suitable for farmers, popularizing scientific information to be better used by farmers, including illiterate farmers. Wyche & Steinfield (2016) discovered a mismatch between this service's design and smallholder farmers' perceptions of their mobile phones' communication capabilities. They find that innovations must not be solely technological; educational innovations are also necessary. They highlight the importance of educational interventions to ease the introduction of all new services and applications. In the second chapter, we show that the main barrier to information dissemination via SMS is education. We also discuss another issue, which is consulting market information and how farmers interact with it. We also discuss another issue that concerns market information, a market price assistant service s, which provides more than just price information but sometimes forecasts and advice and how farmers interact with it.

It is essential to highlight that our thesis focus on the use and accessibility of mobile phone more than the other ICTs such as internet; while the use of mobile telephony is widespread enough in Africa it is not the case for the internet. Mobile internet adoption currently stands at 24% in Sub-Saharan Africa. The region also accounts for 40% of the global population not covered by a mobile broadband network.

In the first chapter, we use a model to explain farmer marketing strategies to compare informed and uninformed and advised farmer profit. We discuss the bargaining game between farmer and tracker and farmer strategies during the sales period. We also discuss whether farmers' marketing behavior or the farmer marketing knowledge and price information are sufficient to make the best market decision. By examining the different market positions: low or high prices, soaring prices, or possible price reductions, it can be said that price information plus the marketing knowledge of the Farmer are sufficient during low agricultural seasons or when the price trend is on the decline. Consulting services can be more useful in atypical selling campaigns with soaring prices.

The second chapter is an empirical complement to the first one related to the experimental field. We examine whether market information enables African farmers to better worth their products. We conduct a randomized controlled trial of a commercial service entitled Nkalo that provides instant information about crop prices, the price tendency, and advice about crop quantities to sell. We focus on one cash crop: sesame, which is mainly intended for export to Burkina Faso. It constitutes a source of income for the farmers who produce this commodity. The question is whether the farmers manage to make better time arbitrage during the sales period and their choice of place of purchase (local market, or at the farm gate, cooperative) and the buyers. The Farmer must know first when to sell, and he must follow price evolution. The Nkalo service via mobile phones provides this information, so buyers are limited in their power to take advantage of the Farmer's

ignorance and buy at a low price. In other words, Farmer negotiates the price as best he can since he has all the elements of market information.

We are also interested in farmers' marketing strategies through a market information service and a market price assistant service that advises farmers on how to market their crop during sales periods. Therefore, we offer two different treatments to analyze farmers' behavior and strategies (the first treatment provides information on the current price in the region; the second treatment provides information on the current price in the area and price trend and advice on the quantity to sell). We focus on the impact of this information on the prices received by farmers, on their turnover, and their marketing behavior by analyzing their selling frequency, where they sell, and to whom. We find that providing price information increases farmers' prices by 4% on average regarding the treatment assignment. However, impacts differ according to the type of information received. Gains are concentrated among those receiving price information only. These gains occur through a change in marketing behavior: sellers reduce their sales frequency and concentrate their sales during peak price periods. We also report a heterogeneous distribution of the treatment between the treated using the quantile treatment effects procedure.

Along with the same perspective as mobile phones in Africa in innovative ways, the third chapter looks at the needs for financial services and how mobile money has overcome barriers faced by the poor population to reach these services. This form of banking has become more common in Africa in the last ten years. It al-

allows users to send and receive funds and to save money, allowing them to transfer purchasing power between households and over time effectively. The mobile phone can also be used to purchase goods and services and share valuable information. It represents an opportunity to overcome geographical constraints in rural African areas with limited or no access to traditional financial institutions. It also offers secure, efficient, and cheap access to financial services. This chapter investigates the impact of the mobile money launch in 2010 on the amount and frequency of funds sent and received among Malagasy households. Our data comes from the survey the 2015 Madagascar FinScope consumer survey.

We use a selection model combined with an instrumental variable approach to deal with the selective participation into the transfer market and the endogeneity of mobile money adoption. We find that mobile money provides effective financial services to populations out of reach of the standard institutional system. Mobile money acts as a substitute for traditional banking services by increasing the probability of sending and receiving money in remote areas.

Chapter 1

Should we inform farmers about market prices? Or advise them on marketing strategies to adopt?

Abstract

In several developing countries, information services via ICTs are developed more in the agricultural sector and mainly in the market price information of cash crops products. Because of physical barriers and distance, farmers in remote areas are disconnected from markets, and their uncertainty on the market price is very high. More information helps the Farmer sell his crop at the right time. He can also sell over a sales period that can extend over several months. The Farmer can sell at the farm gate, or he can move to the local market. Besides information services via ICTs, other consulting forms have emerged that assist the Farmer in his sales

strategies.

We learn through this model that the market price assistant service can be beneficial for farmers. However, it may sometimes disadvantage the bargaining power of the Farmer if the price trend is down. This consulting service can be criticized because it also ignores the knowledge of the Farmer and the local information of the Farmer. Therefore, it is necessary to adapt the information provided by these services to the market's price position.

Résumé

A cause de l'enclavement, des barrières physiques et de la distance, les agriculteurs dans les pays en développement ignorent parfois l'évolution des prix du marché de vente des produits agricoles. En effet, ces obstacles constituent une incertitude dans la prise de décision et leurs stratégies marketing. Dans ce contexte l'expansion des TICs dans les zones rurales représentent une opportunité d'intégration des agriculteurs via la diffusion de l'information des prix agricoles principalement pour des cultures rentières qui constituent une ressource principale de revenue. L'information pertinente diffusée peut permettre aux agriculteurs de vendre au mieux grâce à un arbitrage temporel. En conséquence, vendre pendant les pics de prix. En plus de la diffusion de l'information d'autre service de consulting via TICs accompagne l'agriculteur dans ses stratégies de vente et sa gestion des stocks de sa récolte.

A travers, ce chapitre nous apprenons que le service du consulting peut être utile lors des campagnes agricoles caractérisées par une flambée de prix. Cependant, il

peut affaiblir la pouvoir de négociation des agriculteurs en cas de baisse des prix. La critique principale adressée à ces services se manifeste dans leur négligence du savoir-faire commercial du fermier en le guidant dans ses pratiques de vente. Il est donc nécessaire d'adapter les services via les TICs aux besoins des fermiers et aux fluctuations des prix du marché.

1.1 Introduction

The agricultural sector is a principal source of income for a large part of Africa's population and an important sector in most African economies (23 percent of sub-Saharan Africa's GDP). Agricultural production in Africa is subsistence farming and can also be intended for export, including cotton, cashews, coffee, cocoa, peanut, sesame, etc. Cash crop production represents a direct source of household income, and their gains constitute an opportunity to improve farmers' financial situation. Therefore, farmers try their best to increase their profits by being strategic in their production choices and selling decisions.

Cash crop price received by farmers depends on price transmission from the world to domestic markets, which are central in understanding the extent of the integration of economic agents into the market process. The studies of price signals are founded on concepts related to competitive pricing behavior (Sarris *et al.* (2007)). The absence of market integration, or of complete pass-through of price changes from one market to another, has important implications for economic welfare. Incomplete price transmission arising due either to trade and other policies or due to transaction costs ¹ such as poor transport and communication infrastructure especially in developing countries, results in a reduction in the price information

¹Transaction costs cover essential costs of information (search and acquisition of information about potential transaction partners and their conditions;), costs of negotiation (Intensity and time consumption of negotiations, contract formulation and reach an agreement), costs of control and monitoring (Monitoring or enforcement costs occur ex-post to a transaction and are the costs of ensuring that the terms of the transaction, e.g., quality standards or payment arrangements, are adhered to by other parties to the transaction.)Picot (1981)

² available to economic agents and specifically farmers in this supply chain and consequently may lead to decisions that contribute to inefficient outcomes.

Therefore, asymmetric information can profoundly affect the small farmers' position in the agriculture sector in developing countries where they are often poorly integrated than other agents in the market and suffer from a lack of information in market price fluctuations because of high information costs. Searching for price information is very expensive for farmers. They have to be connected to the market by frequent visits to the marketplace or instantaneously receiving this information through other channels such as other producers and cooperatives. However, it cannot be available for those small farmers because they generally produce small quantities, and traveling to find the best price is not cost-effective. On the other hand, these remote areas suffer from a lack of transportation infrastructure. Better access to information can encourage agents to increase their participation in markets by reducing marketing costs, optimizing their position in markets, and having arguments and the capacity to negotiate the price.

Technology for diffusion information has the potential to provide cost-effective communication and reduce the search costs incurred by farmers and traders in developing countries (De Silva & Ratnadiwakara (2008)) (where the price of information is very high). In this context, mobile phones as the first available

²Price information plays a vital role in arbitrage behavior and market efficiency (Enke (1951), Samuelson (1952), Takayama & Judge (1971). (Stigler (1961)) economists have been trying to explain how asymmetric information (see by Akerlof *et al.* (2001)) and costly search can result in equilibrium price dispersion for homogeneous goods (Malkiel & Fama (1970)).

modern telecommunication infrastructure spreading rapidly ³ in rural Africa connect users and have significantly reduced communication and marketing costs by providing information quickly and cheaply (Aker & Mbiti (2010)). It represents an opportunity for the agriculture sector to increase farmer's welfare by improving access to information (World-Bank (2014)). Farmers' profits can be increased by enhancing sales distribution over time according to local and international demand mainly for cash crops and arbitrage between markets and allowing them to be more strategic on one hand (Jensen (2007), Fafchamps & Minten (2012)), on the other hand by enhancing their bargaining power through mobile phone market information services (Courtois & Subervie (2014), Dixit *et al.* (2010)).

Before selling, the Farmer builds up his inventory management and marketing strategy by seeking relevant information on selling prices. They use their knowledge and know-how and information announced by other farmers closest to the village their price forecast, or their selling price if they have already sold their crop. This information does not give them precise information because some crops' prices can fluctuate over a short period. Besides, the selling cost also includes transportation cost if the Farmer decides to go to the market. Also, it consists of the cost of transporting the tracker if he comes to collect the production at the farm gate (It is the case of some cash crops, which the price depends principally on the foreign demand).

³Mobile phone subscriptions are now almost nine times higher in Africa than in the year 2000, reaching about 4131 million people available at <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx> and last access in 28st of January 2020

Increasing farmers' earnings can be done through two channels, selling at the best price and (at the right time) and all production. This chapter aims to compare Farmer's selling price and profit when they are informed about the market price via a mobile phone and when they do not have this information. We will also test if farmers benefit from the current market information service via mobile phone and which strategy he will adopt when market prices fluctuate. Should we be satisfied with the information on the market price? How could the price expectation affect the current price? What is the main element that impact farmers selling decision? It is more desirable to analyze market price fluctuations and a market price assistant service on crop stock management. How should we help the farmers have more substantial bargaining power?

We begin our study by representing the farmer's profit during the sale period. After that, we report on the Farmer's marketing strategy to determine when he decides to sell his crops and how much he decides to sell, considering the construction of the selling price, which depends on the information acquired. We should emphasize that farmers prefer to sell immediately after harvesting because of liquidity needs. This work is related to Courtois & Subervie (2014) and Fafchamps & Minten (2012). The model describes the interactions between farmers and the tracker at each selling period and how the Farmer decides to manage his stock-taking into account the information received and his own beliefs. At each selling time during the sale period, a farmer and a tracker play a game of negotiation in which each tries his best to buy at a lower price or sell at a higher price at the

farmer's gate. The sale period is simplified to two periods and the negotiation between the two players. The Farmer can store his crop during the sales period instead of the Courtois & Subervie (2014) model. When the Farmer does not subscribe to the MIS (Market Information Service), he assigns a probability to each possible historical state of the market price to establish his price project.

We solve the game by backward induction and compare the equilibrium reached with and without the market information service or consulting service. One of the essential variables to build the uninformed Farmer and the Farmer's strategy with the market information service is the target price P_s , from which the Farmer is ready to sell everything in the first period of sales because they assume that the price doesn't go beyond the target price. To calculate an informed and uninformed farmer's profit, we compare several price situations from this target price P_s . Both types of farmers are ready to sell the entire crop at the beginning of the sales period if the price received exceeds P_s (because of their liquidity needs). Otherwise, they will spread their sales over two periods hoping to attain this price for the next selling period. However, the informed Farmer knows the current market price, unlike the uninformed Farmer, who has a price expectation based on observed historical prices. So, the uninformed Farmer may miss opportunities. He is at a disadvantage if prices are high and may have had a higher price if he was informed. However, he can share the trackers' profit margins who seek to secure the deal if prices are low, according to farmer expectation market is higher than

what is proposed by the tracker.

In the event of a price surge that exceeds the target price P_s throughout the selling period, the most favored Farmer is the Farmer with an assistant market service, even if the price forecast is incorrect because he had a better bargaining power position could use this information as an argument. On the other hand, if the price trend is downward, it weakens the assisted Farmer's bargaining power, who rushes to sell at lower prices. Hence, the information dissemination design is essential; it should not neglect the Farmer's know-how and should strengthen the Farmer's bargaining power. The rest of the chapter is organized as follows. In Section 2 we present the conceptual framework for our explanatory model. More information about the interaction between farmers and trackers is given in Section 3. The fourth section reports intuitions on the profits generated according to the different types of information. It provides recommendations to information consulting services to configure the information adapted to market price fluctuations.

1.2 Conceptual framework

The chapter's objective is to simulate farmers' earnings, informed or not, in different market situations when prices fluctuate (high or low). On the other hand, it is also a matter of understanding their behavior towards stock management advice during the sales period and information on price trend expectations. Therefore, we model a group of informed farmers who receive market information and price information by mobile phone. A group of farmers assisted by offering a market price assistant service on the quantity to be sold and expectations on price trends. We then develop an explanatory model of farmers' different marketing strategies based on the information received or a market price assistant service. This model's objective is to explain how the selling price is constructed instantaneously concerning the negotiation between the different types of farmers (informed or uninformed or advised) and the buyer.

We consider a farmer denoted F, who can sell in the market-place or at the farmer gate to a tracker. The Farmer has a unit transportation cost to travel and sell in the market denoted c_f , which is more expensive than the transportation unit cost incurred by the tracker c_t , $c_f > c_t$ ⁴. We assume that transportation costs don't fluctuate during the selling period. Farmers sell all their production the same campaign, so he can not store and resell in the next year. However, they

⁴In addition to the low costs of the trackers, they can benefit from digressive costs since they can collect several harvests from neighbouring farmers during the same trip.

can hold the harvest during the sales period. We assume that the Farmer is a price taker and adapts to the market price. For this type of cash crop, the government often announces at the start of the sales campaign a floor price P_f . Therefore it is not recommended to sell below P_f . It is emphasized that the Farmer is ready to sell the whole of the production if he reaches a target price that we denote P_s according to his own beliefs on what would be the price peak during the sales period. This price mainly reflects the Farmer's knowledge of market marketing strategies. The tracker, as a market agent, is also aware of this target price. It may correspond principally to the best price observed during previous years.

The tracker joins the Farmer at the farm gate to buy the crop. During the negotiation, they try to reach an agreement that satisfies both parties. Any failure to get a deal is a zero gain for both parties and even a negative one for the tracker, who has minimal travel costs. During the negotiation, the Farmer wants to sell at a high price and the tracker at the lowest possible price. It is assumed that the Farmer cannot sell his crop at a price below his cost of production or the P_f floor price. Besides, he has a reservation price Pr_t , which he constructs from the information received and from his own knowledge and experience.

We consider that $P_f \leq Pr_t \leq P_t^m - c_f$, where P_t^m is the market price at time t . The Farmer can sell at time $t = 0$ or later at $t + n$ where ($n \in 1 \dots N$ where N sequences represent the end of the sales period). We suppose that at any time, a profitable deal between the Farmer and the trader does exist. The Farmer has the totality of the harvest Q at time $t = 0$, and he can sell one time or spread

the crop sale during the sales period.

At any time t , the farmer i tries to maximize his profit π_i based on the information received. To get the best price during his negotiation process with the tracker. The latter seeks to buy at a low price to increase his share of the profit margins. The farmers' budget constraint considers that profit π_i cover at least production cost. $\forall t \in 0..N$,

$$\max \pi_i = \sum_{t=0}^N (\alpha_t) * \frac{E[P_t - Pr_t]}{(1 + \tau)^t} * Q \quad (1.1)$$

$$s.t \quad P_t \geq Pr_t \quad (1.2)$$

Where α_t is the part of sales (and $\sum_{t=1}^N (\alpha_t) = 1$), Pr a reservation price which we denote, $1 + \tau$ is the cost of postponing the sale at the next period. We suppose that the bargaining between the two agents takes place in a finite sequence of two periods during the selling period.

$$\max \pi_i = \alpha_t * (P_t - Pr_t) * Q + (1 - \alpha_t) * \frac{E[P_{t+1} - Pr_{t+1}]}{1 + \tau} * Q \quad (1.3)$$

$$s.t \quad P_t \geq Pr_t \quad (1.4)$$

1.3 Model

This section explains how farmers can manage their inventory over time to sell at the best price based on their knowledge and beliefs or the information they receive or sales advice. We assume that farmers generally prefer to sell immedi-

ately because of their liquidity needs, and this kind of crop is considered cash for farmers. They choose to spread out their sales or sell on once. There are three levels of information from information based on the Farmer's knowledge and the information that is gathered around him, to the second level of the information supplied by a source of instant market information via mobile phones. In addition to the Farmer's knowledge, the Farmer follows the advice of a market price assistant service of scientists on the selling price and the quantity to sell. Three types of farmers are therefore studied" Farmers without market information";" Farmers with price market information via mobile phone," and" Farmers with market information, forecast and a market price assistant service."

It should be emphasized that the model presented does not allow spatial arbitrage. Otherwise, the Farmer can move to sell in distant markets, which is very rare in developing countries given the very high transportation costs and the increased uncertainty of prices' geographical distribution. Furthermore, in the following chapter, it is observed that in the case of Burkina Faso, there are additional insecurity problems. Therefore, believing that the Farmer can take his harvest and go around the different markets is far from reality.

1.3.1 Farmers without market information

This Farmer has not received any market information by mobile phone, so he will have to make do with his knowledge and experience. He has a double game and

strategies to think about it. He has to choose where to sell (in the market or at the farm gate) and when to sell (at t or $t+n$). Note that the Farmer must know the price at time t to make any price forecast at time $t + 1$.

To solve the game with incomplete information, the use of Bayesian Nash Equilibrium is required in uncertain environments. Players choose strategic equilibrium notions, so they maximize their payoffs in response to uncertainty about how other individuals are going to play, and, what the payoffs are from different actions.

In this situation the farmer tries his best according to farmer knowledge and beliefs to construct a good prediction of market prices distribution $E(P_t^m) = F(P_t^m) = b_1[a_1 * P_1^{max} + (1 - a_1) * P_1^{min}] + b_2[a_2 * P_2^{max} + (1 - a_2) * P_2^{min}] + \dots + b_{t-1}[a_{t-1} * P_{t-1}^{max} + (1 - a_{t-1}) * P_{t-1}^{min}]$ during selling period. Where P_t^{max} , P_t^{min} are the maximum and minimum price and observed in the crop year t respectively. a_t the probability that the market price is high and $1 - a_t$ denotes the probability that the market prices is low. b_t a weighting coefficient decreasing over the time that each period represents in the construction of the price. ⁵ At time t , the farmer expects the price to be $F(P_t^m)$.

To increase their profit margins, trackers offer a lower price ⁶ than the farmer will get if they go to market, they take advantage of the farmers' ignorance to generate more income. The farmer also has the bargaining power to increase the price

⁵We can suppose that the farmer retains a market price based on his background on previous crop price to the maximum P_{t-1}^{m+} and minimum price P_{t-1}^{m-} of the market and the price evolution during sells periods. They denoted by β_t the probability that market price is high and $1 - \beta_t$ to denote that the market prices is low as represented by Courtois & Subervie (2014)

⁶We exclude transportation cost on this price

received in order to sell his crop as well as possible according to his expectation of the current price. They must therefore find a compromise to guarantee the sale agreement, otherwise the profit observed for both agents will be zero or even a loss for the tracker and a postponement of sale for the producer. Depending on the price proposed by the tracker, farmers have the possibility to sell all or part of their crop at the moment t . They can also sell on the farm or on the local market if they cannot get a deal from the tracker at time t or postpone their sale to the next period $t + 1$, depending on their beliefs about when it is most profitable to sell. We exclude in our analysis any premature sales caused by farmers' liquidity needs.

The Farmer starts by comparing the price proposed by the tracker to his reserve price minus the transportation cost,

At time $t = 1$ the tracker proposes a price P_1

- If $P_t \geq P_s$: The farmer sells all the harvest Q to the tracker if he proposed a price higher or equal to $F(P_{t-1}^m) - c_f$,
- If $P_r \leq P_t < P_s$: The farmer sells a part of the harvest $\alpha * Q$ at P_1 because he hopes to sell the rest at a better price P_s
- If $P_t < P_r$: He prefers to travel to the marketplaces, and sell all the harvest at $P_m - c_f$. If the farmer chooses to go to the market, he cannot afford to go home with part of the harvest because of the transport costs.

If we want to study the equilibrium in the first period, and discuss the gains

of each player. We need to know if the market prices are higher or if the market is very low. Then when prices are very low, the tracker is not able to offer the farmer the price he was hoping to receive. He can share his profit margin to secure this deal, however he must retain a positive utility.

$$P^m - [b_1[a_1 * P_1^{max} + (1 - a_1) * P_1^{min}] + b_2[a_2 * P_2^{max} + (1 - a_2) * P_2^{min}] + \dots + b_{t-1}[a_{t-1} * P_{t-1}^{max} + (1 - a_{t-1}) * P_{t-1}^{min}] - c_f] - c_t > 0$$

$$P^m - F(P_{t-1}^m) > c_t - c_f$$

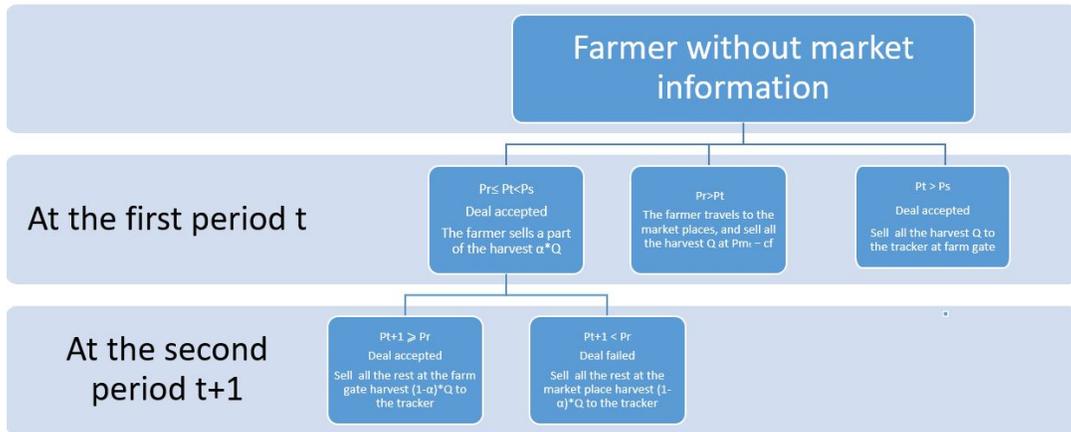
$P^m - F(P_{t-1}^m) \leq c_f - c_t$ The farmer can reject this deal if the cost of transport is close to that of the tracker, or if it is a product with a highly volatile price. The farmer is convinced that he can do better if he goes to market. However, the farmer is sometimes forced to accept this agreement if he lives in an insecure region as we will observe in the case of sesame producers in Burkina Faso in the next chapter.

If the market price is high enough, the tracker takes advantage of the situation to offer the farmer $F(P_{t-1}^m) - c_f$ if $P_t^m - F(P_{t-1}^m) \leq c_f - c_t$. If the market price is higher than the farmers target price $P_t^m > P_s$ the tracker offers P_s and buys all the production, Otherwise he sells a part of the production at time t and the rest at t + 1.

If the market price is rather high, the tracker takes advantage of the situation and offers the farmer P_s to secure the deal. Figure 1.1, draws the farmer's strategy taking into account the possibilities of market price fluctuation as

discussed above.

Figure 1.1: Diagram of Farmer's' strategies without market information service



1.3.2 Farmer with Price market information service

In addition to his knowledge of marketing practices and experiences, this Farmer is informed about current market price Pm_t at time t . However, the SMS didn't notify him about price expectations in the coming period. In this case, the Farmer uses his knowledge presented by the target price P_s , fed by the price market information services. Farmers can, in this case, choose where to sell by comparing the price offered by the tracker minus transportation cost.

At home, without traveling to the market, this Farmer can design the quantity to sell at time t and $t + 1$ using the information market price for time t . The Farmer expects his reserve price at time t to be $P_r = P_m - c_f$ and sets their price expectation and beliefs for time $t+1$.

The information received by the Farmer is in the form of a price range, consisting of a maximum price (the best selling price at time t) and the minimum price below which it is not advantageous to sell $[P_{min}, P_{max}]$. Whether the maximum or minimum price is obtained depends on the local situation since the price range received is a price range for localities as large as the region. Therefore, the farmer's local market price depends on other factors, namely the degree of remoteness of the commune, its security situation on the one hand, and the Farmer's bargaining power on the other. The cost of joining the service is assumed to be zero.⁷ Both farmers and tracker are correctly informed at time t about the market situation,

⁷That was the case in our complementary experiment in next chapter

and the Farmer's reserve price, in this case, is $P_r = P_{min} - c_f$ and the target price P_s .

The idea is to model a bargaining game between the Farmer and the tracker when they meet at the farm to sell the crop. A compromise of sale between the Farmer and the tracker, is to share the benefits that will be realized. Morgenstern (1973), Ståhl (1977) and Rubinstein (1982) propose a procedure of negotiation between these two players with perfect information. The proposed approach is the Nash sub-game equilibrium. The benefits sharing is $B = P_{max} - P_{min} - c_t - c_f$. We solve the problem by backward induction, where both players reach an agreement in the initial phase. The negotiation between the two players is as follows:

- The negotiation phase is active at stages $t \in [1, 2, \dots, T]$. We assume that $T \in N$. In steps pairs, the farmer makes an offer, his profit is $x^t \in [0, B]$. At odd stages, the tracker makes an offer to purchase whose profit $x^t \in [0, B]$. So he offers the complementary share $B - x^t$ to the farmer.
- At each step t , and following the offer of the player $i(t)$ the player $i(t + 1)$ has the choice to accept - action a - or to refuse - action r - this offer. Each player gains discount rate $\zeta \in [0, 1]$ that measure impatience, the closer ζ is to zero, the stronger the incentive to get a deal quickly.
- If $i(t + 1)$ does not accept this offer, two possibilities are available:
 - $t < T$, In this case the negotiation process continues at step $t + 1$. It is the player $i(t + 1)$'s turn to make a counter offer that his partner can

either accept or refuse.

- $t = T$. In this case, the game is over and both players cash gain of zero.

This game is incomplete and perfect information. It describes an offer and counteroffer process such that if agreement on the value x is not reached at a stage in the process, then the negotiation continues to the next step, if possible. If the process has reached T and the players have not reached an agreement on the value taken by x , the negotiation has failed, and the value is zero gain. This negotiation procedure reveals that the passage of time and the passage from one stage to another is an expensive operation for the players because the latter update their rates ζ .

In general, by setting $X = [0, 1]$ and designating by X^t the set of sequences of length $t \in [1, 2, \dots, T]$ of the form $(x_{(k)} : x_{(k)}, K \in [1, 2, \dots, t])$,

- The tracker's strategy is a series of applications $s_1 = (s_1^t : t \in [1, 2, \dots, T])$
 - $s_1^1 : \mathcal{X}_0 \rightarrow X$
 - For each $t > 1$ odd, $s_1^t : X^{t-1} \rightarrow X$;
 - For even t $s_1^t : X^t \rightarrow (a, r)$.
- The farmer's strategy is similar to the tracker one, it is a series of applications.
- The tracker's strategy is a series of applications $s_2 = (s_2^t : t \in [1, 2, \dots, T])$

- For odd t $s_2^t : X^t \rightarrow (a, r)$
- For even $s_2^t : X^{t-1} \rightarrow X^t$

A perfect Nash equilibrium in Morgenstern (1973), Ståhl (1977) and Rubinstein (1982) bargaining sub-games is a strategy profile (s_1, s_2) , which induces a Nash equilibrium in each sub-game following a series of offers. This game admits a unique balance of perfect Nash in sub-games on which the players reach an agreement during the initial stage. This result is contained Morgenstern (1973), and Ståhl (1977) theorem.

We assume that at each instant t there are two negotiation stages. Now considering the sub-games that take root at the first stage. The Farmer accepts a tracker proposal price at the second stage of negotiation if it equals at $P_r = P_{max} - c_f$. To maximize his utility, the farmer accepts any offer

$$P_t \geq (P_{max} - P_{min})\zeta_f + (P_{min} - c_f)$$

We can rewrite as Courtois & Subervie (2014): $P_t \geq (P_{max} - c_f)\zeta_f + (P_{min} - c_f)(1 - \zeta_f)$

The tracker offers $P_t = (P_{max} - c_f)\zeta_f + (P_{min} - c_f)(1 - \zeta_f)$ which the Farmer accepts immediately to sell at the farmer gate. At this time, the Farmer decides on the quantity of crop to sell. In addition to negotiating the price, the Farmer must also decide the quantity to be sold throughout the sales period. The tracker also knows that the Farmer prefers to sell the whole crop in the first sales period at a price at least equal to $P_1 \geq P_s$. Otherwise, the farmer sells a quantity $\alpha * Q$

in the first period and the rest $(1 - \alpha) * Q$ in the second period.

At time t $P_t = (P_{max} - c_f)\zeta_f + (P_{min} - c_f)(1 - \zeta_f)$

- If $P_t \geq P_s$ the farmer sells all the harvest Q and nothing at $t + 1$

– In this case the profit of the farmer and the tracker is as follows

$$\pi_{if} = (P_t - P_f) * Q \quad (1.5)$$

$$\pi_{if} = ((P_{max} - c_f)\zeta_f + (P_{min} - c_f)(1 - \zeta_f) - P_f) * Q \quad (1.6)$$

$$\pi_{if} = (P_{max} - P_t - c_t) * Q \quad (1.7)$$

$$\pi_{if} = (P_{max} - (P_{max} - c_f)\zeta_f + (P_{min} - c_f)(1 - \zeta_f) - c_t) * Q \quad (1.8)$$

In this case, the Farmer bets on the first sales period of t . He will have made the best choice if prices do not increase more in the following period $t + 1$. This is the case of instant price spikes where it is more profitable to sell.

- If $P_t < P_s$ the farmer sells $\alpha * Q$ and he hopes to sell the rest $(1 - \alpha) * Q$ at a better price of at least P_s . The Farmer, in this case, expected to sell at a higher price later. However, he chooses an approach in which he expressed that he has a degree of risk aversion, which drives him to spread sales between periods.

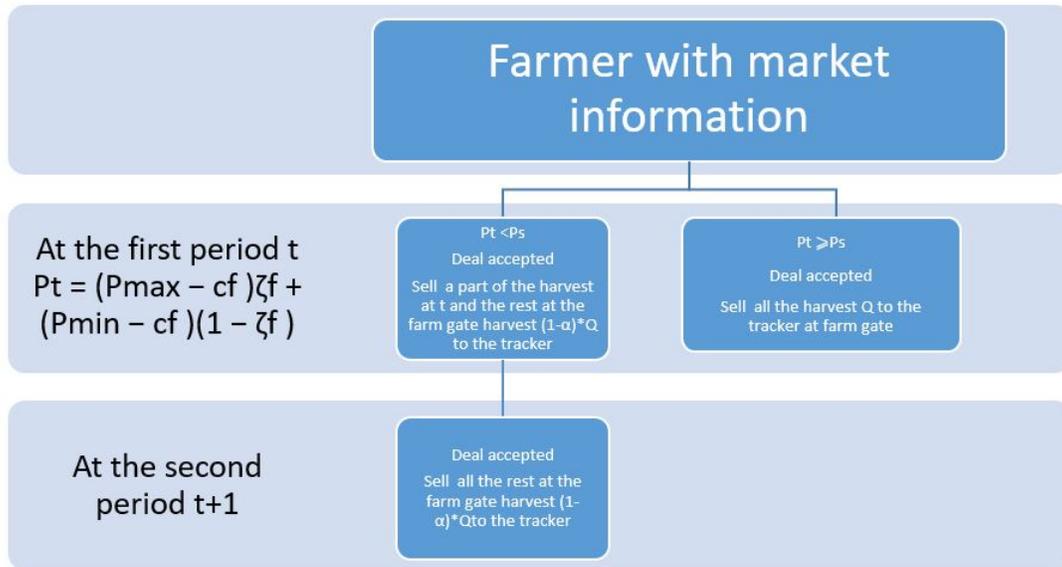
$$\pi_{if} = (P_t - P_f) * Q \quad (1.9)$$

$$\pi_{if} = \alpha_t * (P_t - P_f) * Q + (1 - \alpha_t) * \frac{E[P_{t+1} - P_f]}{1 + \tau} * Q \quad (1.10)$$

$$\pi_{if} = \alpha_t * ((P_{tmax} - c_f)\zeta_f + (P_{tmin} - c_f)(1 - \zeta_f) - P_f) * Q + (1 - \alpha_t) * \frac{E[P_{t+1} - P_f]}{1 + \tau} * Q \quad (1.11)$$

If prices increase during the period $t + 1$, the farmer was right to postpone part of the sales. Otherwise, if the market prices fall or stagnate, its report was wrong. Figure 1.2 summarized farmer marketing strategies taking in account the market information services.

Figure 1.2: Diagram of strategies for farmers with price information



1.3.3 ”Farmer with market information, forecast and a market price assistant service ”

This Farmer has additional information than the previous Farmer and a market price assistant service to help him manage crop stocks during the sales period. Thus, a consulting service is available to give him guidelines for allocating his sales and information on the market price and forecasts on the price trend. At this time, this service advises him to sell part of the crop ($\omega_t * Q$ and $\sum_{t=1}^N(\omega_t) = 1$). We assume that Farmer follows the recommendations received and ignores his knowledge and the local market conditions and situation. This Farmer is less interested in the target price but instead follows the recommendations of the service. The element that determines the quantity to be sold for each instant t is the forecast of the direction of the trend (up or down) and the share of the crop to be sold ($\omega * Q$). On the other hand, the price indicated by these services is in the form of a range $[P_{min}, P_{max}]$, as shown for the Farmer who has market information services, so the construction of the selling price will depend on this price range, the Farmer’s bargaining power which is a function of the market price (whether the forecasts are up or down). The Farmer can use the information of an upward trend to sell at the upper end of the range. Indeed, he can argue that the price will rise even more in the next period, and his proposal is cheap for the tracker. However, he will rush to sell at the lower limit if the trend is downward since he considers that any delay in selling could be an expected loss.

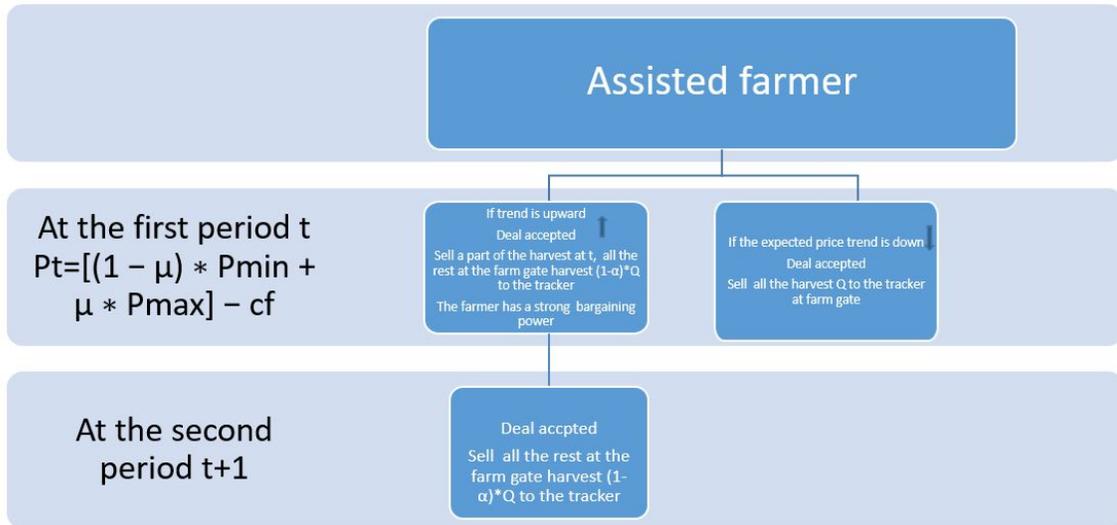
Since he knows the market price, the farmer agrees to sell his crop if he is offered a price higher than $(1 - \mu) * P_{min} + \mu * P_{max} - c_f$, otherwise he goes to the market to sell his crop. Where $\mu \in [0,1]$ represents bargaining power depending on the market situation, excluding price expectations. When prices are expected to rise, the farmer has more bargaining power in the current period. In order to spread sales and risk management, the consulting service advises the farmer to sell part of the crop and later. Figure 1.3 summarizes farmers' market strategies when they are assisted by a market price assistant service .⁸

At the time t=1

- If the trend is upward (we inform the farmer that the price will increase in the next days for the period $t + 1$, the farmer decides to sell little of his crop at the time t ($\omega * Q$) the farmer agreed to sell if and only if the price is equal to $P_t = [(1 - \mu^+) * P_{min} - c_f + \mu^+ * P_{max}] - c_f$ and $P_t > P_{min} - c_f$. His bargaining power is very high, because it can be argued that prices will rise later and sells the rest at $t + 1$ ($(1 - \omega) * Q$) where ($\omega > (1 - \omega)$),
- If the expected price trend is down, the farmer rushes to sell all the harvest Q at the instant t , his bargaining power in this case is very low and accepts any price $P_t = [(1 - \mu^-) * P_{min} - c_f + \mu^- * P_{max}] - c_f$ greater than or equal to $P_t \geq P_{min} - c_f$.

⁸to manage their stock and sales

Figure 1.3: Diagram of strategies for farmers with price information and a market price assistant service



1.4 The gain by group and situation

To calculate the overall gain periods, we suppose we are at $t + 1$, and we list different scenarios

- A variable that is very important for the constitution of our model is the expected sale price;
- P_s The target price, from which the Farmer is ready to sell everything. To calculate the profit of informed, assisted, and uninformed Farmer, we compare several situations from this target price P_s ;
- The price trend mentioned by the service assisting farmers every instant t is a forecast by experts based on their market study to which we can allocate

a probability of realization;

- Another element that determines farmers' profit throughout the sales period is the quantity sold in each period. The time trade-off that farmers adopt as a strategy for marketing cash crops.

In the event of a spike in prices during the sales period, when prices rise and exceed the target price $P_{t+1} \geq P_s$, the group without information and the group informed about the price are the least advantaged. In case they have sold all the harvest Q at the instant t . If the forecast on the price trend was upwards and the market price assistant service advised farmers to sell more at $t + 1$. In this case, this assisted group is more advantageous than the other two groups. If the service had somewhat wrongly predicted a downward trend, the assisted group's situation remains more beneficial than the other two groups. However, its profit would not have reached its optimum value. Furthermore, he could have done better if he had postponed all sales Q at $t + 1$.

Result 1 In the event of a spike in prices throughout the sales period, the most advantaged Farmer is the assisted Farmer, even if the trend price forecast is incorrect. In the event of an instantaneous price peak at the instant t which exceeds $P_t > P_s$, farmers informed of the price will be the most advantaged since they will sell all of the harvest Q at once. The Farmer who is not informed may not take full advantage of this possibility, as he is not informed and prefers not to go to the market, as the tracker will simply offer him the target price. The Farmer will

be satisfied with this deal, unaware that the market has exceeded its target price. The assisted Farmer will benefit in part from this situation because he is informed of the price. His rush to sell due to the expected price cuts can put him in a weak trading position. Any price offered by the tracker greater than P_{min} will be accepted. **Result 2** In the event of an instantaneous price peak at the instant t which exceeds $P_t > P_s$, the most advantaged Farmer, is the informed Farmer.

If prices fall in the second period $t + 1$. A different situation is possible: if at the instant t the market price was more significant than or equal to the target price $P_t^m \geq P_s$ the informed price $P_t^{min} < P_s \leq P_t^{max}$. Farmers without market information have already sold the entire crop. They will not be affected by this price drop. Farmers who receive market price information have already sold in the previous period at a price that may be higher than those obtained by uninformed farmers if the market price has exceeded the target price P_s . Farmers assisted in making their sales will also rush to sell. The only point to note is that this decrease informs them that their bargaining power vis-à-vis the tracker is feeble. He will accept any price offered by the tracker, which is $P_t^{min} - c_f$. In this case, this information - of a downward trend and the advice to sell as quickly as possible - results in a Farmer's weak position. He will be the least advantage compared to other farmers.

Result 3

The price P_s represents the local information of the Farmer's know-how that we neglect if we assisted him with these actions. Not ignoring the knowledge of farm-

ers and local news, a consulting service throughout the sales strategy is not always beneficial.

In the same situation, if the price drops in the period $t + 1$ but this time the market price is lower than the target price. The Farmer not informed by the market price will divide his sales into two periods, so his gains will not be optimal over the whole period. The farmer informed by the price will not obtain an optimal payment because he postponed the sale to the following period. The Farmer assisted in making his sales take advantage of this a market price assistant service because he sold everything in the first period.

The assisted Farmer's bargaining power is feeble if the low-priced crop year drops further as he will rush to sell the entire crop at any price above $P_{min} - c_f$. The informed Farmer can better negotiate at period t . But, if he chooses to sell over several periods, he will be disadvantaged because prices will fall. The uninformed Farmer may profit from his ignorance, and it may require a better price to the previous, where the tracker will share its profit margins to conclude a deal.

1.5 Conclusion

This chapter aims to compare the different situations of the farmer concerning the information received. How the additional information received affects the Farmer's bargaining power. The maximization of the earnings from the sale of

cash crops is based on a temporal arbitration to distribute the crop sales during the sales period, hence the question on the market price assistant service offered. To best assist farmers' sales over time. It turns out that the consulting service is more advantageous during campaigns where prices are very high. However, it disadvantages the Farmer if there is a downward trend that triggers a rushed behavior to sell, which weakens the Farmer's bargaining power. The instant price information is crucial in making the right decision for farmers, given the market price. Indeed, thanks to this information, the farmer will not move to the local market. He can sell at the farm gate with all serenity that he has not missed a better offer on the market. This avoids negotiation failure between the Farmer and the tracker. The model shows that uninformed farmers can benefit if market prices are low; this situation can risk deal failure between Farmer and tracker.

The model also teaches us that local information and the Farmer's knowledge should not be neglected. The consulting service must adapt the information disseminated according to the different market situations. Be content to inform about prices when he considers a fall in the price trend, solicit farmers to sell later when prices have an upward trend.

To summarize the model's assumptions: the Farmer's know-how may not be restricted to a target price. Other elements affect the farmers' target price and marketing decisions, such as their liquidity needs, and assuming that farmers will strictly follow the market price assistant service. In practice, farmers may be more receptive to an upward price trend and, on the contrary, doubt a downward trend,

so in the hope of a price increase, they postpone their sales. These behaviors will be better analyzed in the empirical approach of the next chapter.

The next chapter is a complementary empirical study of this introductory chapter on the perceived gains from market information services, focusing on sesame producers' case in Burkina Faso. We conduct a randomized controlled experiment to quantify the effects of this information and consulting services on farmers' agriculture incomes in Africa.

Chapter 2

The value of information: Evidence from Burkina-Faso sesame producers

Abstract

Does market information through mobile phones enable African farmers to value their products better? To answer this question, we run a randomized controlled trial (RCT) in Burkina Faso, focusing on sesame producers: an important cash-crop production. We consider two types of treatment: the first provides information on prices estimated at the regional level, and the second one includes information on price trends, and gives selling advice. On average, we find that the information signal increases prices paid to farmers by 4%. However, impacts differ according to the type of information received. Gains are concentrated

among those receiving price information only. These gains occur through a change in marketing behavior: sellers reduce the frequency of their sales, concentrating their sales during peak price periods. We proceed by quantile treatment effects to capture the heterogeneous effect that may limit the average effect. To explain how the intervention of the market information services affects the distribution of selling price and turnover.

Keywords: Information technology; agriculture; impact evaluation; Price information; Mobile phone; cash crops; Burkina Faso.

Résumé

La diffusion des informations marchandes permet-elle aux agriculteurs africains de mieux valoriser leurs produits? Afin de répondre à cette question, nous mettons en place une expérience randomisée contrôlée au Burkina Faso en se focalisant sur un produit rentier qui est le sésame. Deux traitements ont été instaurés afin d'estimer leurs impacts sur le prix reçu et chiffre d'affaire des fermiers d'une part et de comprendre leurs comportements et leurs stratégies marketing d'autre part. Le premier traitement consiste à fournir des informations sur les prix à l'échelle régionale. Un second traitement, rajoute des informations sur la tendance des prix et conseille les agriculteurs sur la gestion de leur stock. En moyenne, l'information reçue permet aux agriculteurs d'augmenter leur prix de 4 % en termes d'assignement aléatoire au traitement. Par ailleurs, les impacts des deux traitements diffèrent selon le type d'informations. Les gains sont concentrés principalement chez ceux qui reçoivent uniquement des informations sur les prix. Ces

gains sont fruits d'un changement de comportement marketing. En effet, les producteurs réduisent la fréquence de leurs ventes et les concentrent pendant les périodes de pics de prix. Nous analysons aussi les possibilités de présence d'une hétérogénéité de la distribution du prix et chiffre d'affaires des fermiers traités qui pourrait limiter l'effet moyen du traitement en utilisant une procédure de «quantile treatment effect».

Mot Clés: Expérience contrôlée randomisée, Technologie d'information; Agriculture; Evaluation d'impact; Information marché; Téléphone portable; Produits agricoles rentier; Burkina Faso.

2.1 Introduction

According to economic theory, the spatial equilibrium theory (Enke (1951), Samuelson (1952), Takayama & Judge (1971)) suggests that arbitrage makes the market efficient. After the publication of Stigler's seminal article *The Economics of Information* (Stigler (1961)), economists have been trying to explain how asymmetric information (see by Akerlof *et al.* (2001)) and costly search can result in equilibrium price dispersion for homogeneous goods (Malkiel & Fama (1970)). This asymmetric information situation can profoundly affect the small Farmer's position in the agriculture sector in developing countries where they are often poorly integrated. These farmers are unaware of the international price for commodities designated for exportation and inefficient supply chain caused by the presence of intermediates who take advantage of farmer's ignorance of the fluctuation of prices (Bardhan (1989), Fafchamps & Hill (2008)).

Moreover, access to information is an essential issue in farmers' marketing decisions to enhance their sales strategies. In developing countries, looking for price information is very costly since farmers have to travel to expose their harvest to different markets, which entails substantial transportation costs. Sometimes, it cannot be available for those small farmers because they generally produce small quantities, and traveling to find the best price is not cost-effective. Besides, these remote areas suffer from a lack of transportation infrastructure. Better access to information can encourage agents to increase their participation in markets by re-

ducing marketing costs, optimizing their market position, and having arguments and the capacity to negotiate the price.

In this context, a new technology for diffusion information can have important implications for market agents' behavior and may overcome imperfect information problems using ICTs (Information and Communication Technologies). ICTs have the potential to provide cost-effective communication and reduce the search costs incurred by farmers and traders in developing countries (where the cost of search information is very high). In rural Africa, mobile phones represent the first modern telecommunications infrastructure. The use of mobile phones has been expanding rapidly.¹ Mobile phones connect users and have greatly reduced communication and marketing costs, by providing information quickly and cheaply (Aker & Mbiti (2010)). It represents an opportunity for the agriculture sector to increase farmer's welfare by improving access to information (World-Bank (2014)). Farmers' profits can be increased by improving sales distribution over time according to local and international demand mainly for cash crops and arbitrage between markets and allowing them to be more strategic in one hand (Jensen (2007), Fafchamps & Minten (2012)), in the other hand by enhancing their bargaining power through mobile phone market information services (Courtois & Subervie (2014), Dixit *et al.* (2010)).

This chapter examines whether market information services by mobile phone al-

¹Mobile phone subscriptions are now almost nine times higher in Africa than in the year 2000, reaching about 4131 million people available at <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx> and last access in 28st of January 2020

low African farmers to better worth their products? Besides, which is the relevant information for those farmers? We also analyze through which mechanism this market information enhances farmers' benefits or how they profit from this information signal? (i) is a better arbitrage across space as (Jensen (2007)). Using micro-level survey data Jensen (2007) states that mobile phones help fishermen choose a fish market to sell their fish at the highest prices. He shows that this contributes to increase welfare for both fishermen and consumers. According to this study, fisherman's profits increased by 8%, consumer surplus increased by 6%, and prices declined by 4%. When fishermen are well informed via mobile phones, they can improve their products' allocation across markets. In our case study, we focus on spatial arbitrage between farm gate and selling to the marketplace; farmers produce a limited quantity; therefore, it is not profitable to travel between market if we compare the transportation cost to expected profits. (ii) Or a better arbitrage on time; that is why we analyze the impact of the market information on turnover through semi-perishable cash-crops where trade is critical during the selling period which take several months. We expect that market information through an available ICT service like mobile phones helps farmers better manage their crops' selling stock.

(iii) Or whether this market information strengthens farmers' bargaining position in regards to the trackers(Courtois & Subervie (2014)).

Consequently, we set up a randomized controlled trial (RCT) of a commercial service entitled. N'kalô provides instant information about crop prices, the price

trend, and advice about crop quantities to sell. The RCT procedure consists of providing to a random sample of farmers with information about the agricultural campaign to analyze N'kalô information's impact on farmers' prices received.

This article contributes to the available literature in several ways. First, it complements the work of other impact evaluation studies of assessing the impact mobile phones market information services (m-services agriculture market information services that are developed and offered through the mobile phone², rather than an analysis of mobile phones' spread or an expansion of the network³ in a rural area. It also enriches limited existing papers that have used micro-economic data to assess market information services' direct impact via mobile phones on rural livelihoods. Fafchamps & Minten (2012) study the spatial aspect by working on micro-level data and using a randomized experiment in 100 villages of Maharashtra, India, in micro-level sampling data Fafchamps & Minten (2012) investigate the impact of Reuters Market Light (RML). This service provides farmers with agricultural information through mobile phones in Maharashtra, India. They implemented an experimental evaluation in which a random sample of farmers received a free RML subscription for a year. While the authors find that younger farmers, less experienced farmers get slightly higher prices for their crops, unlike Jensen (2007), they do not find differences in average prices for farmers with RML

²See (Jensen (2007) Fafchamps & Minten (2012) Courtois & Subervie (2014), Camacho & Conover (2010)).

³See (Baumüller (2015), Islam & Grönlund (2010), Nakasone *et al.* (2014)).

subscriptions. They suggest that low levels of actual RML usage and the fact that farmers are mostly sold to a single local market may have contributed to this result.

Other papers are interested in expanding the network distribution in rural areas on the price fluctuation around markets, focusing on the relationship between mobile phone coverage and price realization and waste reduction. In Niger, Aker (2010) compares markets with mobile phone coverage and markets without it. The study finds that the introduction of mobile phone coverage reduces agricultural price dispersion across markets by 10 percent. The effect is more massive for remote markets and those connected by unpaved roads (see Muto & Yamano (2009) and Aker (2010)). Muto & Yamano (2009) estimate the impact of mobile phone network expansion on farmers' market participation in Uganda, focusing on the banana and maize market. They show that mobile phone network reduces the informational asymmetry regarding prices. However, the effects vary across crops, farmers, and the geographical location. They suggest that mobile phone coverage expansion in Uganda has encouraged farmers' market participation in remote areas and perishable crops (Banana). Aker & Fafchamps (2014) assessed mobile phones' impact on agricultural price dispersion in Niger. The study found that while mobile phone coverage reduced the spatial dispersion of producer prices for semi perishable commodities like cowpea; it had no impact on non-perishable commodities such as millet and sorghum. The study further found that farmers owning mobile phones obtained more price information but did not receive higher

prices. The explanation given was the non-participation of farmers in spatial arbitrage.

Second, to understand why the research findings on the impact of price information on farmers' prices received are mixed. Where some studies conclude that farmers using m-services were able to obtain higher prices⁴ for their crops, through a spatial arbitrage, or an increase in the bargaining power.⁵ However, other studies find a limited impact on prices received by farmers (Fafchamps & Minten (2012), Camacho & Conover (2010)) owing to limited spatial arbitrage, where farmers sell at the nearest market. In developing countries, smallholder farmers are not well connected to markets because of the lack of transportation infrastructures or a high transportation cost for small production or security problems. This paper is more interested in better management on harvest selling stock through a relevant market instant market information by giving farmer price information in a semi-perishable cash-crop that they could sell during the selling campaign. Consequently, we analyze another aspect by allowing time arbitrage to consider the farmer's ability to be connected to the market in remote areas. Third, we investigate the impact of information conception by analyzing which market information is much relevant for farmers, is it information on current prices or maybe it is beneficial to assist farmers during their sales period by providing selling instructions; thus, we generate two treated groups, the first group is informed about the cur-

⁴See (Islam & Grönlund (2010), Nakasone *et al.* (2014), Jensen (2007), Courtois & Subervie (2014))

⁵Baumüller (2018) review the empirical literature on agriculture related services that are developed and offered through the mobile phone.

rent price in the region the second treated group is delivered information about current price in the region, price trend and a piece of advice about quantity to sell). In order to analyze the difference between the two treatments it may have been necessary to add only one piece of information compared to the first treatment, but we are now testing the assistance service which consists of giving advice to farmers. Therefore it is wise to justify our advice, for example if we propose to sell part of the harvest even if the prices are high, we have to explain that a price increase is expected, which justifies this advice.

Other studies have looked at the design of the information services and have studied whether it is suitable for farmers. They use a qualitative approach to understand Kenyan farmers' mobile phone usage patterns, and their interactions with MFarm, a commercially available agricultural market information services via SMS (Wyche & Steinfield (2016)). They discovered a mismatch between this service's design and smallholder farmers' perceptions of their mobile phones' communication capabilities. They find that innovations must not be solely technological; educational innovations are also necessary. They highlight the importance of educational interventions to accompany the introduction of all new services and applications. In this experiment, the rate of farmers who affirmed receiving information was 60% among treated group, one of the reasons for the failure to spread this information is illiteracy, therefore farmers could not read N'kalô SMS. Farmers are aware of the importance of market information in selling management.

During the survey, N'kalô users hope to receive information more than once per week because sometimes the price may fluctuate in the same week. Thanks to N'kalô information, they can negotiate their price using an argument (Courtois & Subervie (2014)). They often show the text message received to trackers or intermediates; they do not have to travel to marketplaces.

N'kalô users are more likely to sell at a fair price even if they sell at the farm-gate without traveling to the marketplace. This conclusion is not the same that Fafchamps & Minten (2012) make, where they indicate that farmers are less likely to sell at the farm-gate and more likely to change the market. Furthermore, they are aware of the appropriate timing to sell.

In this paper, we differentiate between market price information and consulting services where we assess farmers by providing instructions on their selling process. In our case of analysis, we show that N'kalô information helps farmers to be strategic by being aware of price fluctuations and enhancing their bargaining power. N'kalô users could sell using N'kalô argument at the current price. According to our estimation, N'kalô impact on price received by farmers is limited to 4% on average for the experiment treatment assignment. The difference in the effect on price and turnover explains the farmers' selling strategy, where the major part of the treated groups' production was sold during the price peaks.

We proceed by quantile treatment effects to capture the heterogeneous effect that may limit the average effect. To explain how the intervention of N'kalô services affects the distribution of selling price and turnover. We conclude that the im-

pact of the treatment on price and turnover is positive and significant for the first three quartiles, refer to farmers who receive low prices and has a reverse impact for farmers who receive high prices.

The rest of the paper is organized as follows. In Section 2, we present the experimental design, describe N'kalô services, and the sesame market. The data are summarized in Section 3. The testing strategy is discussed in Section 5. Estimation results are presented in Section 6.

2.2 The background & Experimental Design

2.2.1 The intervention and program

N'kalô is a commercial service offered by Nitidae⁶, an NGO to diffuse and provide farmers with agriculture market information for several cash crops and inputs in twelve African countries. N'kalô subscribers receive text messages (SMS) to their mobile phone in French once a week for different crops (sesame, cashew nut, peanut..etc). The information includes the current local price (see figure2.2 as an example of the text message sent by N'kalô to farmers), the price trend, and usually a piece of advice on the quantity to sell. This information is based on Nitidae market monitoring, considering the international demand and the transaction cost through a weekly market price survey to analyze the market global demand

⁶Nitidae goals are to design, develop, and lead projects that combine the environment and strengthen local economies.

analysis and other exporter market situations. Nitidae has the farmers' location at the regional level. Therefore N'kalô services inform farmers of the minimum and maximum price at which they can sell (see figure2.2) to account for price differentials within the same region due to transaction costs between remote areas and those closest to major markets.

N'kalô ⁷ services have already been available before we start our study, but the take up is not universal in Burkina Faso. Thus, our incentive design is to provide farmers with free information by SMS.

Burkina Faso is a developing country in West Africa. The population of Burkina Faso is estimated at 19.75 million (according to World Bank 2020)⁸ 70.64% of the population lives in the rural area. In 2014, 43.8% of the population lived with less than 1.9\$ a day. Agriculture is the primary source of income and employs more than 80% of the population. The economy is mainly dependent on the primary sector, including cotton cultivation, which was structured and represented the most extensive export product. However, the Burkina Faso cotton sector has been experiencing problems for several years and is in a crisis state.

Our study focuses on sesame production, a cash crop of which the major production is exported to the Asian market (about 90% of its production is mainly intended for export). Sesame is the second most important cash crop after cotton, making Burkina Faso the fourth-largest producer of sesame in Africa after

⁷N'kalô services have launched early 2019 a voice message service in local Burkinabeze languages.

⁸Available at <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=BF> and last access in 28st of January 2020

Ethiopia, Nigeria, and Sudan. A household may sell all the harvest between November and March. They usually keep a small part of their sesame production to be sowed in their fields. Sesame is not a perishable crop, and farmers can store their output during the sesame campaign; it is considered as a semi-perishable. Sesame represents small farmers' opportunity to improve their revenue because the expected payoff of sesame production sold directly impacting the income of farmer's households. Sesame crops are considered a competitive market compared to other cash crops, owing to the simplicity during the production process (production not required expensive input, as phytosanitary products and it could be planted on slightly degraded soils) and the increase on demand and prices that are holding up better than for other cash crops, such as cotton (the fall in global cotton prices). The global market is growing and remains unfulfilled, so prices continue to rise. Exclusively for export, the country's production has increased by 150% in ten years. However, the market supply chain is not well organized and suffers from many intermediates and no transparency on prices. Even if demand is not completely satisfied, the commercialization of sesame by small farmers is complicated by the presence of a mitigated sales process, and farmers need the best strategy to sell at the highest price. Farmers have more than one option to sell the harvest. They can sell their crop to an intermediary at the farmer gate or to a cooperative or travel to the marketplace and sell the harvest. The development of the sesame value chain presents itself as an opportunity for growth and income sources for the players in this chain. In this context, many public and private organizations

try to enhance the sesame value chain to increase the income and employment opportunities of producers and generate multiple sources of income to improve household economic security.

Several marketing channels are used to bring sesame to market:

The channel from collectors or trackers is the primary channel used for sesame flow in Burkina Faso. This channel is used in the Boucle du Mouhoun, Hauts Bassins, East, and Cascades regions. The collectors group the products to send them to wholesalers who are in charge of exports. This channel is the oldest of the methods used and allows the collectors to have perfect control on trade. However, this weakens producers' bargaining power and excludes producer organizations from the marketing process.

The channel from direct purchases from intermediate traders or wholesalers Through this channel, wholesalers, and exporters (occasional opportunistic buyers) buy the sesame directly to producers for export. This channel's use is estimated at 20.75%⁹ on average for the Boucle du Mouhoun, Hauts Bassins, East, and Cascades regions. However, it should be noted that in the Boucle du Mouhoun region, 66% of producers are involved in this channel. This channel contributes to the disorganization of the sector regarding the quality of the participants and poses the problem of traceability.

Grouped sales channel This channel concerns sesame producers' production within their organizations for a grouped sale generally to wholesalers or exporters

⁹Report "Analyse de la chaîne de valeur du sesame au Burkina Faso 2018."

or to a local trader who resells it to a more massive intermediate trader (wholesaler). This channel's use is estimated at 23.5%¹⁰ on average for the regions of the Boucle du Mouhoun, the Hauts Bassins, the East, and the Cascades.

Rural and urban market channels: In most villages and urban markets in Burkina Faso, sesame is available in varying quantities and prices depending on the period of the year and production level. These markets are mainly supplied through direct sales channels by producers, producers' reserves, and collectors.

The option to sell is made depending on their expected selling price. Farmers also have to choose when to sell their harvest at the beginning or during or at the end of the marketing campaign, they should also the quantity to sell at any transaction and how many times to sell their harvest?

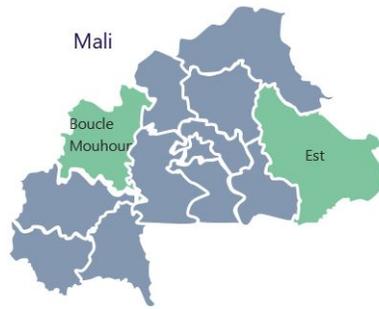
2.2.2 Details about the treatment and the data

We organized a randomized controlled trial (RCT) to test the N'kalô market information service's effect on the price received by farmers; the randomization happened at the household level. The RCT underlying this study has been conducted in two regions in Burkina Faso (Region East and Boucle du Mouhoun). They represent the regions where sesame is widely grown (the main sesame production regions are the Boucle du Mouhoun, the East, the Hauts Bassins, and the Cascades. Over the period, these four regions produced 69.04% of national

¹⁰Report "Analyse de la chaine de valeur du sesame au Burkina Faso 2018."

production, with 70% of the total area under cultivation). Boucle du Mouhoun is situated in the western part of the country. It shares a border with Mali, where the security situation (as represented in figure 2.1) is not stable and subject to frequent attacks. We have to take into account this particular characteristic of this region. The other region is East, as its name indicates, is located in the eastern part of the country.

Figure 2.1: Map of Burkina Faso Regions



For each region, we selected three groups. Two groups were treated by two treatments, and the third is the control group. Farmers in treated groups were given a free subscription to the N'kalô service. They received SMS information alerts (see an example of a text message received in 2.2 for each treated group and region). We have to emphasize that we start the treatment after harvesting to limit any impact of the experiment on farmer production choices and focus on farmers' marketing and commercial behavior.

- In the first treatment group (t_1) we send SMS to farmers about the current regional price during selling period;
- In the second treatment, we inform the second treated group (t_2) by SMS

about the current regional price, the expected short term future price, and suggested quantity to sell during selling periods.

This experimental design is used to investigate which information is relevant for farmers or if they need assistance in managing their harvest stock sale, leading to a better time arbitrage to sell their harvest optimally. Suppose We suppose that any additional and relevant information and advice are helpful. Knowing the price, the trend, and the advisers' recommendations allow farmers to follow instructions and plan the best sale time at the best price regarding the market analysis to maximize their profit. However, we may also expect that the trend information can help farmers make the best strategy by selling at the best moment or may confuse and limit their bargaining capacity immediately if there is a downtrend, because he will rush to sell the harvest, in this case, the farmer may accept a lower price to avoid a price drop.

Price varies between two regions and within each region; thus, the SMS received price information contains a minimum price and maximum price. Price variation inside the region is mainly related to locality remoteness and the transaction cost (see figure 2.2 as an example of SMS received).

On average, the field's surface used to cultivate is about 2.5 hectares and producer about "590 Kg ". Sesame has long been grown in Burkina Faso; we expected that all farmers have different backgrounds in his cultivation and commercialization experience. We take into account this heterogeneity using the date when farmers

start to cultivate sesame. The sample size is 760 farmers.¹¹ The survey was conducted by mobile phone, and the questionnaire focuses on agriculture practices and the use of the information provided by SMS.

We collect data: on the price and the moment of the farmer's transaction; and other characteristics of farmers like education, age, where they live, their needs of liquidity. The same questionnaire was used for treated and control groups. We ask respondents for treated groups if they informed other sesame producers. We ask the control group if other people informed them about the price information provided by SMS N'kalô to catch spillover effects. Our initial data contains information about the localization at the region's level detailed, so we randomized at the regional level.

We stratify our sample considering the other crops cultivated by the farmers and the mobile phone operators; stratifying enhances efficiency. The data used in this paper was collected in March 2019. We choose the third week of March to start the survey as the last week of the harvest, and usually, farmers had already sold the majority of their production, and the information is still fresh in their mind.

¹¹This sample size was determined as reported by Fafchamps & Minten (2012) and Dixit *et al.* (2010). The primary channel through which we expect SMS information to affect welfare is through producers' prices. Therefore, we want a sample size large enough to test whether SMS information raises the price received by farmers. Dixit *et al.* (2010) present results suggesting that price information raises the price received by Indian farmers by 1.6% on average. Based on this estimate and its standard error, a simple power calculation indicates that a total sample size of 500 farmers should be sufficient to identify a 1.6% effect at a 5% significance level. To protect against loss of power due to an expected loss of the sample size between 10% and 25% caused by the SIM change and deactivation's numbers, it is a common phenomenon in Burkina Faso where a large part of the of the population rarely opts for a telephone subscription because of its high price in this case they should feed their sim card with prepaid top-ups to conserve it. We increase our sample size by 25%.

The survey was realized by mobile phone in ten days to avoid any externality effects and includes the three groups.

Figure 2.2: SMS received by both treated groups in regions Boucle du Mouhoun & East

Region Boucle du Mouhoun

BM - Group treated (price, trend, advice)

Nkalo sesame Very high demand at the farm gate. The price Farmgate is : 675-700 FCFA / kg. Short-term trend: a slight increase. Tip: sell a quarter of your stock.

BM - Group treated (price level)

Nkalo sesame Very high demand at the farm gate. The price Farmgate is : 675-700 FCFA / kg.

Region East

E - Group treated (price, trend, advice)

Nkalo sesame Very high demand at the farm gate. The price of Farmgate is 700-735 FCFA/kg. Short-term trend: a slight increase. Tip: sell a quarter of your stock.

E - Group treated (price level)

Nkalo sesame Very high demand at the farm gate. The price of Farmgate is 700-735 FCFA/kg.

Source : Nitidae text message send in 16 November 2018

2.3 Descriptive statistics

In this section, we describe our data collected during the survey. One of the problems that we encountered was non-response (rate of non-response 30%). The main reasons for non-response are (i) farmers may cancel or change their Sim card, (ii) network problems ¹², (iii) security problems in the country, as the farmers are very vigilant and prefer not to talk to foreigners by phone. This phenomenon can affect the quality of our randomization experiment. However, we do not have data on non-respondents, and then we can learn the respondents' effect. We inspect if farmers who respond in the treatment group are similar to the control group by comparing their main characteristics.

Table 2.1 reports baseline summary statistics for the full sample and separately by treatment status. This table resembles a set of household head characteristics, geographical situation and agricultural production choices, and life quality between treated and control groups. In the first column we report the average value for the whole sample, the second for the control group the third and fourth column reports the average of the characteristics for the treated group by the first treatment (information about current price) and the second treatment (information about the current price, trend and a piece of advice about the quantity to sell) respectively.

Farmers who received the first treatment are the least represented in our database.

¹²Frequent situation in Burkina Faso, where we could not manage to call. Sometimes it depends on the location; indeed, there are more efficient network operators than others depending on the location and vice versa

We correct that by re-weighting our data and test characteristics groups to balance between the treatment and control group. In the full sample, farmers are 41 years old on average and predominantly male; women represent less than 5% of the entire sample. The sample is not highly educated as in Burkina Faso and other Sub-Saharan countries: while 37% have completed their primary school, nearly 56% have no formal education. About 9.6% of the sample are farmers and have a commercial activity; they play intermediary roles by buying the crop from other farmers and reselling it.

We consider the life quality ¹³ by two proxy variables: the first is to have electricity in the house, and the second concerns the house's building materials. 85% of the sample have electricity in their houses, and 70% use solar energy to generate electricity. 80% of housing is built from mud brick ¹⁴. We also ask them about their liquidity needs using a proxy variable. Therefore we ask farmers whether they have taken a new debt in the last 12 months and for the following reasons ¹⁵. On average, 26% of the sample goes into debt for agricultural expenses and 7% for other reasons. On average, the control and the treated group have the same distance to the nearest city and local market. Farmers in Burkina Faso

¹³We did not ask farmers about household composition, revenue, and some sensitive issues because farmers see this as a personal issue, and in this situation, we can not finish our questionnaire via mobile phone.

¹⁴Household composition brings us to know their expenditures and liquidity requirements.

¹⁵To pay for school fees or medical needs or everyday needs; to invest in agriculture or other investments; we also ask them about a widespread specific debt in sub-Saharan money from intermediaries at the start of production and pay them credit during the harvest period by nature or in cash

Table 2.1: Farmers Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
	All sample	control	t_1	t_2	Difference (3)-(2)	Difference (4)-(2)
	533	195	148	190		
Individual Characteristics						
Age	41.2	42.8	40.4	40.3	-2.3*	-2.4*
% Mal farmers	95.4	94.68	93.8	97.3	-0.01	0.01
% Finish his primary school	37.3	24.07	42.2	41	18.35***	16.9***
Life quality						
% Having electricity	85	78.9	91.1	84.6	12.22*	5.7
% Being in debt	33.6	27.27	39.2	32.8	11.91**	5.5
Home building						
% of house build by mud brick	81.1	82.5	80.0	81	-4.1	-2.5
% of house build by cement brick	7.97	8.4	6.9	8.5	-1.6	0.0
% of house build by cut stone	8.81	7.7	8.3	10.1	0.4	2.3
Geographical situation						
% of people living in region EST	39	36.36	37.4	41.3	0.79	4.68
% of people living in region BOUCLE DU MOUHOUN	43	51.04	39.5	42.3	-11.85**	-8.94
% of people living in region HAUTS BASSINS	13	6.29	17	12.2	10.6**	5.8*
% of people living in OTHER REGION	5	6.29	3.33	4.2	-2.12	-2.08
Distance to the nearest city	20.6	20.8	21.4	19.7	0.62	-1.25
Distance to the nearest marketplace	7.5	7.78	7.6	6.8	-0.16	-0.95
Agricultural information						
Field Area of sesame production	2.4	2.3	2.4	2.6	0.12	0.28*
% of sesame as a principal crops revenue	61.7	64.1	56.8	63.2	-0.07*	-0.01
% of Cotton producer	49.3	44.1	54.4	50.5	-0.1*	-0.06
% of peanut producer	66.5	65.6	62.6	70.6	0.03*	-0.05
% Of member in a cooperative	69.9	67.7	73.6	69.1	-0.06*	-0.01
Average years of sesame production	7.4	7.2	7.8	7.5	0.39	0.27
% Being visited by buyer more than one time in a week	48.78	50.3	52.03	42.63	1.6	-7
N'kalô Usage						
% of those who know N'kalô	37	26.1	41	45	-0.15***	-0.19***
% of those who use N'kalô	48	26.3	56.2	64	0.29***	0.37***
% of those who use N'kalô need to translate the SMS	41.3	39.4	38.7	44.1	0.18***	0.16***
% less than two sells	71	86.6	90	88	-0.15***	0.02
Commercial						
% of Commercial	9.6	6.3	10.8	12.1	4	6

Note: Authors' computation based on data 2019 after the survey. *** indicates statistical difference of means significant at ***1%, **5%, *10%. t_1 represent the treated group by an unique information on price. t_2 label the treated group by all information (price, trend and advice). *control* present the control group.

produce other cash crops like cotton, shea, and cashew. On average, the control and treated groups have approximately the same percentage of crop production, and more than 60% of farmers view sesame as a principal crop revenue.

2.3.1 Signing up for the treatment

Table 2.1 describes how the experiment was implemented in practice. We note that only 60% of farmers being offered N'kalô service declare to receive information by SMS (56% for the first treatment group and 64% for the second treatment). This is referred to as partial (or imperfect) compliance, one of the reasons for this phenomenon is the capacity to read French, could not read SMS messages, and thus could not use the service. Besides, 26% of those farmers who did not receive a N'kalô SMS did not know if they received text messages or not; all were illiterate and could not read SMS messages and could not benefit from N'kalô service. In table 14 in appendix B, we can observe another phenomenon: a high rate of contamination: 25% of control farmers use N'kalô. The control group who received the information we put in a fourth group separately in column 5 named *treat₃*¹⁶ This is explained by a particular situation in many sub-Saharan countries where the cost of communication at the same operator is lower from one operator to another. Therefore, it is more advantageous to have several sim cards to switch between them to communicate. Thus, they could register at the service using

¹⁶This group was dropped from the control group in the econometric analysis. In table 2.14 we reported the main characteristics of the contaminated group.

different numbers than those registered in the initial database.

Table 2.2 reports the characteristics of the N'kalô farmers who sign up or not. Farmers who sign up have characteristics different from those who did not sign up. They are more educated and live near the city. Living closer to the city promotes the education of the population.

During the survey, treated farmers, who received N'kalô information, asked for such information more frequently because prices may fluctuate during the same week on the one hand, on the other hand, farmers who used the N'kalô information might be more aware of the importance of this information to allocate the sales better. Furthermore, traders have access to information and knowledge of the market through their network organization and their frequent movements in several markets. Due to high transport costs, most of the harvest sales are made in the local farmers' community: 56% of transactions between farmers occur on the local market and 29% at the farm gate to intermediates. Farmers who sign up for the treatment do not have a precarious electricity source; their primary source is solar energy or electricity proposed by Burkina Faso's national electricity company. Besides, their houses are also built of more sophisticated material; we can assume that farmers who are assigned to the treatment but who did not sign up to N'kalô may be different from farmers assigned to N'kalô. These differences may be associated with the outcomes of interest, thereby invalidating simple comparisons of outcomes by treatment received or is potentially subject to self-selection. In other words, the randomization that validates comparisons by

treatment status does not validate comparisons by post-treatment variables such as the treatment received. These issues come up both in randomized experiments as well as in observational studies. The general term for these complications in the econometric literature is the endogeneity of the treatment received. Random assignment ensures that the treatment assignment is exogenous, but it does not refer to the exogeneity of the treatment reception if the receipt of treatment is different from the assignment to treatment. To deal with non-compliance, first, one can ignore the actual receipt of the treatment and focus on the causal effects of assignment to the treatment in an intention-to-treat analysis. Second, we can only identify the average effects for sub-populations induced by the instrument to change the endogenous regressors' value. We refer to such sub-populations as compliers and the average treatment effect identified as the local average treatment effect LATE. This terminology stems from the canonical example of a randomized experiment with noncompliance using an instrumental variables method. Where the instrumental variable is the random variable: assignment to the treatment.

Farmers who sign in to the treatment do not have a precarious source of electricity; their main source is solar energy or electricity proposed by Burkina Faso's national electricity company. In addition, their houses are also built of material that is more sophisticated, we can assume that farmers who are assigned to the treatment however who didn't sign up to Nkalo may be different from farmers who were assigned to Nkalo. These differences may be associated with the outcomes of interest, thereby invalidating simple comparisons of outcomes by treatment

Table 2.2: Individual Characteristics Sign up VS no sign up to treatment

	(1)	(2)
	<i>No – sign – up</i>	<i>Sign – up</i>
	275	254
Individual Characteristics		
Age	42.57 (11.15)	40.55 (10.16)
% Finish his primary school	18.9	56
Life quality		
% Having electricity	82.48	85.31
Geographical situation		
% of people living in region EST	49	51
% of people living in region BOUCLE DU MOUHOUN	53.1	46.9
% of people living in region HAUTS BASSINS	45.6	54.6
% of people living in OTHER REGION	81.5	18.5
Distance to the nearest city	21.2	20
	19.5	17.6
Distance to the nearest marketplace	7.5	7.6
	10.2	12.2
Agricultural information		
Field Area of sesame production	2.3 (2.1)	2.5 (2.5)
Average years of sesame production	7.1 (6.3)	7.8 (5.9)
% of sesame as a principal crops revenue	63	65.4
% of cotton producer	48	50.4
% of arachide producer	64.23	68.65
% Of member in a cooperative	64.73	75.1
% Of member of the executive desk in a cooperative	34.46	50
Nkalo Usage		
% of those who know Nkalo	16.36	59.84
% of those who use Nkalo	0	100
% of those who use Nkalo need to translate the SMS	10.55	54.72
% less than two sells	93	90
Commercial		
% of Commercial	8.7	10.7

Notes: Authors' computation based on data 2019 after the survey, *** indicates statistical difference of means significant at ***1%, **5%, *10%. Let *Sign – up* represent farmers who read Nkalo information. *No – sign – up* represent farmers who not read Nkalo information.

received. In other words, the randomization that validates comparisons by treatment status does not validate comparisons by post-treatment variables such as the treatment received. These issues come up both in randomized experiments as well as in observational studies. The general term for these complications in the econometric literature is endogeneity of the treatment reception. Random assignment ensures that the assignment to treatment is exogenous, but it does not refer to the exogeneity of the treatment reception if the receipt of treatment is different from the assignment to treatment. To deal with non-compliance, first, one can ignore the actual receipt of the treatment and focus on the causal effects of assignment to the treatment, in an intention-to-treat analysis. Second, we can only identify average effects for sub-populations that are induced by the instrument to change the value of the endogenous regressors. We refer to such sub-populations as compliers, and to the average treatment effect that is point identified as the local average treatment effect LATE. This terminology stems from the canonical example of a randomized experiment with noncompliance using an instrumental variables method. Where the instrumental variable

Description of Compliers

As highlighted before and in the appendix A the local average treatment effect (LATE) is the average treatment effect for "compliers": those who are induced to use Nkalo after being selected by the experience. In contrast, "always takers" or "never takers" have uses of Nkalo that are unaffected by the experience. It is

not possible to identify the compliers, but it is possible to describe their average observable characteristics. In table 2.3 we show that compliers are more educated, younger have less credit constraints and live near the village market.

Table 2.3: Characteristics of compliers

VARIABLES	(1) Compliers
Read french	1.30
Finished primary school	1.44
living in region of Boucle du Mouhoun	1.25
living in region EST	1.00
aged more than the mean of the population	0.74
Having credit	0.7
having a lot size more than the mean	1.25
history of producing more than the mean of the population	1.13
Producing sesame as the main crops	1.23
Need to translate sms	0.41
Distance to the nearest market more than the mean 7.5	0.84
Distance to the nearest city more than the mean 20.6	1.05
number of sales more than one sell	0.97
Being a member of cooperative	0.8

Note: Authors' computation based on data 2019 after the survey,

2.4 Empirical strategy

In this section, We are testing the following hypothesis:

- If market price information through mobile phone enables farmers to be strategic during selling campaigns by concentrating their sales during pics prices through a better time arbitrage in the management of crop sales stocks. Therefore, treated farmers should receive a higher turnover for their crops than uninformed farmers.

- We also investigate through which channel this information could impact farmers' profit. Therefore, we compare farmers' marketing behavior between treated and untreated farmers. N'kalô market price information represents an argument for farmers to better negotiate price with traders; in this case, farmers could sell their harvest at farm-gate without traveling to the market place.¹⁷ Besides, in the case of a semi-perishable product, farmers could choose when to sell their harvest, sell in once or several times, so we investigate modifications in the frequency of sales between treated and control groups.
- This experiment also tests what kind of information needs farmers may have. Is it clear information about the current price that they could combine with their knowledge in commercial activities, or they need an analysis of the current market situation and specific commercial instructions.

We present our empirical strategy to quantify the effect of information received via SMS on various outcome indicators through control and treatment groups, such as farmers' price or turnover. Let $t_{1i} = 1$ if farmer i assigned to the treatment 1 the current market price. $t_{2i} = 1$ if farmer i is assigned to the second treatment the current market price, information in trend and advice about the quantity to sell.

So, we are interested in several outcomes, first the intent to treat, which report

¹⁷Fafchamps & Minten (2012) do not find an impact on farmers' marketing behaviors, where most sales take place in diversification on market places in a perspective of a spatial arbitrage.

being randomly assigned to the treatment. The estimation equation is:

$$Y_{irt} = \theta + \beta_1 * t_{1irt} + \beta_2 * t_{2irt} + \tau_r + time_t + \alpha * X_{irt} + \varepsilon_{irt}, \quad (2.1)$$

Where, t_{1irt} is an indicator variable that takes the value 1 for farmer i , in region r assigned to treatment 1 (only price information) and 0 otherwise;

t_{2irt} is an indicator variable that takes the value 1 for an individual, i , in region r assigned to treatment 2 (price information, price trend and the advice)

τ_r is a region fixed effect, $time_t$ is a time fixed effect and X_{irt} ¹⁸ is a vector of characteristics of the farmers i or the sesame field that could affect the outcomes Y_{irt} .

β_1 is a parameter that report the impact of the price information and β_2 the trend information and the commercial instruction about the quantity to sell.

We expected a positive impact of price information, group t_{1irt} may benefit farmers by improving their bargaining power with traders and sharing commission agents.

We may suspect an ambiguous effect of the treatment t_{2irt} , therefore we should investigate if the trend information and the consulting service will help farmers make the best strategy by selling at the best moment or limiting their bargaining capacity immediately.

Next, we look for the direct effect of reading N'kalô SMS on farmers¹⁹. Let

¹⁸As we show in section 2 the price is higher when the quantity sold is bigger, this case represent farmer who are commercial in the same time who sell their harvest and work also as intermediary between sesame producers and grossest by buying their harvests and reselling it or farmer who produce other crops but play the role of intermediary on sesame.

¹⁹To estimate the direct impact of N'kalô services, we should consider that (40%) of treated

$S_i = 1$ if Dummy variable takes 1 if the farmer signed up for the treatment, and 0 otherwise.

$$Y_{irt} = \theta + \gamma * S_i + \tau_r + time_t + \alpha * X_{irt} + \varepsilon_{irt}, \quad (2.2)$$

As explained before, reading N'kalô SMS is not random and can affect the real effect of the outcomes (self-selection effect) where ε_i the error term might be correlated with S_i . We use an instrumental variable approach to deal with the endogeneity problem, using an instrument the assignment to the treatment, t_{1i} and t_{2i} as a random variable where the probability to sign-up is higher among those assigned to the treatment. We can define this IV estimation as the local average treatment effect (LATE) (we explain the approach to estimating the LATE in appendix A). The parameter γ in equation 2 is interpreted as the effect of N'kalô in complier, the farmer who would be induced to sign-up if offered the service for free (In appendix A how could we characterize compliers).

2.5 Results and discussions

2.5.1 Price dispersion

We begin by reporting a holistic view of the N'kalô market information services' impact on price variation during the sesame commercial campaign. We suspect

groups declare not to sign up to N'kalô SMS. Other farmers in the control group declare to receive N'kalô SMS because they were subscribed to the initial data by several numbers of their families. As mentioned before, I put this part of the control group in a separate group named *treat₃*; We remove this noise in the control group in our empirical strategy.

a reduction in price dispersion between markets and treated groups; the information received is a signal that could reduce asymmetric information and enable better market efficiency. We observe that sesame prices do not vary from one region to another on average. The selling price between October and March 2019 in the region of Boucle du Mouhoun is 634 FCFA, an average price higher than that observed in the Eastern region 630; however, the price is more dispersed (the coefficient of variation in Boucle du Mouhoun is 0.19 and region East 0.15). Price variation within the treated group does not exceed that observed in the control group (0.19 versus 0.18).

In contrast to the role anticipated for information to reduce market price fluctuation, and the results observed by Jensen (2007), he shows that the adoption of mobile phones by fishermen and wholesalers was associated with a dramatic reduction in price dispersion. These results are more accentuated if we focus on the region of Boucle Du Mouhoun (the coefficient of variation is 0.18 control group and 0.21 in the treated group). These results are more clearly observed for t_1 (the coefficient of variation is 0.15 and 0.11 in Boucle du Mouhon and region East, respectively). In our analysis, we do not have enough information about the locality, and as explained before, the price naturally varies in the different localities in the same region, but what can be a concern is the high dispersion of the prices of the treated group compared to the control group.

These results, such as average prices, do not consider the quantities sold during the sales period, which hides farmers' strategies during profitable mass sales pe-

Figure 2.3: Average unit price and quantity sold by groups

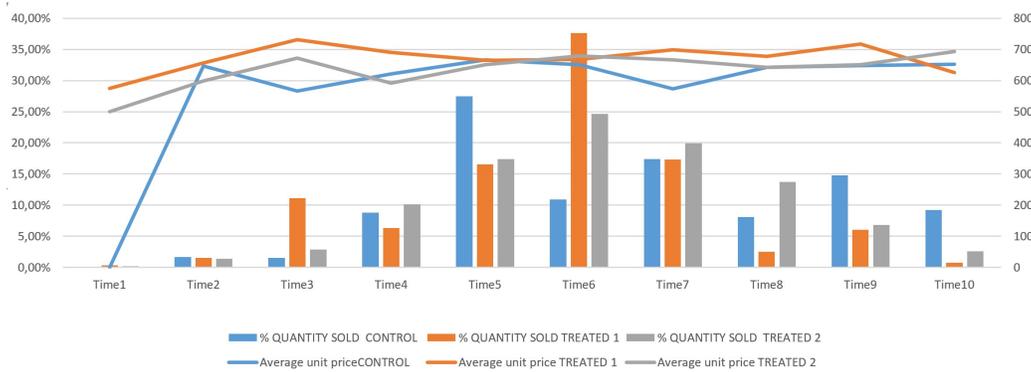


Notes: Authors' computation based on data 2019 after the survey, Time1 to time11 represents a period of two weeks for each point starting from October to March.

riods. Producers can accept low selling prices to meet their immediate liquidity needs and sell more when the price is higher if we calculate the average unit price within the region by the groups and the percentage of the quantity sold during the sales period, as illustrated in figure 2.3 where we observed the average unit price for all treated and control groups. In the EaST region (figure 2.4), this price is greater than or equal to the control group's price during the sales period. Furthermore, at the beginning of the period, we see a remarkable price differential between the treated and control groups. This can be explained by the lack of information circulating in the region, due to an ignorance of the market price position at the beginning of the period intensified by the critical security situation.

In Boucle du Mouhoun region, farmers start selling their harvest effectively

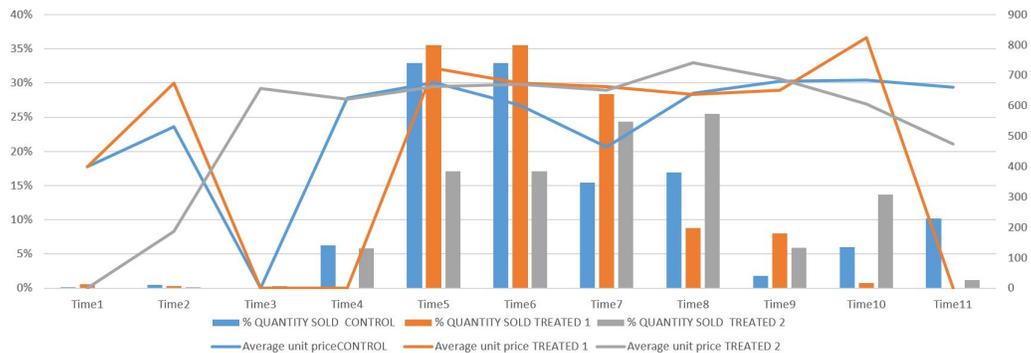
Figure 2.4: Average unit price and quantity sold (Region EAST)



Notes: Authors' computation based on data 2019 after the survey, Time1 to time11 represents a period of two weeks for each point starting from October to March.

six weeks after starting the selling period. The average unit price for the treated group was mostly higher throughout the period (figure 2.5).

Figure 2.5: Average unit price and quantity sold (Region Boucle du Mouhoun)



Notes: Authors' computation based on data 2019 after the survey, Time1 to time11 represents a period of two weeks for each point starting from October to March.

We expect N'kalô information to help farmers make the best profit by receiving the best price on average thanks to their capacity to bargain and to sell at the right moment when the price is higher. As explained before, farmers are con-

strained to make concessions and may sell a part of their harvest at a lower price because of the liquidity needs. Informed farmers sell more during price peaks, as we can see in figure 2.3. So, the farmers' strategy is to sell most of their products when the price is high.

2.5.2 Price received and turnover

Our parameter of interest is the average gain from the N'kalô-based program for the subset of farmers who benefited from the program during the 2018-2019 marketing season. This parameter answers the question: how much informed farmers receive (in terms of price and turnover) compared to what they would have received had they not integrated the program? This is what we investigate in Table 2.4. The dependent variable is the logarithm of the unit price received by the respondent on average over all the sesame sale transactions during the selling period. Similar results are obtained if we use the price level instead of the log. The unit of observation is the sales transaction. Most farmers report a single sale, but some report more than one, which explains why the number of observations exceeds the number of participating farmers.

In column (column 1 to 4 table 2.4), all analysis is conducted in terms of intent-to-treat: the treated are offered a free one-year subscription to the N'kalô market information services, whether or not they accepted it. We also report the local

Table 2.4: Prices received(expressed in $\log(\text{price}/\text{kg})$ Turnover(expressed in $\log(\text{quantity}*\text{price})$)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS _{ITT} log_price	OLS _{ITT} log_turnover	OLS _{ITT} log_price	OLS _{ITT} log_turnover	IV _{Late} log_price	IV _{Late} log_turnover
Being treated	0.0436* (0.0235)	0.124 (0.147)	0.0448* (0.0235)	0.170 (0.128)		
Sign in N'kalô					0.106* (0.0563)	0.647** (0.321)
Being in debt			0.0341* (0.0196)	0.155 (0.107)	0.0318* (0.0192)	0.1440 (0.198)
Productivity			0.000237*** (6.38e-05)	0.00359*** (0.000371)	0.000205*** (4.98e-05)	0.00295*** (0.000572)
Region BM vs EAST	-0.0276 (0.0196)	-0.170 (0.129)	0.00308 (0.0226)	0.0691 (0.120)	0.00902 (0.0218)	0.0263 (0.134)
Constant	6.105*** (0.0790)	10.52*** (0.229)	6.037*** (0.0800)	9.337*** (0.268)	5.997*** (0.103)	9.158*** (0.342)
Cragg Donald F-stat					29.219	29.219
Stock Yogo critical value (10%)					9.08	9.08
Observations	449	449	438	438	490	490
R-squared	0.076	0.066	0.119	0.310	0.083	0.207

Notes: The additional controls are: dummy variable for reading French and being a member in a cooperative, time fixed effects number of year production. Sign in N'kalô refer to those who received N'kalô SMS. treated are those who were offered a free one-year subscription to the N'kalô service.

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

average treatment effect (IVLATE) results in which we instrument actual Nklao usage with random treatment assignment. We refer to these results as IV or LATE estimates interchangeably.

We start in table 4 by evaluating the impact of the information received by N'kalô on sesame price and farmer turnover by combining both treatments t_1 and t_2 farmers to improve efficiency. The first and second columns of Table 2.4 report estimating the impact of treatment on price and turnover respectively ITT obtained using a difference between treated and control groups. As expected, we find a beneficial effect of the treatment on selling price and turnover: the treatment effect is positive and statistically significant for selling price but not significant for

the turnover.

We can suppose that non-significant results are due to omitted variables, but the treatment assignment was randomly conducted. Despite that, we explore this possible missing in Column 3 and 4. I estimate the impact of treatment (ITT) on price and turnover respectively taking account the capacity to read French and fixed effect on time when the N'kalô services advised farmers to sell, and region fixed effect we add controls variables for farmer financial situation his knowledge on sesame market and the productivity of the farm. The debt constraint approximates the farmer's financial situation. We ask farmers if they have any debt to repay, and the productivity of the farm or is calculated by the ratio of sesame production divided by the farm's size.²⁰ The number of years of sesame production is used as a proxy to consider farmer knowledge on sesame strategy of marketing. Again we do not find a significant treatment effect on turnover. Besides, not being in debt is positive but not significant for the turnover estimation. In contrast to that supposed before -being in debt may oblige farmers at any price to pay their loan- farmers with a poor financial situation are more strategic to receive the best price and to make the best turnover. The estimated coefficient of the productivity and number of years of production are positive as expected. The treatment effect coefficient for the selling price is approximately equal to one estimate without a control variable; this result can reveal a good quality of our randomized proce-

²⁰As explain before the inputs the sesame production depends only on the land since the farmer often uses last year's seeds for sowing, and plows it as a source of water.

ture.

Next, in columns 5 and 6, we examine whether the lack of effect is due to non-compliance. Indeed, we have seen that many treated farmers did not eventually use the N'kalô service. To investigate whether non-compliance affected our results, we instrument actual N'kalô usage with the intent-to-treat dummy. The estimated coefficient of receiving the N'kalô service is now significant for the turnover. Furthermore, the estimated coefficient of receiving N'kalô service is more significant using an instrumental variable approach ²¹ or LATE estimation than for ITT that is quite obvious because we focus on compliers those who receive the treatment thanks to the experiment.

One of the objectives of this paper was to identify what information we best assimilated by the farmers. Should we inform the farmer about the actual price or give them information about the future price trend and quantity advice? We expect that all additional and pertinent information is useful. If we informed farmers about the price trend, they could sell at the best price by waiting for the expected price to rise and sell when the price decreases. Alternatively, maybe we can dampen sellers' capacities and strategies acquired over several years by a more programmed procedure with less liberty and flexibility of decision-making.

In table 2.5, we estimate equation 2.1, where the first term t_1 indicates the ef-

²¹Table 2.5 columns 5 provides the first stage estimation where the instruments are being treated by the first treatment t_1 and the second treatment t_2 for the endogenous variable sign in to the treatment (adoption of the treatment). It shows that the two instruments are indeed strongly correlated with N'kalô adoption. In particular the Cragg-Donald F-statistics for the weak instrument test is larger than the critical value for the Stock-Yogo at 10% maximal IV size, which rules out weak instrument issues.

fect of the price and t_2 the trend and advice effect. Columns 1 and 2 report the estimation of the impact of treatment on price and turnover, respectively. The effect of treatment one (price) is positive and significant for price and turnover. When we add the information about the trending price, the effect still positive but not significant. We run the same estimation adding control variables to capture any omitted variables in columns (3) and (4). The result is almost the same as t_1 , while t_2 is still positive but not significant for the trend information and advice.

Table 2.5: Prices received (expressed in $\log(\text{price}/\text{kg})$) and Turnover in $\log(\text{quantity} \times \text{price})$

VARIABLES	(1) OLS ITT log_price	(2) OLS ITT log_turnover	(3) OLS ITT log_price	(4) OLS ITT log_turnover	(5) OLS Fist_stage IV
t_1	0.0712*** (0.0254)	0.214 (0.162)	0.0642** (0.0260)	0.254* (0.149)	0.348*** (0.0611)
t_2	0.0215 (0.0261)	0.0530 (0.166)	0.0244 (0.0260)	0.113 (0.142)	0.412*** (0.0536)
Productivity			0.000243*** (6.29e-05)	0.00361*** (0.000373)	0.000214* (0.000121)
Region BM vs EAST	-0.0271 (0.0194)	-0.168 (0.129)	0.00274 (0.0224)	0.0681 (0.120)	0.0263 (0.134)
Constant	6.096*** (0.0799)	10.49*** (0.217)	6.068*** (0.0852)	9.468*** (0.267)	0.141** (0.0618)
Observations	449	449	438	438	490
R-squared	0.087	0.069	0.135	0.313	0.157
Cragg Donald F-stat					29.22
Stock Yogo critical value (10%)					9.08

Notes: The additional controls are: dummy variable for reading French, being a member in a cooperative and being in debt, time fixed effects number of year production.

t_1 represent the treated group by an unique information on price. t_2 label the treated group by all information (price, trend and advice).

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

What can be drawn from the first estimates is that the effect of the N'kalô information is positive and around 4% from a treatment assignment point of view and 7% for compliers. The treatment effect on turnover is higher than the price; it is 17% for treated assignment and 64% for compliers. Therefore, we can conclude a sales strategy, where the central part of the treated groups' production was sold during the price peaks, which was confirmed in figure 2.3 where the treated groups sell mostly at peak prices. Therefore, the treated groups' behavior was different from that of the control group than the quantities sold during the sales period and the sales frequencies; we suspect fewer sales of the treated groups. We will come back to these behaviors later in the paper. Otherwise, if they had the same behavior, we would observe the same effect for the sale price and the turnover.

In the following, we will analyze two points; the first is the difference in impact according to the two treatments (information on the price versus information on the price, trend, and advice). To better understand if the trend's effect is not significant if we separate the two treatments and if we look at the impact according to the price received and turnover achieved. The second point is to analyze the channels through which farmers benefit from the N'kalô market information services by analyzing farmers marketing behaviors; we also investigate the reasons for the limited impact of the treatments and specifically the assisting service, we explore the possibility of a heterogeneous distribution of the treatment within treated farmers.

Market price information services VS Assisting services

We suspect a difference in the distribution of the treatments impact between farmers; we start by comparing each treatment separately. Table 2.6 reports a comparison between the group who received treatment t_1 (price information) and the control group. The effect on the price is positive and significant. The impact on the turnover is positive and significant when we add control variables.

Table 2.6: Prices received expressed in $\log(\text{price kg})$ & Turnover in $\log(\text{quantity*price})$ t_1

VARIABLES	(1)	(2)	(3)	(4)
	OLS ITT log_price	OLS ITT log_turnover	OLS ITT log_price	OLS ITT log_turnover
t_1	0.0777*** (0.0257)	0.200 (0.166)	0.0813*** (0.0264)	0.264* (0.149)
Constant	6.063*** (0.0991)	10.66*** (0.290)	5.995*** (0.0957)	9.575*** (0.329)
Observations	264	264	257	257
R-squared	0.117	0.078	0.166	0.281

Notes: The additional controls are: dummy variable for reading French, being a member in a cooperative and being in debt, time and regions fixed effects, number of year production and productivity.

t_1 represent the treated group by an unique information on price.

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

Table 2.7: Prices received expressed in $\log(\text{price kg})$ & Turnover in $\log(\text{quantity*price})$ t_2

VARIABLES	OLS ITT	OLS ITT	OLS ITT	OLS ITT
	log_price	log_turnover	log_price	log_turnover
t_2	0.0224 (0.0259)	0.0707 (0.165)	0.0227 (0.0258)	0.112 (0.143)
Constant	6.099*** (0.0705)	10.23*** (0.255)	6.079*** (0.0972)	9.204*** (0.216)
Observations	335	335	327	327
R-squared	0.081	0.104	0.134	0.365

Notes: The additional controls are: dummy variable for reading French, being a member in a cooperative and being in debt, time and regions fixed effects, number of year production and productivity.

t_2 represent the treated group by an unique information on price, trend price and advice.

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

Besides, we run in table 2.7 to estimate the impact of being informed about (price information, price trend, and being assisted by a consulting service) and the control group. This treatment's impact on price and turnover is positive but not significant, even if we add control variables. Moreover, the magnitude of the effect is different; it is less significant for group t_2 than group t_1 , both in price and turnover.

Heterogeneous impact within treated group

To analyze this experiment's intervention's limited effect, we suspect a heterogeneous effect between treated farmers. The effect may differ between the different

farmers, living far away, the security problems experienced by Burkina Faso can help mitigate the effect of the treatment. Although we have taken into account the fixed region effect, it is not precise enough as given. Living in a village where access is complicated implies lower selling prices because the transaction cost is very high for the farmer who has to travel to the marketplace to sell his harvest and the intermediary if he comes to the farmer to buy his crop. According to the farmers, the price difference at an instant t depends not only on the market information but also on the transaction cost. This explains why we observe dispersed price intervals due to information asymmetry on the one hand and transaction costs (road access and security situation). The treatment effect can further increase the surplus for a part of the population and not impact another part of the population, making the average effect positive but not significant. Besides, living in remote rural areas may weaken farmers' bargaining power; they must sell their harvest at a lower price. We suspect that the treatment's effect may differ depending on different price ranges accepted by farmers to sell their crops. We proceed by quantile treatment effects to capture this heterogeneous effect. To explain how the intervention of N'kalô services affects the distribution of selling price and turnover. It concerns differences between (statistics of) the distribution of outcomes with the N'kalô services intervention and the distribution of outcomes without it, such as the impact of this intervention on the variance or a specific quantile of the outcome distribution.

Quantile treatment effects are the difference between the quantiles of potential

outcomes. In graphical terms, they measure the horizontal distance between outcome distributions Firpo (2007). We formally define quantile treatment effects on the treated (QTT) as:

$$Dif_{Quantile}(\tau) = q_1(\tau) - q_0(\tau) \quad (2.3)$$

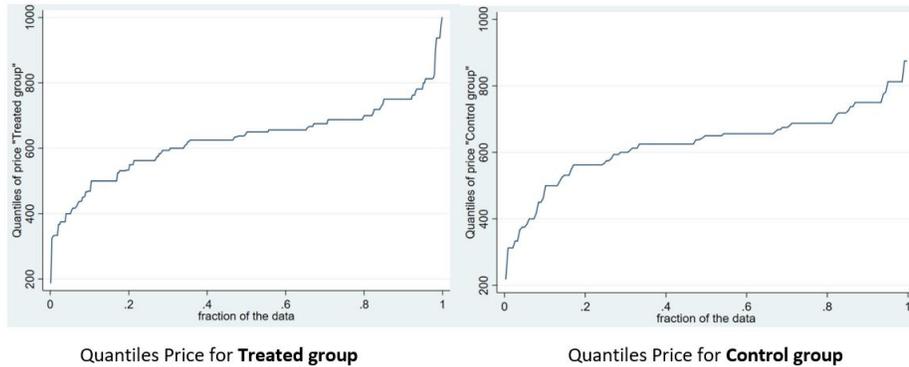
Where $q_1(\tau)$ is the τ -th quantile of the potential outcomes Y for the treated, and $q_0(\tau)$ the counterfactual quantile from untreated observations.

We focus on compliers, since part of the farmers for which the treatment was intended did not receive it. We use the procedure proposed by Frölich & Melly (2013). The idea consists of re-weighting our sample by giving negative weights to the outcomes of non-compliers from the treatment group makes them “cancel out” counterfactual non-compliers in the control group, leaving us with the distribution of for counterfactual compliers²². We proceed by estimating $Dif_{Quantile}(\tau)$ the difference between the quantiles $q_1(\tau)$ and $q_0(\tau)$ of the re-weighted sample.

We start by reporting price distribution by quantile for treated and control groups in figure 2.6. Price varies between 200 to 900 Franc CFA for the control group and 200 to 1000 Franc CFA. A variation of 700 Franc CFA between the lowest and the highest price. There is a rapid increase in the first and last quantile price, unlike the middle of the distribution.

²²For more explication see Frölich & Melly (2013)

Figure 2.6: Quantile price distribution for control treated group



Source : Note: Authors' computation based on data 2019 after the survey,

In table 2.8, I report the quantile treatment effect for compliers in the logarithm of price and turnover for the 25th, 50th, 75th quantiles in the first, the second, the third, fourth, fifth, sixth columns, respectively. On average, receiving N'kalô service increases the selling price, but the impact on turnover is mitigating; it is positive and significant for the first and last quartile but is negative for the 50th quantile. The effect differs from a quartile to another, and the confidence interval of the OLS estimator does not cover some value quantile.

In table 2.9, and 2.10 we report the estimation of the quantile treatment effect for the 25th, 50th, 75th quantiles in the logarithm of price and turnover respectively in the third, fourth, fifth, and sixth, column respectively for compliers in the treated group 1 those who receive the first treatment (information about current regional price) in table 2.9. And the second treated group received the second treatment (information about price, trend, and advice about the quantity to sell)

Table 2.8: Quantile regression; Prices received expressed in log(price kg) & Turnover in log(quantity*price)

	(1)	(2)	(3)	(4)	(5)	(6)
	25th quantile	25th quantile	50th quantile	50th quantile	75th quantile	75th quantile
VARIABLES	log_price	log_turnover	log_price	log_turnover	log_price	log_turnover
Sign in N'kalô	0.0187*** (0.00317)	0.105*** (0.0162)	0.0105*** (0.00195)	-0.0547*** (0.0140)	0.0104*** (0.00215)	0.0413*** (0.0135)
Constant	5.956*** (0.0142)	9.598*** (0.0814)	6.008*** (0.00791)	9.716*** (0.0629)	6.319*** (0.00947)	10.29*** (0.0598)
Observations	480	480	480	480	480	480

Notes: The additional controls are: dummy variable for reading French, being a member in a cooperative and being in debt, time and regions fixed effects, number of year production and productivity.

Sign in N'kalô refer to those who received N'kalô SMS. .

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

in table 2.10. We note that on the 25th and 50th, we could increase the sale prices and their turnover, unlike the last quartile, mainly for treatedlevel (price, trend price, and the advice), which was not significant on average. The impact of the treatment on price and turnover is positive and significant for the first three quartiles, refer to farmers who receive low prices and have a reverse impact on farmers who receive high prices.

Another phenomenon that could reduce the treatment's real effect is the spillover effect; farmers in the control group might receive the treatment through farmers in the treated group. Therefore, we ask farmers during the survey if they receive any market information through other farmers related to information services. 14% of the control group declare receiving N'kalô market information through other farmers. Consequently, we consider the following analysis we put those farmers

Table 2.9: Quantile regression t_1 ; Prices receives expressed in $\log(\text{price kg})$ & Turnover in $\log(\text{quantity*price})$

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	25th quantile log_price	25th quantile log_turnover	50th quantile log_price	50th quantile log_turnover	75th quantile log_price	75th quantile log_turnover
Sign in n'kalo (0.00260)	0.0490*** (0.0168)	0.416*** (0.00144)	0.0350*** (0.0106)	0.266*** (0.00183)	0.0334*** (0.00908)	0.254***
Constant	5.938*** (0.0112)	9.327*** (0.0721)	5.971*** (0.00618)	9.698*** (0.0454)	5.982*** (0.00788)	9.862*** (0.0390)
Observations	250	250	250	250	250	250

Notes: The additional controls are: dummy variable for reading French, being a member in a cooperative and being in debt, time and regions fixed effects, number of year production and productivity.

Sign in N'kalô refer to those who received N'kalô SMS in t_1 .

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

in a separate group to identify the real impact of the treatment. The effect is not significant for price and turnover, as reported by Nakasone *et al.* (2014), who does not find any evidence to support the presence of spillover effects: there are no apparent price benefits to farmers who did not receive the information directly.

Table 2.10: Quantile regression t_2 ; Prices receives expressed in $\log(\text{price kg})$ & Turnover in $\log(\text{quantity*price})$

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	25th quantile log_price	25th quantile log_turnover	50th quantile log_price	50th quantile log_turnover	75th quantile log_price	75th quantile log_turnover
Sign in N'kalô	0.0199*** (0.00302)	0.117*** (0.0137)	0.0170*** (0.00151)	0.0170 (0.0107)	0.0173*** (0.00158)	-0.0310*** (0.00974)
Constant	5.990*** (0.0169)	9.338*** (0.0767)	6.002*** (0.00842)	9.083*** (0.0598)	6.329*** (0.00881)	9.672*** (0.0545)
Observations	318	318	318	318	318	318

Notes: The additional controls are: dummy variable for reading French, being a member in a cooperative and being in debt, time and regions fixed effects, number of year production and productivity.

Sign in N'kalô refer to those who received N'kalô SMS in t_2 .

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

2.5.3 Farmers information sources and marketing strategies

To identify channels through which farmers realize the benefit from N'kalô market information, we take advantage of a rich database that allowed us to study the behavior and strategies of farmers treated and untreated to sell their products. At first, we estimated the effect of access to N'kalô information on farmers' strategies where to sell and whom to sell and the frequency of selling.

In the rural area in Burkina Faso, farmers can sell their harvest at the farm gate, in the local market, or to sell to a cooperative. Table 2.15 and 2.11 report the percentage of farmers' sales in the marketplace to middleman or cooperatives or several buyers for those who cannot specify respectively for the reception and the assignment to the treatment. The groups who received or to whom the information N'kalô was assigned to sell less to the market and sell more to middleman than those who did not receive the N'kalô information or were assigned to receive it.

We use a multinomial Probit for estimating where-to-sell and whom-to-sell to test whether there is a statistical difference between treatment. Table 2.12 we report results in columns 1 to 3 by combining all treated groups in the first column and looking for each column at the second column (t_2) and (t_1) at the third column. We complete these estimations with a look at the effect of access to N'kalô service on the frequency of transaction (selling) in which the dependent variable takes ordered values (column 4 to 6 in Table 2.12) as once per sesame campaign, twice

per sesame campaign, and more than twice.

Table 2.11: Source for marketing information

	(1)	(2)	(3)	(4)
	All sample	control	t_1	t_2
The important source to consult				
% Using last year price	63.5	58.6	61.8	69.2
% An other nearest producer	20.8	18.5	25	20.3
% Information by N'kalô or other services	30.9	22.2	36.4	31.1
% Cooperative information	13.8	17	12.1	14.7
% Information listen in the nearest local market	34.5	42.2	26.4	33.9
Most important information				
%Assisted by indicating current price, trend and quantity to sell	49	40	45	
% Information about current price level	51	60	55	
Where to sell the harvest				
% In local market	53.3	57.3	47.4	54.3
% To a middleman	33.9	25.8	41	34.5
% To a cooperative	4.9	5.8	6.4	3.1
% Not have precision	7.9	11	5.2	8.1

Note: t_1 represent the treated group by an unique information on price. t_2 label the treated group by all information (price, trend and advice). *control* present the control group.

We take on account additional control variables to control for observable heterogeneity within the sample.²³ Farmers who receive t_1 (price information) are more likely to sell to Middleman than the local market. Providing price information allows farmers to negotiate the selling price without moving to sell on the local market, as suggested by Fafchamps & Minten (2012). The effect of t_2 (price information, trend, and advice) is positive but not significant.

We have listed in table 2.11 the sources of price information that we ask farmers to find out what is essential information to determine the selling price. Over

²³These are geographical position (region fixed effect; market access variables such as physical distance from the nearest market; the principal crops providing revenue; and the household financial situation being in dept to take into account their need on liquidity; numbers of years of sesame production to indicate the farmers' experience; the size of land for production sesame) to control for the quantity of sesame produced.

Table 2.12: To whom is the harvest sold and Number of farmers sales

VARIABLES	(1) 1 Middelman	(2) 1 middleman	(3) 1 middleman	(4) nbr_sells	(5) nbr_sells	(6) nbr_sells
Treated groupe	0.375 (0.248)			-0.146 (0.142)		
t_1			0.521 (0.321)		-0.442** (0.184)	
t_2		0.221 (0.291)				0.0695 (0.156)
Not being in debt	-0.542** (0.254)	-0.798*** (0.301)	-0.766** (0.323)	-0.0227 (0.139)	-0.187 (0.179)	0.107 (0.159)
Region EAST vs Region BM	-1.498*** (0.253)	-1.563*** (0.299)	-1.586*** (0.325)	0.279* (0.155)	0.267 (0.206)	0.241 (0.175)
Visited by middleman	-0.188 (0.138)	-0.128 (0.159)	-0.434** (0.175)			
Productivity	0.000482 (0.000679)	0.000173 (0.000733)	0.00104 (0.000796)	0.000587* (0.000317)	0.000439 (0.000393)	0.000506* (0.000307)
Distance to the market				-0.0118* (0.00673)	-0.0111 (0.00805)	-0.00978 (0.00769)
Production years				0.0256** (0.0106)	0.0294* (0.0172)	0.0181* (0.0103)
/cut1				0.978*** (0.218)	0.860*** (0.276)	0.988*** (0.228)
/cut2				1.764*** (0.233)	1.620*** (0.294)	1.765*** (0.245)
Constant	0.645 (0.417)	0.819* (0.464)	1.083** (0.495)			
Observations	439	238	272	371	239	276

Notes: t_1 represent the treated group by an unique information on price. t_2 label the treated group by all information (price, trend and advice). *** indicates statistical difference of means significant at ***1%, **5%, *10%. The dependent variable takes ordered values (column 4 to 6) as once per sesame campaign, twice per sesame campaign, and more than twice.

30% of treated groups consider information received by N'kalô is the most relevant information for their marketing choices. The control group instead believes what he hears directly from the market. However, sesame prices and market conditions (demand) can change quickly. The price disseminated at time t for this market will also not be the same as the next market at $t + 1$. Indeed, several members of the N'kalô service ask for more than one SMS during the week to be aware of various changes on the market (farmers who consider sesame as a principal source of revenue are more likely to mention N'kalô as their main source of information). The treated and control group uses last year's price as a reference. In table 2.13, we run different regressions to estimate whether N'kalô is a source of information.

The first column reports the average treatment effect on the treated or ATT is calculated using the nearest neighbor matching methodology described in Abadie *et al.* (2004), where matching is performed by region dummy and other characteristics of farmers. We take on account additional control variables to control for observable heterogeneity within the sample.²⁴ IVLATE estimation is reported in the second column in the third, fourth, and fifth column we look for heterogeneous effects by farmer education and capacity of reading french, knowledge on producing and selling sesame and farm size.

Farmers in the treated group are more likely to mention N'kalô as the source of the sesame price.²⁵ Educated farmers working on a small farm are more likely to mention the importance of N'kalô as a source of marketing information. This result contrasts with Fafchamps & Minten (2012) where they find that farmers with larger acreages are significantly more likely to mention the RML (a market and production information service) as a source of information. Farmer's age is never significant, found by Fafchamps & Minten (2012) and the number of years of production.

Table 2.11 (appendix B) explains farmers' information needs and knows their

²⁴These are geographical position such as region fixed effect: market access variables such as physical distance from the nearest market, the principal crops providing revenue, being a trader, farmers who declare to look for information before to sell, numbers of years of sesame production to take into account the farmers experience, size of land for production sesame to control for the quantity of sesame produced and the main crops providing revenue.

²⁵We take on account other characteristics as age, the capacity to read in french the main source of revenue, region fixed effect, the size of their farm, and commercial farmers.

Table 2.13: Probability need information like N'kalô (Use of N'kalô)

VARIABLES	(1) Matching	(2) IV Late	(3) Heterogeneous effect (3)	(4) Heterogeneous effect (4)	(5) Heterogeneous effect(5)
treated group			0.359* (0.208)	0.380** (0.164)	0.122 (0.155)
Sign up in N'kalô		0.254* (0.142)			
Not read french		-0.0787 (0.0681)	-0.320 (0.218)	-0.472*** (0.126)	-0.511*** (0.124)
treated group* Not read french			-0.236 (0.266)		
Farmer age		0.000330 (0.00202)	-0.000164 (0.00600)	-0.000598 (0.00606)	
production years		-0.00120 (0.00344)	0.000398 (0.0110)	0.00113 (0.0112)	0.00799 (0.0140)
being a trader		-0.0983 (0.0689)	-0.391* (0.231)	-0.384* (0.231)	-0.376* (0.220)
Need information		0.0826* (0.0428)	0.215* (0.126)	0.216* (0.127)	0.218* (0.125)
Not have electricity		-0.0404 (0.0576)	-0.197 (0.182)	-0.195 (0.183)	-0.166 (0.179)
Nearest neighbor matching	0.0594*** (0.00889)				
Treated group*surface				0.186 (0.222)	
Treated group* production years					-0.272 (0.266)
Constant		0.178 (0.159)	-0.654* (0.370)	-0.623* (0.357)	-0.492* (0.256)
Observations	493	493	493	493	505
R-squared		0.033			

Notes:(1) matching : We take on account other control variable region fixed effect, access to electricity, market access variables such as physical distance from the nearest market, the principal crops providing revenue, being a trader, farmers who declare to look for information before to sell, numbers of years of sesame production, size of land for production sesame and the main crops providing revenue. (2) Sign up in N'kalô to receive N'kalô information, we take on account other control variable the principal crops providing revenue, region fixed effect. (3) To indicate Heterogeneous effect on education, we take on account other control variable the principal crops providing revenue, region fixed effect.

(4) To indicate Heterogeneous effect on farm size, we take on account other control variable the principal crops providing revenue, region fixed effect. (5) To capt Heterogeneous effect on experience of production approximated by number of year of production, we take on account other control variable the principal crops providing revenue, region fixed effect.

*** indicates statistical difference of means significant at ***1%, **5%, *10%.

information services expectations; we ask farmers what the most important information to sell at the best price is? Did they need to be 100% assisted by indicating the price and quantity for sale during the entire agricultural campaign? Or, instead, be directed by the forecast of price developments during this period? More than half of the sample needs asking for more than one market information in a week as what was said before the sesame price fluctuates rapidly. Even the treated t_2 offered information on forecast prices and advice on how much to sell 54% of them consider forecasts on the price is sufficient information.

In table 2.12, we complete these estimations to look at our experiment's effect on the frequency of farmer's sales²⁶ -the column 7 treated group to t_1 and t_2 in column 8 and column 9- and -to whom farmers sell their harvest at the farm gate or the closet market (between Middleman or nearest market column 1, 3 and 5). The treated group sells more to intermediaries than market results are positive but not significant. The treated group sells less frequently, confirming a change in the sales strategies of group t_1 . They sell 44% than the control group; They took advantage of price peaks for their production. These results coincide with the previous results where, despite a limited impact on the price, the group treated t_1 received higher turnover than the other groups and was due to their strategy of reducing the number of sales during the campaign and focusing on price peaks to sell the majority of their production.

²⁶The different modalities of the ordered probit are: "one sell" "two sell", "more than three sell"

2.6 Conclusion

This paper presents the results from a randomized control trial studying the impact of providing SMS-based agriculture market information in Burkina Faso. This market information service, called N'kalô, sends weekly SMS to farmers with information on prices, trends and gives them advice on the quantity of harvest to sell during the campaign period. The information provided by the service should help farmers to sell their production at the best price by improving their bargaining power with buyers and enable them to better arbitrate in the sale of the campaign (sell the harvest when the price is high). We also study farmers behavior through different information by providing two treatments (treatment1 current price level in the region treatment2 current price in the region, price trend and advice about quantity to sell) in order to understand different farmers strategies according to the different information received, how this impacts the price received, turnover, and marketing behaviors. The crop of interest is sesame, a cash crop production destined for exportation.

The experiment was conducted in collaboration with the NGO Nitidae, supplier of N'kalô, and involved 533 farmers living mainly in this region of Burkina Faso (East and Boucle du Mouhoun). Treatment was randomized across regions; we stratified our sample considering the other crops cultivated by the farmers and

the mobile phone operators. Even if our survey suffers from nonresponse and contaminated control groups, randomized appears good because the control and treated groups are balanced on most relevant variables.

In our experiment, only 60% of the individuals who are offered the treatment (N'kalô information) take it up. That refers to imperfect compliance, that's why we report the intention to treatment where the receipt of treatment is ignored, and outcomes are compared by the assignment to treatment. We also reported IV estimation in which the assignment to the treatment is used to instrument reception of N'kalô SMS.

The impact of N'kalô information on price is about 4%. This impact varies according to the treatments received. Farmers who received only up-to-date price information perform better than those who received price and trend information and advice on how much to sell; the results are not statistically significant for them. N'kalô users, especially those who have received price information, modify their marketing behavior by reducing their sales frequency and selling the majority of the production peaks prices. They were more strategic than those who received the second treatment using N'kalô information to better allocate their sales on time. Distribution of the treatments impact differs through farmers, living far away generate a high transaction cost, the security problems experienced by Burkina Faso can help mitigate the effect of the treatment. That is why we have a high price dispersion that is due to asymmetric information and transaction costs. Using a quantile treatment effect on the treated and focusing on compliers,

the impact of the treatment on price and turnover is significantly positive for the first three quartiles, referring to farmers receiving a lower price and having an opposite impact on farmers receiving higher prices.

Appendix A

Let $z_i \in 0, 1$ a dummy variable denote the randomly assigned treatment by N'kalô (instrument variable). Let $Y_i(z)$ denote the potential treatment outcome given assignment Z_i as sales price and the turnover during the sales period, and $t_i \in 0, 1$ a dummy variable denote if the treatment was received (endogenous variable). Define two potential outcomes $t_i(0)$ and $t_i(1)$, representing the value of the status of treatment received given the two values of the instrument z_i . $Y_i(z, t)$ denote the potential outcome corresponding to assignment z and treatment received t .

Intention to treat analyses

In an intention-to-treat analysis the receipt of treatment is ignored, and outcomes are compared by the assignment to treatment (Imbens & Rubin (2015)). The intention-to-treat effect is the average effect of the assignment to treatment. In terms of the notation introduced above, the estimation is

$$D^{itt} = \frac{\sum_{i=1}^N (Y_i(1, t) - Y_i(0, t))}{N}$$

(2.4)

Where N is the number of the observations the intention-to-treat principle provides

an unbiased assessment of the efficacy of the intervention at the level of adherence observed in the trial. This level of adherence could be similar to that observed in the community, and the results could inform community-based decisions about the effectiveness of the experimental intervention Montori & Guyatt (2001).

Local average treatment effects

An alternative approach that deals directly with the non-compliance is to use instrumental variables methods and related methods based on a set of assumptions. The first one is INDEPENDENCE: $z_i \perp (Y_i(1), Y_i(0), t_i(1), t_i(0))$ It requires that the instrument is as good as randomly assigned, and that it does not directly affect the outcome. The second assumption requires a Random Assignment $z_i \perp (Y_i(1, 1), Y_i(1, 0), Y_i(0, 1), Y_i(0, 0), t_i(1), t_i(0))$. The third one is Exclusion Restriction It requires that there is no direct effect of the assignment on the outcome without passing through the receipt of treatment. Formally, using the form used in Angrist, Imbens and Rubin (1996).

The last one is is monotonicity (Imbens and Angrist, 1994), or no-defiance, which requires

$$t_i(1) \geq t_i(0)$$

Table X summarizes the information about compliance behavior from observed treatment status and instrument taking in account this monotonicity assumption. This rules out the presence of defiers, units who always (that is, whether assigned to control or treatment), do the opposite of their assignment.

Table X summarizes the information about compliance behavior from observed

treatment status and instrument taking in account this monotonicity assumption.

To estimate the average treatment effect on compliers only or the local average treatment effect LATE. Let denote π_c , π_n and π_a be the population proportions of compliers, never-takers and always-takers respectively. We consider the least squares regression of Y on a constant and Z . The slope coefficient in that regression estimates.

$$E[Y_i|z_i = 1] - E[Y_i|z_i = 0]$$

Consider the first term:

$$\begin{aligned} E[Y_i|z_i = 1] &= E[Y_i|z_i = 1, \text{compliers}].Pr(\text{compliers}|z_i = 1) + E[Y_i|z_i = 1, \text{never-taker}].Pr(\text{never-taker}|z_i = 1) \\ &+ E[Y_i|z_i = 1, \text{always-taker}].Pr(\text{always-taker}|z_i = 1) \\ &= E[Y_i(1)|z_i = 1, \text{compliers}].\pi_c + E[Y_i(0)|z_i = 1, \text{never-taker}].\pi_n + \\ &E[Y_i(1)|z_i = 1, \text{always-taker}].\pi_a \end{aligned}$$

(2.5)

Similarly

$$\begin{aligned}
E[Y_i|z_i = 0] &= E[Y_i|z_i = 0, compliers].Pr(compliers|z_i = 0) + E[Y_i|z_i = 0, never - \\
&taker].Pr(never - taker|z_i = 0) + E[Y_i|z_i = 0, always - taker].Pr(always - \\
&taker|z_i = 0) = E[Y_i(0)|z_i = 0, compliers].\pi_c + E[Y_i(0)|z_i = 0, never - taker].\pi_n + \\
&E[Y_i(1)|z_i = 0, always - taker].\pi_a
\end{aligned}$$

(2.6)

Hence the difference is $E[Y_i|z_i = 1] - E[Y_i|z_i = 0] = E[Y_i(1) - Y_i(0)|complier].\pi_c$

The same argument can be used to show that the slope coefficient in the regression of W on Z is $E[W_i|z_i = 1] - E[W_i|z_i = 0] = \pi_c$

Hence the instrumental variables estimated, the ratio of these two reduced form estimates, is equal to the local average treatment effect.

Given the monotonicity assumption and the exclusion restriction we can identify the average causal effect of the receipt of treatment on the outcome, what is known as the local average treatment effect (Imbens and Angrist, 1994):

$$D^{late} = E[Y_i(1) - Y_i(0)|Complier] = \frac{E[Y_i|z_i=1] - E[Y_i|z_i=0]}{E[t_i|z_i=1] - E[t_i|z_i=0]} \quad (2.7)$$

AppendixB Guide d'enquête de mesure d'impact du SIM Nkalo

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Questionnaire traités

1. Identification
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Questionnaire non traités

Speech de départ

Pour introduire l'entretien, il est primordial de soigner son introduction pour instaurer un climat de confiance avec le producteur enquêté.

- Se présenter
- Bien insister sur les formules de politesse

Bonjour, je suis (votre prénom et nom), je travaille avec l'association Nitidae qui a pour objectif de venir en aide aux paysans en leur proposant des services adaptés à leurs besoins en matière d'information et conseil agricole. En particulier le service Nkalo qui conseille les agriculteurs sur le prix des produits agricoles.

Table 2.14: Farmers Characteristics

	(1)	(2)	(3)	(4)	(5)
	All sample	control	t_1	t_2	$treat_3$
	533	144	148	190	51
Individual Characteristics					
Age	41.2 (10.7)	42.8 (11.9)	40.4 (10.5)	40.3 (10.2)	43.2 (8.8)
% Mal farmers	95.4	85.7	93.8	97.3	92
% Finish his primary school	37.3	24.8	42.4	41	46.1
Life quality					
% Having electricity	85	79	91.1	84.6	86
% Being in debt	33.6	27.1	39.2	32.8	39.2
Geographical situation					
% of people living in region EAST	39	25.4	26.8	38	9.7
% of people living in region BOUCLE DU MOUHOUN	43	31.7	25.2	34.8	8.27
% of people living in region HAUTS BASSINS	13	14.5	36.2	33.3	15.9
% of people living in OTHER REGION	5	33.3	33.3	35.6	9.6
Distance to the nearest city	20.6 18.6	20.8 18.1	21.4 19.6	19.7 18	20.6 19.1
Distance to the nearest Market place	7.5 11.2	7.7 11.1	7.6	6.8 11.7	9.4 9.8
Agricultural information					
Field Area of sesame production	2.4 (2.3)	2.4 (2.3)	2.4 (2.4)	2.6 (2.2)	1.9 (1.6)
% of sesame as a principal crops revenue	61.7	67.4	56.8	63.2	54.9
% of Cotton producer	49.3	40.3	54.4	50.5	54.9
% of Arachide producer	66.5	66.5	62.6	70.6	62.7
% Of member in a cooperative	69.9	61.1	73.6	69.1	86.3
Average years of sesame production	7.4 6.1	7.1 6	7.8 6.3	7.5 6	6.5
Home building					
% of house build by Mud brick	80.1	82.6	80	81	70.6
% of house build by cement brick	8.3	8.3	6.9	8.5	11.8
% of house build by cut stone	9.5	7.6	8.3	10.1	15.7
% of house build by other materials					
N'kalô Usage					
% of those who know N'kalô	37	14	41	45	58
% of those who use N'kalô	48	0	56.2	64	100
% of those who use N'kalô need to translate the SMS	41.3	25	38.7	44.1	44
% Being visited by buyer more than one time on a week	50.3	50.7	54.6	3.7	61.2
% less than two sells	71	72	76	67	65
Commercial					
% of Commercial	9.6	5.6	10.8	12.1	8.2

Note: Authors' computation based on data 2019 after the survey, *** indicates statistical difference of means significant at ***1%, **5%, *10%. t_1 represent the treated group by an unique information on price. t_2 label the treated group by all information (price, trend and advice). *control* present the control group. *treated₃* present contaminated in the control group.

Table 2.15: Source for marketing information

	(1)	(2)
	<i>nonsignup</i>	<i>signup</i>
The important source to consult		
% Using last year price	60	67
% An other nearest producer	22.47	19.55
% Information by N'kalô or other services	25	39
% Cooperative information	17	12
% Information listen in the nearest local market	35	30
Where to sell the harvest		
% In local market	55	50
% To a middleman	33	40
% To a cooperative	5	6

Notes: Authors' computation based on data 2019 after the survey, *** indicates statistical difference of means significant at ***1%, **5%, *10%. Let *Sign-up* represent farmers who read N'kalô information. *No-sign-up* represent farmers who not read N'kalô information.

Nous travaillons sur une étude qui a pour vocation de connaître vos pratiques et vos besoins d'information pour vous proposer dans le futur un service de conseil tel que Nkalo plus adapté à vos besoins. Pour cela nous avons besoin de réponses les plus précises et objectives possibles.

La réponse au questionnaire ne prendra pas plus de 20 min de votre temps (Si la personne n'est pas disponible prendre rendez-vous avec elles, à un moment où elle sera disponible, et le notez dans l'enquête. Le moment de l'enquête doit aussi être aléatoire entre traité et non traité) Pour le groupe des traités : « Vous avez dû recevoir, sur la dernière campagne du sésame, un message Nkalo par semaine vous informant sur le prix du sésame.

Pour le groupe des non traités : « Nous avons besoin de faire une enquête pour évaluer leur besoin en matière d'information commerciale afin de leur proposer

dans un futur proche un service d'information tel que Nkalo en conseil mieux adapté à vos besoins.

En cas de non réponse à toutes questions mettre la cellule en noir.

1) Appeler l'enquêté s'il décroche et accepte à participer renseigner 1 oui 2 : non Si réponse oui à la question R0 et passer à la question Q1. Sinon R1 2) Si l'enquêté répond (5 disponibilité plus tard) passez à la question R2 et mettre la ligne en vert Si réponse 1 et 4 mettre la ligne en Rouge Passez à un autre enquêté. Si réponse 2, 3 mettre la ligne bleu et choisir une date et une heure si c'est le matin mettre comme heure l'après-midi et vice versa Si réponse 3. Au cas où l'enquêté rappel il faut le prendre demandez qu'il raccroche et que vous le rappeliez car c'est long. Et il sera l'enquêté à rappeler en priorité. Désactiver la couleur bleu ligne en blanc si vous finissez l'entretien avec lui. 3) Pour la colonne R2 Renseigner la date et l'heure du rendez vous

Questionnaire traités

Identification

1. Lui demander la langue qui l' arrange et dans laquelle il se sent le plus à l'aise pour l'enquête et la mentionner . 1. Français; 2. Dioula; 3. Mooré; 4: Gourmantchéma
2. Demander le nom et prénom. En écrivant le nom,

3. Demander la profession de l'enquêté.
4. Lui demander son âge sinon son année de naissance en aaaa.
5. Est-il un homme ou une femme ? 1. Féminin 2. Masculin à mentionner par vous-même.
6. Lui demander sa région
7. Lui demander sa province
8. Lui demander son département
9. Lui demander le nom de sa ville ou son village
10. Lui demander s'il parle français.
11. Lui demander s'il était à l'école publique ? si la réponse est non passez à la question Q12
12. Lui demander s'il a achevé le cycle des études primaires
13. Demander de quelle grande ville la plus proche
14. Leur faire estimer une distance à la grande ville la plus proche, en Km
15. Leur faire estimer une distance du marché hebdomadaire le plus proche. En Km Maintenant je vais vous poser des questions sur les équipements de votre logement.

Qualité de vie

16. Lui demander le matériel principal qui constitue les murs de son logement
01: Terre battue (trouver nom local) 02: brique en banco 03: brique en ciment
4: pierre taillée 5 : autres
17. Avez-vous l'électricité à la maison? Si oui, est-ce la SONABEL ou bien votre propre investissement plaque solaire Maintenant je vais vous poser des questions sur vos pratiques financières
18. Lui demander si pendant les 12 derniers mois il a eu recours à l'emprunt sinon Q20 Si oui continuer à Q19
19. Lui demander l'objectif de cet emprunt était pour payer 01: besoin de tous les jours (manger, paiement de facture d'électricité ou d'eau) 02: charge de santé (achat des médicaments, hospitalisation...) 03: dépenses liées à l'exploitation agricole en début de production 04:préfinancement de la production du sésame ou autre produits agricoles 05: frais de scolarité 06: investissement non agricole 07 : autres Maintenant je vais vous poser des questions sur votre production agricole
20. Lui demander avez-vous cultivé du sésame cette année ; sinon, l'enquête se termine et la ligne du contact est mise en Orange.
21. Lui demander la superficie dédiée à cultiver le sésame dans son champ en

Hectare

22. Lui demander depuis combien d'année il produit le sésame ? réponse en an
(aa)
23. Lui demander s'il cultive de la noix de cajou? 1 oui, 2 : non
24. Lui demander s'il cultive du coton ? 1 oui, 2 : non
25. Lui demander s'il cultive de l'arachide ? 1 oui, 2 : non
26. Lui demander s'il est membre d'une coopérative ? sinon question
27. si oui question suivante :
28. Quelle est sa fonction dans la coopérative (1. Membre simple; 2. Membre du Bureau Exécutif (ou Membre du bureau de direction))
29. Lui demander Quelle est votre principale culture destinée à la vente? 01: Noix de cajou, 02: Coton, 03: Sésame, 04: Arachide, 05: Autres
30. Lui demander Selon vous, quelle information est la plus importante pour vendre au meilleur prix? 01: le prix local par région et la quantité à vendre pour chaque période de la campagne agricole, 02: les prévisions des experts sur l'évolution future des prix
sinon PASSER ENSUITE A LA section utilisation de l'information
Maintenant je vais vous poser des questions sur l'utilisation de l'information. 3. Utilisation de l'information
31. Lui demander s'il connaît le service proposé par N'kalô, 1 oui, 2 : non

32. Lui demander Avez-vous reçu des sms sur le marché du sésame del la part de N’Kalô pendant la campagne sésame? , 1 oui, 2 : non Sinon passez à la Question Q34 Si oui question suivante Q32
33. Lui demander s’il a eu le besoin de traduire le message reçu de N’kalo ? Sinon Q34 Si oui Q33
34. Dans quelle langue ? 01: Dioula; 02: Mooré, 03: Golmancema
35. Lui demander si D’autres personnes vous ont-ils oralement ou par SMS communiqué les conseils fournis par le service N’kalo? , 1 oui, 2 : non
36. Si réponse oui à la question Q31 ou Oui à la question Q34 : Avez communiqué cette information? 01 oui, 02 non, sinon question Q37 si oui question Q36
37. à qui avez communiqué cette information? 01Producteurs de votre famille
02 autres producteurs 03 Les 2 à la fois
38. Lui demander Combien de fois avez vous montré les SMS aux acheteurs?pour négocier le prix ? 01: non jamais, 02: oui quelque fois,03: oui très souvent
39. Lui demander s’il a reçu d’autre information de conseil sur le prix du sésame par d’autres services que N’kalo (service public ou M agri ..)
40. Si réponse oui à la question Q38 Avez communiqué cette information? 01 oui, 02 non, sinon question Q41 si oui question Q40

41. à qui avez communiqué cette information? 01Producteurs de votre famille
02 autres producteurs 03 Les 2 à la fois

Maintenant je vais vous poser des questions sur votre récolte de sésame et
votre stratégie de vente

42. Stratégie de vente

PASSER ENSUITE A SECTION **stratégie de vente**

43. Demander aux producteurs la quantité obtenue du sésame cette année unité
de mesure 1 :Kg 2 :plat yourba 3 tine 4 boite 5 sac de 80kg

44. Demander aux producteurs la quantité vendue du sésame cette année depuis
le mois octobre unité de mesure 1 :Kg 2 :plat yourba 3 tine 4 boite 5 sac de
80kg

45. Lui demander si avant de vendre sa récolte il cherche à obtenir de l'information
afin de déterminer votre prix de vente? 1 oui, 2 : non sinon question Q41
Si oui question suivante

46. lui demander quelle information la plus utile selon eux 01: l'information
obtenue auprès d'autres producteurs voisins, 02:l'information reçue auprès
d'un service de conseil agricole M'agri ou N'kalo ou d'autres services publics,
03:l'information reçue auprès d'une coopérative

47. Les prix du sésame de l'année passée, vous ont-ils été utile pour déterminer
votre prix de vente? 1 oui, 2 : non

48. Demander aux producteurs combien de fois ils étaient visités par des pisteurs ? 1 : pas du tout, 2 : Une fois pas semaine, 3 : plusieurs fois par semaine, 4 : une fois par mois.
49. Combien de ventes de sésame avez-vous effectué durant la campagne?
50. Est-ce qu'il vous reste des stocks de sésame? Si oui, en kg Si non, 0 kg
- Il s'agit de la partie cruciale qui doit accaparer l'essentiel du temps.
51. Renseigner la quantité vendue selon l'unité de mesure annoncée par le producteur pour la première vente : unité de mesure 1 :Kg 2 :plat yourba 3 tine 4 boite 5 sac de 80kg . Lui demander à qu'il a vendu principalement sa récolte à chaque période : choix entre 01pisteur, 02 : coopérative, 03 : sur le marché local, 4 plusieurs acheteurs (si le producteur n'arrive pas à choisir un seul acheteur) mentionné le prix par unité de mesure et s'assurer que c'est la même unité exprimée
52. Renseigner la quantité vendue selon l'unité de mesure annoncée par le producteur pour la deuxième vente : unité de mesure 1 :Kg 2 :plat yourba 3 tine 4 boite 5 sac de 80kg . Lui demander à qu'il a vendu principalement sa récolte à chaque période : choix entre 01pisteur, 02 : coopérative, 03 : sur le marché local, 4 plusieurs acheteurs (si le producteur n'arrive pas à choisir un seul acheteur) . mentionné le prix par unité de mesure et s'assurer que c'est la même unité exprimée

53. Renseigner la quantité vendue selon l'unité de mesure annoncée par le producteur pour la troisième vente : unité de mesure 1 :Kg 2 :plat yourba 3 tine 4 boîte 5 sac de 80kg . Lui demander à qu'il a vendu principalement sa récolte à chaque période : choix entre 01pisteur, 02 : coopérative, 03 : sur le marché local, 4 plusieurs acheteurs (si le producteur n'arrive pas à choisir un seul acheteur) mentionné le prix par unité de mesure et s'assurer que c'est la même unité exprimée
54. Renseigner la quantité vendue selon l'unité de mesure annoncée par le producteur pour la quatrième vente : unité de mesure 1 :Kg 2 :plat yourba 3 tine 4 boîte 5 sac de 80kg . Lui demander à qu'il a vendu principalement sa récolte à chaque période : choix entre 01pisteur, 02 : coopérative, 03 : sur le marché local, 4 plusieurs acheteurs (si le producteur n'arrive pas à choisir un seul acheteur) mentionné le prix par unité de mesure et s'assurer que c'est la même unité exprimée
55. Renseigner la quantité vendue selon l'unité de mesure annoncée par le producteur pour la cinquième vente : unité de mesure 1 :Kg 2 :plat yourba 3 tine 4 boîte 5 sac de 80kg . Lui demander à qu'il a vendu principalement sa récolte à chaque période : choix entre 01pisteur, 02 : coopérative, 03 : sur le marché local, 4 plusieurs acheteurs (si le producteur n'arrive pas à choisir un seul acheteur) mentionné le prix par unité de mesure et s'assurer que c'est la même unité exprimée

Pour la partie du groupe traité poser les questions suivantes

56. Vendez-vous chaque année à ces mêmes périodes? 1-oui 2-non sinon passez à Q55

57. Demander aux producteurs quelle était la tendance des prix de vente pendant les 15 derniers jours de mars ? 01: les prix ont baissé, 02: les prix sont restés constant, 03: les prix ont augmenté 04: je ne sais pas

Questionnaire non traités

Le questionnaire non traités est le même que les questionnaires pour les traités

Chapter 3

Mobile money and inter-household financial flows: Evidence from Madagascar

Abstract

Mobile money is expanding rapidly across the African continent with the potential to raise financial inclusiveness. In this paper we investigate the impact of the introduction of mobile money in 2010 on the amount and frequency of funds sent and received among Malagasy households. We use a selection model combined with an instrumental variable approach to deal with the selective participation into the transfer market and the endogeneity of mobile money adoption. We show that access to mobile money has triggered more financial transactions between households at both the extensive (number of potential users) and intensive mar-

gin (level of funds) Our results suggest that transactions costs are important and act as a barriers to entry for the poor. The advent of new communication technologies has the potential to alleviate these barriers and bring into secure financial transactions a large segment of a previously excluded population.

Keywords : Mobile Money, Remittances, Transaction costs, Africa, Financial inclusiveness, Madagascar.

Résumé

On observe, en particulier en Afrique, un développement rapide des transferts financiers entre les ménages par l'intermédiaire du téléphone portable, le « mobile money ». Cette innovation technologique pourrait contribuer à améliorer l'inclusion financière des populations. Dans cet article, nous étudions l'impact de l'introduction du mobile money en 2010 à Madagascar sur les volumes et les fréquences des transferts d'argent entre les ménages. Pour traiter de la sélection des ménages dans leur décision d'envoyer ou de recevoir des fonds et de l'endogénéité de l'adoption du mobile money, nous estimons un modèle de sélection combiné à une approche par variable instrumentale. Nous montrons que l'accès au mobile money a permis, d'une part, d'accroître le niveau et la fréquence des transferts entre les ménages et, d'autre part, d'envoyer et de recevoir des fonds entre un plus grand nombre de participants. Nos résultats suggèrent que les coûts de transaction associés aux formes traditionnelles de transferts constituent un obstacle à l'accès des plus pauvres aux services financiers. L'introduction

des nouvelles technologies de communication pourrait permettre d'atténuer ces barrières et de développer des services particulièrement attractifs et adaptés aux moyens et aux besoins des populations auparavant exclues.

Mots clés: Mobile Money, Transfert d'argent, Coûts de transactions, Afrique, Inclusion financière , Madagascar JEL Code: D14, G21, O16

3.1 Introduction

Redirecting financial services toward the poor in developing countries is often viewed as a central pillar of development policies. Advancement of new communication technologies has tremendously reduced the transactions costs and is currently reshaping the landscape of financial services provided and demanded in the developing world. In this paper we investigate the effect of such technology, the *mobile money*, on financial flows across households in the context of a very poor African country.

Financial inclusion means the access to all financial services, including credit, saving, insurance, and payment. Transaction costs such as physical barriers, geographic and linguistic distance and informational issues, are impediments to financial inclusion raising the price to access financial services. In this context the advancement of communication and technology, reduces the need for brick and mortar offices and employees, lowers physical and interpersonal constraints, resulting in lower operational costs, but also improved and more affordable financial services. In this paper we aim to shed light on the effect of mobile money on financial transfers between households, in terms of participation and volume of flows.

The African continent is expected to be particularly impacted by the advent of new communication technologies. First, the banking sector in Africa is much less penetrated than that in any other major regions of the world (with about 21% on

average of adult population having a bank account, whereas in OECD countries the average is 90%) (World-Bank, 2014). Though there is significant heterogeneity across the continent in terms of the development of the banking system. The financial sector is more developed in Southern Africa and North African countries than in East and West African countries.¹ Second, the banking system in Africa is less inclusive than in other developed countries, and is characterized by high operating costs. Recently we observed the development of new forms of the banking system. In fact, many African banks have moved from a manual to a digital system effectively reducing operation costs. In particular, access to mobile phone in rural African areas has promoted the development of Mobile Money (MM). This form of banking has become more common in Africa in the last ten years. It allows users to send, receive funds, and to save money, allowing to effectively transfer purchasing power between households and over time. The mobile phone can also be used to purchase goods and services and share valuable information. Customers can send money directly using their own mobile phone and mobile money account after being registered in a mobile money agency. Customers can also send or receive money via a mobile money agency using a certified account for the agency if they don't have a mobile phone or mobile money account. It represents an opportunity to overcome geographical constraints in rural African areas with limited or no access to traditional financial institutions. It offers also

¹In Southern Africa the percentage of registered credit people rose from less than 1% in 2005 to around 7% in 2013. In North African countries this share rose from 3% in 2005 to around 9% in 2013. Over the same period the percentage of registered credit people rose from less than 1% to only 3% in East and West African countries (Nyantakyi & Sy, 2015).

secure, efficient and cheap access to financial services. For instance Blumenstock *et al.* (2015) show that mobile money in Afghanistan (M-PAISA) has reduced firm's administration costs and increased efficiency. Moreover, M-PAISA users are more likely to save money than individuals who are paid in cash.

Despite its potential benefit for providing a mechanism for saving, credit, insurance, payments, and transfers to the world's poor, mobile money remains a recent phenomenon and the available research and empirical evidence remain scant. Therefore there is a need to understand users' acceptance of mobile money and to identify factors affecting intentions to use Mobile Money Transfer services. This information can assist mobile network operators (MNOs) and service providers of Mobile Money Systems in creating services that consumers want to use, or help them discover why potential users avoid using the existing system.

In this paper we fill the knowledge gap in this area with a specific focus on the case of Madagascar, a large and poor African country with a highly underdeveloped financial service sector. In Madagascar the mobile money service was launched in 2010 and has been relatively successful in terms of adoption. Besides looking at the determinants of use we also investigate the effect of Mobile Money Services (MMS) on the probability of sending and receiving funds (extensive margins of financial demand) and on the level of fund sent and received (intensive margin). We deal with two important identification issues. First the participation in the transfer market as senders or recipients of funds is non-random which raises a sample selection issue. Second the decision to use mobile money

is very likely endogenous to non observable determinants of household decision to send and receive money and on the level of funds sent or received. We deal with these two issues by introducing a correction for sample selection (Heckman, 1979) within an instrumental variable approach to correct for both endogeneity and sample selection.

Our results are two folds. First we show that access to MMS has increased the probability of both sending and receiving money. Which suggests that transactions costs are barriers to access financial services for households, and that mobile technology helps financial services to reach the poor. For instance, we find that more remote households are more likely to use these services. Second, regarding the intensive margin, we found that MMS users send and receive more. These effects are robust to selection and endogeneity issues. Overall our results suggest that MMS have contributed to deepen financial inclusion in Madagascar.

The paper is organized as follows. In section 2 we provide a brief overview of the experiences of mobile money services in Africa and its potential economic effects primarily at the household level. In section 3 we provide background on the specific mobile money experience in Madagascar. In section 4 we present our empirical methodology and raises identification issues related to the endogeneity of mobile money adoption and the selection into transfer markets. In section 5 we present our empirical results regarding the determinant of mobile money adoption and its effect on the incidence and quantity of money received and sent by households. In the last section we conclude by highlighting open questions and

issues deserving further investigation.

3.2 Mobile money experience in Africa

3.2.1 Mobile money to reduce transaction costs

Households in Sub-Saharan Africa send or receive money using formal institutions (banks and post offices) but most often they have to rely on informal, costly and insecure ways such as bus companies, friends and family members. Money transfer services are not available or affordable for most senders. One of the reasons of the adoption of mobile money is the strong financial relation between urban and rural populations due to internal migrations. This generates an important potential domestic demand in Africa due to important flows of transfers within networks of family members and friends (Jack & Suri, 2014). Weil *et al.* (2012a) have examined data on the frequency of M-PESA use from the 2009 FinAccess Survey. They show that urban and more educated users, and wealthier individuals are using M-PESA relatively more frequently. Another factor explaining the development of mobile money in Africa is the positive regulatory positions of the Central Banks and the consciousness of the importance of the opening the door to new technologies in the financial sector. We should highlight that mobile money reduces the costs of sending and receiving money relative to traditional mechanisms. It also greatly reduces uncertainty associated to informal method of transfers. Sending remittances via money transfers companies (MTC), such

as Western Union, MoneyGram, Money Express, though it is secure, is widely considered as expensive.²

Transactions costs are particularly important impediment to the use of financial services in remote rural areas. Mobile money has the potential to reduce the costs of transferring resources between individuals, essentially by abolishing the distance between the suppliers and providers of funds, via the simple and convenient use of Short Message Services (SMS). For instance King *et al.* (2012) using the 2006 and 2009 Kenyan FinAccess surveys finds that the distance between survey respondents and their nearest bank branch fell only marginally between 2006 to 2009 from 14.54 km to 14.36 km. He analyzes the relation between proximity to a bank branch, the decision to be banked and to be an M-PESA user and finds that the negative relationship between distance to bank branch and the likelihood of being banked has increased. In contrast, he provides evidence supporting the hypothesis that mobile money in Kenya is helping to overcome the costs associated with bank infrastructure and has promoted the financial inclusion of all economic groups in Kenya.

²According to the survey of Mbiti & Weil (2011), the cost of instantly sending US \$100 through formal channels ranged between US\$12 (MoneyGram) and US\$20 (bank wire transfer), while the cost of slower formal channels ranged from \$3 (bus companies) to \$6 (postal money order). Compared to these alternatives M-PESA offered a significantly cheaper method of instantly transferring funds, where the cost of sending US \$100 to a non-registered user by M-PESA was approximately US \$2.50 in early 2008, the cost of sending to a registered user was even less.

3.2.2 Mobile money income and welfare

Availability and use of mobile money (MM) services can affect household welfare through different channels and in particular through their effects on household income and consumption, due to improved risk sharing within networks of family members and friends. Some studies focused on the role of mobile money in generating new resources in agricultural household economy context. Using panel data between 2009 and 2011 for 320 smallholder farmers in Kenya, Kikulwe *et al.* (2014) show that mobile money use has a positive and sizeable net impact on household welfare, increasing total income by 40% on average. Mobile Money contributes to increase the purchasing of inputs, like fertilizers, pesticides, and hired labor. Farmers can also sell a larger proportion of their production. Overall MM users have 35% additional profits per acre of banana production owing to the lower transaction costs (in terms of paying and receiving money from business partners).

A related study by Munyegera & Matsumoto (2016) confirm that MM for the case of Uganda has positive effects on income, consumption, and food security. They evaluate the impact of MM on household welfare using panel data covering 846 households. They find that MM has a positive and significant effect on household welfare via additional remittances received from relatives and friends. The main reason for the increase in remittances is due to lower transaction, transport, and time costs associated with mobile phone-based financial transactions in

particular in remote rural locations.

Further evidence is given by Aker *et al.* (2011) using a randomized evaluation of a cash transfer program delivered via the mobile phone. The program involves 96 ‘food-deficit’ villages in Niger villages. Households in targeted villages received monthly cash transfers as part of a social protection program. One-third of targeted villages received a monthly cash transfer via a mobile money, whereas one-third received manual cash transfers and the remaining one-third received manual cash transfers plus a mobile phone. The authors show that the program has substantially reduced the cost of distributing and obtaining the cash transfers, and households used their transfers to purchase a more diverse set of goods, increasing the diversity of their diets, depleted fewer assets, and grew a wider variety of crops, including marginal crops typically grown by women. Both the time savings for recipients of these M-transfers and the added security and privacy of electronic transfers explain these effects.

Mobile money allows users also to receive more remittances and save money to reduce risk and liquidity constraints. To show that Jack *et al.* (2013) and Jack & Suri (2014) use a panel data on users and non-users of M-PESA and exploit the exogenous gradual expansion of MM agents network throughout Kenya. They found that MM, by lowering transaction costs, provided effective risk sharing between households allowing to smooth their consumption. Therefore beside offering financial services mobile money has also the potential to improve existing informal insurance markets that relies essentially on inter-households financial

transfers. As argued by Jack & Suri (2014) high level of transaction costs is an important source of incomplete risk sharing that is typical in informal networks. In this context MM by lowering transaction costs has the potential to increase the efficiency of available informal insurance mechanism inducing more demand and supply by the participants on both side of the market. If this happens we should observe an increase of financial transfers between households, following MM adoption. These transfers could be interpreted as purchasing power or risk exchange between households.

3.2.3 Mobile money and monetary policy

Weil *et al.* (2012b) analyze the impact of M-Pesa on monetary aggregates in Kenya. In December 2011 the balance of e-float outstanding was only Ksh. 17.4 billion, however currency outside of banks (M0) was 137 billion shillings, while currency plus demand deposits (M1) was 623 billion shillings (Central Bank of Kenya, 2011). The balance of e-float was very small in comparison to the money supply, e-money didn't have a higher velocity than other types of money. Then, it didn't change the components of the money supply. Furthermore, they find that there is no concentration of withdrawals at amounts corresponding to price notches. They conclude that the monetary policy implications of MM are currently nugatory in Kenya. These conclusions are tentative because the diffusion rate for mobile money was still relatively modest at the time of the study. However, the

authors argue that this conclusion may change in the future since the diffusion of mobile money was still relatively modest at the time of their study. Ndirangu & Nyamongo (2015) update and extend Weil *et al.* (2012b) study on Kenya. They find that the fast pace of financial development in Kenya has not caused structural shifts in the long-run money demand relation, and has therefore not undermined the conduct of monetary policy in Kenya. Ndirangu & Nyamongo (2015) analyze the effects of financial innovation in the banking sector on the conduct of monetary policy in Kenya during 1998- 2012 (a number of financial innovations have taken place in the country in this period). The study focuses also on how financial innovations have impacted on the transmission mechanism of the monetary policy. The results show that innovations have improved the monetary policy environment in Kenya as the proportion of the unbanked population has declined and there has been a gradual reduction of currency outside banks. They find that the financial innovation has improved the effectiveness of the monetary policy. While earlier studies found no significant effect of monetary policy on the real sector, this analysis shows for instance that an interest rate shock impacts on GDP within 4 quarters and the effect remains effective until the 9th quarter. However, these innovations can destabilize the velocity of money and money demand. The authors suggest to adopt a more flexible monetary policy so that adjustments can be made in case of transitory shocks.

3.3 The experience of Madagascar

3.3.1 Background on mobile money in Madagascar

In April 2010 Telecom Malagasy (Telma) in partnership with the bank BFV-SG (part of the Société Générale banking group) launched "MVola", the first mobile money service in Madagascar. After three months, Orange, the French mobile network operator, in collaboration with BMOI (the group BNP Paribas) entered the market. Airtel Madagascar joined the service two years after the first launch on Madagascar in partnership with the Bank Of Africa-Madagascar. Lately, Airtel Money jointed the pool of MM service providers. Mobile money in Madagascar offers the possibility to deposit, transfer and withdraw money all over the country. Users of Mvola or Orange Money can also receive money from abroad and between the three operators. Madagascar is actually the second African country after Tanzania offering this interconnection between operators. They have also developed a payment mechanism, giving clients the option to pay for goods and services and Airtel Money creates a connection between the bank account and the MM user's account.

3.3.2 Data and summary statistics

To explore the impact of Mobile money on inter-household financial transfers we use the 2015 Madagascar FinScope consumer survey. The survey describes financial inclusion in Madagascar and identifies drivers of, and barriers to financial

access. This survey represents a benchmark for financial inclusion in Madagascar and provides a tool to assess future changes in this area. Data are collected using either simple random or random stratified sampling. Sampling frame and data weighting is conducted by the INSTAT. The weights are validated against data from the General Population and Housing Census in 1993 and subsequent projections. According to the listing conducted by INSTAT, the total adult population is estimated to be 11 million in 2014. Our sample includes 4795 interviews conducted by INSTAT from September 2015 to April 2016. In the context of a very poor country, indeed much poorer to Kenya, with a very low account penetration rate, it was unclear whether mobile money will represent a viable alternative. However, according to the national strategy of inclusive finance (SNFI 2013-2017) the number of users of mobile money has tremendously increased from 136000 subscribers and 1160 sales market in 2010 to 4640000 subscribers and 24680 sales market in 2016. This represents a very large increase in the penetration rate. The success is similar in magnitude to what has been observed in other acclaimed experiences in some eastern African countries, and notably Kenya where the technology has deeply changed the financial landscape of the poor (Jack & Suri, 2011).

According to the most recent World Bank country report data,³ Madagascar is the fifth poorest country in the world, with a GDP per capita equal to \$392.6. The country is plagued with a very high rate of extreme poverty (below \$1.90/day

³Available at <http://www.worldbank.org/en/country/madagascar/overview> and last access in 31st of october 2018.

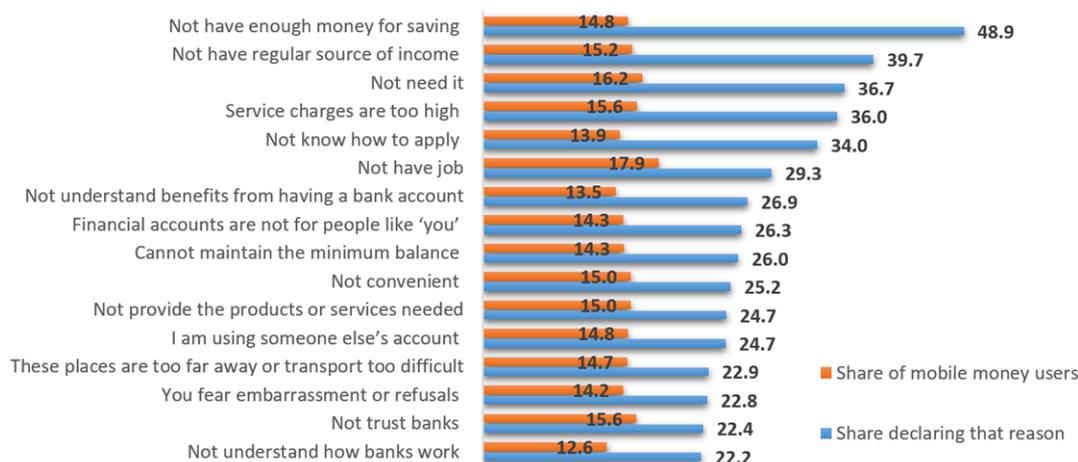
in purchasing power parity terms) which stood at 76.2% in 2017. Its population is young (41% are less than 30 years old), and largely rural (73% reside in rural areas) and has one of the lowest rates of education in the world (82% have no formal education, primary education or less) and the fifth largest country in the world with the highest number of unschooled children. Subsistence farming is very important; with 80% of households being involved in farming. Statistics derived from our sample are presented in Table 1 and portray a very similar picture.

Focusing on financial inclusion using our sample, we find that only one tenth of the population has a formal bank account. This share is much higher among mobile money users. Indeed, 12% use a combination of bank, and/or other formal and/or informal mechanisms to manage their financial needs. This combination of formal and informal services indicates that households' needs are not fully met by the formal sector alone. In this regard, it is instructive to look at principal barriers of this financial inclusion. In Figure 1 we present the main impediments for holding a bank account which are reported in our sample. For each type of reason reported we also indicate the share of mobile money users. Not surprisingly, the single most important reason for not holding a bank account is related to the lack of a sufficient and regular source of income. The costs of services are also reported for more than one third of the sample, however cost issues came only as the third reason. In general literacy and lack of knowledge to the use and benefits of a bank account are more frequently reported reasons for not holding a bank account. The share of mobile money users for each reported reason does not allow

to point out a clear single specific constraint on holding a bank account which will lead to a strong adoption of mobile money. Interestingly, the share of MM users is relatively equal and positively spread among all type of reasons reported. This suggests that MM may not only alleviate access to banking services by merely reducing costs, but also because it provides easier and more convenient access to these services. This is particularly important in our context where illiteracy is very high in the population (above 80% according to the World Bank (2018)). Indeed, this is also what is suggested in Figure 2, which shows the different reasons that lead individuals to use MM. By far the single main reason for using MM is related to the specific services it provides and how convenient it is in particularly in terms of time required. Overall, results of Figure 1 and Figure 2 suggest that mobile money will not only substitute standard formal structure, but also bring specific financial services that are tailored to the need of households which are excluded because of their poor adaptability to existing traditional banking institutions. As we shall see in the econometric section this may explain that mobile money will also increase the probability to send or receive money, beyond the level of amount sent. In that sense mobile money has the potential to create a deeper financial market by allowing a large segment of the non-bankable population to enter the market for inter-household transfers.

In this paper we seek to identify the potential causal impact of mobile money on access to finance and transfers. For that purpose it is important to bear in

Figure 3.1: Reasons to not use bank (%)

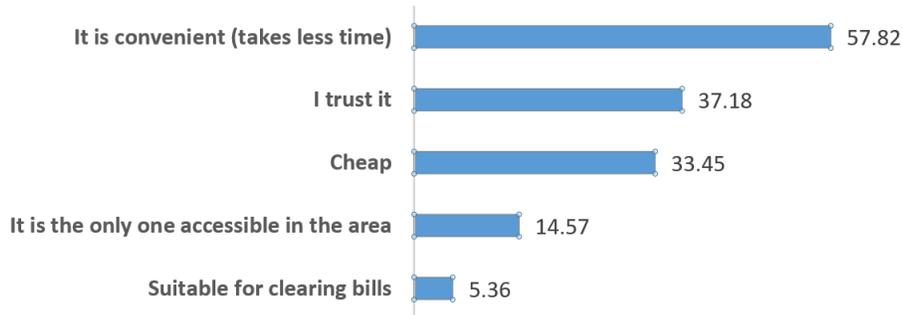


Source : Authors' computation based on Madagascar FinScope consumer survey 2015

mind that the use of mobile money is not randomly distributed among individuals. Indeed, users are very likely to be selected along characteristics explaining their potential demand and supply of money. This selection, on observable characteristics, can be seen in Table 1 and Figure 3 where we contrast the characteristics of mobile money users with that of non-users. The single most important determinant of transfer is probably the household level of income. We can see from Figure 3 that the distribution of income among mobile money users dominates that of non-users: mobile money users are clearly wealthier. In Figure 3, we also distinguish income distribution among mobile money users in two categories: those that are net senders and those that are net receivers. Comparing these two densities, it appears clearly that transfers flow from a relatively rich fringe of the population to a relatively poorer part. Interestingly, the income distribution of mobile money net receivers is relatively close to the income distribution observed among the

non-users, suggesting that mobile money has the potential to redistribute income from the relatively rich to the relatively poor which will increase global welfare.⁴

Figure 3.2: Reason to use mobile money (%)



Source :Authors' computation based on Madagascar FinScope consumer survey 2015

Besides income, mobile money users, which represent almost one fifth of our sample (see Table 1), are specific along several dimensions. Not surprisingly, they are much more likely to hold a mobile phone (66% against 26% for non-users). Note however that holding a phone is not necessary for using the service. Mobile money services can be accessed with the help of specific mobile money agents in various kind of commercial locations (shopkeepers, drug and food stores, gas stations, banks, and other institutions).⁵ Households can also use the mobile phone of friends and relatives.⁶ We notice in Table 1 that mobile money users are

⁴This will be clearly the case if the marginal utility of consumption is decreasing and if most remittances that flow to the poor are used to smooth consumption.

⁵Mobile money agents are very important for the functioning of the service. The most important services they provide are cash-in and cash-out (i.e. loading value into the mobile money system, and then converting it back out again). In many instances, agents also register new customers. Agents earn commissions for performing these services. As they are the human touch point for the mobile money service, they also often provide front-line customer service, such as teaching new users how to initiate transactions on their phone. Typically, agents will conduct other kinds of business in addition to mobile money.

⁶As shown by Jack & Suri (2014), the success of M-PESA for instance is indeed due to the

indeed less distant from mobile money agent, mobile money agents are important to transform virtual money in real cash (and vice versa) providing effective cash-in and cash-out services.

Overall mobile money users are already more financially integrated, they are more likely to hold a bank account, more likely to live in urban areas and to be better educated. It is therefore not surprising that users are wealthier than non-users as shown in Figure 3. Overall Table 1 portrays a situation where MM users are better connected and are already more financially integrated in the economy. It is therefore important to know whether MM can have an impact that is not already accounted for by the fact that users have a relatively higher propensity to already use financial services. We will tackle this issue in our econometric analysis.

large network of mobile money agents rather than the availability of mobile phones.

Table 3.1: Households' characteristics

	(1)	(2)	(3)	(4)
	All sample	MM Users	MM Non-Users	Difference (2)-(3)
Proportion of mobile money users	19.07		-	
% of mobile phone owners	37.66	66.03	26.03	0.40***
Time to reach to the nearest MM agent (mn)	83.02	51.13	90.53	-39.40***
Number of mobile phone by commune	10.02	12.55	9.35	3.20***
% of bank account owners	10.55	22.32	6.10	0.16***
Household income ('100000)	2.38	3.51	2.1	1.41***
Share of savers (%)	46.35	50.86	45.26	0.05***
Age of household head	44.80	46.01	44.51	1.51***
Education				
% with no formal education & primary education	78.88	65	82.16	-0.17***
% married	47.45	49.76	46.76	0.03***
Area type				
% living in rural area	74.23	56.28	78.46	-0.22***

¹ Note: Authors' computation based on Madagascar FinScope consumer survey 2015, *** indicates statistical difference of means significant at 1%

Table 3.2: Remitters and remittances characteristics

	(1)	(2)	(3)
	MM Users	MM Non-Users	Difference (1)-(2)
Remittances received			
Proportion of receivers (%)	79.09	5.01	0.74***
Amount received ('100000)	5.56	0.11	5.45***
Uses of money received (%)			
To pay for living expenses	48.18	44.22	0.04***
For medical and non medical emergency	36.66	32.86	0.04***
To invest and pay for debt	11.3	10.29	0.01***
To pay for education and school fees	17.37	15.08	0.02***
Remittances sent			
Proportion of senders (%)	48.93	6.47	0.42***
Amount sent ('100000)	0.73	0.061	0.67***
Destination of money sent (%)			
Family receiver	94.86	90.86	0.04***
Friend receiver	10.78	2.29	0.08***
Credit destination	2.4	0.40	0.02***

Note: Authors' computation based on Madagascar FinScope consumer survey 2015, *** indicates statistical difference of means significant at 1%

As said previously mobile money also has the potential to change the financial practices. By lowering transaction costs it may promote more frequent transfers, a wider use of these transfers among an enlarge set of senders and receivers. These aspects are considered in Tables 3.2 and Table 3.3 The results of these two tables can be summarized as follows: mobile money users are both more likely to send

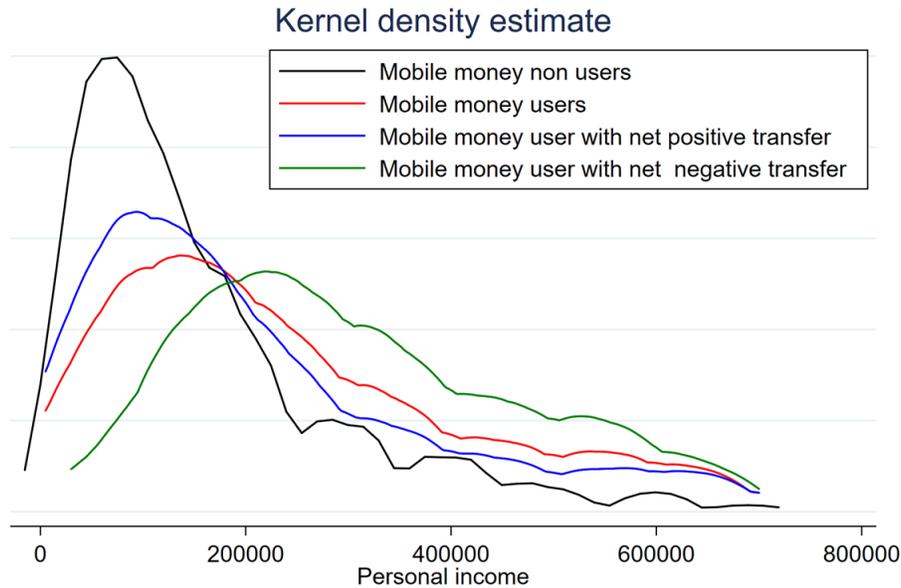
and receive transfers. Amounts received are particularly much higher for mobile money users. Money received is used for more or less the same reason as for non-users. Therefore, the use of mobile money does not seem to result from a specific demand of funds of households. Almost all funds sent occur within the family though we note that mobile money users are more likely to send money to friends; this is in line with the idea that mobile money may allow transactions within a wider network (Jack & Suri, 2014). Overall, funds sent and received via mobile money occur more frequently than those sent via informal channels but as frequently or just slightly more frequently than transfers occurring via formal channels.

Table 3.3: Frequency of sending and receiving remittances by channels

	(1)	(2)	(3)
	Non formal channel	Formal channel	Mobile money
Remittances sent			
% of remittances sent	42.02	2.75	55.21
% of Frequency of sending remittances by channel			
% of Weekly or Fortnightly or Monthly	39.36	55.30	52.10
% of Every six months	29.35	13.83	20.46
% of Once a year	31.29	30.87	27.44
Remittances received			
% of remittances received	6.30	2.59	91.11
Frequency of receiving remittances by channel			
% of Weekly or Fortnightly or Monthly	17.24	45.57	29.24
% of Every six months	39.98	34.85	44.66
% of Once a year	42.78	19.58	26.10

Notes: Authors' computation based on Madagascar FinScope consumer survey 2015

Figure 3.3: Distribution of income



Source : Authors' computation based on Madagascar FinScope consumer survey 2015

3.4 Empirical strategy

3.4.1 Model specification

In this section, we estimate three major equations, the determinants of mobile money adoption at the household level. The impact of mobile money adoption on financial inclusion measured by the total amount of remittances received and sent. The effect of mobile money adoption on the probability (and frequency) of receiving and sending remittances and on the amount remitted. Overall these three outcomes will provide a broad and deep picture on how mobile money impact financial inclusiveness.

Determinants of mobile money adoption

We can model the decision to adopt mobile money services as a function of characteristics of households which determine their net gain from using the services. This includes differences across individuals that are due to their geographical localization:

$$Mmoney_{id} = \alpha + \beta' * x_i + \varepsilon_{id}, \quad (3.1)$$

where "*Mmoney_{id}*" is a dummy variable which takes the value of 1 if the household *i* living in region *d* uses mobile money and 0 otherwise.⁷ We denote by *x_i* a vector of household level characteristics including household's head age, marital status and education, the revenue of the household, whether the household own a mobile phone, and indicators for household region of residence and rural status. We also include the average time to reach the closest mobile money agent and the number of mobile phones by commune as determinant of ease of access to mobile money services. We estimate Eq. (3.1) using a linear probability model. We also report estimations obtained using a probit model.

Mobile money and household remittance decision

First we evaluate the effect of mobile money adoption on the probability of receiving or sending money, that is on the probability to participate in the transfer

⁷Each observation represents a household represented by household head.

market. Similar to mobile money choice, we model the decision to send (supply) or receive (demand) funds as a standard threshold crossing binary choice model:

$$D_{id} = \theta + \beta_1 * Mmoney_{id} + \beta_2' * \tilde{x}_i + \mu_{id} \quad (3.2)$$

The random variable D_{id} takes the value of 1 whenever (the household is a sender or a receiver) and zero otherwise. The vector of control variable \tilde{x}_i includes all the variables of vector x_i of Eq. (3.1) except the number of mobile phone in the commune and the average time to reach the nearest mobile money agent in the commune. As we will be discussing below we assume that, conditional on variables included in \tilde{x}_i , these two variables impact the decision to receive or send fund ($D = 1$) only through their effect on mobile money adoption. Clearly, the adoption of mobile money services, $Mmoney$, may be correlated with unobservable characteristics that affect the probability to send or receive remittances. For instance, since it is a more secure and cheaper technology, having received or sent remittances on the past could determine current adoption of mobile money services. At the same time money sent or received in the past can affect the current probability of receiving or sending funds, through an income effect, or because households gave back money they have borrowed. In this case, we should take into account the endogeneity that result from the dynamic nature of inter households financial flows.

Accordingly, we use an instrumental variable estimation approach to identify the

effect of mobile money on the decision to supply or to demand funds. We use as an exogenous determinant of mobile money adoption the average time to reach the nearest mobile money agent, as in Jack *et al.* (2013) and Munyegera & Matsumoto (2016), and the total number of mobile phones in the locality. Our exclusion restrictions here is that, once we control for the full set of variables included in Eq (3.2), the average time to reach the nearest MM agent and the total number of mobile phones is not correlated with other determinants of inter-household financial flows (supply and demand) and affect these flows only through their effects on MM adoption. It is therefore crucial that we control for important determinants of financial transfers that may be correlated with our instruments. The most important determinant is household income which is clearly correlated with the number of mobile phone and probably with distance as well. Indeed, wealthier communities may be less remote and are also more likely to be connected. The level of education and age of household head are also very likely to be correlated with mobile money usage, since young and more educated individuals are more open to new technologies. Lately, we shall also control for whether the household own a mobile phone. Holding a mobile phone can have a direct effect on transfers by easing communications between senders and receivers. We want to isolate the effect of mobile money that is beyond the mere effect of better communication on transfers that is provided by owning a mobile phone.

Additionally, controlling for the direct effect of the mobile phone make our exclusion variable on the community level mobile phone usage more credible. This

allows to partial out the indirect effect that community level usage of mobile phone may have on transfers that goes through its effect on the probability for a household to have a phone. We emphasized that a substantial share of mobile money users do not have a mobile phone (34%), and at the same time a substantial share holding a phone don't use mobile money (63%). This allows us to identify the effect of mobile money conditional on whether the household has a mobile phone.

Another issue in our identification of Eq. (3.2) is that our endogenous regressor appears in a binary choice model. Most of the literature estimates such models by relying on an instrumental variable approach of the linear probability model (LPM), or a bivariate (bi-probit) model with an exclusion restriction and a restrictive joint normality assumption for the error terms.⁸ Despite its advantage of simplicity, the fitted probability in the LPM can go well below zero or above one which as shown by Lewbel *et al.* (2012) may seriously bias estimated coefficients due to model mis-specification. To overcome drawbacks of the linear probability model and the restrictive joint normality assumption of the bivariate probit we use the special regressors estimator proposed by Lewbel (2000). The special regressors estimator consistently estimates β under a specific set of assumption on an exogenous variable that enters Eq (3.2) (Lewbel, 2000). The special regressor approach to estimation does not require a specific model of the endogenous regres-

⁸Control function approaches to endogeneity are not applicable in our context as they required the endogenous regressors to be continuously distributed Wooldridge (2010). Which is clearly not the case here since mobile money is a dummy variable.

sors like continuity (for control function approaches) or normality (for maximum likelihood estimation of bivariate probit). Lewbel (2000) shows that other constraints of the linear probability model, such as overfitting at the boundaries, and of other estimators are lifted by using a special regressor. Applying the special regressor estimator requires (1) an exogenous regressor to be conditionally independent of ϵ_{id} in Eq. (3.2), and (2) to appear additively to the error term in the outcome equation, and (3) to be conditionally and continuously distributed with a large support. Any normally distributed variable will satisfy these conditions. Aside these conditions the special regressor does not require any constraints on the instrument or the endogenous variable. The requirements on the instrument are those of the standard 2SLS (conditional independence and full rank). Intuitively, under the assumption that the support of the special regressor contains the support of the latent variable (W^* , determining the threshold crossing), the special regressor can be used to recover all the distribution function of the latent variable (F_{W^*}). This is done by estimating the (conditional) probability of crossing the threshold at each value of the special regressor. Practically, the special regressor allows transforming the discrete endogenous dummy variable into a continuous endogenous function and applying an otherwise standard 2SLS estimation using the transformed continuous variable in place of the initial dummy variable.⁹ Inter-

⁹The transformation into a continuous variable is done by estimating a conditional density function for the special regressor as follows: let's Z denotes our excluded instrument, V the special regressor and D the endogenous dummy variable (*Money*). The transformation T is the following $T = \frac{D - I(V \geq 0)}{f_{V|Z}}$ where $f_{V|Z}$ is the conditional density function of V given Z . Once T is estimated we apply a standard 2SLS using Z as an instrument for \hat{T} which replace our endogeneous dummy variable. We refer the reader to Dong & Lewbel (2015) for additional

estingly, only one special regressor is required, no matter how many endogenous regressors appear in the model (Lewbel, 2000; Dong & Lewbel, 2015).

Mobile money and the level of financial transfers

To analyze the impact of mobile money in the amount of remittances received (or sent) we should take into account the fact that the process leading a household to decide whether to remit money or not can be separated from the decision on the amount remitted. The decision to remit may be influenced by the existing channels used to transfer money taking into account their costs. The amount of remittances can be influenced by the household income, variable transfer costs, and other characteristics that affect continuously the utility from receiving or sending remittances. Particularly important in the decision to send or receive money is whether the household can overcome the fixed transfer costs. Let's consider the simple decision problem where each household i decides on remittances by solving the following standard maximization program:

$$\max U_i = U(C_i, R_i) \tag{3.3}$$

$$s.t \quad Y_i = (C_i + R_i + \tau_{ij} \cdot I(R_i > 0)) \tag{3.4}$$

Where $U()$ is a continuous and differentiable utility function, C_i , R_i and Y_i indicate respectively consumption, remittances and income of the household i . We

details on available methods to estimate T .

denote by τ_{ij} the cost for each services j available to household i to transfer remittances (mobile money, western union, by bus, etc...) while R_i is the amount of remittances (sent or received). We assume that the marginal utility of consumption and remittances are strictly positive. The marginal utility of remittances (for receivers or senders) is positive as well.

There are various reasons why household wishes to transfer money, it can be for altruistic motives (Rapoport & Docquier, 2006), self-interest or reciprocity purposes (Jack *et al.*, 2013)).¹⁰ For whatever reason households send or receive remittances; there are some households for which we do not observe any utility from remitting. This will be the case if the fixed costs of sending or receiving funds are too high. The amount remitted will be zero whenever the minimum amount of remittances under which the additional utility that the household derives from remitting is lower than utility loss from transfer costs. The parameter τ_{ij} is unobserved and specific to each household. This property challenges the hypothesis of linearity and shows that the least square is not applicable.

More generally, a continuous density can not be used here to explain the conditional distribution of the remittances with respect to income: indeed, a continuous distribution is incompatible with the fact that for a large share of the population remittances are equal to zero. This amount may be zero also if the household does not attach any utility to remittances, due to differences in preferences for

¹⁰An alternative explanation proposed by Lucas & Stark (1985) is that remittances are based on self-interest motives, whereby the remitter expect private gains from remitting (in heritage, assets, reputation, status, etc.).

instance. Therefore, the estimations of equations for remittances must take into account the fact that the dependent variables (amount sent and received) are only observed if the household had actually sent or received money. However, since this observation is not random, it depends on how each household values the utility from remittances, estimations using OLS are therefore subject to a selection bias. A popular approach to this issue is the Heckman selection model (Heckman, 1979) which we will be using to correct for the self-selection of suppliers and recipients of funds.

Applying the approach requires having an exclusion variable which appears in the selection equation but not in the outcome equation. We have two instrumental variables for mobile money which by assumption are both (conditionally) not correlated with the unobserved error terms in our outcomes, the amounts equations. Therefore, we will be using one of those instruments exclusively in the selection equation. We will be using the mean time to reach the nearest mobile money agent in the locality as an exogenous (conditionally on x_{it}) determinant of selection into the decision to send or receive transfers. The rationale for using the variable "mean time to reach the nearest agent" as the excluded variable is the following: sending or receiving funds involve transaction costs. We consider these transaction costs as having two components: a fixed cost component for accessing the least costly technology (all sort of informal channels, banking system, mobile money, etc.) and a variable component that acts as a tax on each unit of amount sent or received. In such a standard conceptual framework we need to find a variable

which introduces randomness in the fixed costs of sending or receiving money. We consider the time to reach the nearest mobile money agent as one source of exogenous variability of fixed costs. Indeed mobile money agent in Madagascar provide important cash-in and cash-out services. These services are crucial to transform mobile money into real cash and therefore tangible good and services and vice versa. Distance to such services may act as an impediment to send or receive funds, even conditionally on mobile money. Distance to the nearest mobile money agent affect the decision to participate in a financial transaction (sending or receiving) by making mobile money a relatively more attractive means to send money. It increases the set of available methods for households and therefore the benefits from sending or receiving the first unit amount of money. The travelling and opportunity costs to reach the mobile money agent can be considered as an irreversible lump-sum tax on transfers sent or received in the household decision making process. These costs will introduce some discontinuity in the net benefit of transferring/receiving money generating the bunching of funds at zero value.

3.5 Results

3.5.1 Mobile money determinants

Table 2 presents the determinants of money adoption at the household level. We consider two different specifications. We report in the first column the result of a linear probability model and in the second column the result of a probit model,

in both cases we control for a full of set region fixed effects. The two models lead to very similar results. In the rest of the paper we shall mostly rely on the linear probability model. Results of Table 2 confirm previous statistical evidence. Households having a mobile phone are more likely to use mobile money services. This is expected: money is transferred through dedicated applications embedded in the mobile phone. Though, the magnitude of the coefficient also suggests that a substantial share of mobile money users do not own a mobile phone. Being younger, more educated and living in urban areas increases the probability of using mobile phone. Households are more likely to use mobile money if they live closer to mobile money agents. Households choose to subscribe and use mobile money services when the time to arrive to the nearest mobile money agent is relatively shorter. This confirms results of Munyegera & Matsumoto (2016) and Jack & Suri (2011) who use the distance to the nearest mobile money agent as a measure of access to mobile money services. They explain their results by the important role of mobile money agents in facilitating transactions in a way that provides cash-in and cash-out type services, effectively transforming virtual purchasing power in real cash and vice versa. The negative coefficient also supports the notion that relative urban concentration of banks is partially responsible for the slow adoption of formal financial services. The longer it takes to reach a bank agent the more likely is the household to use mobile money.

Table 3.4: Determinants of mobile money adoption

VARIABLES	(1) Linear probability model	(2) Probit (marginal effects)
If owns mobile phone	0.0908*** (0.000332)	0.101*** (0.000376)
Average time to mobile money agent per commune (per 100 mn)	-0.434*** (0.000500)	-0.326*** (0.000419)
Number of mobile phone by commune	-0.00255*** (1.60e-05)	-0.00307*** (1.78e-05)
Household income per 100000	0.0135*** (9.43e-05)	0.0191*** (0.000126)
Household Head Age	-0.00594*** (5.16e-05)	-0.00581*** (5.24e-05)
Being Married	0.0115*** (0.000283)	0.00760*** (0.000345)
Being educated	0.0187*** (0.000377)	0.0153*** (0.000418)
Rural Area	-0.0832*** (0.000434)	-0.0995*** (0.000488)
Constant	0.742*** (0.00157)	
Cragg Donald F-stat	69.39	
Stock Yogo critical value (10%)	10.83	
Observations	3493	3493

Notes. For the probit model the reported estimates are the marginal effects at the mean. The additional controls are age squared and region fixed effects. The R^2 in the linear probability model is equal to 0.273 and the likelihood ratio test in the probit model is equal to 1029.05. Hubert-White robust standard errors are reported in parenthesis under estimated coefficients. The statistical significance are: ***1%, **5%, *1%.

3.5.2 Mobile money and household remittances

Mobile money and net financial flows between households

We start quantifying the impact of mobile money impact by measuring its effect on the level of transfers between households which we take as a measure of financial inclusion. At that stage we limit our sample to only those households that are engaged in financial transfers. We calculate the net transfers by calculating the differences of all remittances received and sent over the last 12 months for each household. In column (1) of Table 5 we report the impact of mobile money on the net household transfer. In column (2) we report the results that take into account the endogeneity of mobile money using an instrumental variable approach. We use as instruments the average time to get to the nearest mobile money agent and the number of mobile phone in the commune. These two variables are measures of ease of access to mobile money services. Once we control for the determinant of money transfer between households, and in particular household income, there is no clear reason why the number of mobile money and the distance to a mobile money agent should have a direct impact on the amount of transfers. If there is an impact of these variables it is likely to be the case that it goes through the decision to transfer through mobile money technology which is done by going either to a mobile money agent or by using a mobile phone, which is not necessarily her own mobile phone.¹¹ Indeed the mobile phone and mobile money account could

¹¹It could be argued that the distance to reach the closest mobile money agent, or the number of mobile phones in the locality, are correlated with some local infrastructures facilitating communications. To check for such correlation, we have regressed the level of transfers on the

be that of friends or relatives. Table 4 provides the first stage estimation. It shows that the two instruments are indeed strongly correlated with mobile money adoption. In particular the Cragg-Donald F-statistics for the weak instrument test is larger than the critical value for the Stock-Yogo at 10% maximal IV size, which rules out weak instrument issues. Results of Table 5 show a significant and positive effect on net transfers, this is important as a lot of households are both senders and recipients of transfers. According to our IV results financial net flows among users of mobile money are 350000 MGA (87 euros) (Malagasy Ariary). This is a large impact representing a net gain of 25% of average yearly household income observed in our sample.¹² The fact that OLS overestimate the effect of mobile money suggests that mobile money users have unobserved characteristics that are correlated with the fact that they are more likely to be involved in inter-household financial transactions and at the same time are also more likely to be users of mobile money. Indeed the direction of the bias is consistent with the results regarding mobile money determinants. In particular

all explanatory variables included in Table 5 plus the instruments, for the sub-sample of mobile money users only. If the instruments were strongly correlated with any omitted variables affecting transfers, estimated coefficients for the instruments should be different from zero. Running such regression for both money sent and received, we obtain a very small effects of instruments on transfers. The impacts are not statistically different from zero. We have run similar regression over the sub-sample of non-users, and we still found a small and non-statistically significant effect of instruments. This suggests that our instruments are unlikely to be correlated with important omitted factors, and that the only reason why transfers are affected is through the indirect effect of instruments on mobile money adoption. Of course, we are not claiming that we are proposing a test of exclusion. However, had we found a strong positive and significant effect, this will cast serious doubts on the validity of our instrument, though not finding an effect does not allow us rejecting the hypothesis that our instrument is excluded from the structural equation. Results are available from the authors upon request.

¹²Note though that it not exceptional; Munyegera & Matsumoto (2016) find for the case of Uganda a net gain in household per capita due to mobile money of about 65%.

the fact that mobile money users are richer and more educated which explains also that they are more likely to be involved in any financial transactions. Beside this observable heterogeneity, other unobserved heterogeneity goes in the same direction in generating estimation biases in the least squares estimation.¹³

Does mobile money substitutes or complements other mode of transfers? We saw in Figure 1 and Figure 2 that the demand for mobile money may be offering specific services that are tailored to the need of a population which may not have access to standard method of transfers. Moreover, it is argued that mobile money, which is cheaper and more reliable, is a competitive substitute to existing modes of transfers. In order to tease out whether mobile money is a substitute or a complement to already existing channels, we regress the number of channels used

¹³An additional issue comes from the fact that transfers are reported by household. In principle users of mobile money may have a better reporting of their transfers since they are registered in their phone. The consequences in terms of coefficient bias are nevertheless ambiguous depending on the nature of measurement errors which is unclear since this does not necessarily mean systematic over or under reporting by those not using mobile money. To see the point let's assume that the random variable observation of transfer is $Y^* = Y + v$, where Y is the true observation and v is the measurement error. We can easily show that the asymptotic bias in OLS is equal to: $cov(v, M)/VAR(M)$, where M is a dummy for mobile money adoption. The bias due to miss-measured transfers can usefully be written $E(v|M = 1) - E(v|M = 0)$. Without loss of generality, we can assume that mobile money users correctly report their transfers. In that case the bias is simply $-E(v|MM = 0)$. We can see that if non-mobile money users systematically under-report ($E(v|MM = 0) < 0$) we will overestimate the effect of mobile money. Instead if they systematically over-report, we will under-estimate the true effect. But we could as well assume that the reporting errors occur at random. In that case they do not systematically under-report or over report and the bias is equal to zero. Though we will have $E(v^2|MM = 0) > E(v^2|MM = 1)$ which is a source of heteroscedasticity and loss of precision. In any case these measurement errors affecting the dependent variable will introduce additional noise in the estimated coefficients but coefficients may still be consistently estimated (see Hyslop & Imbens (2001), for a more thorough discussion). To control for this additional source of heteroscedasticity, in our paper we systematically report standard errors of coefficients which are robust to arbitrary form of heteroscedasticity using the Hubert-White (1980) correction. Lately, we highlight that the use of an IV strategy will also correct for the source of bias due to greater miss-measurement of transfers among non-mobile money users. Our instruments are not correlated with these measurement errors and are therefore valid to correct for this issue.

by households for transferring money (sending and receiving remittances) on the use of mobile money. Specifically we run the following regression:

$$nbchannels_{id} = \pi_0 + \pi_1'x_{id} + \pi_2 Mmoney + \zeta_{id} \quad (3.5a)$$

where x_{id} is the vector of control variable included in the estimation of net transfers of column (1) and (2) of Table 5. We estimate Eq. (3.5a) by 2SLS, using the same previous instruments, to deal with the potential correlation of ζ_{id} with the number of channels used. In Eq. (3.5a) testing for substitutability amount testing, the null $\pi_2 = 1$ against $\pi_2 < 1$. The results presented in column (3) of Table 5 show that the coefficient is slightly, but statistically significantly, below 1. Therefore mobile money is rather a substitute to existing channels. However, the fact that the coefficient estimated remains relatively close to one suggests that probably a large share of users are still using mobile money as a complementary channel.

Table 3.5: Mobile money and household net transfer and transfer channel

VARIABLES	(1)	(2)	(3)
	OLS Net transfer	Instrumental Variable Net transfer	Instrumental Variable Number of channels
Mobile money	0.570*** (0.0139)	0.354*** (0.0993)	0.921*** (0.0381)
Constant	0.713*** (0.0166)	2.099*** (0.0708)	-0.269*** (0.0777)
Observations	3605	3605	3308

Notes. Additional controls include, age, income, a dummy for educated household and for being married, a rural area dummy and region fixed effects. Average time to reach a mobile money agent is used as the exclusion variable in the participation equation and the number of mobile phone by commune is used as instrument for mobile money. Hubert-White robust standard errors are reported in parenthesis under estimated coefficients. The statistical significance are: ***1%, **5%, *1%

Mobile money and household remittances

We now consider the effect of mobile money on the probability to receive (Table 6) and to remit (Table 7). For each decision we run four different regressions: a linear probability model (columns 1 in Table 6 and 7), a probit model (columns 2 in Table 6 and 7), a linear probability model estimated by instrumental variable to take into account the endogeneity problem (columns 3 in Table 6 and 7). Additionally due to the dichotomous nature of our dependant and independent endogenous variable, we use a special regressor estimator in an IV framework (columns 4 in Table 6 and 7). We use as a special regressor the logarithm of household income. The logarithm of household income is a good candidate for a special regressor: (1) it is plausibly contemporaneously exogenous to current transfers and receipts, (2) it has a large support and (3) in the context of a poor and unequal country a thick tail.¹⁴ These conditions, as shown by Lewbel (2000), are required for the special regressor to be consistent, and not sensitive to outliers.¹⁵ We complete these estimations with a look at the effect of mobile money on the frequency of transfers and receipts. For that purpose we employ an ordered probit model (columns 5 in Table 6 and 7) using a control function approach involving the inclusion of first stage residual

¹⁴Informally, small sample biases tend to be small when the variance of income has comparable or greater magnitude than the variance of other determinant of financial flows including unobserved components (see Lewbel (2000)).

¹⁵We recognize though that the exogeneity of income in our context is disputable, indeed unobserved shocks may affect both income and decisions to send or receive money. Therefore we better view the application of the special regressor as a complement to the LPM which relies on other assumptions.

in the structural form ordered probit as suggested by Wooldridge (2010).¹⁶ As before, our excluded instruments are the average time per commune to reach the nearest mobile money agent, and the number of mobile phones per commune. Again, the OLS estimation of the linear probability model and the ML estimation of the probit model give similar marginal effects. Moreover users of mobile money are on average more likely to send or receive funds than non-users. Qualitatively, the effects remain similar once we take into account endogeneity of mobile money using the IV linear probability and the IV-special regressor estimator. However, the effect size are of an order of magnitude much larger with the linear probability model estimated by IV and much lower once we use the special regressor approach. This suggests that special regressor corrects for potential important drawback of the linear probability model in our context as emphasized by Lewbel *et al.* (2012). In this later estimation, access to mobile money increases the probability to receive by 33%, and the probability to send funds by 24%. The direction of the bias suggests that users of mobile money on the demand side of funds have characteristics explaining that they are more likely to receive while sender have characteristics explaining that they are more likely to send. These confirm that mobile money is positively correlated with characteristics of households explaining their greater propensity to participate in inter-household financial transactions. The last column of Table 6 and Table 7 show that MM users send and receive

¹⁶The different modalities of the ordered probit are: "No transfer" "Once a year", "Every six months", "Fortnightly", "Monthly", "Weekly".

money more frequently, this is consistent with the idea that mobile money by lowering transaction costs allows more frequent transactions. This is an important result. Indeed, in a poor country context with low saving capacity, remittances are very often used by households to smooth their consumption Jack & Suri (2014). Overall our results show that MM has contributed to increase the incidence and frequency of inter-households financial transfers.

Table 3.6: Mobile money and probability to receive

VARIABLES	(1) OLS prob_receive	(2) Probit prob_receive	(3) iv ols prob_receive	(4) Specialreg prob_receive	(5) IV Ordered Probit frequency of receiving
Mobile money	0.654*** (0.0181)	0.654*** (0.0201)	0.734*** (0.174)	0.331* (0.175)	2.206*** (0.109)
Constant	0.417*** (0.0567)		0.409* (0.226)	-0.207 (0.159)	
Observations	3,065	3,113	3,113	3,113	2696
R-squared	0.513		0.505		

Note. Additional controls include, age, the household log income, a set of dummy variables for education, marital status and rural area, and full set of region fixed effects. In the estimation of column (4) the household log income is used as a special regressor. In columns (3), (4) and (5) average time to reach the mobile money agent in the commune and the number of mobile phones by commune are used as excluded instruments. The estimation sample of column (5) includes also households receiving no remittances. Robust standard errors are reported in parentheses. The statistical significance are: ***1%, **5%, *1%

Next we turn to the effect of mobile money on the intensive margin of financial flows, that is the level of funds send and received conditionally on observing such flows. Results are reported in Table 8. Since we are considering these effects conditionally on sending or receiving money we should deal with one additional issue, which is the sample selection due to the endogenous participation decision. Therefore, beside the estimation with standard OLS (columns 1 and 4), we also present results that correct for sample selection using the estimated inverse mills

Table 3.7: Mobile money and probability to send

VARIABLES	(1) OLS prob_send	(2) Probit prob_send	(3) iv ols prob_send	(4) Specialreg prob_send	(5) IV Ordered Probit frequency of sending
Mobile money	0.376*** (0.0200)	0.398*** (0.0239)	0.910*** (0.282)	0.245** (0.123)	0.850*** (0.00172)
Constant	-1.572*** (0.110)		-1.133*** (0.266)	-0.155* (0.0939)	
Observations	2,596	2,548	2,596	2,596	3284
R-squared	0.371		0.110		

Note. Additional controls include, age, the household log income, a set of dummy variables for education, marital status and rural area, and full set of region fixed effects. In the estimation of column (4) the household log income is used as a special regressor. In columns (3), (4) and (5) average time to reach the mobile money agent in the commune and the number of mobile phones by commune are used as excluded instruments. The estimation sample of column (5) includes also households sending no remittances. Robust standard errors are reported in parentheses. The statistical significance are: ***1%, **5%, *1%

ratio (columns 2 and 5). Lately in columns (3) and (6) we deal with both endogeneity of mobile money access and sample selection, using an IV approach while also controlling for selection by including the estimated mills ratio in the structural form which is estimated. Since we have two instrumental variables, we can deal with the two exclusion restrictions. We use the average time per commune to reach to nearest agent as excluded instrument for the participation equation and the number of mobiles in the IV estimation.¹⁷ Our results are sensitive to the method of estimation which suggests that both selection into the decision to participate in a financial transfer and endogeneity of mobile money are impor-

¹⁷The exclusion restriction in the selection equation remains disputable. As an alternative we also estimated a Tobit model which does not rely on such exclusion restrictions, but which assumes that zero is an optimal solution in the transfer decision. We obtained a very large coefficient regarding the effect of MM. This cast some doubts on the Tobit specification to model remittances. These doubts are reinforced by looking at remittances distribution around zero. As stressed by Greene (2012), the Tobit model pred ICTs not only a cluster of zeros but also a grouping of observations near zero. This is clearly not the case in our data as we observe a clear discontinuity in the transfers away from zero.

tant issues to deal with in order to recover meaningful estimates. Interestingly, the coefficient associated to the IMR indicates opposite selection in each outcome equations. There is a positive selection in the level of fund received, suggesting that those receiving funds have high propensity to receive, while those sending funds, have unobserved characteristics that makes them less likely to be senders. Results presented in columns (3) and (6), i.e. after controlling for both selection and endogeneity issues, show that using mobile money increases substantially the amount of fund sent and received. The effect on the amount remitted (+39%) is larger than that on the amount received (+31%).¹⁸ Results of Table 6, 7 and 8 portray a situation where mobile money has deepen the financial flows at both the extensive margins (more participants in both side of the markets) and the intensive margin (more demand and supply of funds). In general controlling for the endogenous participation in inter-household transactions, and the endogeneity of the decision to use mobile money increases the estimated impact of mobile money on the amount of fund received. The direction of the bias, here negative, suggests that mobile money has pushed into the transfer market households with relatively

¹⁸The fact the coefficient is negative in the OLS and positive in columns (3) and (6), suggests that mobile money adopters receiving funds have unobserved characteristics that makes them less likely to receive funds. This suggest that MM is negatively correlated with the propensity to receive funds in our population. We think that this is the case if mobile money users are drawn from the lower income segments, those that are indeed excluded from standard channel of transfers, because the levels of transfers involved are too low to cover transaction costs. A similar reasoning can be applied to the population of mobile money senders. We also find a negative bias in OLS, which suggests that among senders mobile money adopters are drawn from the population with low propensity to send money. However, it is important to bear in mind that in our context, we face two sources of bias: one from selective participation in the financial transfers, and one from selective adoption of mobile money. This renders the interpretation of the direction of the bias not straightforward since both sources can push in opposite directions.

low propensity to send and receive transfers. This interpretation suggests that mobile money has bring into this market new participants, those whose transfer decisions are sensitive to costs and other barriers identified in Figure 1.¹⁹

Table 3.8: Mobile money and remittances amount

VARIABLES	(1) OLS log receive	(2) Heckman log receive	(3) Iv Heckman log receive	(4) OLS log send	(5) Heckman log send	(6) Iv Heckman log send
Mobile money	-0.364*** (0.00228)	-1.316*** (0.00611)	0.311*** (0.0126)	0.139*** (0.00283)	1.310*** (0.00536)	0.390*** (0.0450)
Inverse Mills ratio		0.777*** (0.0102)	0.811*** (0.0103)		-0.511*** (0.00828)	-0.742*** (0.00695)
Constant	5.373*** (0.0180)	5.722*** (0.0183)	3.656*** (0.0162)	6.936*** (0.0228)	-1.013*** (0.0394)	-6.958*** (0.0213)
Observations	763	763	763	654	654	654
R-squared	0.359			0.265		

Notes. Additional controls include, age, income, a dummy for educated household, marital status and rural area, and a set of region fixed effects. Average time in the commune to the nearest mobile money agency is used as an excluded variable in the participation equation and the number of mobile phone by commune is used as instrument for mobile money in the amount equations. Columns (1) to (3) include households that received remittances and columns (4) to (6) include households that sent remittances. The participation equations used to estimate the inverse mills ratio include all the sample. The inverse mills ratio is included in the estimated amount equations in columns (2), (3), (5) and (6) and it is always statically significantly different from zero ($p < 0.001$). Standard errors in parentheses. The statistical significance are: ***1%, **5%, *1%.

¹⁹We use the average time per commune to the nearest mobile money agency as an exclusion variable.

3.6 Conclusion

The banking sector in Africa is less penetrated than those in other major regions of the world. The lack of access to products and services for the facilitation of financial transaction and other related activities like loans, insurance, investment opportunities entrenches growth, increases vulnerability to shocks, and have important welfare consequences for households. Mobile money is booming around the developing world effectively bringing new financial services, for paying, for sending and receiving money and for saving. In this paper we quantify the impact of mobile money access on the incidence, amounts and frequency of inter-household financial flows in Madagascar, one of the world's poorest country. A country where mobile money was introduced in 2010 and whose usage among households has tremendously increased since then. Using data from the FinScope consumer survey of 2015 we find that mobile money acts as a substitute to standard banking services by increasing the probability to send and receive money in remote areas. Though not unequivocal; our results show that mobile money provides effective financial services to populations that are out of reach of the standard institutional system, allowing purchasing power to be redistributed from a fringe of better-off senders to poorer recipients.

Our results reveal an important financial role of mobile money in Madagascar. Mobile money technology has allowed households to integrate into the financial system readily. Our findings are robust to the type of model used to deal with

censoring at zero value of remittances and endogeneity of mobile money usage. However, we also stress that lacking a pure natural or field experiment our estimations do not allow us to draw a definite answer regarding the causal impact of mobile money on remittances. Moreover while we can probably conclude that mobile money access has deepened the financial market by bringing more participants and by rising financial flows an important question left for the future is the impact on household welfare. This is a particularly important role for inter-household money transfers in the context of high vulnerability which are characteristics of poor and rural populations in Africa.

Part III

conclusion

In today's digital world, firms and individuals in developing countries need to keep up with the evolution of these technologies. These economies need to benefit from innovation in the use of ICTs tools to boost productivity and bustling business, promote growth and improve the living conditions of people in particularly to the poorest. ICT services can overcome the lack of access to information and improve the ability to communicate that farmers face.

In the first chapter of this thesis, we use an explanatory model to explore farmer marketing strategies vis à vis market information services. So, we compare informed or advised and uninformed farmers and profit vis-à-vis the different market positions: low or high prices, soaring prices or possible price reductions, it can be said that price information plus the marketing knowledge of the farmer are sufficient during low agricultural seasons or whose price trend is on the decline. Farmers can profit from consulting selling services during more atypical crop years, precisely when prices tend to rise more than normal. The service provided by the information services must adapt to the market position and must not neglect the farmers marketing knowledge. The message sent must be clear, simple and understandable to the target population. Sending written messages is not the best solution for a population a large part of which is illiterate. This is what we learn in the second chapter, where the rate of using market information service was 48% due to illiteracy, sometimes also poor quality network facilities and inadequate infrastructure. A problem that limits better uses of ICTs in rural regions of African countries.

The second chapter, represents a complementary empirical study to the first one. To examine whether market information services enables African farmers to better value their products. We run a randomized control trial studying the impact of providing SMS-based agriculture market information in Burkina Faso. This market information service called Nkalo, sends weekly SMS messages to farmers with information on prices, trend and gives them an advice about the quantity of harvest to sell during the campaign period. We Focus on sesame producers: an important cash-crop production. We consider two types of treatment. A first one provides information of prices estimated at the regional level, a second one, adds information on price trends, and gives selling advice. On average, we find that providing price information increases prices paid to farmers by 4%, and their turnover by 17% a result of the intention to treatment where receipt of treatment is ignored, and outcomes are compared by the assignment to treatment. Because of imperfect compliance ²⁰, I reported also IV estimates in which the assignment to the treatment is used to instrument reception of Nkalo SMS, as expected the impact on compliers was greater than on the assignment to the treatment. In addition, impacts differ according to the type of information received. The gains are concentrated among those who only receive price information. These gains occurs though a change in marketing behavior: sellers reduce the frequency of their sales, concentrating their sales during peak price periods.

²⁰Noncompliance is an important issue in the design and conduct of randomized controlled trials (RCTs). It arises when participants do not receive the treatment or intervention to which they were randomly allocated (see Hewitt *et al.* (2006)).

In the last chapter, We are interested in one of the central pillars of development policies, which is access to financial services for the poor in developing countries. The banking sector in Africa is less penetrated than that of any other major regions of the world. The banking system in Africa is less inclusive than in other developed countries, and is characterized by high operating costs. Recently we observed the development of new forms of the digital banking system ; mobile Money. This form of banking has become more common in Africa in the last ten years. It allows users to send and receive funds, and to save money, allowing to effectively transfer purchasing power between households and over time. Mobile money remains a recent phenomenon and the available research and empirical evidence remain scant. Therefore there is a need to understand users' acceptance of mobile money and to identify factors affecting intentions to use Mobile Money Transfer services. This information can assist mobile network operators (MNOs) and service providers of Mobile Money Systems in creating services that consumers want to use, or help them discovering why potential users avoid using the existing system. We fill the knowledge gap in this area with a specific focus on the case of Madagascar. We show that access to MMS has increased the probability of both sending and receiving money. Which suggests that transaction costs are barriers to access financial services for households, and that mobile technology helps financial services to reach the poor. For instance, we find that more remote households are more likely to use these services. Second, regarding the intensive margin, we found that MMS users send and receive more. These effects are robust

to selection and endogeneity issues. Overall our results suggest that MMS have contributed to deepen financial inclusion in Madagascar.

This thesis enlightened us on the needs of access to market information in agriculture, the behavior of farmers with regard to this information, and how they can benefit from it. ICTs services and mobile telephony as a digital technology are rapidly spreading even in the poorest countries, this access is much lower in rural areas compared to urban areas. In addition, these services can be further developed by offering digital marketplaces ranging from price information, advice, proposing and connecting potential buyers, facilitating the connection of transport logistics and the overall sales process.

The mobile money service is a tool that facilitates financial transfers to the entire population. However, mobile money can act as a digital bank, as the financial or banking needs of the population are not limited to money transfers in developing countries, especially for farmers who often lack the financial means to produce, such as micro-credit services, and insurance services given the high risk rate in the agricultural sector.

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RÉSUMÉ

Cette thèse a comme objectif de mettre l'accent sur le potentiel des technologies d'information et de communication TICs et précisément le téléphone mobile en Afrique subsaharienne afin d'améliorer les conditions de vie des ménages à travers la diffusion d'information, la redistribution des rentes et en favorisant l'inclusion financière. L'Afrique est le continent le moins développé, qui souffre de pauvreté, d'un manque d'infrastructure essentielle, des problèmes de famine, des taux les plus élevés d'analphabétisme et d'accès limité aux services financiers... Par ailleurs, des organismes internationaux tel que la banque mondiale estime que l'expansion de l'adoption de la téléphonie mobile représente une opportunité pour surmonter une partie de ses obstacles à travers des utilisations innovantes dans le monde rural qui souffre davantage de ces barrières physiques. À travers cette thèse nous évaluons l'impact de l'usage de ses services via le téléphone portable dans le secteur agricole, afin de tirer des conclusions sur leurs bénéfices et les quantifier, pour éclairer les autorités publiques, privées et des organismes non gouvernementaux sur leurs réels apports et les orienter vers des services adaptés aux besoins de la population.

MOTS CLÉS

Économies de développement, Évaluation des politiques, Valeur de l'information, Domaine expérimental, Essai contrôlé randomisé, Technologies d'information et de communication, Téléphone portable, Afrique, Secteur agricole, Inclusion financière

ABSTRACT

The objective of this thesis is to capture the potential of information and communication technologies (ICTs) , specifically mobile phones in Africa to alleviate the living conditions and empower households in rural areas, particularly in Sub-Saharan Africa through information dissemination, rent redistribution, and financial inclusiveness. As the last developed continent, Africa suffers from poverty, lack of essential infrastructure, famine problems, the highest illiteracy rates, and limited access to financial services, so International organizations such as the World Bank argues that the expansion of mobile telephony adoption represents an opportunity to overcome some of Africa's obstacles through innovative uses in the rural world, which suffers more from physical barriers.

We focus on assessing the impact of the innovative uses of mobile phone services in the agricultural sector where I will draw conclusions on mobile phone services' benefits, quantify them, and advise public and private authorities and organizations to set up suitable services to the populations' needs.

KEYWORDS

Development economics, Evaluation policy, Information Value, Experimental field, Randomized controlled trial, Information and communication technology, Mobile phone, Africa, Agriculture sector, Financial inclusiveness