博士論文

Performance of Rural Markets and Smallholder Farmers' Participation in Commercialization in Burkina Faso: Their Determinants and Welfare Implications

(ブルキナ・ファソにおける農村市場のパフォーマンスと小規模農家の

商業活動への参加：その決定因と厚生に及ぼす帰結**)**

ニキエマ　レルウェンデ　アポリネール
NIKIEMA　Relwendé　Apollinaire

ABSTRACT

The transition from subsistence to commercial agriculture has long been considered as a means of enhancing incomes, ensuring food security, and reducing poverty. However, to achieve this, the coordination of economic activities by market institutions should necessarily contribute to minimize transaction costs and facilitate exchange between economic agents. This dissertation analyzed the role that the rural market functioning has on the use of modern inputs as well as the welfare gain from crop commercialization for small farm households in Burkina Faso. More specifically, this research tried to answer the following questions: (i) How do transaction costs affect staple food crops markets functioning in a context with reversible trade flows? (ii) Does crop market efficiency enhance farmer adoption decision on yield-increasing technologies? (iii) What are the factors that matter in the farm household's market participation? (iv) How does crop commercialization affect the rural households' welfare?

First, this dissertation analyzed price transmission between domestic markets in Burkina Faso where reversible trade flow between producing and big cities markets is commonly observed. For this, it used cowpea monthly price data collected over fifteen years in 44 local markets. The results suggest that transaction costs between central market and secondary markets are asymmetric. Moreover, the sign and the amplitude of adjustment parameters are consistent with the spatial equilibrium even though prices respond quickly to positive shocks than negative shocks. Also, the results show that there are few violations of competitive spatial equilibrium, which, associated with the consistency in the adjustments parameters suggest that the local market of cowpea is relatively performing well.

However, high transaction costs between producing and consuming localities may negatively affect the economic return of yield-increasing adoption and then discouraging from farmers adopting them. Thus, this dissertation also analyzed the effect of cowpea market integration on farmers' use of modern inputs. To achieve this, it combined price data with a five years panel from the farm continuous survey of Burkina Faso. The results suggest a strong association between crop output market integration and farmer decision to adopt modern inputs. More specifically, an increase in the price gap between the central market and secondary markets during the last 12 months preceding the planting season reduces the likelihood of

adopting modern inputs. Moreover, the results suggest that the association between the crop market performance measures and the adoption of these yield-increasing inputs is stronger for farmers who previously adopted these yield-increasing inputs.

Second, this dissertation used data from the nationally representative household cross-section survey collected in 2014 in Burkina Faso under the Living Standards Measurement Study – Integrated Surveys in Agriculture (LSMS-ISA) to analyze the effect of farmer's comparative advantage in the crop production on farm household market participation. The findings suggest that crop net selling is associated with farmer's comparative advantage, regardless of the market access factors. That is, farmers are net sellers of crops for which they are relatively more efficient.

Finally, this research analyzed the welfare gain from crop commercialization, with a focus on the relationship between the intrahousehold distribution of sales revenues and household nutrition. The results show that raising the wife's share of farm revenue increases household food demand and nutrition diversity. Moreover, increasing the wife's share of farm revenue induces a reallocation of the household budget away from high caloric food towards micronutrient foods purchase. The findings also suggest that the effect of the wife's share of farm revenue on the household nutrition is greater than the effect of the overall level of household commercialization and income, which supports that intra-household distribution of farm commercialization revenue affects household nutritional status.

The policy recommendations are clear-cut. First, better transportation infrastructures, storage, and logistics facilities, which would help to reduce trade costs, are of tremendous importance improve the commercialization of agriculture and its impact on farm households' welfare in Burkina Faso. Next, facilitating the smallholder's integration to the marketing channel through contract farming or warehouse receipt system could improve the economic returns to investment in yield-increasing technologies and then stimulate their adoption. Promoting access to land and labor-saving technologies by women may help to increase the share of farm revenue they owned and then contribute to improving the household nutrition outcomes.

DEDICATION

To the

Power (Holy Spirit) and Son (Jesus Christ)

of the LORD God

&

my Parents:

KOUDOUGOU LAZARE and TOUDBA LOUISE

ACKNOWLEDGEMENTS

The completion of this dissertation would not be achieved without the support of a number of people whom I am greatly indebted to.

First of all, I wish to express my sincere thanks and deep gratitude to my supervisor, Professor Sakurai Takeshi for accepting me as his doctoral student and encouraging me to pursue my doctoral degree with the award of the Japanese Government scholarship. He guided me through his academic advice. He gave me intellectual freedom to decide my own directions to do my research, while at the same time demanding a high quality of work in all my endeavors. I would like also to thank him for his welcome and kind assistance which enabled me to live for my first days in Japan. I feel very happy and incredibly privileged to have had Professor Sakurai as my supervisor.

I sincerely thank Associate Professor Yurugi Takao for his valuable comments, suggestions, and assistance for improving my dissertation during our Lab seminars. I would like to express my sincere thanks to the faculty and staff members of the Department of Agricultural and Resource Economics for their assistance and their comments through the dissertation seminar and general discussions. I also thank Dr. Kentaro Kawasaki (Policy Research Institute of the Japanese Ministry of Agriculture, Forestry, and Fisheries) for reviewing part of this dissertation and providing very helpful comments and suggestions.

I thank the Ministry of Agriculture of Burkina Faso for providing me the data used in this dissertation through its departments such as the SONAGESS and the DGESS.

Moreover, I wish to thank all the friends and colleagues I met at the University of Tokyo for sharing ideas and offering encouragement, particularly, Ozaki Ryosuke, my friend, and classmate who enormously helped me with the daily life during the past years in Japan.

Finally, I would like to express my special thanks to my beloved parents in Burkina Faso for their encouragement and patience for a long period of study in Japan. Last but not least, I want to thank my wife, Wendlasida, for supporting my career decision and encouraging me to pursue my dream. She comforted me when I most needed it and rejoiced with me when I achieved little toward my goal. Without her endless support, faith, and love; this Ph.D. would never have started and completed. I am incredibly fortunate to have a wife like her.

NIKIEMA Relwendé Apollinaire
Tokyo, Japan
March 2021

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AA	Aide Alimentaire/ Food Aid
CDR	Comite de Defense de la Revolution/ Committee for Defense of the Revolution
CDR	Comités de défense de la révolution/Committees for the Defense of the Revolution
CILSS	Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel
CONASUR	Conseil national de secours d'urgence et de réhabilitation/ National Emergency Relief and Rehabilitation Council
DGESS	Direction Générale des Études et des Statistiques Sectorielles/Sectoral Studies and Statistics Service
DGPER	Direction Générale de la Promotion de l'Économie Rurale / Rural Economy Development Service
DPSAA	Direstion de la Prospective et des Statistiques Agricoles et Alimentaires
DSS	Directions des Statistiques Sectorielles / Sectoral Statistics Divisions
ECOAGRIS	Système Régional Intégré d'Information Agricole/Regional Agricultural Market Information System
ECOWAS	Economic Community of West African States
EPA	Enquête permanente agricole/ Continuous Farm Survey
FAO	Organisation des Nations Unies pour l'Agriculture et l'Alimentation
FEWS NET	Famine Early Warning Systems Network
GDP	Gross Domestic Product
INERA	Institut de l'Environnement et de Recherche Agricoles/Institut for Enviroment and Agricultural Research
INSD	Institut national de la statistique et de la démographie/National Statistics and Population Institute
kg	Kilogram
MAAH	Ministère de l'agriculture et des aménagements hydro-agricoles/Ministry of Agriculture and Hydro- agricultural Development
MAFAP	FAO's Monitoring African Food and Agricultural Policies
MASA	Ministère de l'agriculture et de la sécurité alimentaire/Ministry of Agriculture and Food Security
MIDT	Ministère des Infrastructures, du Desenclavement et des Transport/Ministry of transportation
mm	Millimeter
MT	Metric Tons
NGO	Non-Governmental Organization
NPK	Azote phosphore potassium
OFNACER	Office national des céréales/National Grain Board
OP	Organisation de producteurs/ Farmers Association
ORD	Organisation Regional de Development/ Regional Development Organization

PAS	Programme d'Ajustement Structurel/ Structural Adjustment Program
PASA	Programme d'Ajustement Structurel de l'Agriculture
SCR	Stock commercial de régulation/ Commercial regulation stock
SI	Stock d'intervention/ Intervention stock
SIM	Système d'information de marchés/Market Information System
SNS	Stock national de sécurité/National Security Stock
SONAGESS	Société Nationale de Gestion du Stock de Sécurité Alimentaire/National Food Security Stock Management Company
SP/CPSA	Secretariat Permanent de la Coordination des Politiques Sectorielles Agricoles/Permanent Secretariat for the Coordination of Agricultural Sectoral Policies
TVECM	Threshold Vector Error Correction Model
USD	United States Dollar
WAEMU	West African Economic and Monetary Union
WFP	World Food Programme
XOF	West African CFA (African Financial Community) franc

1. INTRODUCTION

This chapter discusses the relevant background relative to the role of market institutions in facilitating smallholder farmers' market participation. It also presents the research questions and the motivation for this study, followed by an overview of the dissertation.

1.1. Background

The transition from subsistence to commercial agriculture, often referred to as commercialization of agriculture, has long been considered as an essential part of the agrarian transformation of low-income economies and a means of ensuring food security, enhanced nutrition, and improved incomes (Kurosaki, 2003; Pingali, 1997; Von Braun & Kennedy, 1994). The commercialization of output from small-scale farming and its direct link to higher productivity and greater specialization is increasingly gaining recognition (Barrett, 2008; Govereh et al., 1999; Strasberg et al., 1999). More specifically, in a world of efficient markets, commercialization leads to the separation of household production decisions from consumption decisions, supporting food diversity, and overall stability (Gabre-Madhin, 2009). At the macro level, commercialization improves allocative efficiency (Fafchamps, 2004; Timmer, 1997), and then the maximization of social welfare.

However, to achieve welfare maximization, market institutions must contribute to minimize transaction costs and facilitate exchange between economic agents. Transaction costs (search, negotiation, and enforcement costs), which are distinct from physical marketing costs such as those for transport and storage, arise from the coordination of exchange among market actors. These costs have been identified in the literature to cause market failures which may hamper and, in some cases, completely stop economic development (Bardhan, 1989; North, 1990; Todorova, 2016). Specifically, information costs which constitute an important part of transaction costs, seem to be at the heart of the coordination of economic activity by the market (Bardhan, 1989). That is, the transmission of information on prices, quantities supplied, quantities demanded, actors and their actions, product quality and attributes, and processes is the key to market coordination (Akerlof, 1970; Stiglitz, 1989).

In the African context, most researches have shown that in addition to transport costs and market prices, information, negotiation, and monitoring costs are the main causes of low commercialization of staple food crops (Chowdhury et al., 2005). The production of these crops is generally carried out by small and geographically dispersed producers. This situation gives rise to thin markets with dispersed buyers (traders), operating with low levels of working capital, buying in small lots (Gabre-Madhin, 2001; Staatz et al., 1989), and without formal norms and standards on the transacted products. Moreover, traders and producers' behavior are seriously affected by institutional deficiencies in Africa. These deficiencies refer to a lack of market information, an underdeveloped infrastructure, non-transparent market rules, and inaccessible capital markets. To achieve welfare maximization for all actors, Gabre-Madhin (2009) suggested that building institutions for markets in developing countries should consider the following aspects:

- The need for mechanisms to transparently grade and standardize products for the market, from the production level on throughout the market chain;
- The need for market information that is accessible to all market actors;
- The need to foster competitive practices among all market actors, across all levels of the chain;
- The need for financial markets to respond to market needs for trade finance, for inventory finance, and alternative financial products;
- The need for dispute settlement and regulatory systems to evolve according to market needs, and in a way that also relies on the private incentives for self-regulation, notably through the potential role of trade associations;
- The need for risk-transfer through mechanisms such as forward contracts and transferable warehouse receipts, and,
- There is also the need for concerted efforts to build capacity throughout the marketing system, including cooperatives, small and medium private traders, and public actors.

This implies that market development is viewed as a long-term agenda, requiring a progressive and integrative perspective through a holistic consideration of essential market institutional components. As emphasized by Joffe & Jones (2004), piecemeal interventions have been the primary source of post-liberalization market reforms failure.

1.2. Research questions and motivation of the study

This dissertation aims to analyze the role of rural market functioning on the use of modern inputs as well as the welfare gains from crop commercialization for small farm households in developing countries. The dissertation will specifically try to answer the following questions: (i) How do transaction costs affect staple crops market functioning in a context of reversible trade flows? (ii) Does crop output market efficiency enhance farmers' adoption decisions on yield-increasing technologies? (iii) Does comparative advantage in crop production affect smallholder farmers' market participation? (iv) How does crop commercialization affect rural households' welfare?

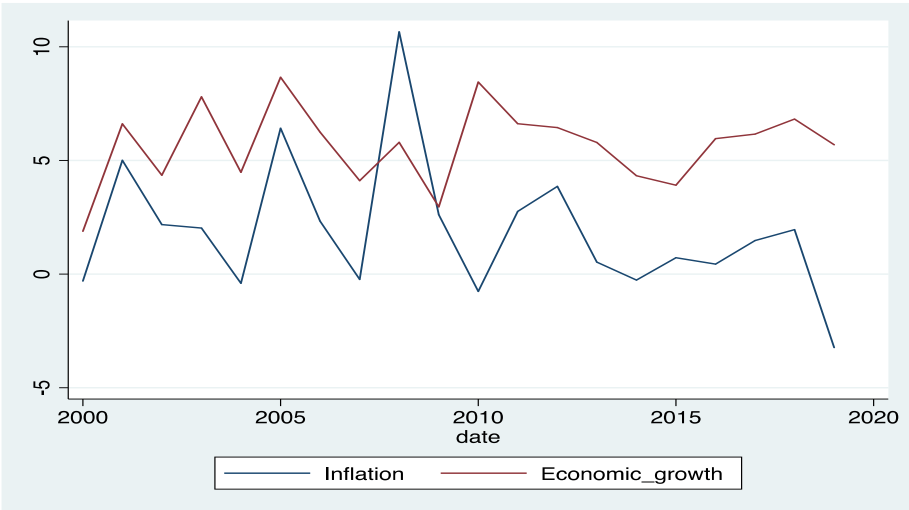
The existing literature did not provide a conclusive answer to the above questions. First, the literature related to food crops price transmission has occulted the fact that in most of the developing countries, the direction of trade flow between rural production areas and big urban cities is often reversible. As a result, for the same distance, the trade costs may vary depending on the direction of trade flow and then affecting food crop markets' performance and the welfare distribution along the marketing chain.

Secondly, although the role of crop output markets' efficiency in small farmers' technology adoption has been conceptually recognized in the previous research, there is little empirical evidence of how it affects farmers' decisions on yield-increasing technologies. It has been argued that with the expansion of output through a technological change in the face of relatively inelastic demand, the significant drop in output prices that results has not only adverse income consequences for technology adopters but threatens the very process of sustained technological advance itself (Gabre-Madhin et al, 2003). However, well-integrated markets transmit excess supply to distant locations; the returns to increased output diminish less quickly there than they do in segmented or poorly integrated markets, and the potential for adverse welfare effects on adopters is likewise lower (Barrett, 2008).

Thirdly, while market access factors such as distance, transportation, and communication assets have received greater attention previous researches, less is done on how the farmers' comparative advantage affects their decision to participate in a specific crop market. This is very crucial since the literature has recognized that transaction costs are unique to each market participant, implying that economic actors are not interchangeable. The presence of transaction costs, which are specific to each market actor, implies that there is no single effective market price at which exchange occurs (Sadoulet & de Janvry, 1995). More specifically, to maximize its welfare, farm household makes its production and the marketing decision by comparing the transaction costs to its specific prices, which in turn depend on its comparative advantage. Barrett (2008) pointed that farm household tends to specialize in the production of those goods in which it is relatively skilled – i.e., holds comparative advantage – consuming some portion and trading the surplus for other goods and services it desires but for which it holds no comparative advantage in production.

Lastly, the contribution of crop commercialization to farm household's food and nutrition security is widely recognized. However, the answer to how the intra-household distribution of the revenue generated from crop sales affects household welfare is scarce in the literature. The share of the revenue from crop sales controlled by each socio-demographic group in the household affects the allocation of income between alternative uses and thus the household's welfare. The intended contribution of this dissertation is to fill these gaps in the literature by answering the above questions.

Figure 1.1: The inflation and economics growth in Burkina Faso 2000-2019



Source: Authors construction based on World Bank

This dissertation focuses on the case of Burkina Faso which is a landlocked country located in West Africa, with an estimated population of 20 million (INSD, 2017). The country's economy has been steadily growing at an average rate of over 5 percent a year since 2005 (Figure 1). In 2018, the gross domestic product (GDP) per capita was estimated at USD[1] 735 (World Bank, 2020)[2]. Agriculture is the mainstay of the national economy, accounting for over 30 percent of the GDP, and employing

[1] 1 US dollar= 602.389 XOF approximately
[2] https://donnees.banquemondiale.org/indicateur/AG.CON.FERT.ZS?locations=BF

approximately 80 percent of the working population (DGESS/MAAH, 2020). The poverty headcount ratio in rural Burkina Faso at USD 1.90 a day was 47.5 percent in 2014. The mining sector is growing rapidly and contributes to approximately one-third of GDP. Gold extraction and export earnings are particularly important. The average inflation rate for the past decade is 0.75 percent, which is below the WAEMU's upper threshold of 3 percent (Figure 1.1). These trends were affected by the high inflation in 2008, fueled by the rising international market prices of oil and food. These characteristics make Burkina Faso an appropriate context to investigate the above research questions.

1.3. Structure and Overview of the dissertation

This dissertation is divided into seven chapters. Chapters 1 and 2 provide a general background on the research and overview of staple crops production and marketing in Burkina Faso. Chapters 3 to 6 comprise the core of the dissertation and address each of the research questions respectively. Finally, Chapter 7 concludes the dissertation.

Brief descriptions of the core chapters are as follows. Chapter 3 answers the first research question. To do so, it applied the newly developed regularized Bayesian estimator to a Threshold Vector Error Correction Model (TVECM) to analyze the nature of price relationship and adjustment between local markets of cowpea in Burkina Faso. The data used is the monthly price collected by the SIM/SONAGESS from 07/2004 to 08/2018 across 44 local markets. First, the estimated thresholds suggest that not only transaction costs between the central market and secondary markets are asymmetric but also higher for producing markets. Second, the sign and the amplitude of adjustment parameters are consistent with the spatial equilibrium even though prices respond quickly to positive shocks than negative shocks. Finally, the distribution of observations across different trade regimes shows that there are few violations of competitive spatial equilibrium, which, associated with the second result suggest that the local market of cowpea is performing well.

In chapter 4 addresses the second research question. To achieve this, it analyzes the relationship between crop output market integration and the use of modern inputs of farmers in Burkina Faso. A five years panel dataset comprising 2402 rural households collected by the Ministry of Agriculture and Food

Security of Burkina Faso is used for this purpose. The results show evidence that crop output market integration matters in farmer decision to adopt modern inputs. Moreover, the results suggest that the association between the crop market performance and the adoption of the yield-increasing technologies is stronger for farmers who previously adopted these yield-increasing inputs.

Chapter 5 deals with the third research question. For this purpose, it developed an empirical strategy to test the hypothesis that farmers enter the crop market according to their comparative advantage. The data used is from the nationally representative household cross-section survey collected in 2014 in Burkina Faso under the Living Standards Measurement Study – Integrated Surveys in Agriculture (LSMS-ISA). The results suggest that crop net selling is associated with farmer's comparative advantage, regardless of the market access factors.

Chapter 6 tackles the question of how the intra-household distribution of farm income affects household food security. The chapter uses four years panel data of rural households in Burkina Faso to analyze the effect of the wives' share of farm revenue on nutrition outcomes. The estimates show that raising spouses' share of farm revenue increases household food demand and nutrition quality. Moreover, the findings suggest that the effect of the wives share of farm revenue on household nutrition is greater than the effect of the overall level of household commercialization index and income per capita, which implies that intra-household distribution of farm income affects household nutritional status. The results also shows that the reallocation of the household food budget towards highly nutritious foods, could represent the channel through which the control of farm revenue by wife improves the household nutrition outcomes.

2. STAPLE FOODS PRODUCTION AND MARKET CHARACTERISTICS IN BURKINA FASO

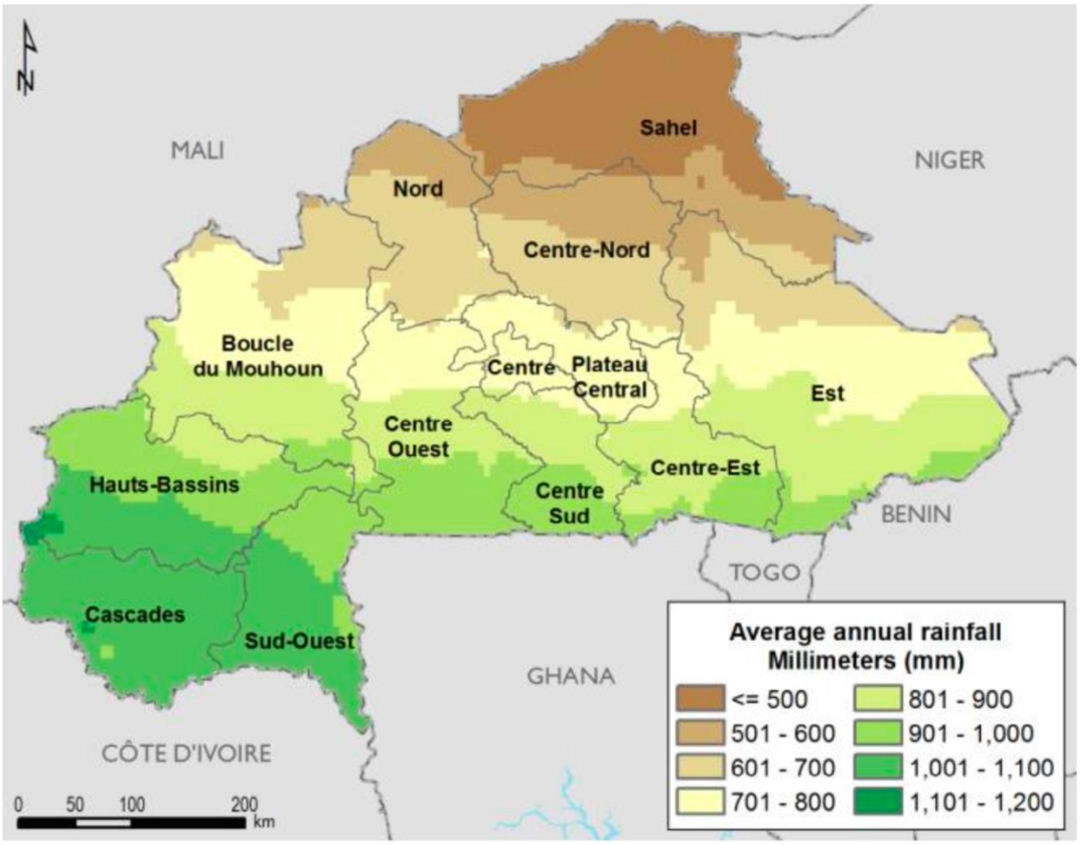
This section reviews the general features of the staple foods market, such as the market actors, the infrastructures, and institutions involved in grain commercialization in Burkina Faso. However, before doing so, it presents an overview of crop production and demand in Burkina Faso.

2.1. Production and Demand for staple food crops

2.1.1. Production of staple food crops

The staple food crops production in Burkina Faso is almost entirely based on rain-fed agriculture and is characterized by a planting season between May and July and a harvest season between October and December. The rainy season ranges from 3 months to 6 months, depending on the agro-climatic zones. More specifically, the country is divided into three main agro-climatic zones, namely the Sahelian zone in the north, with less than 600 mm of rain per year and large variations in temperature, the Sudano-Sahelian zone in the center, and the Sudano-Guinean zone in the south, with over 900 mm of rain per year and relatively low average temperatures (Figure 2.1).

Figure 2.1:Average rainfall in Burkina Faso 2000-2014



Source: FEWS Net (2017)

The production is carried out by small-scale farmers with limited agricultural technology. The increase in production is driven by the extension of cultivated areas, rather than intensification (Figure 2.2). For example, the yield per ha of main staple food crops has remained constant between 2003-2018 (Figure 2.2c). The low yield could be explained by the low adoption of modern inputs. As shown in Figure 2.3, the share of land cultivated with modern inputs is very low, though steadily increasing. For example, at the national level, on average, only 37 and 23 percent of the cultivated land[3] uses NPK and improved seed, respectively, during the five-last year (Figure 2.3a, Figure 2.3d).

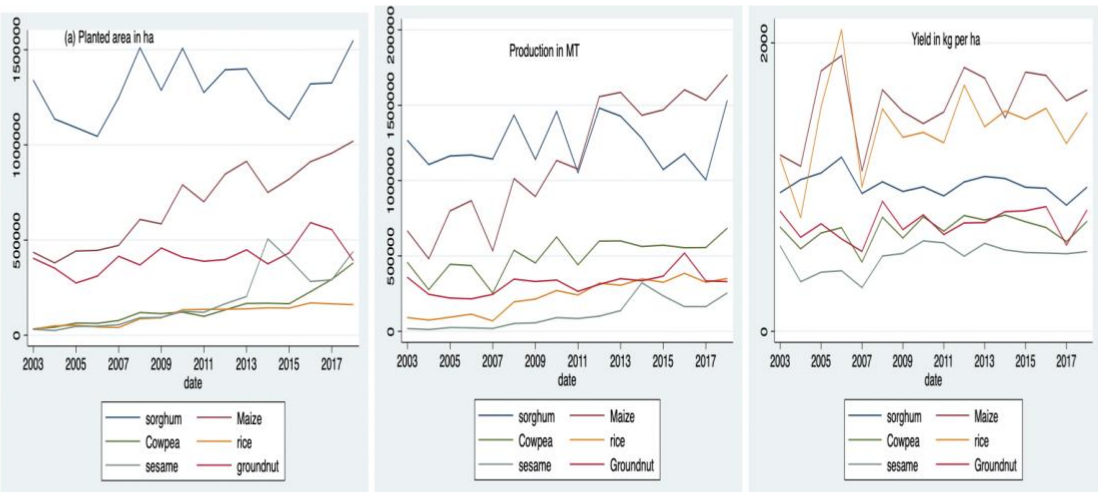
However, these numbers at the national level may hide some important heterogeneity between crops. Maize has the highest percentage of land that uses modern inputs. It is followed by rice, while other crops such as sorghum, cowpea, and groundnut have four times less usage of modern inputs (Figure 2.3).

[3] This includes cotton which occupies a large share of chemical fertilizer and improved seed.

These differences may be explained by the recent effort of public policies to increase the production of maize and rice. For example, following the different food crisis of 2004 and 2008, the effort has been made in terms of irrigation for rice production[4]; cotton producers have received additional chemical fertilizer for maize production, and the INERA have developed varieties of improved seeds of maize that more convenient to Burkina Faso agro-climatic conditions.

Another important characteristic of staple crop food production is low mechanization, which makes the production labor-intensive. The common form of mechanization is the use of animal traction. For example, in 2018, more than 75 and 71 percent of farm households owned a plow and a draft animal, respectively (DGESS/MAAH, 2020).

Figure 2.2: Area planted, Production and yield of staple crop/cash crops in Burkina Faso



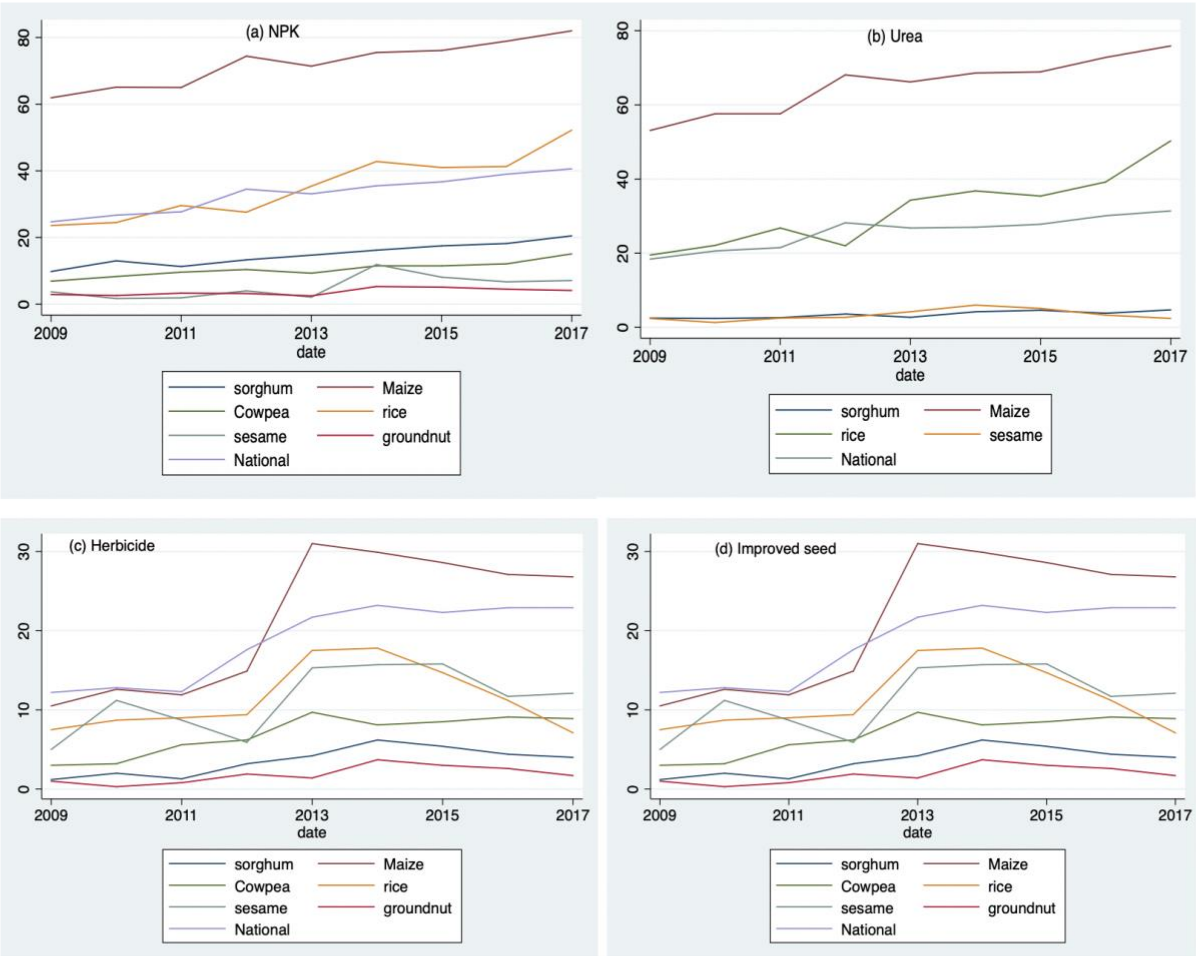
Source: Construction of author based on MAAH/DGESS

The production of most staple food crops is increasing over time but highly unstable in Burkina Faso (Figure 2.3b). Rainfall variability is the main cause of this instability. The country frequently experiences climatic hazards that affect crop production and availability, the most important of which are droughts and floods. For example, in 2017, the percentage of the production loss due to the droughts and floods was 23.9 and 6.2 respectively (DGESS/MAAH, 2017).

[4] The irrigated land for rice and maize has increased by almost 100 and 200 percent between 2003-2013 respectively (DGESS/MASA, 2014).

The main staples food crops grown in Burkina Faso are cereals such as sorghum, maize, millet and rice, and semi-cash crops such as groundnut and cowpea. In terms of volume, sorghum[5] is the most important crop with 1.95 million MT in 2018, making the country the 5th largest producer of Africa (FAO, 2020)[6]. Maize and rice have the highest yield. However, because of the low yield of sorghum and the recent increase in the area planted of maize, the quantity produced of maize is catching up that of sorghum (Figure 2.2a-2.2b).

Figure 2.3: Share of planted area with modern inputs in Burkina Faso



Source: Construction of author based on MASA/EPA

[5] There are two types of sorghum grown in Burkina Faso: Red and White. Figure 2.2 shows statistics about white sorghum, which is the most popular.

[6] http://www.fao.org/faostat/en/#data/QC

2.1.2. Financing agricultural production in Burkina Faso

Burkina Faso has no banks or financial institutions devoted specifically to financing agricultural activities. Agricultural credit is made available through three types of structures, namely traditional banks, decentralized financial systems, and farmer associations, and non-governmental organizations (NGO). The amount of credit furnished by traditional banks does not meet needs. There is very little financing for crop production outside of cotton-growing areas. Bank loans to the agricultural sector account for only two percent of their volume of lending. They are mostly in the form of short-term loans (farm input credit, financing for trading activities), leaving large unmet medium and long-term financing needs for the purchasing of necessary equipment for the modernization of production systems (FEWS Net, 2017a). For example, between 2013 and 2018, on average less than 20 percent of rural households got access to credit (DGESS/MAAH, 2020). The main constraints on access to formal credit for agricultural sector stakeholders are the lack or inadequacy of physical and financial collateral and the lack of synchronization between loan payment schedules and farmers' income cycles. Moreover, although households are vulnerable to several climate shocks, crop insurance[7] is almost non-existent in Burkina Faso. The first crop insurance is introduced just in August 2020 in an experimental phase. It covers only four out of thirteen regions of the country and subsidies 50 percent of the premium. Also, an alternative source of finance, such as *warrantage* or warehouse receipt system is at its extension phase in Burkina Faso. According to Yameogo (2014), the warehouse receipt system was practiced in 2013 by 133 OP, involving 4,021 producers from 10 regions (out of 13) and 28 provinces (out of 45) of the country. In 2013, it had mobilized 216 million XOF in credit, guaranteed by 3,429 MT of cereals (maize, sorghum, millet, rice, and fonio), 705 MT of oilseeds (groundnuts, sesame, soya), and 238 tonnes of pulses (cowpea, voandzou). The *warrantage* is promising in Burkina Faso due to strong demand from farmers and strong institutional supports. The main weaknesses relate to the dependence of donors on storage infrastructure and the lack of mastery of stock conservation techniques (Coulter, 2012).

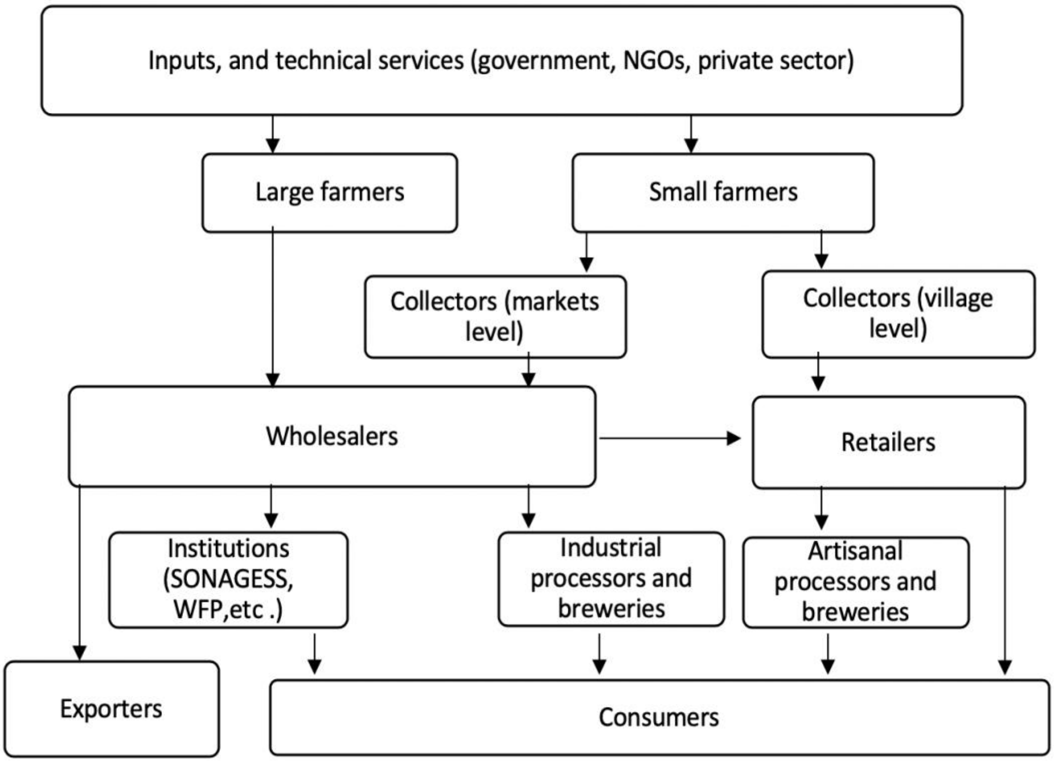
[7] See https://www.agriculture.bf

2.1.3. Demand for staple food crops

The most important grains in terms of consumption are maize, sorghum, and millet, which together constitute roughly two-thirds of caloric intake in Burkina Faso. Cereal consumption in Burkina Faso is estimated at 190 kg per person per year (DGESS/MAAH, 2017). However, this consumption differs from rural to urban areas. For example, the per capita cereal consumption in rural areas is 110.5 kg per person per year, compared with 202 kg per person per year in urban areas. A large share of farm households relies on the market to satisfy their grain demand. For example, DGESS/MAAH (2020) data shows that only 45 percent of farm households were grain self-sufficient during 2013-2018 on average (Table A2.1).

Both grain-surplus areas and the grain-deficit centers in Burkina Faso have geographically dispersed accordingly to agro-climatic zones. In general, the cereal need is tightly covered at the national level (Table A2.2). However, every year some households are threatened by food insecurity due to difficulty in transferring the production from surplus to deficit regions. The provinces located in the center and Sahel regions are almost always in deficit, while those in the southern part of the countries are always in surplus (Table A2.2). Urban areas with high population growth are centers of strong demand for agricultural products. For example, in 2017 urban demand corresponds to 50.1 percent of total national demand (DGESS/MAAH, 2017).

Figure 2.4:Grain marketing channel in Burkina Faso



source: FEWS NET, 2017

2.2. Commercialization of staple food crops

2.2.1. Main actors in the marketing chain

Figure 2.5 shows a simplified marketing channel of staple food crops that are produced and commercialized in Burkina Faso. There are mainly five categories of agents, each at different stages of the commercialization.

Producers: Small-scale farmers produce 95 percent of grain in Burkina Faso (SP/CPSA/MASA, 2013). They are geographically dispersed across all provinces of the country. Grain reaches the market from the farm in four principal ways: through direct sales to rural consumers, direct sales to rural collectors (at the farm gate or at the local market), direct sales to retailers, and direct sales to either regional wholesalers or mills (DGPER/MASA, 2012).

Rural assemblers or collectors*:* Assemblers, mainly farmer-traders, buy grain from other farmers in rural markets to resell it to consumers or regional wholesalers. Although they typically operate independently, they may also act as agents for wholesalers on a fixed-fee or commission basis.

Wholesalers*:* They are mainly private traders, NGOs, and the government through the SONAGESS. At the level of the regional market, wholesalers purchase grain either from large scale farmers or from rural assemblers. They repack the grain and store it for up to 9 months on average (DGPER/MASA, 2012). A large share of the stocks held by the main wholesalers and semi-wholesalers comes from collectors. For example, in 2012, 43 percent of their millet stocks come from collectors, 29 percent come from other wholesalers and only 24.8 percent are purchased directly from producers. For maize, 50.7 percent of stocks are purchased from collectors, 24 percent from producers, and 23.9 percent from other wholesalers (DGPER/MASA, 2012). They have four major market outlets; they may sell it in the Ouagadougou central market or another terminal market through the services of rural collectors, they may sell it to nearby mills (for maize), to retailers, to NGOs, or the government through the SONAGESS or directly to local consumers and restaurants. The grains exporters[8] are included in this category. They export mainly maize, millet, cowpea, and groundnut to the neighboring countries.

Retailers: In the regional markets located in deficit areas or urban centers, retailers purchase grain in semi-wholesale quantities (less than 1 MT) from the regional wholesalers. They can also purchase directly from farmers, from mills, or the central market using the services of brokers.

Consumers: They have several supply sources. They can purchase grain directly from farmers, from assemblers, from regional traders, from processors (mills), or from retailers.

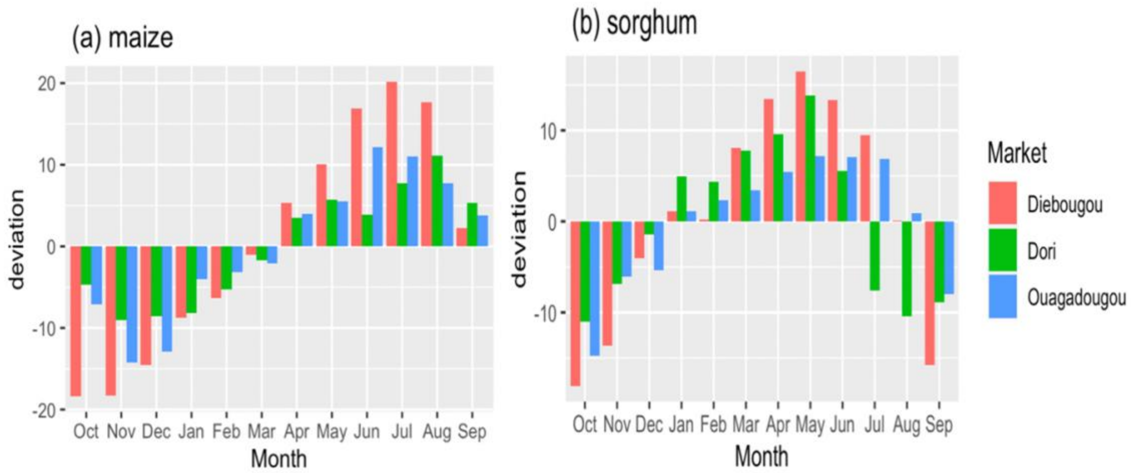
---

[8] At the international level, non-staple foods such as sesame, Cashew nuts, and shea fines are exported. Indeed, 80 percent of these products are exported to Asia.

2.2.2. High seasonality in staple foods crops commercialization.

There is an important seasonal pattern to the marketing of grains in Burkina Faso (Figure 2.6). Due to the rain-fed nature of agriculture, the grain market depends primarily on the harvest season, which occurs from October through December. In this first phase, there is a flurry of buying on the part of traders, and prices are at their lowest given the large supply that floods the market as farmers seek to sell their crops to meet cash obligations related to loan and tax payments, children school fees, weddings, and food purchases. Thus, 79 percent of the annual sales of farmers occur during this period (Pemou, 2016). During that phase, trade flows go mainly from rural producing areas to big urban cities.

Figure 2.5: Maize and Sorghum average seasonal price deviations (2010-2019)



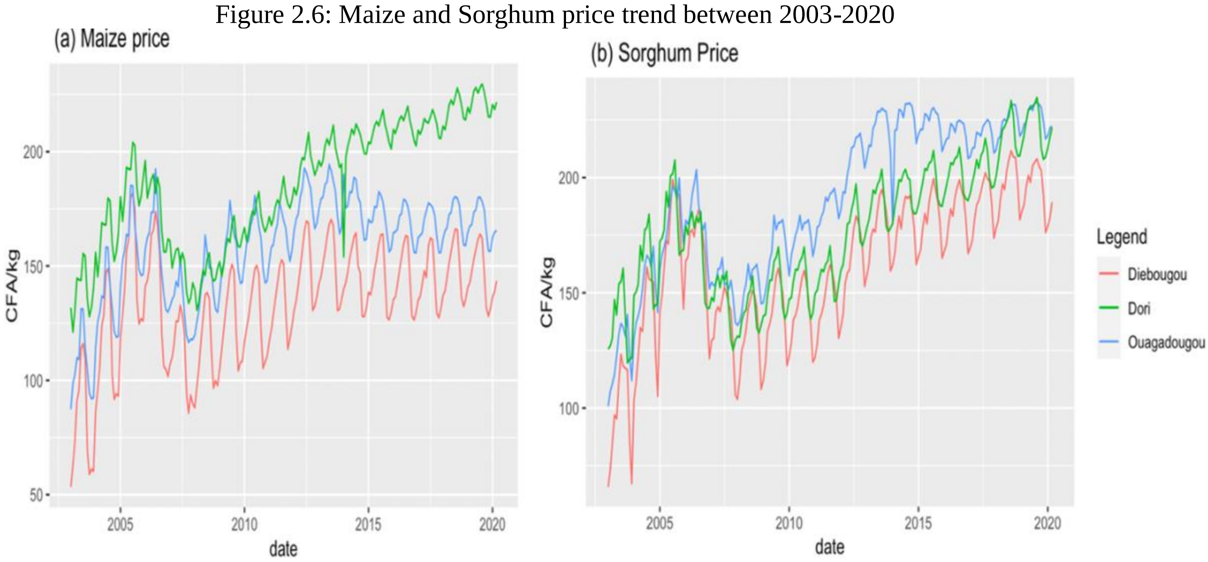
Source: Author construction from SIM/SONAGESS

In the second phase, there is a slight rise in prices (of less than 5 percent) between January and April with the tightening of market supplies from on-farm inventories (particularly those of small farmers) (Figure 2.6). These supplies are appropriated by traders busy responding to calls to bids for the rebuilding of institutional food stocks and meeting needs for cereal transfers from high-production to high-consumption areas during this period (FEWS Net, 2017a). In the last phase, prices continue to steadily rise between April and September, peaking in August or September (Figure 2.6). This period also coincides with the lean season, which is generally marked by an increasing household demand on local markets. Thus, trade flows mainly go from big cities to rural areas. In some cases, these remote villages are physically inaccessible to traders due to the poor road conditions.

Figure 2.6 shows, the retail price trend in three markets located different types of regions. Ouagadougou and Dori are located in a grain deficit region, while Diebougou is located in a surplus region. The atypical surges in prices in 2008 and 2012 were attributable to the negative effect of world prices in the former instance and the shortfall in crop production in 2011 (Figure 2.6). However, since 2012, sorghum price kept an ascending trend except maize price became relatively stagnant after 2015 in Diebougou and Ouagadougou for some reason that we ignore. Also, Figure 2.5 shows that price seasonality is more pronounced in the surplus region market (Diebougou)[9]. This is expected since, in most of rural producing localities, farmers lack facilities for grain storage in addition to the urgent need for cash, which obliges them to sell a large part of the grain just after the harvest. This increases price gaps between harvest time and lean season. As opposed to the rural small farmers, traders in the urban cities like Ouagadougou and Dori possess extensive facilities that allow them to accumulate grain during the harvest time and smooth the supply throughout the rest of the year. High transport costs, especially during the rainy season, and high storage losses also affect seasonal price differences considerably (Ruijs, 2005).

[9] Diebougou is in the region of Boucle de Mouhoun; Dori in the Sahel; and Ouagadougou, the capital city of Burkina Faso in the Centre (see Table 1)

Figure 2.6: Maize and Sorghum price trend between 2003-2020



Source: Author construction from SONAGESS

2.2.3. Transportation infrastructures

Burkina Faso transport is composed of paved roads (24%) called national roads, improved dirt road called departmental roads (14%), and ordinary roads (62%) or rural roads (MIDT, 2015). The roads in Burkina Faso are built in a radial configuration, with the capital city, Ouagadougou, at the center[10]. This radial structure implies that regional markets cannot trade directly with each other without physically passing through the capital city. The central market of Ouagadougou then has a natural advantage as a national clearinghouse for grain, with sellers bringing grain to the capital and buyers coming to that city to acquire grain.

Road transport in Burkina Faso is characterized by high operating costs, a shortage of total truck capacity to meet peak demand, low capacity utilization, and load factors, lack of private sector competition. In addition, a large section of most departmental and rural roads is not passable during the rainy season. The majority of staple food traders do not own means of transport; they rely on rented trucks, for which markets are incomplete and linked to the transport of manufactured goods, fertilizers, and livestock. This renders the scale of individual trader operations very small. All these factors contribute to exacerbating the

[10] Details can be seen in Part 3 (Figure 3.1: Cowpea trade flow map)

cost of commerce between surplus and deficit provinces. For example, transportation costs represent 55 percent of the domestic trade costs for maize (MAFAP/FAO, 2013).

2.2.4. Storage of staple food crops

Storage is one of the weak links across agricultural value chains in Burkina Faso. On-farm storage systems have limited capacity and do little to help ensure good supply management in time and space. Farm-level storage is carried out utilizing primarily traditional granaries. This situation is associated with a postharvest loss of 0.9 percent (DGESS/MAAH, 2017). Postharvest losses are low in Burkina Faso due to the dry weather and low perishable nature of most cultivated crops. At the traders' level, almost all (95%) of the warehouses located in the markets have a storage capacity of less than 50 MT with poor ventilation and dirt floors. The large-capacity warehouses are located outside the market with storage capacities ranging from 250 to 5,000 MT of cereals (Pemou, 2016). The low quality of storage infrastructure leads to potentially high storage losses, with crop vulnerability to damage from weevils, termites, rodents, birds, and moisture. For example, Bassolet (2000) observes storage losses of 8 percent for 5 months.

Moreover, the spatial distribution of staple food crops stocks held by traders is very unequal. A large share of grain stocks is concentrated in the main urban cities. For example, in 2017, Ouagadougou, the capital city holds 66.74 percent of the stocks, followed by Bobo Dioulasso, the second-largest city with 8.78 percent (DGESS/MAAH, 2017). Moreover, these stocks are mainly cereals (maize, millet, and sorghum) which represent 66 percent of the stocks, followed by sesame 19 percent; cowpea 12 percent, and groundnut 3 percent (DGESS/MAAH, 2017).

2.2.5. Institutional food stocks management in Burkina Faso.

Public storage of cereals began in 1971 with the establishment of the National Grain Board called OFNACER (see Table A2.3). The aim was to regulate the cereal market, which had been booming at the end of the 1960s, and to counter the strategies considered to be abusively speculative by traders. A major food crisis was to change the primary mission of OFNACER. The drought in the Sahelian countries in 1973-1974 proved deadly and shook the international community. OFNACER will then naturally be led to specializing in the management of food aid. It sold cereal food aid at the same price as local cereals except for "more or less damaged" stocks sold at a lower price.

In the early 1990s, the liberalization of the economy under the Structural Adjustment Programme (PAS) led to the withdrawal of the Burkinabe state from agricultural trade. The Agricultural Sector Adjustment Programme (PASA) set up in 1991 thus led to the abolition of OFNACER, whose storage system was deemed too costly (Poussart-Vannier, 2006). The economic reforms of the PASA aimed at boosting the agri-food sector also led to the creation of SONAGESS in 1994, a department affiliated with the Ministry of Agriculture and Food Security. This structure replaced OFNACER but with prerogatives limited to the management of the physical food security stock (SNS), the receipt of food aid (AA) and the operation of the Cereal Market Information System (SIM). SONAGESS has the largest storage capacity, estimated at approximately 86,000 MT in facilities spread across the country, but concentrated mainly in the country's Centre (26 percent), Sahelian (20 percent), and Boucle du Mouhoun regions (9 percent)(Alpha & Pemou, 2019).

There has also been an evolution in the operations of SONAGESS since its creation, with more and more stocks to manage and more and more permanent operations. From the creation of national food security stock (SNS) in 1994, through intervention stock (SI) in 2005 and the commercial regulation stock (SCR) in 2010 (Table 2A.4). The SNS has a clear food security objective despite its technical rotation, while the SI and SCR have market regulation objectives (Alpha & Pemou, 2019).

The SONAGESS pays grain from private traders or farmers through their associations (OP) and stores it in its warehouses located across all 13 regions of the countries (Table 2A.4). The stocks are sold during the lean season at a social price through its *boutiques témoins* (or charter shops). Prices across charter shops in the country are equal and are set up about 20 percent below the market price. This operation has a double objective: Facilitate foods access to most vulnerable households and lessens prices spike during the lean season.

However, the SONAGESS operations affect the grain market in deficit regions, even though marginal at the national level given the relatively small quantities handled. For local stocks aiming to sell at the best price, the upward effect on producer and consumer prices appears positive (Alpha & Pemou, 2019). However, Yaméogo (2014) points out the downward effect on sales prices of social prices is particularly negative for *warrantage*, which is based on the anticipation of seasonal price increases. He notes that the public storage period (lean season) has a negative impact on the extent of *warrantage*[11] for OP. For example, he observes a 48 per cent drop in the average number of producers practicing *warrantage* per OP and a 75 percent drop in the average quantity of products warranted per PO. However, he recognizes that direct purchase from producers by SONAGESS leads to a 16 percent increase in the average price per kg.

2.2.6. Information and the role of SIM/ SOANAGESS

Access to market information is extremely limited in the Burkina Faso staple foods market. At the producer level, farmers' have very little information on prices prevailing even in nearby markets. Previous studies have shown that farmers primary source of market information is the marketplace itself, as well as conversations with neighbors and traders (Bassolet, 2000; Bassolet & Lutz, 1999). Grain traders rely on contact with rural collectors and transporters to obtain market information regarding prices and quantities in different markets. In recent years, efforts have been made by the government to establish a Market Information System (SIM). The SIM is monitored by the SONAGESS. To improve the efficiency of the grain markets, the SONAGESS diffuses grain prices on a weekly basis using several channels: Local radio, written press (local newspapers), internet, and mobile phone. However, Bassolet and Lutz (1999), who evaluated the impact of SIM on the price transmission after a decade of functioning, found that the SIM had a limited impact on the performance of the grain market. SIM prices are not reliable indicators or signals that can guide them in their grain supply and sale operations. The reasons given are that these prices do not reflect market conditions or that their dissemination is late (Bassolet, 2000; Galtier et al., 2014; Galtier & Egg, 2003). Finally, grain grading and standardization are limited to visual inspection, at the time of the transaction, of the color of the grain, as well as the amount of foreign matter, pest damage, and kernel breakage. The lack of grain standardization results in prices that are difficult to compare.

It is evident in this chapter that in Burkina Faso, the production of staple food crops is mainly carried out by small farmers with limited use of modern inputs. The staple food markets are characterized

[11] Warehouse receipt system in French.

as follows: i) The marketing channel is composed of small-scale farmers geographically dispersed; wholesalers based in the major urban cities; collectors who act as intermediaries between producers and traders; and retailers who supply rural and urban consumers. ii) Urban wholesalers have a large capacity of storage though not adequately maintained, while producers use small and traditional storage facilities. iii) High seasonality in marketing due to the rain-fed nature of agriculture production and the limited capacity of storage. 4i) High transportation costs due to the poor transportation infrastructures and the low scale of operation of traders. 5i) Market actors have limited access to information related prices, quantities, and quality due to the lack of reliable source of information, lack of standards on the transacted commodities. This chapter has shown that trade flows go from rural areas to big urban cities during the harvest time and then reverse from urban cities to rural areas during the lean season. Thus, a consequent question is how the reversibility of trade flows affects price transmission. The next chapter tries to answer this question.

2.3. Appendix of Chapter 2

Table A 2.1: Proportion of farm households who are not cereals self-sufficient (%) 2009-2018

Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Boucle du Mouhoun	21	13	24	18	18	21	24	26	30	18
Cascades	14	11	17	12	25	34	29	33	33	23
Centre	72	46	52	57	68	54	59	62	69	69
Centre_Est	55	38	45	45	52	43	52	50	62	51
Centre_Nord	70	58	55	58	62	65	66	77	84	67
Centre_Ouest	40	32	49	36	45	38	34	41	53	32
Centre_Sud	47	42	55	50	51	41	40	36	41	40
Est	54	46	48	51	53	49	45	37	57	41
Haut_Bassins	26	19	27	21	22	17	21	21	23	22
Nord	67	44	62	57	54	49	54	64	74	54
Plateau_Central	56	42	50	44	48	45	34	48	61	44
Sahel	69	51	64	63	60	72	56	65	62	56
Sud_Ouest	17	15	34	28	42	37	30	31	38	30
Burkina Faso	47	36	45	42	45	43	42	46	53	42
Source: DGESS/MAAH (2020)										

Table A 2.2: Coverage of grain requirement by region (%) 2009-2018

Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Boucle du Mouhoun	190	239	182	241	258	187	189	178	165	214
Cascades	123	124	138	152	142	117	101	114	105	123
Centre	11	14	11	15	13	17	13	12	9	9
Centre_Est	81	131	104	103	106	158	169	111	75	95
Centre_Nord	69	103	60	84	75	70	49	43	41	77
Centre_Ouest	118	123	114	175	135	135	200	111	96	144
Centre_Sud	106	104	111	110	131	69	55	135	113	116
Est	102	141	90	151	114	108	88	107	84	112
Haut_Bassins	144	154	147	177	191	160	186	162	167	156
Nord	89	107	58	94	102	85	80	75	63	72
Plateau_Central	84	11	92	112	111	111	71	77	68	98
Sahel	70	92	70	100	92	81	93	85	88	113
Sud_Ouest	165	188	133	129	116	156	121	132	108	152
Burkina Faso	99	121	96	124	120	106	96	99	88	109
Source: DGESS/MAAH (2020)										

Table A 2.3: Changes in the regulation of grain commercialization

Date	Interventions
Before 1971	Private sector: mainly traders
1971-1974	OFNACER: monopoly of the grain trade under the Ministry of Commerce
1974-1984	ORD: Monopoly for the purchase of cereals from producers and village groups under the supervision of the Ministry of Agriculture on behalf of OFNACER. ONACER :Monopoly for the sale of cereals. Fixing of official prices to the producer and the consumer. Illegality of the private cereal trade.
1975-1984	Abolition of the monopoly of OFNACER and the ORDs on the cereals trade and redefinition of a regulatory framework authorising private trade in cereals only for private traders approved by the ORDs. Strict respect of official prices by private traders.
1984-1988	Approval to private traders by the Committee for the Defence of the Revolution (CDR). Constitution of Economic Interest Groups for the private grain trade (Faso Koodo) and the obligation for traders to be members. Restriction of inter-regional movements of cereals. Control of traders by the CDRs: confiscation of grain stocks from traders suspected of not respecting official prices. Removal of RDC control
1992	Liberalization of trade and grain prices following the PAS (Structural Adjustment Program)
1994	SONAGESS: manage food security stocks and the Grain Market Information System (SIM), which reveals the prices of agricultural products on a weekly basis.
Source: Author construction based on Bassolet (2000),	

Table A 2.4 : Procurement methods and distribution of public food stocks by SONAGESS

Objectives	national food security stock (SNS)	Food aids (AA)	Intervention stock (SI)	Commercial regulation stock (SCR)
Storage capacity	50,000 MT (+ 25 000 MT financial stock)	22,250 MT	25,000 MT	Depending on the year: 16,000 MT in 2014 and 4,000 MT in 2015
Staple food products	maize, millet, and sorghum	mainly imported rice	maize, millet, sorghum, and rice	Maize, rice, cowpea, potatoes, and processed foods
Procurement	Call for bids to traders and for OPs (20%)	In kind and cash for local purchases	Call for bids to traders and for OPs (20%)	Contract, direct purchases (80% from OPs) and Call for bids.
Distribution	Sales at social prices by CONASUR	Cash transfer and target/non targeted food distributions	Sales at social prices by CONASUR	Institutional sales
Note : SNS= Stock National de Sécurité ; AA= Aides Alimentaires ; SI= Stocks d'Intervention ; SCR= Stock Commercial de Régulation ; OP= Organisation Paysannes, CONASUR= Conseil national de secours d'urgence et de réhabilitation				
Source: Adapted by author from Alpha and Pemou (2019)				

3. ASYMMETRY IN TRANSACTION COSTS AND PRICE TRANSMISSION: THE CASE OF COWPEA MARKET IN BURKINA FASO

3.1. Introduction

Prices drive resource allocation and output mix decisions by economic actors, and price transmission integrates markets vertically and horizontally (Meyer & von Cramon-Taubadel, 2004). Moreover, price transmission is used to assess the nature of price relationships and the direction of the causal relationship between agricultural prices in surplus and deficit locations. According to Barrett and Li (2002), spatial price transmission can be defined as the process by which demand, supply, and transaction costs in spatially separated markets jointly determine prices and trade flows, as well as the transmission of price shocks from one market to another.

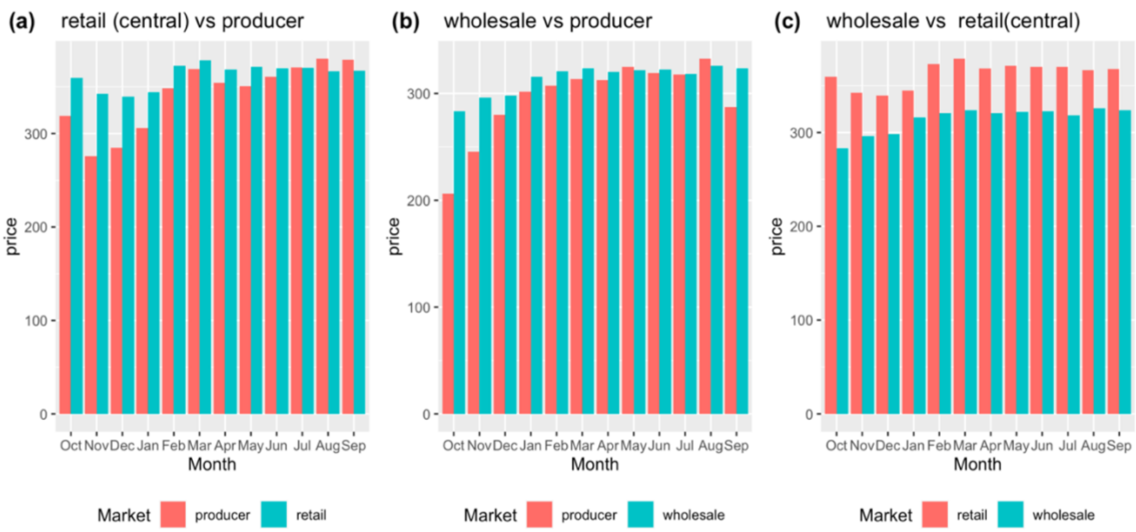
Indeed, an efficient price transmission mechanism is important to promote food security and agricultural development. The lack of spatial price transmission is often associated with food insecurity because there is no connection between markets. In addition, poor spatial transmission of prices can convey inappropriate information in the price system leading to incorrect production and marketing decisions. As a result, agricultural producers fail to specialize in the long term based on comparative advantages and gains from trade will not be realized (Baulch, 1997).

Several factors are listed in the literature to explain the low price transmission in the developing countries: the market power of some intermediaries (Abdulai, 2000), the oligopolistic behavior, the asymmetric information (Meyer & von Cramon-Taubadel, 2004), intervention policies (Krivonos, 2004), transaction costs (Goodwin and Piggott, 2001), and market structure and security (Wu et al., 2019).

Although this study is in line with the existing literature, instead of identifying the factors causing low transmission, it focuses on reversible trade flow and analyzes its implication on market efficiency, particularly on the asymmetry in price transmission (APT). APT means that the transmission of shocks between importing and export markets differs according to whether prices are increasing or decreasing. APT could have important welfare policy implications. Specifically, APT implies that a group is not benefiting from a price reduction (buyers) or increase (sellers) that would, under conditions of symmetry, have taken place sooner and/or have been of a greater magnitude than observed. Hence, APT implies a different distribution of welfare than would obtain under symmetry, because it alters the timing and/or the size of the welfare changes that are associated with price changes (Meyer & von Cramon-Taubadel, 2004). Also, the reversible trade flow is often observed in developing countries, where rural households are sellers of a specific crop during harvest time but most of them become buyers of the same product during the lean season.

The contributions of this study are twofold. First, although the reversible trade flows are common in the developing countries including Burkina Faso and have influences on the food security of the rural and urban poor population, they are not well investigated in the context of price transmission. This study will be one of the few studies to the authors' best knowledge. Second, as oppose to previous studies in developing countries, we use the regularized Bayesian estimator to estimate a threshold vector error correction model (TVECM) with three regimes, which allows not only to distinguish between price transmission and spatial competitive equilibrium but also to study price transmission in a context with reversible trade flows.

Figure 3.1: Comparison of average monthly price in type of cowpea markets (2013-2018)

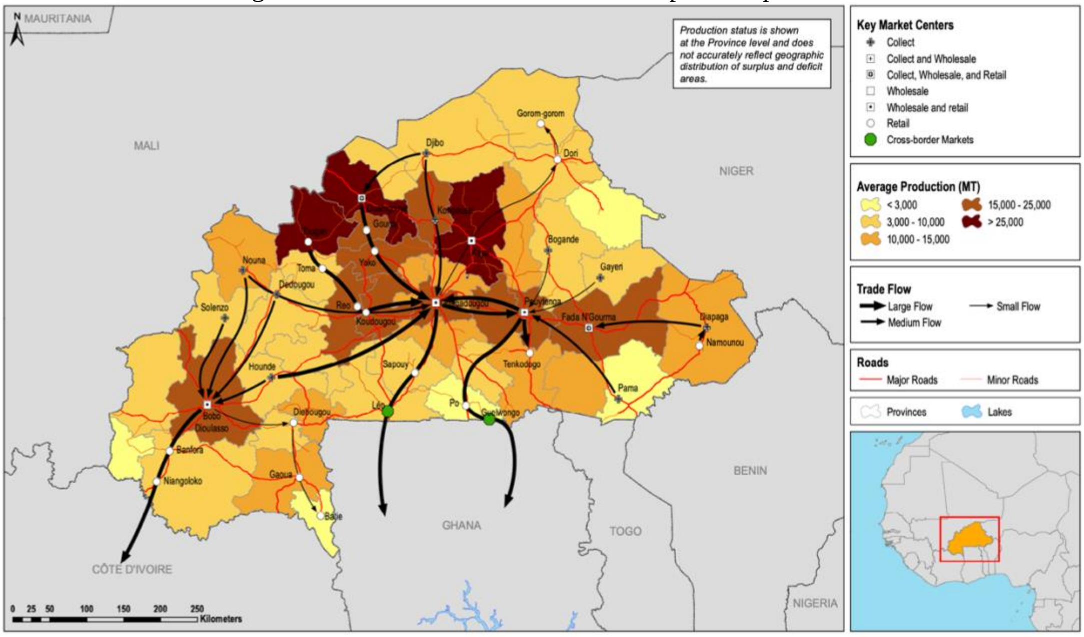


Source: Construction of author from SONAGESS data

This analysis focuses on cowpea because of its significant contribution to household food security and income in Burkina Faso. Cowpea is produced by over 1.2 million farmers in almost everywhere in the country (SP/CPSA/MASA, 2013). The production is very unstable as it depends on variable rainfall and variable planted area. Moreover, the plot size varies from 0.25 to 12 hectares and the yield per hectare is 700kg on average. As a subsistence crop, cowpea has been known to be an important source of cheap protein to combat protein deficiencies in rural areas (Langyintuo et al., 2003). It is a cheap protein source for urban consumers as well. Because of the rapidly growing urban population and the development of transportation infrastructures, a significant amount of cowpea is sold in the urban markets. For example in 2010, 50% of cowpea produced was sold and income generated from this sale accounted for 5.8% of agricultural income (SP/CPSA/MASA, 2013). Cowpea export is also increasing due to growing demand in neighboring countries: from 5421 Mt in 2005 to 19500 Mt in 2010 (SP/CPSA/MASA, 2013). Thus, cowpea has now become an important cash crop. It is the most typical crop with which we can observe the reversible flows. Although many subsistence crops are sold for cash to some extent, cowpea's dual nature is prominent. Famers sell cowpea just after the harvest to satisfy their need for cash which pushes prices down to their lowest level. However, during the lean season farmers buy the same product and often at a price three times higher than the price they sold it. As figure 3.1 shows, during harvest time (October-December) the prices in producing regions are lower than those in assembling and retail markets. However, as time goes by, prices in rural producing localities increase and catch up with those in urban retail and assembling markets. As a result, trade flows reverse and go from urban cities to rural producing localities. This makes the cowpea market suitable to investigate price transmission when trade flow is bidirectional.

The marketing system of cowpea in Burkina Faso can be presented as a spider's web with converging and diverging connections depending on the level of marketing considered. The marketing starting signal is given by farmers according to the maturity of their crops and their financial needs; and the circuit is piloted by wholesalers located in major urban centers. The latter deploy their network to rural areas to collect cowpea and other products through the intervention of collectors who play an important role in the marketing channel. For example, in 2012 only 19.3% cowpea stocks held by wholesalers come directly from producers, while 40.4% from semi-wholesalers, and 40.3% from other wholesalers respectively (DGPER/MASA, 2012). These large traders store the product in their stores and then redeploy their network for sale either to the country's deficit areas or for export to neighboring countries (Figure 3.2).

Figure 3.2: Production and trade flow map of cowpea in Burkina



Source: FEWS Net (2017)

3.2. Methods

3.2.1. Theoretical framework

The analysis of the spatial price transmission is based on a concept developed in three economic theories. First, in 1916, the Swedish economist Heckscher called it the "commodity points" principle (Obstfeld & Taylor, 1997). Second, in 1980, Marshall formulated it as the Law of One Price (LOP). Third, the Enke-Samuelson-Takayama-Judge (ESTJ) spatial equilibrium model which links price behavior to trade (Enke, 1951; Judge & Takayama, 1971; Samuelson, 1952).

The LOP stipulates that in an efficient market, an identical good must have the same price at every point in that market. The LOP is maintained between geographically separated markets through spatial arbitrage. That is any price difference between two markets of an identical good, will create an arbitrage rent in the absence of transaction costs. This rent will motivate merchants to transfer the product from the low-price market to the high-price market until the rent is eliminated and prices equalize again.

To take into account the transaction cost between a pair of trading regions the LOP is reformulated as a spatial equilibrium model (Judge and Takayama, 1971) and can be summarized as follows:

$$P_t^j \begin{cases} < P_t^i + \psi_{i\to j} \quad q_t^{ij} = 0 \quad (3.1a) \\ \geq P_t^i + \psi_{i\to j} \quad q_t^{ij} > 0 \quad (3.1b) \end{cases} \qquad (3.1)$$

where p_t^i is the price of the good in the surplus market i and p_t^j is the price in the deficit market j at time t, $\psi_{j\to i}$ is the cost of trade from market i to market j , and q_t^{ij} represents trade flows from market i to market j . These costs include transportation costs; market search, negotiation, and enforcement costs; trader' margin, risk premium.

The spatial equilibrium model stipulates that the prices of a given good at two locations should not differ by no more than the transaction costs of trading the good between these locations. Otherwise, traders will engage in spatial arbitrage, which increases the price at the low price market and reduces the price in the high price market until the spatial equilibrium $p_t^j - p_t^i = \psi_{i\to j}$ is restored. The equation $(3.1a)$ characterizes the price relationship of two segmented markets while $(3.1b)$ characterizes integrated markets. For the above model (equation 3.1), it is assumed that trade is unidirectional and only profitable in relation (3.1b).

However, in a context with reversible trade flows such as the case of the cowpea market in Burkina Faso, there are two cases where trade is profitable:

1rst case: Trade from i to j is profitable if and only if $p_t^j - p_t^i > \psi_{i\to j}$, implying that trade is not profitable when

$p_t^j - p_t^i < \psi_{i\to j}$ (3i)

2nd case: Trade from market j to market i is profitable if only if $p_t^i - p_t^j > \psi_{j\to i}$, implying that trade is not profitable when $p_t^i - p_t^j < \psi_{j\to i}$ or $p_t^j - p_t^i > -\psi_{j\to i}$ (3ii)

From $(3i)$ and $(3ii)$ we obtain that is not profitable when :

$-\psi_{j\to i} < p_t^j - p_t^i < \psi_{i\to j}$ (3iii)

For any price gap between trading markets $p_t^j - p_t^i \in [-\psi_{j\to i}, \psi_{i\to j}]$, trade is not profitable and then there will be no arbitrage in either direction. The existence of such an interval[12] is called a "neutral band". Based on the LOP and the existence of hidden transaction costs, studies such as Lo and Zivot (2001) have shown that arbitrage is only profitable outside the band of transaction costs around the prices of the good in two markets. The only difference between equation (3iii) and the neutral band in Lo and Zivot (2001) is that we relaxed the hypothesis that the transaction costs of trade between two markets are symmetric.

[12] Equation (3iii) can be re-arranged such that the neutral band is expressed in terms of price relationship between two markets as follows: There exists a $p_t^j \in [p_t^i - \psi_{j\to i}, p_t^i + \psi_{i\to j}]$ such that trade is not profitable in either direction.

3.2.2. Empirical specification

Following Greb et al. (2014), a Threshold Error Vector Correction Model (TEVCM) with three regimes is specified to models price relationship between a central market c (capital city market) and secondary markets s(collecting markets, assembling markets (local wholesale), and retail markets) as follow:

$$\left.\begin{aligned} \Delta p_t^c &= \theta_i^c + \rho_i^c (p_{t-1}^s - p_{t-1}^c) + \sum_{m=1}^{M} \beta_{im}^c \Delta p_{t-m}^c + \sum_{n=1}^{N} \alpha_{in}^s \Delta p_{t-n}^s + \varepsilon_{it}^c \\ \Delta p_t^s &= \theta_i^s + \rho_i^s (p_{t-1}^s - p_{t-1}^c) + \sum_{m=1}^{M} \beta_{im}^s \Delta p_{t-m}^s + \sum_{n=1}^{N} \alpha_{in}^c \Delta p_{t-n}^c + \varepsilon_{it}^s \\ & i = 1, 2, 3 \end{aligned}\right\} (regime\ i)$$

if $p_{t-1}^s - p_{t-1}^c \leq \psi_1$, then regime 1

if $\psi_1 < p_{t-1}^s - p_{t-1}^c \leq \psi_2$, then regime 2, and

if $\psi_2 < p_{t-1}^s - p_{t-1}^c$, then regime 3 (3.2)

where $\Delta p_t = p_t - p_{t-1}$and $t = 1, \dots, n$. θ, ρ, β and ψ are the parameters to be estimated. All parameters in the three regimes are simultaneously estimated by the regularized Bayesian method. We restricted the co-integration vector to $\gamma = (1, -1)$ to simplify the interpretation of the estimated threshold.

The parameters of greatest interest are ρ and ψ. The ρ are the adjustment parameters that measure how quickly a deviation from the equilibrium relationship is corrected by changes in p^C and p^S. For example, ρ_k^S measures the speed of adjustment of the secondary market in trade regime k. The stability condition for cointegration is given by $\left|1 - (\rho_k^S - \rho_k^C)\right| \leq 1$ such that deviations from the long-run equilibrium are corrected and specifically, for the outer regimes $k = 1$ and $k = 3$. However, as discussed in Greb et al. (2014), when price deviates from equilibrium in the context of spatial arbitrage, trade restores equilibrium by causing the higher price to fall and the lower price to rise. Hence it is reasonable to expect $\rho_k^S \leq 0$, $\rho_k^C \geq 0$ and $0 < (\left|\rho_k^S\right| + \rho_k^C) \leq 1$.

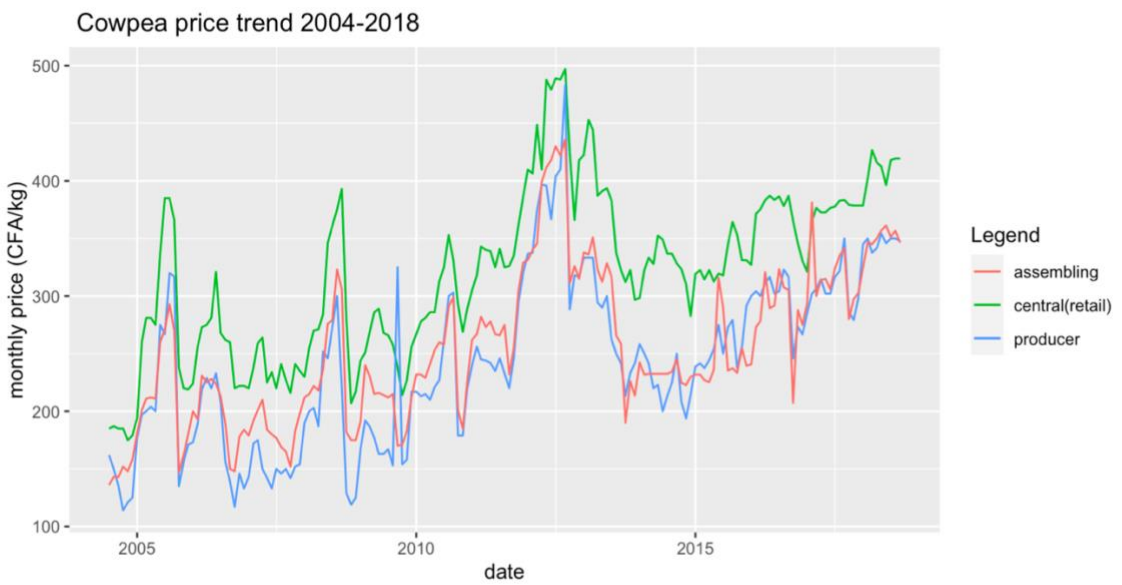
To sum up it is expected that: (i) in regime 2, ρ to be zero or not significantly different from zero, since, in accordance with the competitive spatial equilibrium, no correction is required; and (ii) in regime 1 and 3, ρ to be significantly different from zero and the total adjustment to be higher than in regime 2 as they are violations of the competitive spatial equilibrium and then should trigger arbitrage and price adjustments to restore equilibrium.

ψ are the thresholds value and are interpreted as the estimated transaction costs. Data on transaction costs are rarely available, especially in developing countries. The estimation of threshold parameters in TVECMs is typically performed using the profile likelihood method (Hansen and Seo, 2002) and computed using a grid search

(Goodwin & Piggott, 2001). However, Greb et al. (2013) show that the profile likelihood estimation produces biased estimates, particularly for a small sample. The high number of the parameters in TVECM combined with the need to set a trimming parameter are the sources of bias. They proposed a regularized Bayesian estimator that penalizes differences between regimes to minimize differences when the data contain little information. As a consequence of this regularization, the posterior density is well-defined over the entire range of the threshold parameters, which eliminates the need to choose an arbitrary trimming parameter and produces estimates with less bias than the profile likelihood method. Thus, we make the use of the regularized Bayesian estimator in this analysis. Moreover, prices are taken at a level and then making the interpretation of the error correction term as the transaction costs in the same monetary unit as prices.

Furthermore, we adapt the strategy employed by Jamora and von Cramon-Taubadel (2016). First, the null hypothesis of linear cointegration against threshold cointegration is tested using the test proposed by Hansen and Seo (2002). Next, the TVECM in equation (2) for each pair of markets is estimated using the regularized Bayesian estimator adopting the R code provided by Greb et al. (2013).

Figure 3.3: Cowpea price trend in different type of markets from 2004 to 2018



Source: Construction of Author from SONAGESS data

3.3. Description of data and Results

3.3.1. Data and Descriptive statistics

This study uses monthly price data collected in local markets by the Grain Market Information System (SIM) of Burkina Faso. In these markets, three types of prices are collected: farm gate price, retail price, and wholesale price. The SIM is monitored by SONAGESS. The SONAGESS collects weekly price data in 48 local markets include all 45 provinces. From these weekly prices, monthly average prices are computed and made available to the public. For this study, 44 local markets are retained. This comprises 18 farm gate prices, 19 retail prices, 6 wholesale price series, and price in the reference market price covering the period 07/2004-09/2018 (Table 3.1). The markets are categorized by the SONAGESS according to the type of actors that prevail in the markets. In this research, a producer market (collect market in Figure 3.2) is a market dominated by producers or/ and rural collectors while .In an assembling market (wholesale in Figure 3.2) the main actors are traders and/or collectors while in a consumer market (retail in Figure 3.2), retailers and consumers prevail. However, it is possible to observe different type of prices in the same market as it is shown in Figure 3.2. For example, in Ouagadougou market, wholesale and retail price are observed. The capital city Ouagadougou is chosen as the central (reference) market because of its key role in staple food crops' commercialization in Burkina Faso. For instance, a recent survey supports that Ouagadougou traders detain more than 70% of national cowpea stocks (Pemou, 2016). In the central market, the main operating agents are retailers and wholesalers but only retailer price is available.

Table 3.1 shows the descriptive statistics of prices in different types of local markets used in this study. As expected, price in the central market is higher than prices in other markets while the lowest price is observed for the producer. While Figure 3.2 shows the price trend for a subsample of different types of markets. It suggests that cowpea price has an ascending trend with some spike in 2005, 2008, and 2012. The years 2005 and 2012 correspond to negative production shocks due to droughts while the year 2008s'spike corresponds to international shock due to high inflation.

Table 3.1: Descriptive statistics of cowpea price in different type of markets

Market	**Mean**	**Standard deviation**	**Min**	**Max**	**Number of markets**
Central	320.64	71.74	175	497	1
Producer	263.21	76.6	126.4	466.65	18
Wholesale	268.4	76.17	129.33	487.2	6
Consumer	274.05	71.77	146.94	470.95	19

Note: Number of months is 171 (from 07/2004 to 09/2018)

3.3.2. Results

Before estimating the equation (2), We checked the price series properties (Table A 3.1 of the appendix). It comes out that most of the price series are integrated ($I1$) and the Hansen and Seo (2002) test identified 31 over 43 of markets displaying threshold cointegration with the central market. The results of the econometric estimation are shown in Table 1. It shows the average of estimates of the thresholds and the adjustment parameters across trade regimes and different types of market.

Table 3.2: Estimation results of TVECM with Ouagadougou as the central market

Market Type	N	Regime 1 ρ_1^S	Regime 1 ρ_1^C	Regime 1 $\sum \boldsymbol{\rho_1}$	ψ_1	Regime 2 ρ_2^S	Regime 2 ρ_2^C	Regime 2 $\sum \boldsymbol{\rho_2}$	ψ_2	Regime 3 ρ_3^S	Regime 3 ρ_3^C	Regime 3 $\sum \boldsymbol{\rho_3}$
Producer (collecting)	18	-0.10 (89)	0.26 (94)	**0.36 (0.20)**	-82.75	-0.08 (11)	0.13 (28)	**0.21 (0.77)**	40.35	-0.55 (89)	0.07 (50)	**0.62 (0.03)**
Wholesale (assembling)	6	-0.10 (83)	0.28 (100)	**0.38 (0.29)**	-63.71	-0.01 (00)	0.12 (00)	**0.13 (0.70)**	31.65	-0.55 (100)	0.21 (100)	**0.76 (0.01)**
Consumer (retail)	19	-0.08 (68)	0.34 (78)	**0.42 (0.16)**	-64.67	-0.13 (00)	0.17 (00)	**0.30 (0.81)**	34.50	-0.61 (100)	0.08 (73)	**0.70 (0.03)**
All	43	-0.09	0.29	**0.38 (0.21)**	-70.37	-0.07	0.14	**0.21 (0.76)**	35.5	-0.57	0.12	**0.69 (0.03)**

Note: The numbers are the average of estimated parameters of each pair of market for each market type. In the case of All, the average parameters of each market type are averaged using the number of price series as weight. N= number of price series. Distribution of observations across trade regimes is in bold parentheses and percentage of pair of market with significant parameters in non-bold parentheses.

We begin with the estimated thresholds (ψ). First, transaction costs are higher for collecting markets. For example, the estimated threshold for collecting markets is 82.75 XOF/kg for lower bound and 40.35 XOF /kg for the upper bound[13]. One possible explanation for these results is the high transportation cost between the capital city and producing localities not only because the majority of collecting markets are located in remote regions as compared to other types of market but also because the quality of transportation infrastructure is lower. For example, Table 3.3 shows that costs related to the cowpea transportation between producing and central market are 25 XOF per kg on average, which represents 40 percent of the estimated transaction costs approximately.

Table 3.3: Distance between markets, trade costs

Market	Distance (km)	Min Distance (km)	Max Distance (km)	Transportation costs (XOF /kg)	Other trade costs (XOF /kg)	Total trade costs (XOF /kg)
Producer	250.265	35.4	473	19.60	5.34	24.94
Assembling	236.33	102	406	18.52	5.34	23.86
Consumer	213.463	42.4	441	16.72	5.34	22.06

Note: Costs are computed based on the average distance. Based on the estimation made by MAFAP/FAO (2013), which covers the period 2005-2010 trade costs, we apply the inflation rate to complete the costs from 2011 to 2018. Next, we computed the average cost for the period 2005-2018.

Transportation costs: truck location or/and fuel cost.

Other trade costs comprise packaging, handling and labor, loss and illicit fees during transportation.

Source: Computation of author based on MAFAP/FAO (2013)

Second, the estimated thresholds are asymmetric. That is, the per-unit transaction costs depend on the trade flow direction. Although this analysis does not take into account the seasonality of the transaction cost, since the trade flow has a seasonal pattern, we can assume that the transaction cost is also seasonal. On average, the unit transaction cost from secondary to the central market is 70.37 XOF /kg while it costs only 35.5 XOF /kg to transfer cowpea in the opposite direction. A rational for the asymmetry in transaction cost may be the presence of the economies of scale as well as the economies of scope in favor of cereal traders as they own larger transportation

[13]) The XOF is the currency of francophone West Africa (WAEMU). The exchange rate with the Euro is fixed at 1 € = 655,957 XOF since 1999.

capacities carrying cowpea with other commodities when operating compared to rural farmers or collectors who handle small quantities individually. The lower transaction cost from the central markets to rural markets may make the reversible trade flow possible.

Finally, the “neutral band” is [-70.37; 35.5] implying that price deviations within this interval do not triggers arbitrage between deficit and surplus market as trade is not profitable. Moreover, the distribution of observations across different regimes suggests that more than 76% of observations fall under regime 2. This may suggest that cowpea local markets are performing well (integrated) in the sense that they display fewer violations of spatial equilibrium (Barrett & Li, 2002; Baulch, 1997). However, since the size of the neutral band is quite large compared with the average price of cowpea (320 XOF /kg in the central market and 270 XOF /kg in the secondary markets in Table 3.1) the observed fewer violations (deviation from the equilibrium) may be owing to the high transaction cost. Also, because trade volume is not included in our analysis, the conclusion that the cowpea market is performing well should be taken with precaution.

Now we turn to the speed of adjustment (ρ). First, the signs and the amplitudes of estimated adjustment rates are consistent with the prediction of the spatial equilibrium model across different types of markets and regimes. For example, in regime 1, when a shock causes price difference to be lower than the lower threshold, on average, prices in other markets will fall by 9% and price in the central market will increase by 29% given a total adjustment of 38% per month until the equilibrium be restored. This is true for all price relationships between the central market and secondary markets. Also, a high percentage of significant ρ_i^c suggests that shocks from the secondary market affect prices in the central market.

Moreover, adjustment parameters in regime 2 are lower than their counterparts in regime 1 and in regime 3. For example, for the entire sample, the total adjustment rates are 38% and 69% in regime 1 and in regime 3 respectively while it is only 25% in regime 2. However, we found that adjustment parameters are significant for some pairs of markets in regime 2, specifically for collecting markets. This is not predicted by the spatial equilibrium model. This result may be explained by the fact that collecting markets are relatively small and located further and hence may be only connected to the central market through trade with neighboring markets (Jamora and von Cramon-Taubadel , 2016). To sum up, lower and /or non-significant adjustments in regime 2 suggests that cowpea traders are behaving rationally in the sense that such behavior is consistent with profit maximization.

Second, adjustment speed is asymmetric. Specifically, prices respond more quickly to positive shocks than negative shocks. For example, on average a positive shock (regime 3) causes a total adjustment of 69% per month while the total adjustment is only 38% for a negative shock in the same market (regime 1). That is 5 weeks

5 days are required for one-half negative deviation from the equilibrium to be eliminated while only 2 weeks 2 days is necessary for positive deviation. This result is consistent with the asymmetry in transaction costs discussed above. This finding supports the results of previous studies in developing countries. However, the extent of price transmission between domestic markets seems to be higher when using TVECM with three regimes.

To examine the effect of transportation on the transaction costs and price adjustments, we regress the estimated thresholds and adjustment parameters on the log of the distance. We include dummy variables for border and collecting markets. A market is considered as a border market when it is located in a commune that shares a border with a neighboring country. For example, green points in Figure 3.2 are border markets. Since the dependent variables in these regressions are estimates, we follow Lewis and Linzer's (2005) recommendation and compute heteroskedastic consistent standard errors in the regression analysis.

The results are shown in Table 3.4. First, we find that the estimated thresholds are positively and significantly associated with the distance (column 1 and 2) and as a result, a lower price adjustment between markets (columns 3 and 4). These results are expected as the distance captures the transportation cost that is a major component of transaction costs in most developing countries like Burkina Faso.

Table 3.4: Determinants of estimated thresholds and adjustment parameters

Explanatory variables	Lower bound (1)	Upper bound (2)	Total adjustment in Regime 1 (3)	Total adjustment in Regime 3 (4)
Log of distance	8.15**	16.76***	-0.15**	-0.09*
Border market (1/0)	-6.57	-0.18	0.11	0.01
Producer market (1/0)	18.9***	5.58	-0.17**	-0.43
Number of observations	205	205	205	205
R^2	0.05	0.07	0.07	0.02

Note: We consider two majors urban city markets and 3 major assembling markets as central markets in equation 2. **, and *** indicate significance level at 5% and 1%. We regress these estimates from 205 ((44-5) *5+5*2) pairs of markets on the explanatory variables in the first column.

Second, we find that collecting markets are associated with higher transaction cost and lower price transmission. But this result is significant for only trade in regime 1. This result is consistent with TVECM results that emphasize higher transaction costs for trade between collecting and central market.

Finally, the border does not have a significant effect on threshold values and adjustment parameters. This result is not expected as one may assume that markets located at the border are likely to be affected by border trade. One explanation is that even if border markets are closer to neighboring consumers than the central market in Burkina Faso, there is not a close big market in neighboring countries that can affect significantly prices in these markets.

3.4. Conclusion

In this study, we use TVECM to model price relationships of cowpea in the presence of transaction costs, focusing on reversible trade flow between rural markets and the central market. We find the following. First, the results suggest that transaction costs depend on the direction of trade flow and this asymmetry is larger for trade between rural producing markets and the central market. Second, the signs and the amplitudes of the price adjustments are consistent with the spatial equilibrium model even though prices respond more quickly when price in the central market falls than when it increases. Also, market actors seem to behave rationally as there are fewer violations of spatial equilibrium. Third, lower price transmission seems to be associated with a longer distance between markets suggesting that transportation cost is limiting cowpea market performance in Burkina Faso.

Overall, the cowpea market in Burkina Faso seems to perform well in the sense that the price adjustments are consistent with the spatial equilibrium prediction and display fewer violations from it. However, presence asymmetric price transmission suggests an unequal distribution across the marketing channel, specifically to the detriment of rural producers who face high transportation cost.

The first limitation of our analysis is that we only consider price and not trade flows although our interest is on the reversible trade flow. This is a common limitation of price transmission literature as trade data are rarely available in developing countries, especially in high frequency. It is also important to note that this study focuses only on the relationship between the largest market and other markets. However, the trade between other secondary markets prevails. This may affect the price relationship described in the econometric model. Next, the data collection and our analysis do not distinguish between the variety of cowpea for which the price is collected. However, while black-eyes cowpea is popular in most of the provinces, households in the northern part tend to prefer red-eyes cowpea. Since the reference market is the capital city market where both types of cowpea can be found, the assumption of the product homogeneity may not affect extensively the consistency of our findings. Lastly, it appears a somewhat structural break in price trend from the year 2012. However, because the model is computationally intensive, we ignored it.

3.5. Appendix of chapter 3

Table A 3.1: Test of unit root and threshold cointegration of Hansen & Seo (2002)

No. of Market	Name of the Market	Type of price	Test of Unit root (ADF-GLS)		Test of Hansen&Seo
			At level	First difference	
1	Ouagadougou	Central	-2.8318**	-	-
2	Mogteodo	Producer	-1.2624	-6.6486***	25.27***
3	Ziniare	Producer	-2.9137	-6.6038**	18.34**
4	Guelwongo	Producer	-0.9639	-7.2735***	18.5***
5	Manga	Producer	-2.1333	-7.0888***	27.66***
6	Sapouy	Producer	-2.1828	-6.7015***	22.09***
7	Zabre	Producer	-1.3025	-7.5547***	31.66***
8	Founza	Producer	-0.8344	-7.7959***	24.89***
9	Ndorola	Producer	-1.4988	-4.1541***	17.23**
10	Faramana	Producer	-2.3404**	-	12.33
11	Kompienga	Producer	-0.659	-7.7247***	15.44**
12	Ouargaye	Producer	-1.7282	-7.4754***	19.2***
13	solenzo	Producer	-1.3022	-7.1730***	19.44***
14	Fara	Producer	-1.1804	-7.6964***	21.56***
15	gassan	Producer	-1.0745	-6.0163***	11.61
16	Hamele	Producer	-1.471	-7.886***	12.08
17	Batie	Producer	-0.5774	-6.005***	17.34***
18	Gaoua	Producer	-1.2874	-5.298***	9.67
19	Bogande	Producer	-1.2506	-8.3054***	9.17
20	Dedougou	Grouping	-0.5799	-6.7911***	15.56**
21	Diapaga	Grouping	-1.4491	-8.0143***	16.43**
22	Djibasso	Grouping	-0.4402	-7.9424***	13.76*
23	Kaya	Grouping	-0.406	-6.7117***	10.25
24	Pouytenga	Grouping	-0.9865	-6.5099***	19.18***
25	Leo	Grouping	-0.6382	-5.3424***	8.17
26	Banfora	Comsumer	-0.7965	-2.4946**	5.98
27	Bousse	Comsumer	-0.6443	-7.332***	19.54***
28	Diebougou	Comsumer	-1.4038	-5.77862***	16.45**
29	Djibo	Comsumer	-0.8662	-6.3016***	14.71
30	Dori	Comsumer	-1.1743	-6.4288***	16.98**
31	Fada	Comsumer	-0.8662	-4.3016***	8.4
32	Gorom	Comsumer	-0.667	-1.77888	17.88**
33	Gourcy	Comsumer	-0.4814	-6.6966***	21.57***
34	Kombissiri	Comsumer	-2.0172	-7.0814***	21.37***

35	Kongoussi	Comsumer	-2.7133	-6.8839***	23.38***
36	Koudougou	Comsumer	0.6697	-6.668***	16.14**
37	Bobo Dsso	Comsumer	-0.4909	-7.241***	13.38**
38	Ouahigouha	Comsumer	-2.8652	-7.3527***	20***
39	Tenkodogo	Comsumer	-2.6245	-5.8172***	28.7***
40	Tita	Comsumer	-1.2234	-6.7412***	16.06**
41	Titao	Comsumer	-2.7452	-4.7979***	28.9***
42	Tougan	Comsumer	-0.698	-7.2154***	20.73***
43	Yako	Comsumer	-0.650	-2.609***	19.04***
44	Yalgo	Comsumer	-0.7255	-6.6038***	19.04***

Note: *, **, and *** represent statistical significance at 10%, 5%, and 1%.
ADF-GLS: Augmented Dickey-Fuller- Generalized Least Squares

4. ADOPTION OF YIELD-INCREASING TECHNOLOGIES IN POORLY INTEGRATED CROP MARKETS: A PANEL ANALYSIS

4.1. Introduction

Why is the rate of adoption of modern inputs persistently low in developing countries? Previous works have investigated the supply-side constraints to technology adoption such as the high cost of inputs (Croppenstedt, et al., 2003), the lack of information (Beaman et al., 2018), the imperfection in credit markets (Abdul-Hanan, 2016), the learning externalities (Conley & Udry, 2010) and the high production risks in agricultural in developing countries (Mcintosh et al, 2013). These studies assume implicitly that the adoption of modern inputs is always profitable, and that the crop markets are performing well. However, commodity markets in developing countries are not only disconnected from the international market, but they are also domestically fragmented in many cases (Baquedano & Liefert, 2014; Bekkers et al., 2017). This may affect the profitability of yield-increasing technologies. As pointed out by Gabre-Madhin et al. (2003), the more segmented the market is, the less responsive demand is to changes in price and the lower the producer share of the gains from increased production.

The role of profitability in the adoption decision on crop yield-improving technologies is advocated in some recent works. For instance, Suri (2011) shows that individual comparative advantage as measured by the rate of return determines the decision to adopt. In Michler et al (2018), it was found that high adoption is explained by economic gain through cost reduction rather than the farmer's comparative advantage. However, these studies are focused on physical output and the constraints in accessing inputs. In so doing, they do not account for the change in the relative output price that follows the wide use of the modern inputs, neither do they explain farmers year-to-year switching behavior from being adopters to non-adopters of modern inputs and vice-versa.

Furthermore, previous researches have tackled the conceptual issues around the effects of crop market efficiency on the adoption of yield-increasing technologies by agricultural producers (Barrett, 2008; Cochrane, 1958; Gabre-Madhin et al., 2003; Hayami & Herdt, 1977). However, only a few of them have provided empirical evidence. In this study, we attempt to fill this gap in the literature by analyzing how the performance of the crop market affects the farmers' decision to use modern inputs in Burkina Faso. Here, we posit and test the hypothesis that crop output market integration affects farmers' decision to adopt yield increasing technologies. In doing so, we use a more direct measure of profitability, which allows us to analyze the effect of the market access as well as the economic return to adopting the modern inputs.

4.2. Methods

4.2.1. Conceptual framework

This study is based on the strand of literature that investigates the conceptual issues around the fundamental problem of the negative price effects of technological change on agricultural producers. First, Cochrane (1958) formulated it as the ''technology treadmill" effect, in which farmers operate in a fully commercialized economy. Hayami and Herdt (1977) later applied this theory to the context of semi-subsistence economies where a large fraction of the commodity is consumed in the household or local village. The theory is based on the underlying notion of a dynamic process in which, over the long run, aggregate demand and aggregate supply are engaged in a race. Following Cochrane (1958), in a small open economy in which producers face infinitely elastic demand, the social gains from any technological change accrue entirely to producers in the form of higher profits. By contrast, if demand is perfectly inelastic, all the social gains accrue to consumers in the form of lower prices. The distribution of the gains from technical change, therefore, depends crucially on the price elasticity of demand for the product, which in turn depends heavily on how well integrated the local market is with broader national, regional, and global markets. Producers adopt new technologies because they reduce unit costs, thereby increasing productivity and output. But in general equilibrium, when enough producers adopt the cost-reducing technology that the aggregate supply curve shifts and prices fall too, it potentially leaves producers worse off than before if demand is sufficiently inelastic. Therefore, since most agricultural products exhibit highly inelastic demand, maintaining efficient market integration is that much more important to ensure producers benefit in the long run from technological change (Barrett, 2008).

Following Fackler and Goodwin (2001), market integration can be thought as a measure of the degree that to which demand and supply shocks arising in one region are transmitted in another region. This definition is suitable for our aims of examining the effect of market integration on the adoption of modern inputs. Specifically, we focus on price differentials between two markets to explore market performance under a spatial equilibrium approach and its effect on smallholder farmers technology adoption.

The spatial equilibrium model can be summarized as follows (Judge and Takayama, 1971) :

$$p_t^i - p_t^j \leq \psi_{j \to i} \quad (4.1)$$

where p_t^i is the price of the good in the deficit market i and p_t^j price in the surplus market j at time t and $\psi_{j \to i}$ is the cost of the trade from market j to market i. The spatial equilibrium model stipulates that the prices of a given good at two locations should not differ by no more than the transaction costs of trading the good between these locations. Otherwise, traders will engage in spatial arbitrage, which increases the price at the low-price market and reduces the price in the high price market until the spatial equilibrium $p_t^i - p_t^j = \psi_{j \to i}$ be restored.

In a context of limited sales opportunities, due to missing or poorly functioning markets, the assumed equivalence between yields and economic returns may have led the literature astray: First, when producer price levels either rise or fall in absolute terms, this leads to severe negative consequences for either consumers or farmers, respectively. Secondly, year-to-year variations around the moving price level induces uncertainty, where a commodity may rise one year and fall the next, farmers are required to make planning decisions without knowing the following year price, which can lead to the inefficient distribution of resources (Gabre-Madhin et al, 2003). Adoption of modern input such as chemical fertilizer, pesticides, and crops protection products constitute an investment of for farm household. Also, such inputs are particularly expensive in developing countries. Farmers will invest in modern inputs if the marginal revenue from crop sale is at least equal to the marginal cost of using such inputs. However, in fragmented markets, small shifts in supply can affect local market prices (Burke et al., 2017). This is mainly due to the very severe price inelasticity of agricultural products. The effect of price inelastic demand is compounded at the producer level by the wedge between retail and producer prices (Cochrane, 1958). Therefore, investments that increase production may result in lower prices for that crop, reducing the incentive to further invest in new technology (Karlan et al, 2015).

4.2.2. Empirical model

The baseline specification is as follows:

$$Adopt_{hit} = \gamma Market\_perf_{it-1} + Province'_{it-1}\theta_1 + W'_t\beta + X'_t\theta_2 + u_{ih} + \varepsilon_{iht} \quad (4.2)$$

$$Price\_dispersion_{it-1} = |\ln(P_{it-1}) - \ln(P_{rt-1})| * 100 \quad (4.3)$$

where $Adopt_{hit}$ is a binary indicator or a count of modern inputs used (a measure of intensity) at time t for household, h, in province i. This paper focuses on four modern inputs that are commonly used in crops' production in Burkina Faso. The intensity of the adoption of modern inputs ranges from 0 to 4. The key regressor is $Market\_perf$, market performance, for which two measures are constructed. The first measure, constructed in equation (4.3), is the average price dispersion between the reference market (indexed r) and prices in the market of the i^{th} province during the 12 months preceding the cropping season. P_{it-1} is the average market price in province i at time $t-1$ and P_{rt-1}, average market price in the reference market. Following Salazar et al.(2019), we used the log transformation to remove trends in prices induced by a common factor (for example, general consumer prices) and are naturally interpreted as the percentage price gap. The reference market is the market of the capital city. The second measure is price coefficient of variation in the province i during the 12 months preceding the cropping season. This variable measures also price volatility in the province i. Since our measures of market performance are based on province-level market prices, it is exogenous.

The parameters are to be estimated are $\gamma, \theta_1, \theta_2$ and β. The parameter of primary interest is γ which measures the impact of the output price dispersion (or price volatility) on the use of modern inputs. $Province_{it-1}$ is a vector of province i characteristics. W and X are vectors of plot and household's socio-demographics characteristics respectively. u_{ih} is the household fixed-effects and ε_{iht} the error term. The exogeneity of market performance notwithstanding, the identification of parameters is strengthened in the model using household fixed effects. The potential correlation of ε_{iht} and household characteristics motivated this decision.

4.3. Data and Results

4.3.1. Data

To test our hypothesis, we used data from the Enquête Permanente Agricole (EPA), that is "Continuous Farm Household Survey" of Burkina Faso. The data is collected every year by the Ministry of Agriculture and Food Security. The survey is a two-stage design with Probability Proportional to Size (PPS) sampling. The units in the first stage are the villages in each province and the unit of the second stage are households. The EPA panel is renewed every five years. EPA data collection takes place in seven (7) months, from June to December each year, using questionnaires now grouped into different sections, some of which are administered twice over two different periods. One of the survey objectives is to estimate farm input use, production, area, and yield of crops at the national level. Since 2014, the new EPA panel is made up of approximately 4131 households in more than 887 villages, with no more than 6 households per village.

This study uses the five recent rounds of the EPA survey data (that is 2014-2018). Market prices[14] come from the data collected from all 45 provinces by the SIMA/SONAGESS of the same ministry (chapter 3). We focus on the use of modern inputs in cowpea production. Cowpea is a legume produced in all provinces in Burkina Faso and more than 50% of the output is commercialized. Also, we only consider households who produced cowpea twice or more between 2014 and 2018. This yields an unbalanced panel of 2448 households. The most common modern inputs used in the production of cowpea in Burkina Faso are chemical fertilizer (1); improved seed (2); herbicide (3); and pesticide and post-harvest crop protection products (4).

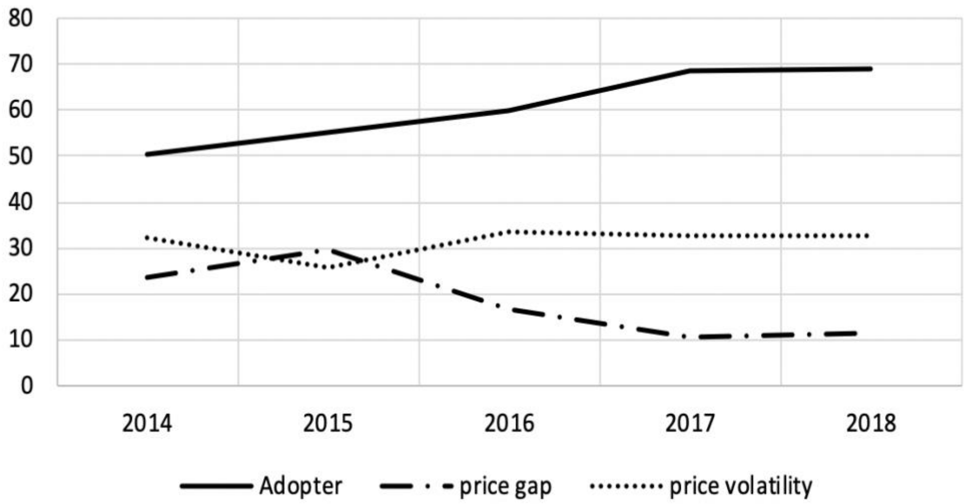
The description of the variables used in the econometric analysis is presented in table 4.1. It shows that on average more than 60 percent of farmers have used at least one modern input while the intensity of use of those inputs is less than 1. This intensity of modern inputs usage is low and suggests that farmers do not use modern inputs complementarity. This in turn associated with the low rate of application of fertilizer may explain the low yield per ha of cowpea, which is around 770kg/ha (Table 4.1).

Figure 4.1 shows the rate of modern inputs use, the price dispersion, and volatility (standard deviation) of cowpea at the national level during five consecutive years. From 2014 to 2018, the price gap between producing rural markets and the capital city market has decreased by 51% while the rate of

[14] See Nikiema and Sakurai (2020) for a full description of the price data used in this study.

adoption of modern inputs has increased by 37 %. These results are expected and may be explained by the recent improvement in transportation infrastructures, access to information due to the wide use of mobile phones. This in turn has reduced the transaction costs and then improved market access by rural farmers. However, this improvement at the national level may hide some heterogeneity at the province level as well as the individual farmer's level. While the price gap between the reference market is 16 percent on average, for some provinces it may reach 68 % percent. Also, prices are very volatile and weakly transmitted between rural producing markets and the central market (see chapter 3).

Figure 4.1: Trend in market integration and modern inputs adoption



Source: Author construction from EPA

4.3.2. Results

First, we examine the effect of modern inputs adoption on the cowpea yield at the plot level. Columns 1 and 2 of Table A4.1 show that the adoption as well as the number of modern inputs used is significantly associated with higher yield per ha of the cowpea. This result confirms the findings of previous studies in the Burkina Faso context that yield response to modern inputs is positively significant (Koussoubé & Nauges, 2017; Theriault, Smale, & Haider, 2018). However, as discussed in the previous section, yield increase does not imply an increase in farmers' income in the context of poorly integrated markets such as the case of cowpea in Burkina Faso.

Now we turn to the effect of market efficiency on the use of modern inputs. The results of the econometric estimation are presented in Table 4.2 and Table 4:3. First, columns (1), (2), and (3) of Table

4.2 show that an increase in price dispersion is significantly associated with a decrease in the probability of using modern inputs. For instance, a 10% increase in the price gap during the 12 months preceding the planting season lowers the probability to use of modern inputs by 0.04 points. Consistent with the results in Table 4.2, columns (1), (2), and (3) of Table 4.3 suggests that the number of modern inputs used decreases by 0.12 inputs with a 10% increase in the price gap, which is equivalent to decrease of 12.5% approximately relative to the sample mean. Consistent with the conceptual framework, the large price gap between trading markets implies that farmers received lower prices as compared to what they would have received if markets were perfectly integrated; thus, reducing farmers' incentive to invest in yield-increasing inputs.

Second, the column (3), (4), and (5) of Table 4.2 show the estimates of price volatility on the decision to adopt modern inputs. The results suggest that price volatility does not significantly affect the decision to use modern inputs. However, as opposed to the results of Table 4:2, columns (3), (4), and (5) of Table 4:3 suggest that price volatility significantly decrease the number of modern inputs used by farmers. More specifically, an increase in price C. O. V by 10 percentage points (0.1) is associated with a decrease in the number of modern inputs used by about 0.0032, which represents a decrease of 0.3% relative to the sample mean (columns (4) Table 4.3). These results suggest that the association between price dispersion and the adoption of modern inputs is stronger than those between price volatility and the adoption of modern inputs. One explanation is that price volatility is likely to follow a seasonal pattern. As a result, farmers may predict price variations such that they only affect their revenue weakly. In other words, in each locality, farmers are likely to know approximately which months are or are not better in terms of prices. The result remains consistent when we use the standard deviation as a measure of the price volatility.

However, local price volatility may also be affected by the extent to which the local market is integrated into other markets. Therefore, we also interacted with the price gap with high price volatility (measured by the coefficient of variation greater than 0.8, the median value of the C.O>V) in columns (3) of Table 4.2 and Table 4.3.

Table 4.1: Descriptive statistics: Market integration and use of modern inputs

Variables	Mean	S.D.	Min.	Max.
Adopter (=1 if use at least 1 modern inputs)	0.62	0.48	0	1
Intensity of modern input use	0.96	0.930	0	4
Yield (kg/ha)	768.21	410.08	0.04	4000
Average Price dispersion (12 months preceding planting season)	16.71	13.48	0.09	68.05
Average Price dispersion in provinces with collect markets	21.68	15.58	0.101	59.61
Average Price dispersion in provinces with wholesale markets	15.66	10.86	0.52	45.71
Average Price dispersion in provinces with retail markets	16.41	14.65	0.091	68.05
Price standard deviation	31.72	11.35	8.00	116.35
Price coefficient of variation (C. O. V)	0.62	1.07	0.063	2.35
C. O. V in provinces with collect markets	0.76	1.76.	0.121	2.35
C. O. V in provinces with wholesale markets	0.53	0.86	0.063	1.01
C. O. V in provinces with retail markets	0.67	1.43	0.110	2.01
Average Price at planting season (May-July)	339.07	58.06	174.83	642.36
Production shock at t-1[a]	1.46	20.61	-93.39	180.05
Access to transportation (=1 if HH has a transportation mean)	0.50	0.50	0	1
Use of a mobile phone (= 1if HH has a mobile phone)	0.86	0.34	0	1
Age of the head of the HH	43.40	14.6	18	99
Literacy (=1 if HH head has a primary education)	0.29	0.45	0	1
OP (=1 if the HH head is member of farmer organization)	0.27	0.44	0	1
AGR (=1 if HH generate a non-farm income)	0.954	0.21	0	1
Training (=1 if HH has received agricultural training)	0.27	0.44	0	1
Credit (=1 if HH has received a credit)	0.15	0.35	0	1
Working members (the number of active adults in the HH)	5.74	3.50	1	35
TLU (Tropical Livestock Unit)	1.99	5.65	0	414.54
Crop diversification (number of crops planted)	3.22	1.14	1	9
Number of plots	6.19	3.99	1	44
Plot size in ha	2.98	2.603	0.005	28.57
Plot location (=1 if bush and 0 if near house)	0.230	0.42	0	1
Plot landscape (=1 if sloped plot and 0 otherwise)	0.07	0.26	0	1
CES (=1 if used soil conservation technologies in the plot)	0.06	0.24	0	1
Agroforestry (= 1 if agroforestry is practiced in the plot)	0.68	0.46	0	1
Restored (=1 if the plot is newly restored)	0.02	0.13	0	1

Note: **HH**= household head ; C. O. V: Coefficient of variation. Since households have in general more than one plot of cowpea, we only consider the household larger plot. Number of the observations: 7,829. [a] yield deviation from its last 10 years trend.

Table 4.2: The effect of commodity market performance on the adoption of modern inputs (Linear probability Household fixed-effects)

Variables	(1)	(2)	(3)	(4)	(5)
Price dispersion	-0.0054***	-0.004***	-0.004***		
	(0.000)	(0.000)	(0.000)		
Price volatility (C. O. V)			-0.0005	-0.0002	-0.0009
			(0.0008)	(0.0006)	(0.0012)
Adoption at t-1	0.181***	0.108***	0.180***	0.185***	0.115***
	(0.002)	(0.001)	(0.004)	(0.004)	(0.008)
Price dispersion*High volatile			-0.007***		
			(0.000)		
Price dispersion*Adoption at t-1		-0.009***			
		(0.000)			
High volatile*Adoption at t-1					-0.043***
					(0.004)
Access to transportation	0.067***	0.080***	0.077***	0.062***	0.1115***
	(0.014)	(0.016)	(0.0161)	(0.014)	(0.0254)
Use of mobile phone	0.021	0.023	0.0245	0.023	0.0715**
	(0.018)	(0.020)	(0.020)	(0.018)	(0.031)
Province covariates	YES	YES	YES	YES	YES
Household covariates	YES	YES	YES	YES	YES
Plot covariates	YES	YES	YES	YES	YES
Year*Region dummy	YES	YES	YES	YES	YES
R-squared adjusted	0.168	0.1721	0.218	0.158	0.161

Notes: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors in parentheses are robust clustered at household level. C. O. V: Coefficient of Variation. For columns (3) and (5) High volatile is a dummy variable (=1 if C. O. V>0.8 and 0 otherwise). Province characteristics include production shock, the type of market (collect ,wholesale, or retail), and average price at the planting season. Number of the observations: 7,829. Number of groups: 2,404. Please see Table A4.2, A4.3, and A4.4 for full regression outputs.

Table 4.3: The effect of commodity market performance on the intensity of adoption of modern inputs (Household fixed effects)

Variables	(1)	(2)	(3)	(4)	(5)
Price dispersion	-0.012***	-0.0102***	-0.0101***		
	(0.001)	(0.001)	(0.001)		
Price volatility (C. O. V)			-0.0027**	-0.0032**	-0.0002*
			(0.0046)	(0.0016)	(0.0001)
Adoption at t-1	1.0213***	0.833***	0.693***	1.331***	0.285***
	(0.000)	(0.000)	(0.004)	(0.0042)	(0.0043)
Price dispersion*High volatile			-0.019***		
			(0.000)		
Price dispersion*Adoption at t-1		-0.113***			
		(0.004)			
High volatile*Adoption at t-1					-0.019***
					(0.004)
Access to transportation	0.0014**	0.002***	0.120***	0.079***	0.123***
	(0.000)	(0.000)	(0.030)	(0.014)	(0.0302)
Use of mobile phone	0.121***	0.130***	0.069**	0.024	0.0735**
	(0.025)	(0.030)	(0.036)	(0.020)	(0.0365)
Province covariates	YES	YES	YES	YES	YES
Household covariates	YES	YES	YES	YES	YES
Plot covariates	YES	YES	YES	YES	YES
Year*Region dummy	YES	YES	YES	YES	YES
R-squared adjusted	0.169	0.177	0.190	0.181	0.172

Notes: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors in parentheses are robust clustered at household level. C. O. V: Coefficient of Variation. For columns (3) and (5) High volatile is a dummy variable (=1 if C. O. V>0.8 and 0 otherwise). Province characteristics include production shock and average price at the planting season. Number of the observations: 7,829. Number of groups: 2,404. Please see Table A4.2, A4.3, and A4.4 for full regression outputs.

The result shows that an increase in price gap by 10 % in provinces with high volatile prices is associated with a decrease in the probability of adopting modern inputs by 0.07 points (column (3) of Table 4.2) and the number of modern inputs used by about 20% relative to the sample mean (column (3) of Table 4.3). This implies that the effect of spatial price dispersion on the adoption of modern inputs is stronger in provinces with a high volatile price. This is expected since the effect of weak spatial market integration is compounded by the negative effect of the risk generated by high price volatility. This result remains stable when we set a higher level of cut-offs of price volatility.

Finally, another important question is whether or not a low performance of the crop market discourages previous adopters of modern inputs. For this purpose, we add an interaction variable of the market performance measures and the past adoption status. The results are shown in columns (2) and (5) of Table 4.2 and Table 4.3 for the decision to adopt and the intensity of adoption, respectively. As expected, there is a strong association between previous years' adoption status and the current adoption of modern inputs. However, when interacted with high price volatility and price dispersion, its coefficients become significantly negative. For example, an increase in the price gap between the reference market and the province market by 10% reduces the probability of adoption of modern inputs by 0.09 points for farmers who adopted modern inputs in previous years (column (2) of Table 4.2). This finding is not only consistent with the above results but also suggests that lower output market performance in the previous months before planting season effect is stronger for previous adopters. Consistent with the conceptual framework, in developing countries, the lower performance of the output market is often coupled with a sales slump. As a result, adopters of modern inputs get discouraged and then dis-adopt.

The overall results sustain our hypothesis that commodity market performance fundamentally alters the use of modern inputs by farmers in developing countries. Moreover, the effect is stronger when price dispersion is compounded by high price volatility. High price gaps between producing and consuming locations imply that farmers cannot take full advantage of the price increase in the consuming market. Hence, gain from technology adoption is not efficiently optimized. One explanation is that the use of modern inputs increases farmer income when markets between producing and consuming locations are well integrated (Porteous, 2020). Otherwise, the negative effect on prices that follows the wide adoption of yield-increasing inputs discourages farmers from investing in such inputs in the following cropping season.

4.4. Conclusion

Despite the wide acknowledgment that modern inputs are the key to enhance agricultural productivity in developing countries, the rate of adoption of such inputs remains low. In this study, we have shown that there is a negative association between the use of modern inputs by smallholder farmers and the low integration of crop market. Moreover, the results suggest that this association is stronger for farmers who previously adopted these yield-increasing inputs. Our findings remain robust after controlling for households' fixed effects and geographic heterogeneity. Our results imply that in order to succeed, agricultural interventions that target the adoption of modern inputs should be accompanied by market development measures. Physical or economic access to modern inputs may not be enough to stimulate their adoption if the economic return of such inputs is undermined by the lack of crop output market integration. Further investigations, specifically those which are based on general equilibrium modeling may be useful in confirming our findings.

4.5. Appendix of chapter 4

Table A 4.1:The impact of modern inputs adoption on the log of cowpea yield: Household fixed effects

	(1)	(2)
Variables		
Adoption (0/1)	0.0788***	
	(0.021)	
Intensity of inputs use (0-4)		0.0436***
		(0.0113)
Adoption at t-1	0.001	0.002
	(0.000)	(0.000)
Province production shock	0.000	0.0004
	(0.000)	(0.0005)
Access to transportation	0.020	0.0209
	(0.025)	(14.120)
Use of mobile phone	0.051*	0.050
	(0.031)	(0.0312)
Age of the head	0.000	0.000
	(0.000)	(0.000)
Literacy of the head	-0.0319	-0.033
	(0.021)	(0.0214)
Membership to OP	0.047*	0.0469*
	(0.0271)	(0.0271)
AGR	-0.017	-0.0139
	(0.047)	(0.0473)
Training	-0.017	-0.032
	(0.047)	(0.0249)
Access to credit	0.0302*	0.0582*
	(0.031)	(0.0315)
Working members	0.008***	0.008**
	(0.002)	(0.0028)
Plot size	0.087***	0.083**
	(0.028)	(0.0278)
TLU	0.002	0.002
	(0.0016)	(0.001)
Crop diversification	-0.0104	-0.0096
	(0.0108)	(0.0108)
Number of plots	0.006*	0.0063*
	(0.003)	(0.0033)
Plot location	0.000	-0.0012
	(0.0238)	(0.0237)
Plot landscape	-0.009	-0.0124
	(0.0390)	(0.0389)
Practice of CES	0.0198	0.019
	(0.038)	(0.038)
Agroforestry	0.0283	0.0281
	(0.022)	(0.0219)
Plot newly restored	-0.029	-0.029
	(0.073)	(0.073)
Year*Region dummy	Yes	Yes
R-squared adjusted	0.1060	0.1063

Note: *Note*: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors in parentheses are robust and clustered at household level. Number of the observations: 7,829. Number of groups: 2,404. See table A4.1 for the definition of variables.

Table A 4.2: The effect of price dispersion on the use of modern inputs (Household fixed effects)

	Adoption: linear probability model		Intensity of inputs use	
Variables	(1)	(2)	(3)	(4)
Price dispersion	-0.0054***	-0.004***	-0.012***	-0.0102***
	(0.000)	(0.0008)	(0.001)	(0.001)
Adoption at t-1	0.181***	0.108***	1.0213***	0.833***
	(0.002)	(0.0018)	(0.000)	(0.000)
Price dispersion* Adoption at t-1		-0.009***		-0.113***
		(0.000)		(0.000)
Planting price	0.000	0.0006***	0.000	0.001***
	(0.000)	(0.0002)	(0.000)	(0.000)
Province production shock	0.000	0.000**	0.0014**	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Access to transportation	0.067***	0.080***	0.121***	0.130***
	(0.014)	(0.016)	(0.025)	(0.030)
Use of mobile phone	0.021	0.023	0.068**	0.073**
	(0.018)	(0.020)	(0.031)	(0.036)
Age of the head	-0.000	0.0002	0.000	0.000
	(0.000)	(0.0004)	(0.000)	(0.000)
Literacy of the head	0.0127	0.0163	0.028	0.061**
	(0.011)	(.0139)	(0.022)	(0.027)
Membership to OP	0.043***	.0163	0.117***	0.0401
	(0.014)	(0.017)	(0.030)	(0.035)
AGR	0.0701***	0.088***	0.090*	0.092*
	(0.025)	(0.028)	(0.046)	(0.050)
Training	0.061***	0.071***	0.177***	0.190***
	(0.013)	(0.016)	(0.030)	(0.036)
Access to credit	0.032**	0.050***	0.045	0.126***
	(0.015)	(0.018)	(0.034)	(0.040)
Working members	-0.001	-0.000	-0.004	0.000
	(0.0015)	(0.001)	(0.003)	(0.003)
Plot size	0.113***	0.114***	0.293***	0.285***
	(0.015)	(0.018)	(0.036)	(0.039)
TLU	0.000	-0.0001	-0.000	-0.0004
	(0.000)	(0.0008)	(0.001)	(0.001)
Crop diversification	-0.033***	-0.025***	-0.073***	-0.064***
	(0.005)	(0.007)	(0.010)	(0.013)
Number of plots	0.000	-0.0016	0.001	-0.000
	(0.001)	(0.0021)	(0.003)	(0.004)
Plot location	-.00413***	-0.048***	-0.073***	-0.083***
	(0.0130)	(0.015)	(0.024)	(0.029)
Plot landscape	0.0149	0.0067	0.077**	0.088*
	(0.0193)	(0.022)	(0.039)	(0.045)
Practice of CES	0.0416*	0.0410	0.074*	0.070
	(0.021)	(0.026)	(0.042)	(0.049)
Agroforestry	0.043***	0.0400***	0.087***	0.076***
	(0.012)	(0.0147)	(0.022)	(0.026)
Plot newly restored	0.044	0.0299	0.098	0.053
	(0.039)	(0.0455)	(0.074)	(0.087)
Year*Region dummy	YES	YES	YES	YES
R-squared adjusted	0.168	0.1721	0.169	0.177

Note: *Note*: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors in parentheses are robust and clustered at household level. Number of the observations: 7,829. Number of groups: 2,404. See table A4.1 for the definition of variables.

Table A 4.3:The effect of price volatility on the adoption of modern inputs (Linear probability household fixed effects)

Variables	(1)	(2)	(3)
Price volatility(C. O. V)	-0.0002	-0.0005	-0.0009
	(0.0006)	(0.0008)	(0.0012)
Price dispersion		-0.004***	
		(0.000)	
Adoption at t-1	0.185***	0.180***	0.115***
	(0.004)	(0.004)	(0.008)
Price dispersion*High volatility (C. O. V>0.8)		-0.007***	
		(0.000)	
Adoption at t-1*High volatility (C. O. V>0.8)			-0.043***
			(0.004)
Planting price	0.0002	0.001***	0.0007**
	(0.0001)	(0.0002)	(0.0003)
Province production shock	0.0002	0.0011***	0.0014**
	(0.0003)	(0.000)	(0.0006)
Access to transportation	0.062***	0.077***	0.1115***
	(0.014)	(0.0161)	(0.0254)
Use of mobile phone	0.023	0.0245	0.0715**
	(0.018)	(0.020)	(0.031)
Age of the head	0.000*	0.0004	-0.0002
	(0.000)	(0.0004)	(0.0006)
Literacy of the head	0.0135	0.017	0.029
	(0.011)	(0.013)	(0.022)
Membership to OP	0.045***	0.0165	0.122***
	(0.0145)	(0.0176)	(0.0305)
AGR	0.073***	0.088***	0.097**
	(0.025)	(0.0287)	(0.046)
Training	0.059***	0.0712***	0.174***
	(0.013)	(0.0166)	(0.030)
Access to credit	0.0385**	0.0539***	0.059*
	(0.015)	(0.0189)	(0.034)
Working members	-0.001	-0.000	-0.005
	(0.0015)	(0.0018)	(0.003)
Plot size	0.1142***	0.1147***	0.295***
	(0.016)	(0.0180)	(0.037)
TLU	0.0001	-0.0001	-0.0002
	(0.000)	(0.000)	(0.001)
Crop diversification	-0.034***	-0.0256***	-0.076 ***
	(0.006)	(0.0072)	(0.0109)
Number of plots	0.001	-0.0013	0.0034
	(0.001)	(0.0021)	(0.0032)
Plot location	-0.0398***	-0.048***	-0.070***
	(0.013)	(0.0155)	(0.0245)
Plot landscape	0.0209	0.009	0.092**
	(0.019)	(0.0221)	(0.039)
Practice of CES	0.043**	0.0429	0.0781*
	(0.022)	(0.026)	(0.042)
Agroforestry	0.042***	0.039***	0.085***
	(0.012)	(0.0147)	(0.0226)
Plot newly restored	0.048	0.029	0.1077
	(0.039)	(0.045)	(0.0757)
Year*Region dummy	YES	YES	YES
R-squared adjusted	0.158	0.218	0.161

Note: *Note*: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors in parentheses are robust and clustered at household level. Number of the observations: 7,829. Number of groups: 2,404. See table A4.1 for the definition of variables. C. O. V: Coefficient of Variation.

Table A 4.4: The effect of price volatility on the intensity of adoption of modern inputs (household fixed effects)

Variables	(1)	(2)	(3)
High Price volatility (C. O. V)	-0.0032**	-0.0027**	-0.0002*
	(0.0016)	(0.0046)	(0.0001)
Price dispersion		-0.0101***	
		(0.001)	
Adoption at t-1	1.331***	0.218***	0.285***
	(0.0042)	(0.003)	(0.0043)
Price dispersion*High Price Volatility(C. O. V>0.8)		-0.009***	
		(0.000)	
Adoption at t-1*High Price Volatility(C. O. V>0.8)			-0.019***
			(0.004)
Planting price	0.0004***		0.0022***
	(0.0002)		(0.0004)
Province production shock	0.000**	0.000***	0.002***
	(0.000)	(0.000)	(0.0007)
Access to transportation	0.079***	0.120***	0.123***
	(0.014)	(0.030)	(0.0302)
Use of mobile phone	0.024	0.069**	0.0735**
	(0.020)	(0.036)	(0.0365)
Age of the head	0.0002	0.000	0.0004
	(0.000)	(0.000)	(0.0004)
Literacy of the head	0.0163	0.061**	0.063**
	(0.014)	(0.027)	(0.0275)
Membership to OP	0.0163	0.0401	0.0394
	(0.017)	(0.035)	(0.0394)
AGR	0.086***	0.089*	0.093*
	(0.028)	(0.050)	(0.050)
Training	0.070***	0.191***	0.191***
	(0.016)	(0.036)	(0.0361)
Access to credit	0.048***	0.126***	0.134***
	(0.018)	(0.035)	(0.040)
Working members	0.000	0.000	0.0001
	(0.001)	(0.003)	(0.003)
Plot size	0.112***	0.282***	0.2843***
	(0.018)	(0.039)	(0.0391)
TLU	0.000	0.000	-0.0003
	(0.000)	(0.001)	(0.0010)
Crop diversification	-0.025***	-0.064***	-0.064***
	(0.007)	(0.013)	(0.0138)
Number of plots	-0.001	-0.000	0.0002
	(0.0021)	(0.004)	(0.0041)
Plot location	-0.032***	-0.081***	-0.0820***
	(0.015)	(0.030)	(0.0295)
Plot landscape	0.0055	0.072*	0.097**
	(0.022)	(0.045)	(0.0457)
Practice of CES	0.0410	0.070	0.0749
	(0.026)	(0.049)	(0.0504)
Agroforestry	0.040***	0.075***	0.0762***
	(0.014)	(0.026)	(0.026)
Plot newly restored	0.032	0.051	0.0536
	(0.045)	(0.087)	(0.089)
Year*Region dummy	YES	YES	YES
R-squared adjusted	0.181	0.190	0.172

Note: *Note*: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors in parentheses are robust and clustered at household level. Number of the observations: 7,829. Number of groups: 2,404. See table A.1 for the definition of variables. High volatile is a dummy variable (=1 if C. O. V>0.8 and 0 otherwise).

5. DOES COMPARATIVE ADVANTAGE MATTER IN FARM HOUSEHOLD MARKET PARTICIPATION? EVIDENCE FROM SMALLHOLDERS IN BURKINA FASO

5.1. Introduction

It is widely recognized that smallholders' market participation is a key to foster agricultural development and thus to reduce poverty in less developed countries. Commercialization contributes to farmers' income by offering sale opportunities for the surplus of production and to the improvement of household food security (Dorosh et al., 2016; Montalbano et al., 2018; Ogutu et al., 2019). However, evidence suggests that smallholders' market participation remains low in sub-Sahara Africa despite the wave of market-oriented liberalization (Barrett, 2008). Hence, what the driving factors of smallholders' market participation in low-income rural areas remains an important question for policy makers as well as for researchers.

A farm household participates in a specific crop market when it sells and/or buys some quantity of that crop (Bellemare and Barrett, 2006). Previous empirical works have focused on the role of the transaction costs and household assets in the smallholders' commercialization. First, transaction costs associated with weak institutional and physical infrastructure affect marketing behaviors significantly (Alene et al., 2008; Barrett, 2008; Renkow et al., 2004). Second, there is a strong association between households' asset holding, especially land, and the share of the output sold (Boughton et al., 2007; Mather et al., 2013).

The strand of empirical works that is closer to our study recognizes the importance of farm productivity on marketing behavior. Some studies show that the use of modern inputs is positively associated with the decision to participate as well as the quantity sold (Burke et al., 2015; Mather et al., 2013; Olwande et al., 2015). However, the reverse causality between market participation and modern inputs use limits their results to a simple correlation.

Other studies have tried to quantify the causal relationship between farm productivity and the surplus marketed using instrumental variables. For example, Rios et al. (2008) examined the direction of causality between productivity and market participation. They find that households with higher productivity tend to sell a larger share of their output regardless of the market access factors while having better access does not necessarily lead to higher productivity. Also, Tirkaso and Hess (2018) show that farmers with high technical efficiency are likely to have a high level of surplus commercialization.

These previous studies rather focus on the sole index of commercialization but do not answer the question as to why a farm household decides to enter or opts out of the market. It has been acknowledged in the literature that factors that dictate market entry decisions may differ from those determining the quantity sold. Also, these studies do not explain the marketing behavior when a farmer has relatively high productivity in more than one crop.

We contribute to the literature by giving an empirical insight into the role played by the comparative advantage in smallholders' decision to enter into a specific crop market as well as the quantity sold in that market when alternative marketable crops may be produced by the household. More specifically, we hypothesize is that for alternative marketable crops, a farmer enters as a net seller in the crop market for which he holds a comparative advantage. To test this hypothesis, we use a nationally representative sample of farm households that produces two well domestically commercialized staple-food crops in Burkina Faso to test this hypothesis.

5.2. Methods

5.2.1. Theoretical framework

Following Barrett (2008), a farm household maximizes its utility over a bundle of consumption goods produced and/or purchased from the market, subject to an income constraint. The marketing decision of the smallholder farmer can be expressed by the following equation:

$$\mathrm{M}_h^i = \mathrm{M}_h^i(P, Z, A, G, C) \tag{5.1}$$

where M_h^i is the net quantity of crop i sold in the market by household h. The vector P is the observed market prices. Other vectors are household characteristics (Z), household productive assets (A), public goods and services (G), and the household comparative advantage (C).

In this study, it is assumed that crop specificities generate a comparative advantage for farmers according to their management capacity, experience, and endowment of production factors. The comparative advantage in turn is expressed in terms of heterogeneity in productivity across farm households and between crops within the same household. As a result, the farm household chooses to produce and commercialize the crop for which he has a comparative advantage, and earns income to satisfy the demand for food crops for which he does not hold a comparative advantage.

5.2.2. Econometric model and empirical strategy

Market participation and quantity sold

A reasonable assumption is that the factors influencing the participation choice (hurdle 1) may differ from those affecting the level of commercialization (hurdle 2). Following Olwande et al. (2015), Cragg's double-hurdle model is used. More specifically, in the first stage, a Probit maximum likelihood estimator (MLE) is used to obtain the estimates for hurdle 1 and a Truncated normal estimator is used for hurdle 2.

The regression equations to be estimated are the following:

$$P\left(\mathrm{M}_h^i > 0\right) = \alpha C_h + x_h'\beta + \varepsilon_{1h} \quad (5.2)$$

$$\mathrm{S}_h^i = \gamma C_h + w_h'\theta + \varepsilon_{2h} \quad (5.3)$$

Equation (5.2) defines the market entry model (hurdle 1) and equation (5.3) represents the share of output marketed by the household (hurdle 2). M_h^i is the net supply of crop *i* by household *h* and S_h^i the share of the output sold. The parameters of the greatest importance are α and γ representing the effects of the farmer's comparative advantage (C_h) on the decision to participate in a specific crop market as a net seller and the share of output sold respectively. x *and* w are vectors of some covariates representing household socio-demographic variables, market access factors, and province characteristics.

Following Burke et al. (2015), the Heckman selection procedure is used to correct for sample selection bias in hurdle 2. More specifically, the Inverse Mills Ratio $(\widehat{IMR})$ from equation (5.2) is predicted and then used it as an explanatory variable in equation (3). Moreover, the average and the variance of province level price for the last five years are used to impose exclusion restriction in equation (5.2).

The measure of household's comparative advantage

In this study, the score of technical efficiency (TE) is used to measure the household's comparative advantage in producing a specific crop. Let suppose that a farm household h produces two alternative marketable crops i and j. For the purpose of this paper, the farm household has a comparative advantage in the production of crop i if the ratio of the efficiency score between i and j is greater than 1. Otherwise, it has a comparative advantage in the production of crop j (equation 5.4).

$$\mathrm{C}_h^i = \begin{cases} 1 \; if \; \frac{\text{The predicted score of } \mathrm{TE}_i}{\text{The predicted score of } \mathrm{TE}_j} > 1 \\ 0 \text{ otherwise} \end{cases} \tag{5.4}$$

The stochastic Frontier Analysis (SPA)

The technical inefficiency effects model of Battese and Coelli (1995) is adopted, with a Cobb-Douglass production function specification as follows:

$$\ln(y_i) = \beta_0 + \sum_{k=1}^{n} \beta_k \ln(X_{ik}) + \theta W_i - u_i + v_i,\; u_i = Z_i\delta + \varepsilon_i \tag{5.5}$$

Where β_0, β_k and θ are the parameters to be estimated. The y_i and X_i are respectively the Output and the productive inputs per ha. The θ is a vector of parameters, conformable with W_i, including the categorical variables plot landscape, soil texture, plot location, and province dummies. Managerial variables (Z_i) include gender, age, education, credit access, and association membership dummies as well as the number of crop plots, the size of cash crops and cereals planted. Much of the stochastic frontier analysis is directed towards the prediction of the inefficiency effects. The technical inefficiency is given by:

$$TE_i = \exp(-u_i). \tag{5.6}$$

The SFA has several advantages over other methods of inefficiency, including the data envelopment analysis and the deterministic frontier model. The SFA takes account of measurement and other random errors upon the frontier and allows the estimation of standard errors and hypothesis tests using maximum-likelihood methods, which were not possible with different approaches (Coelli et al., 2005).

Given the potential simultaneity between farm productivity and market participation, the comparative advantage as measured is potentially endogenous. Therefore, a two-stage procedure is used in which household's head education, the number of the educated adults in the household, land cultivated per adult member and plot characteristics such as soil texture, landscape, and plot location, and production shock at the plot level such as drought, flood and insect's invasion are used in the first stage to predict plot-level TE (Table A5.1). From this plot-level technical efficiency (TE), the weighted (by plot size) average predicted technical efficiency at the household level is computed. This is because most households have several plots of cowpea and groundnut in our sample. Lastly, the farm household average score of technical efficiency is then used to derive the farm household's comparative advantage following equation (5.4).

5.3. Data and Results

5.3.1. Data and descriptive statistics

We use data from the nationally representative household cross-section survey collected in 2014 in Burkina Faso under the Living Standards Measurement Study – Integrated Surveys in Agriculture (LSMS-ISA) initiative that is made available by the World Bank[15]. The survey contains 6540 rural households. It collects detailed crop and plot-level information, as well as a rich set of households' socioeconomic characteristics.

The crops of interest in this study are cowpea and groundnut. Cowpea and groundnut are planted and consumed in almost all regions of Burkina Faso. Both crops are alternative sources of cash for farm households in Burkina Faso. For example, cowpea and groundnut accounted for 5.8% and 8.8% of agricultural income in 2010 respectively (SP/CPSA/MASA, 2013). Also, the share of the production that is sold domestically and the share exported are almost the same for both crops and represent respectively 50% and 10% of the total output (SP/CPSA/MASA, 2013). Although both crops can be grown in the same agro-ecological conditions, their inputs requirement differs (Table 5.1).

[15] https://microdata.worldbank.org/index.php/catalog/2538

Moreover, we selected households growing both cowpea and groundnut. After dropping households with missing values, the total number of sample households becomes 1,335. The share of net sellers is 48% of the total sample. The percentage of cowpea net sellers is 23.4% while that of groundnut net sellers is 31.6%. This implies that 7% of households in the sample are net sellers of both crops (Table 5.1). Province level price data used in this study is collected by the Système d'Information des Marchés (SIM/SONAGESS) of the Ministry of Agriculture (see chapter 3 for a full description of the price data).

Table 5.1 provides the descriptive statistics of the key variables. First, the sample average technical efficiency scores are 0.675 and 0.585 respectively for cowpea and groundnut, suggesting that farmers in our sample are more efficient in the production of cowpea. Second, 74% of our sample have a comparative advantage in the production of cowpea while only 26% is more competitive in groundnut farming, which is consistent with the means of the technical efficiency score. Lastly, 80.5% of the cowpea net sellers hold a comparative advantage in the production of cowpea and 89% of the groundnut net sellers are more efficient in the production of groundnut. Without controlling for other factors, net commercialization seems to be associated with the farmer's comparative advantage. The description of other variables is shown in Table 5A.2 of the appendix.

Table 5.1: Descriptive statistics: Comparative advantage and marketing behavior

	Cowpea	Groundnut
Variable	Mean	Mean
Revenue per hectare (XOF)	204600	226005***
Labor cost (0-1) [a]	0.40	0.55***
Phytosanitary products cost (0-1) [a]	0.06	0.023***
Technical efficiency (0-1)	0.675	0.585***
Comparative advantage (C=1)	0.74	0.26
Net seller 1 (% of total sample)	0.234	0.316
Net seller 2 (conditional on C=1)	0.805	0.89
Conditional share of output sold	0.54	0.60
Observations	1335	1335

Note: *** indicates that the difference between the two means is statistically significantly at 1% level. [a] These are the shares of labor and phytosanitary products costs per unit of output. Sample average output price and inputs cost are used for computation. XOF is the currency of francophone West Africa. The exchange rate with Euro is fixed at 655,957 XOF since 1999.

5.3.2. Results of the econometric model

The results of the econometric model (equations 5.2 and 5.3) are presented in Table 5.2. It shows the average partial effect (APE) and the conditional average partial effect (CAPE) of the market participation choice and the intensity of sale respectively.

First, the coefficients of the household's comparative advantage are positive and statistically significant in hurdle 1 for both crops. For example, the comparative advantage in the production of cowpea increases the likelihood of net selling by 0.095 points (column 1) while having a comparative advantage in groundnut production increases the probability of being a net seller by 0.35 points (column 3). These results suggest that market entry decision is driven by the comparative advantage and thus confirm our hypothesis.

Second, the comparative advantage has a positive and significant effect on the share of the output sold (columns 5 and 7). The comparative advantage increases the share of the output sold by 29.3% points and 61.5% points for cowpea and groundnut respectively. These findings are consistent with the hurdle 1 results. More specifically, it suggests that not only the market entry decision is guided by the comparative advantage, but also relatively efficient farmers sell a large share of their output. As explained in Section 2, crop specificities generate some comparative advantage for households depending on their endowment in productive resources. For example, Table 5.1 shows that while groundnut production is labor intensive[16)], the production of cowpea uses crop protection products heavily. Also, for the same level revenue, more land is needed to produce cowpea (Table 5.1). Furthermore, the first stage results suggest that the effects of the plot characteristics (soil texture and plot landscape) on the technical efficiency differ depending on which crop is grown. This may be one explanation of why market participation behavior varies across different crops within the same household.

Third, we turn to the other factors that can potentially affect the cowpea and groundnut net selling. The production of pure cash crops such as cotton and sesame decreases significantly the likelihood to be a net seller as well as the sale intensity of both crops. This result is expected because cotton and sesame are alternatives sources of cash for farm households in Burkina Faso. More specifically, like groundnut, the production of cash crops such as cotton is labor-intensive, particularly for the harvest. As a result, they are competing activities. Also, the results show that the revenue from other farm activities (all other activities except pure cash crop, cowpea, and groundnut revenue) affects only the commercialization of the cowpea . One possible reason for this is that there is a high competition between cowpea cropping and other cropping activities because cowpea production requires a large size of land as discussed above. All these results are consistent with our hypothesis. All these results are consistent with our hypothesis. However, non-farm revenue does not seem to have an impact on the commercialization of both crops.

Finally, the results show that market access variables do not influence marketing behavior. This result is consistent with the recent findings of Mather et al. (2013) and Chamberlin and Jayne (2013). They have shown that different measures of market access may be misleading as they may not reflect the household's actual transaction costs. However, in this research, this may be explained by the fact that those factors have been controlled by the measure of the farmer's comparative advantage. Also, as in Bellemare

[16)] For example, Labor cost represents 40% of the value of 1 unit of the cowpea and 55% for groundnut (Table 1).

and Barrett (2006), the farm household asset value does not seem to influence the farm household commercialization.

The scope of this study goes beyond the simple crop choice model by focusing on the market entry decision. For example, we do not focus on how farmer chooses between cash versus staple food crops or domestic versus export crops, but rather focus on how comparative advantage in the production guides farmers in making commercialization choice when several alternative cash crops can be produced.

For robustness check[17)], we used a continuous variable defined as the ratio of technical efficiency between crop *i* and *j* to measure of the comparative advantage. Also, we used the labor cost per unit of output to define the comparative advantage of the farm household. Yet, the results remain stable and consistent although the size of coefficients differs.

Conclusion

Previous studies on farm household market participation have conceptually explained how the transaction costs, the household-specific, commodity-specific, and location-specific factors as well as the household shadow prices shape smallholders' marketing behavior in developing countries. More specifically, they recognized that household compares its specific prices to the transaction in order to decide on its production and marketing behavior. However, these specific factors to the farm household determine its comparative advantage in crop production. As opposed to previous empirical studies that have mainly focused on transaction costs related factors, this chapter develops an empirical strategy to test whether or not the farm household's market orientation is guided by the comparative advantage. Our findings suggest that comparative advantage affects the household's decision about the market entry as well as the share of the output sold regardless of the market access factors. Also, in line with our hypothesis, we find that the alternative sources of revenue affect negatively the commercialization of the semi-cash crops.

Our findings imply that caution should be taken when analyzing the market participation of small-scale farmers based on a single crop. When alternative marketable crops exist, it is important to consider the comparative advantage of the individual farmer. Findings from single-crop studies could be misleading because the conclusions cannot be generalized to all crops, even within the same household.

[17)] These are available upon request to the authors.

However, the interpretation of the findings of this research should be carried out with some caution. Since cross-sectional data has been used, the identification power is limited. The two-stage procedure we use may not be able to purge completely the endogeneity bias from simultaneity. Using panel data in future research could be interesting to corroborate the findings. Additionally, further investigations could be done in constructing alternative measures of farm household's comparative advantage or extend the indicator to the case of several alternatives crops.

Table 5.2: Model Estimates for market participation and intensity of sale

Explanatory variables	Hurdle 1: Market participation decision Probit estimator (Net seller 1)				Hurdle 2: The share of crop sold Log normal estimator			
	Cowpea		Groundnut		Cowpea		Groundnut	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	APE	S.E	APE	S.E	CAPE	S.E	CAPE	S.E
Comparative advantage	0.095***	0.024	0.350***	0.032	0.293***	0.068	0.615***	0.059
Farm characteristics								
Pure cash crops[a] (1/0)	-0.075**	0.020	-0.167***	0.049	-0.180***	0.040	-0.422**	0.193
Log (Rev. other activities)	-0.009***	0.002	0.003	0.002	-0.024***	0.005	0.003	0.004
Log (Non-farm income)	0.002	0.002	0.004*	0.002	0.007	0.005	0.008	0.007
Log (Household asset value)	0.009	0.006	0.000	0.007	0.033	0.024	0.010	0.013
Market access factors								
Phone (=1 if yes)	0.038	0.031	0.039	0.034	0.006	0.075	0.095	0.062
Motorcycle (=1 if yes)	0.028	0.026	0.046	0.030	0.046	0.063	0.081	0.054
Time to food market> 30 minutes	-0.001	-0.008	-0.03	0.03	-0.001	0.021	-0.098*	0.054
Time to tarmac road >30 minutes	-0.002	0.007	-0.02	0.02	-0.002	0.018	-0.002	0.052
Province characteristics	Yes		Yes		Yes		Yes	
Household covariates	Yes		Yes		Yes		Yes	
Inverse Mill Ratio					-1.720***	0.203	-0.67***	0.032
Observations	1335		1335		315		419	

Note: *, ** and *** indicate the level of significance at p < 0.1, 0.05, and 0.01, respectively. S. E are robust Standard errors. a) takes 1 if plant is cash crop (cotton, sesame and soybean) and 0 if otherwise. Household covariates include gender, age, access to credit, membership to farmers' association of the head of the household , and ratio of dependency. Province characteristics include population density, province-level price at planting season, average price, and variance of price of last five years.

5.4. Appendix of chapter 5

Table A 5.1: Stochastic frontier model estimates and determinants of Technical Efficiency

Variables	Cowpea Coefficie	SE	Groundnut Coefficient	SE
Stochastic Frontirer Analysis				
Family labor_male (man/day/ha)	0.045***	0.045	0.029***	0.007
Family labor_female (man/day/ha)	0.065***	0.019	0.098***	0.012
Family labor_children (man/day/ha)	0.014	0.011	0.015***	0.006
Phytosanitary products used (gram/ha)	0.061***	0.019	0.011**	0.004
Chemical fertilizer (1 if yes)	-0.001	0.021	0.028*	0.016
Available capital per ha	0.035**	0.014	0.022***	0.008
Input expenditure per ha	0.009	0.006	0.011***	0.003
Gamma	0.52***	0.138	0.76***	0.037
Lambda	1.04***	0.289	1.78***	0.186
Log likelihood value	949.28		-2390.51	
First stage results: *Determinants of Technical Efficiency*				
Area planted of legumes (except cowpea and groundnut)	-0.098**	0.032	0.003	0.027
Area planted of cereals	-0.03	0.026	0.014*	0.008
Household head has primary education	0.0143	0.0102	0.0142***	0.0044
Number of educated adult members	0.019***	0.003	0.0111	0.0011
Land cultivated per adult member	0.0042**	0.0004	0.022***	0.003
Soil landscape (base: *Bottom)*				
Mid-slope	-0.007	0.022	-0.011**	0.0049
Upper-most	-0.010	0.020	0.0054	0.0076
Soil quality (base: *Lateritic)*				
Sandy	0.040***	0.013	0.000	0.005
Clay	0.016	0.011	0.004**	0.0019
Soil location (base: *Bush*)				
Near house	-0.003	0.029	-0.0001	0.009
Camping[a)]	0.009	0.019	0.000	0.003
R-squared	0.162		0.144	
Number of observations	2651		2476	

Note: *, ** and *** indicate the level of significance at p < 0.1, 0.05, and 0.001, respectively. SPF and First stage include province dummy and other households level covariates (gender, age, access to credit, membership to farmers' association of the head of the household , ratio of dependency, and markets access factors). Also, First stage results control for production shocks at plot level (drought, floods, insects invasion). **a)** The family moves and settles on the plot site temporarily during the rainy season. These settlements are called camps. This is because the plot is far away from the village or is located in another village.

Table A 5.2: Definition and summary statistic on the variables used (Number of observations=1335)

	mean	min	max	Std
variables				
Quantity sold conditional on market participation of Cowpea (kg)	234.2	9	900	127.4
Quantity sold conditional on market participation of Groundnut (kg)	270.2	12	3600	344
Household characteristics				
Household size	9	1	63	5.8
HH's gender (=1 if male)	0.86	0	1	0.34
Ratio of dependency	2.31	1	8.00	0.83
HH's age (years)	47.28	19	97	14.5
Education (=1 if HH received primary educ)	0.21	0	1	0.41
Number of educated members	1.3	0	12	1.53
Access to credit	0.24	0	1	0.43
Association (=1 if HH is member of farmer' organization)	0.42	0	1	0.49
Household asset value (in XOF)	457050	4500	3236555	48550
Motorbike (1 if household owns a motorbike)	0.42	0	1	0.49
Radio (1 if household owns a radio)	0.45	0	1	0.5
Mobile phone (1 if household owns mobile phone)	0.79	0	1	0.41
Time to food market (=1 if more than 30mn)	0.46	0	1	1.42
Time to tarmac road (=1 if more than 30mn)	0.47	0	1	1.59
Farmland size (in ha)	6.72	0.45	200	11.7
Number of cultivated plots	6.53	2	31	3.75
Land size allocated to cash crops (cowpea, groundnut, sesame, coton)	1.38	0	7	4.89
Total planted area for cereals (millet, sorghum, maize, rice)	3.94	0	15	5.77
Capital per ha of farmland (XOF /ha)	448000	3750	12745800	68587
Input expenditure per ha of land cultivated (XOF /ha)	41679	1250	2292000	10453
region and Province characteristics				
Regional road density (km/square km)	0.07	0.12	0.04	0.01
Regional rainfall (mm)	808.9	432	1278	185.9
Regional number of rain days	72.36	42	101	15.54
Province population density	108.5	15.3	866.2	145.2
Average Cowpea price during planting period	262.5	174.7	642.7	86.33
Average peanut price during planting period	310.3	169.3	500	75.47
Province last 5 years price average of cowpea	280.6	197.8	393.8	32.45
Province last 5 years price average of groundnut	285.5	114.2	380.6	44.4
Province price variance of cowpea price	73.25	36.53	113.5	11.2
Province price variance of groundnut price	76.88	23.33	118.8	18.2

Note: Std is the standard deviation. XOF is the currency of francophone West Africa. The exchange rate with Euro is fixed at 655,957 XOF since 1999.

6. INTRA-HOUSEHOLD DISTRIBUTION OF SALES REVENUE AND HOUSEHOLD NUTRITIONAL OUTCOMES: WHAT IF WOMEN CONTROLLED FARM REVENUE?

6.1. Introduction

The recent literature in agricultural economics has experienced a revival of interest in the link between agriculture and nutrition. More particularly, it sustains that income generated through crop sales contributes to improve household nutrition in developing countries (Carletto et al., 2017; Montalbano et al., 2018; Ogutu et al., 2019; Ruel et al., 2018; von Braun, 1995). This is known as the income pathway[18] (Kadiyala et al., 2014; Ruel et al., 2018). However, the effectiveness of this pathway depends on who controls the sale revenues. More specifically, the gender pathway of the link between agriculture and nutrition sustains that female-controlled agricultural income tends to have a larger impact on household nutrition and food security than male-controlled revenue (Rao et al., 2019). Although the importance of the gender control on the agricultural income on the nutrition has been acknowledged, only a few studies have empirically investigated the impact of the gender distribution of sales revenue on household nutrition and food security (Fischer & Qaim, 2012). One reason for the absence of such studies is that household income and expenditure surveys rarely record the identity of the person controlling the income. This study aims at filling this gap by analyzing the impact of the share of the farm revenue controlled by wife on the household nutrition outcomes. For this, it used a nationally representative panel data covering the years 2014 to 2017 through four annual rounds of survey in Burkina Faso where more than eighty percent of the population relies on agriculture for their livelihood.

Social norms in most parts of Burkina Faso are patriarchal and patrilineal. The head of the household is responsible for ensuring the household's food security and supervising the use of household labor and inputs on collective plots (Haider et al., 2018). The harvests from the collective fields are shared

[18] Kadiyala et al. (2014) have identified six pathways through which agriculture contributes to nutrition.

as meals consumed together. More specifically, cereals and other staple foods are provided by the head to wife according to some specific schedule. However, condiments and foods which are not produced by the household are mostly provided by wife at their own cost. The revenue from sales is used to purchase common goods such as ceremonial expenses or pay taxes (West, 2010). Alongside the collective field, the head of the household may also allocate plots among individual members of the household according to both norms and negotiation. As opposed to collective plots, the product of the individually managed plot is controlled by the member in charge. Cereals and most semi-cash crops such as legumes, roots, and tubers are grown in these plots. The product is either used to supplement the food supply or to obtain cash which is in turn used to purchase food products not produced by the household or non-food products such as children's clothing and school fees.

Moreover, like other countries in sub-Saharan Africa, Burkina Faso is under constant threat of food insecurity and malnutrition. For example, between 2016-2018, the average prevalence of undernourishment was 20% of the total population. During the same period, 9.1% of the population were severely food insecure (FAO et al., 2019). This negatively impacts the anthropometric indicators for children under five years of age. For example, according to the Ministry of Health of Burkina Faso (2016), the prevalence of stunting and wasting for children of this age was 27.3% and 7.6% respectively in 2016.

The remainder of this chapter is organized as follows: Section 6.2 reviews the relevant literature and develops concrete research hypotheses. Section 6.3 explains the data and the measurement of key variables. Section 6.4 describes the econometric approach to test the hypotheses. Section 6.5 presents and discusses the results, and section 6.6 is the conclusion.

6.2. Literature review and hypotheses

This research follows the strand of studies that maintain that changes in gender-specific control of income translate into changes in expenditures (Duflo & Udry, 2004; Hoddinott & Haddad, 1995; Tommasi, 2019). This proposition stems from the non-cooperative bargaining model of household expenditures. It states that if the assumption of the income pooling within the household is relaxed, the share of household expenditures devoted to a specific good is a function of the intra-household distribution of income. For example, Hoddinott & Haddad (1995) show that income shocks that benefited females positively affect household food expenditure. More specifically, raising wives' share of cash income increases the budget share of food and reduces the budget share of alcohol and cigarettes. Also, Duflo & Udry (2004) in the case of Cote d'Ivoire, supports that different sources of income are allocated to different uses depending on both the identity of the income earner and on the origin of the income. A recent study by Tommasi (2019) supports these earlier studies in Mexico. He has found that if the mother controls a larger share of the revenue than the father, the household food demand increases significantly.

With respect to studies that focus specifically on the link between agricultural income and household nutrition, Fischer& Qaim (2012) show evidence that male control over banana revenues does not affect household calorie consumption but has a negative marginal effect on dietary quality. In the same vein, Ogutu et al. (2019) show that male-controlled revenue in maize and bean production has a negative association with Vitamin A consumption. However, these studies did not use any identification strategy to causally analyze the relation between the gender-control of farm revenue and nutrition.

While most of the previous studies tend to support the negative effect of male-controlled farm revenue household food and nutrition security, Carletto et al (2017) show that female crop commercialization has also a significant negative effect on child nutrition. This suggests that greater involvement in agricultural works by women may result in a somewhat negative effect on short-term nutritional outcomes, due to the decrease of the time allocated to child care and homemaking (Rao et al., 2019). However, Komatsu et al. (2018) have shown that women's time allocation and nutrition responses to agricultural interventions are likely to vary by socioeconomic status and local context. They have found in Mozambique that working long hours in agriculture is negatively associated with women's dietary diversity score in non-poor women but is positively associated with poor women's dietary diversity and poor children's minimum acceptable diet.

Furthermore, some studies have shown that commercialization can be associated with women losing control of agricultural income (Chege et al., 2015; Von Braun & Kennedy, 1994). Early research by von Braun & Kennedy (1994) has shown that the loss of women's control may have a negative marginal effect on household nutrition, although income gains from commercialization may outweigh this negative marginal effect. They argue that the production of cash crops is associated with the adoption of new technologies that in turn limit the role of women in the production process. Cash crops are most often associated with some specific marketing channels that may exclude women. For example, Chege et al.

(2015) has shown that supermarket supplying channels increase the likelihood of male control over farm revenue, which has negative impacts on dietary quality. However, the recent market development in crops such as semi-cash crops has given women the opportunity to control some part of the farm income (Njuki et al., 2011). This study takes advantage of this change to evaluate the impact of the intra-household distribution of farm revenue on household nutrition.

There is also a parallel strand of literature that focuses on the link between women's work in agriculture and nutrition and supports that there is a complex and often ambiguous relationship (Johnston et al., 2018; Komatsu et al., 2018). A variant of this literature focuses on the relationship between women's empowerment on nutrition (Cunningham et al., 2015; Malapit et al., 2015; Sraboni et al., 2014). Our research contributes to better understanding these relationships by quantifying the effect of the share of revenue controlled by wives on household nutrition.

One major limitation of the existing studies that examine the impact of crop commercialization on the nutrition is they rely on cross-section data, which may weaken the identification strategy. For example, omitted variables such as market access conditions, local market food diversity, nutrition knowledge, distribution of bargaining power among individuals within the household are likely to affect gender revenue control as well as household nutrition (Headey et al., 2019; Hirvonen et al., 2017; Stifel & Minten, 2017). As a result, cross-section data analysis may suffer from endogeneity if a good instrumental variable is not found. Furthermore, they have used a binary variable to capture gender control on sale revenue. Given the large share of women involved in crops sale, the use of a binary variable to capture gender revenue control may not be appropriate.

We add to the existing literature in three ways. First, we capture the comprehensive share of sale revenue accruing to wives as opposed to the previous studies that have only focused on the identity of who controls a cash crop revenue. This allows us to measure the extent of wives' control on the farm revenue and its impact on household nutrition. Second, the distinction between wives-controlled revenue share and the overall commercialization index allows us to better understand the transmission channel of household food security gain and income from market participation. Third, we used panel data that allows us to remove endogeneity due to time-invariant unobservable factors. To our knowledge, this study is the first to analyze the relationship between the intrahousehold distribution of farm income and food security and nutrition using panel data in the context of sub-Saharan African countries.

In light of the literature, the main hypotheses of this study are as follows:

- **Hypothesis 1**: An increase in the wife's share of farm revenue improves the nutritional status of the household.

How can the share of revenue controlled by female members affect the household nutritional outcomes? To investigate the transmission channel, we test the following hypothesis:

- **Hypothesis 2:** Household food expenditure per capita increases with an increase in the wife's share of farm revenue.

However, income gains can increase economic access to food, which in turn possibly increases the consumption of calories but not necessarily micronutrients (Remans et al., 2015). Moreover, it is important to see how the relative farm revenue of wife affect the allocation of food expenditure toward nutritious foods. Hence, to deepen the analysis, we also test the following hypothesis:

- **Hypothesis 3:** The wife's share of farm revenue positively affects the budget share on non-staple food groups.

6.3. Data and variables measurement

6.3.1. Data and sampling

This study used data from the Enquête Permanente Agricole (EPA), the "Continuous Farm Household Survey" of Burkina Faso (see Chapter 4). The survey is used to estimate farm input use, production, area, and yield of crops; it also provides information about livestock holdings and expenditures and income of rural households (Haider et al., 2018; Nakelse et al., 2018). More interestingly, not only does the EPA record the transaction realized by the household in terms of crops and livestock sale and purchase during the last twelve months, but it also provides a large number of nutrition and food security indicators of the household based on seven-day food consumption recall questionnaire. This study uses the four recent rounds of survey data including the years 2014, 2015, 2016 and 2017. Consistent with the theoretical framework, single-parent household are excluded (section 6.4). After dropping households with missing values, we end up with an unbalanced panel of 15571 observations. The average attrition rate is 2 % with 3 787 household participating in all four survey rounds.

6.3.2. Measurement of key variables

The main dependent variables

Following Shikuku et al. (2019), the household dietary diversity score (HDDS) is constructed based on twelve (12) food groups constituted from eighteen (18) food items. The food groups used in the construction of the HDDS include (1) cereals; (2) roots, and tubers; (3) legumes, nuts, and seeds; (4) vegetables; (5) fruits; (6) eggs; (7) red meat, organ meats, (8) fish, and seafood; (9) dairy products; (10) sweets and sugars; (11) oils and fats; (12) and spices, condiments, and beverages. Each group is a binary variable equal to one, if the household consumed the food during the 24 hours preceding the survey, and zero if otherwise. The score is thus a summation across the ten food groups and ranges from zero to twelve. Recent studies in other geographical contexts show that the household level food consumption indicators are positively and significantly correlated with individual dietary diversity scores and micronutrient intakes by male and female adults and children and food security (Fongar et al., 2019; Verger et al., 2019). In other words, the HDDS can be used as a proxy of dietary quality in the absence of individual-level data (Parlasca et al., 2020).

The second indicator is a count of the food groups that are sources of vitamin A or beta-carotene, called ‘‘vitamin A diversity” during the twenty-four hours preceding the survey (Shikuku et al., 2019). More specifically, it includes the following food group: (1) dairy products; (2) vegetables rich in vitamin A; (3) fruits rich in vitamin A; (4) organ meat; (5) red meat; (6) and eggs. The vitamin A diversity indicator ranges from zero to six. A particular attention is paid to Vitamin A because the deficiency of this type of vitamin is one of the major forms of micronutrient related malnutrition in developing countries. For example, in SSA, more than 40 percent of the children under five years of age suffer from Vitamin A deficiency (Black et al., 2013; Low et al., 2017). This indicator approximates child nutrition quality in the household.

Finally, following the WFP (2008)[19], the food consumption score (FCS) is constructed based on a 7-day recall questionnaire. More specifically, all food items were first grouped into nine specific food

[19] The United Nations World Food Programme.

groups (Table A6.2). Next, the consumption frequencies[20] of food items in the same group were then summed up, and the values of each group above seven were recoded as seven. For each food group, the value obtained was then multiplied by its weight to generate the weighted food group scores. Lastly, a sum of the weighted food groups produced the FCS. It ranges from 0 to 112. Since the weight of each food is proportional to its nutrient intake, the FCS captures both dietary diversity and dietary quality (Jones et al. 2014).

Expenditure per capita and Expenditure Shares

Expenditure shares are built using available information about purchases of a variety of items consumed by households. We consider the main categories of items consumed by households in the sample, including food, tobacco, clothing, schooling, health, utilities, and other goods. The reference periods are one week for food and three months for other expenses. Since the survey did not capture the consumed quantities, this analysis was not able to include home consumption. Nevertheless, whether or not the market is the main source of consumption of a particular food item is provided by the survey. Therefore, using this information, we performed some robustness checks. The food budget share is defined as the ratio between the expenditure on food and the total household expenditure (multiplied by 100). The staple (non-staple) food budget share is defined as the ratio between the expenditure on staple food (non-staple food) and the total household food expenditure (multiplied by 100).

The variable of interest

The variable of interest

The main variable of interest is the wife's share of farm revenue. For each plot, the question is asked "who controls the revenue?" From this answer, we sum up the revenues from all plots whose revenues are controlled by wife (wives) within the household. Land allocation across crops differs between socio-groups within the household. For example, figure 6.1 shows that husbands allocate a large share of land to maize and cotton while wives allocate more land to sorghum, cowpea, and groundnut. Moreover, it is important noting that a larger share of land cultivated by wives is allocated to semi-cash crops such as legumes (cowpea, groundnut, and vouandzou) and vegetables, which constitutes a source of cash for them.

[20] The consumption frequency is the number of days per week the household has consumed the food items.

Since the survey did record the input cost at the plot level, we focus only on the sales revenues. The wife's share of farm revenue is defined as follows:

$$S = \frac{sum\ of\ sale\ revenues\ controlled\ by\ wife\ (wives)}{Total\ sale\ revenue\ of\ the\ household} * 100 \quad (6.1)$$

We valued the production and quantities sold by using the province level price data of cereals and other staple foods collected by the market information system of the Ministry of Agriculture and Food Security (SIM/SONAGESS). For the crops whose prices are not collected by SIM/SONAGESS, we used the sample yearly mean. We exclude livestock sales because, in most parts of rural Burkina Faso, women's ownership of livestock is uncommon. However, women in the northern part of the country are likely to get involved in livestock rearing more than crop production given that agro-climatic conditions are favorable to for animal husbandry. Therefore, we control for wife's ownership of livestock.

Figure 6.1: Land allocation across crops by demographic group

Source: Constructed by the author based on EPA (2014-2017)

6.4. Theoretical framework and estimation strategy

6.4.1. Theoretical framework Theoretical framework

Following Bourguignon et al (2009), let consider that household has two adult decision makers A and B. There are n private consumption goods on which the household can spend, q_i^A and q_i^B, where q_i^j, denotes the private consumption of good i by member j and $i = 1, \dots . n$ and Q denotes the m vector of household consumption of public goods. Household consumption of good i is $q_i = q_i^A + q_i^B$. Vector q^A is the vector of private good consumption of individual A, and similarly for B. Household private consumption is $q = q^A + q^B$. Individual preferences are defined on the consumption of private goods and public goods, and they also depend on a set of demographic taste shifters d, called preference factors $\upsilon^A(q^A, q^B, Q; d)$ and $\upsilon^B(q^A, q^B, Q; d)$ With exogenous total expenditure denoted by y , the budget constraint is:

$$p'(q^A + q^B) + P'Q = p'q + P'Q = y \qquad (6.\ 2)$$

where p and P are the price vectors of private and public goods, respectively. Individual preferences are in general not identical so that there must exist some mechanism by which households reach decisions. In the literature there are two leading mechanisms: The unitary model and the collective model. Recent studies in Burkina Faso have been rejected the unitary model in which all household resources are pooled and then reallocated according to some common rules (Haider et al., 2018; Kazianga & Wahhaj, 2013). Therefore, this study follows the collective model framework.

Following the collective model[21] (Chiappori, 1988, 1992) individuals are characterized by their own preferences and the household's decisions are efficient. Thus, household decisions can be represented as resulting from the maximization of a generalized household welfare function, subject to the household budget constraint (6. 2).

$$\max_{q^A, q^B, Q} \mu(y;\ p;\ P;\ d;\ z)\upsilon^A(q^A, q^B, Q; d) + [1 - \mu(y;\ p;\ P;\ d;\ z)]\upsilon^B(q^A, q^B, Q; d) \qquad (6.3)$$

with $y,\ p;\ P$, and d as above; and $\mu(y;\ p;\ P;\ d;\ z)$ are the weights of the decision makers A and B. z is a vector of observable factors that play a role in the negotiation but do not affect either the budget constraint

[21] The main difference between the unitary model and the collective model is the functional dependence of μ on the distribution factors.

or individual preferences. Following the literature, these are called distribution factors. More specifically, a variable $z_k$is a distribution factor if it does not enter individual preferences nor the overall household budget constraint but it does influence the decision process (Bourguignon et al., 2009). For any good, private, or public, the demand function for good i derived from the maximization of equation (6.3) $x_i(y;\ p;\ P;\ d;\ z)$, which depends on total expenditure y , prices p and P, preference factors d, and distribution factors z.

Many variables that have been used in the literature as distribution factors including relative incomes, relative wages, the “marriage market” environment, and the control of land (Armand et al., 2020; Bourguignon et al., 2009; Hoddinott & Haddad, 1995; Tommasi, 2019). In this study, we focus on the household non-labor revenue, more specifically the wife’s relative revenue generated from crops commercialization by farm households.

6.4.2. Econometric strategy

To test the hypothesis (1) and (2), the following equation is estimated:

$$y_{it} = \delta_0 + \delta_1 S_{it} + \delta_2' W_{it} + \delta_3' X_{it} + \delta_4' T_t + \mu_i + \varepsilon_{it} \tag{6.4}$$

y_{it} is the nutrition outcome or expenditure per capita of the household i at the time t. S_{it} is the wife’s share of farm revenue in the household i at the time t. The parameter of interest is δ_1 representing the effect of S on the household nutrition outcomes. Based on previous researches, wife level characteristics (W) are included. (X) is a vector of time-variant household characteristics including household socio-demographic variables and the commercialization index (see Table A6.1). T_t is a vector of time dummies for the years 2014,2015, 2016, and 2017, which captures all structural changes such as economic growth, improvements of communication and transportation infrastructure, and climate shocks. Year-province dummy is also added for each of the 45 provinces to account for heterogeneous structural change. μ_i is the household fixed effect. It is reasonable to adopt the Poisson estimator for the Household Dietary Diversity scores and Vitamin D scores since they are nonnegative count variables. However, as it is shown in Figure 6.2, only Vitamin A diversity fits well with the Poisson distribution. For this reason, we used a gaussian distribution.

To test the hypotheses (3), the following model is estimated:

$$w_{it}^n = \beta_0 + \beta_1 S_{it} + \gamma_1 \ln(exp_{it}) + \gamma_2 \ln(exp_{it}^2) + \beta_2' W_{it} + \beta_3' X_{it} + \mu_i + \nu_{it} \tag{6.5}$$

With w_{it}^{n}, the share of the expenditure allocated to the food component *n* by the household *i* at time t. S , W , X, and μ_i as above, and exp the total weekly food expenditure. ν_{it} is the error term. We based on the food items used to construct HDDS to group the food items in the food basket into six components for two reasons. The first reason is that including all 18 food items in regression be computationally heavy and the second motivation is that there is a large number of zero expenditure for some food items. These six components include (1) Staple foods (cereals, legumes, roots, and tubers); (2) meat, fish, (3) dairy products; (4) vegetables and fruits), (5) drinks and other sugars (soft and hot drinks and other high caloric foods), (6) and other foods (salt, seasoning, other condiments). A seemingly unrelated regression is used to estimate equation (6.5). However, we have estimated the staple food group separately to avoid singularity in the system of equations. Following Papke and Wooldridge (2008), the time-average of all right-hand variables are included in the demand system to control for household fixed effect.

6.4.3. Endogeneity issues

There are two potential sources of endogeneity that can bias the estimates in equation (6.4). First, the time-invariable unobservable factors captured by μ_i. For example, Botosaru and Muris (2020) have shown that half the variation in women's resource shares is due to time-invariant unobserved household heterogeneities. Using a household fixed-effect model, these factors can be removed. The second source is time-variant unobservable variables that may be correlated with both S_{it} and y_{it}. More specifically, there are potential time-variant unobservable factors that may affect resource distribution in the household as well as household food expenditure and nutrition outcomes. To address this source of endogeneity, we combine the control function approach (CFA) with the household fixed effects model. More specifically, we use land size cultivated by women, women-controlled plot characteristics to instrument the share of farm revenue controlled by wives. The argument is that the amount of land cultivated by women and women-controlled plot characteristics are unrelated to S and the error term in the second stage after controlling for household fixed effect and other covariates. Moreover, commune-year dummies are included. Doing so would not only pick up any common shifts in relative prices at the commune[22] level but also control for the land access by wives which is guided by local community social norms in Burkina Faso,

[22] In Burkina Faso, a commune is an administrative unit that is larger than a village, but smaller than a province.

and then resulting in more robust exclusion restrictions. The results of the first stage are shown in Table A6.3.

In addition to the endogeneity of *S*, the total expenditure is endogenous in equation (6.5). If taste shocks to the system that determines total food consumption are correlated to the unobserved shocks to food components, then total food will be endogenous in the demand system (Attanasio & Lechene, 2014). Also, measurement error in total expenditure is also a likely cause of endogeneity. While the fixed effect model can deal with the endogeneity due to the unobserved taste of the households, it is not the case for measurement error. Therefore, we expended the CFA by including residuals obtained from the regression of total expenditure on a set of instruments. An instrument for total expenditure often used in the literature is household income, which implicitly assumes that the measurement error in total expenditure is uncorrelated with measured income (Attanasio et Lechene, 2010; 2014). Fortunately, the survey has recorded the household total income during the last 3 months. We use this income as an indicator of household wealth and then instrument the total food expenditure as well as the weekly food expenditure. We also included the commune-year dummies in the first stage. Thus, after controlling household and commune fixed effects, it is defendable that income level only affects nutrition through expenditure. Following Attanasio & Lechene (2010), since we do not observe prices, we use province-year dummies to proxy for prices. The first stage regression results are shown in Table A6.4

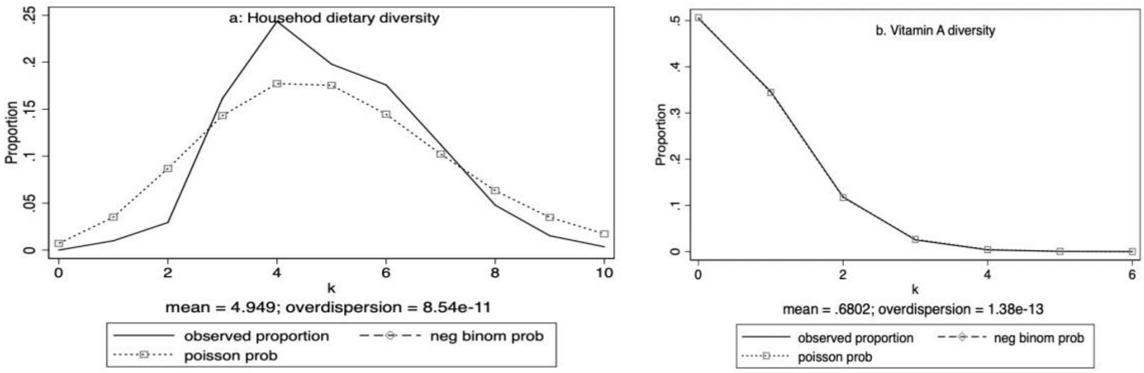
6.5. Results

6.5.1. Descriptive statistics

Table 6.1 presents the descriptive statistics of the variables of interest and the outcome variables in panels A and B, respectively. The proportion of households that commercializes farm output is on average 93% during the period of the study. This suggests that a large share of rural households in Burkina Faso relies on farming activities to earn income, even though only 26% of the farm production is sold (Panel A). The share of the farm output that is sold is low as compared to recent studies in other countries of Sub-Saharan Africa (Carletto et al., 2017; Ogutu et al., 2019; Ogutu & Qaim, 2019; Tirkaso & Hess, 2018). However, a key difference is that this study uses a national representative sample as compared to the listed studies. Therefore, the comparison is not straightforward.

The farm products that are commercialized include cereals, cotton, legumes and roots farming, and livestock. A large share of the agricultural income comes from livestock rearing (20.4%), and cereals (13.3%), followed by cotton (12.3%), and legumes, roots, and tubers (11.6%) (DGESS[23], 2018).

Figure 6.2: Fitting a Poisson distribution on household dietary diversity score and Vitamin A diversity.



Source: Author (Number of observations=15571)

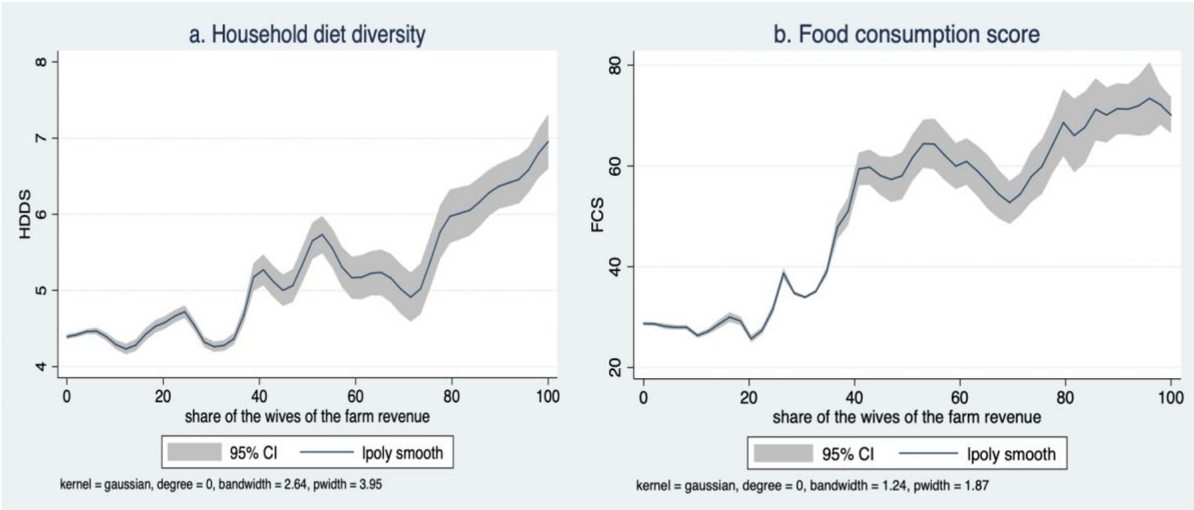
Panel A of Table 6.1 also indicates that 70% of wives earn their income through crops or livestock commercialization. However, the share of agricultural revenue controlled by wives represents only 15% of the household total sale revenues. This share seems to be low in the sense that women provide 52 % of agricultural labor in Burkina Faso (DGPER[24], 2011).

Moreover, the average variation in the wife's share of farm revenue is approximately 7% per survey round. This represents a large variation in the sense that our sample is nationally representative. Also, this variation is statistically significant (not shown in Table 6.1), suggesting that the fixed effect model is appropriate. The definition and the mean of other covariates such as spouse and household level variables are presented in Table A6.1 of the appendix.

[23] DGESS: Direction Générale des Études et des Statistiques Sectorielles/Sectoral Studies and Statistics Service

[24] DGPER: Direction Générale de la Promotion de l'Économie Rurale / Rural Economy Development Service

Figure 6.3: Polynomial regression of nutrition outcomes against the share of the revenues owned by wives.



Source: Author (Number of observations=15571)

Turning to the outcome variables, first, panel B of Table 6.1 shows that the mean of the household dietary diversity is 4.76. This is lower than the Minimum Dietary Diversity score for Women (FAO & FHI 360, 2016)[25]. Moreover, when reducing food groups to the vitamin A-rich food groups (Vitamin A diversity), the score drops to 0.82 approximately which suggests that the consumption of Vitamin A remains very low in rural Burkina Faso. Consistent with the dietary diversity score the Food Consumption Score (FCS) is lower than the acceptable score of 35 recommended by the WFP (2008).

Next, the total expenditure (weekly) per capita is 1014 XOF. This is approximately equivalent to $0.24 US dollars per day per capita which is very low compared to the $1.90 US dollars a day poverty line[26] . Moreover, in Burkina Faso, a large share of the total expenditure of farm households is allocated to food. For example, table 6.1 shows that the household budget share on food is about 47%. More specifically, 70% of the household's total food expenditure is allocated to non-staple. This suggests that households rely mainly on their own production to satisfy their demand for staple food products.

[25] FAO: Food and Agriculture Organization of the United Nations, FHI 360: Family Health International
[26] The poverty headcount ratio in rural Burkina Faso at $1.90 a day is 47.5 % (World Bank, 2016). 1 US dollar= 602.389 XOF approx.

6.5.2. Results and Discussion

The wife's share of farm revenue and nutrition outcomes

Figure 6.3 estimates a locally weighted regression of the association between the wife's share of farm revenue and the household nutrition outcomes. Panel (a) and panel (b) shows a positive association between the wives' share of farm revenue and household nutrition outcomes. However, this relation seems to be highly nonlinear. Therefore, in the econometric estimation, the quadratic term of wife's share of farm revenue is included.

To better understand these relationships, we run the model presented in equation (6.4). The estimates of models with household fixed effects are shown in Table 6.2. The joint significance of the residuals from the first stage indicates a strong rejection of exogeneity of the wife's share of farm revenue in the household nutrition outcome model. First, the coefficients of the wife's share of farm revenue are positive and statistically significant across all the three measures of household nutrition outcomes. Since the coefficients of the quadratic term are too small, we ignored them in what follows. A coefficient of 0.083 in the model (1) means that raising the wife's share of farm revenue by 0.1 (10 percentage points) increases the household dietary diversity score by 0.83 point, which is equivalent to a 17.43% increase relative to the sample mean. Likewise, 0.024 and 0.345 in models (2) and (3) mean that raising the wife's share of farm revenue by 10% is associated with an increase of the Vitamin A diversity by 0.24 and food consumption score by 3.45. This represents a 29% and 10.8% increase relative to the sample mean of vitamin A diversity and FCS, respectively. These effects support the hypothesis that an increase in the share of farm revenue controlled by women improves farm household nutrition. This result is consistent with the findings of Ogutu et al. (2019) in Western Kenya.

Furthermore, the impact of the share of the farm revenue controlled by wives is greater for Vitamin A diversity. One explanation is that Vitamin A diversity includes only food groups that are most likely not to be produced by the household and but rather purchased. It seems reasonable then to see a greater impact when shifting from HDDS to Vitamin A diversity. The effect on the food consumption score is the lowest. One argument is that FCS gives more weight to micronutrient-rich food groups which are mainly food groups rich in Vitamin A (Table A6.2).

Table 6.1: Summary descriptive : Commercialization and nutrition outcomes

	2014	2015	2016	2017	All	
Variables	Mean	Mean	Mean	Mean	Mean	S. D
A. Summary descriptive of variables of interest						
Share of farm revenue controlled by wives						
Wife commercialization (0/1)	0.604	0.64	0.66	0.87	0.70	0.45
Share of farm revenue (in %)	14.22	15.57	14.67	15.60	15.02	17.64
Household Commercialization						
Dummy (=1 if has sold some output)	0.804	0.984	0.985	0.97	0.93	0.23
Share of output sold (in %)	27.18	25.67	22.50	30.00	26.14	17.00
B. Summary descriptive of outcome variables						
Household Dietary Diversity Score	4.58	4.92	4.90	4.64	4.76	2.02
Vitamin A diversity	0.734	0.750	0.781	0.850	0.820	0.780
Food Consumption Score (FCS)	36.70	31.20	30.50	28.90	31.81	14.44
Income per capita (x1000 XOF)	96.20	117.91	108.56	96.52	104.87	103.67
Total expenditure on food	980.00	265.00	796.00	1016.0	1014.0	1177
Expenditure on staple food	290.00	427.00	198.00	283.00	300.00	700
Expenditure on non-staple food	690.00	837.00	597.00	732.00	714.00	735
Budget share on food (%)*	49.14	45.50	46.90	45.16	46.67	19.63
Number of observations	3,942	3,926	3,830	3,873	15571	

***Notes*:** Wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). Commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). * The *food budget share* is defined as the ratio between the expenditure on food and the total household expenditure (multiplied by 100). The *staple (non-staple) food budget share* is defined as the ratio between the expenditure on staple food (non-staple food) and the total household food expenditure (multiplied by 100). XOF stands for Franc de la Communauté Financière Africaine, the currency of francophone West Africa. The exchange rate with Euro is fixed at 1 € = 655,957 XOF since 1999.

Next, we turn to wife level characteristics. As expected, the proportion of wives relative to adult members in the household affects positively the household nutrition. Also, consistent with the theory, the age of the wife is positively associated with the nutrition outcome. This is explained by the fact that the wife's bargaining power increases with the age. It is also important to note that the proportion of female members (relative to total adult members) who earn income from non-farm activities does not affect significantly household nutrition outcomes. This lack of impact may be due to the fact that while non-farm activities are widespread across wives in rural Burkina Faso (60% in our sample), incomes from those activities often involve small amounts which fail to have a significant impact on household nutrition. However, given that most sources of income are not exogenous to household nutrition choices, it is difficult to interpret this relationship as causal. The other wife level covariates do not significantly affect household nutrition. One explanation is that most of the spouse level variables are time-invariant or vary very slightly across different time periods (Table A6.1). The results remain consistent when we the subsample of households who have reported positive sales (93%) (Table A6.7).

Finally, we turn to the commercialization at the household level and the income per capita. As expected, the results show that both commercialization and income per capita have positive and significant impacts on dietary diversity and food consumption score (Table 6.2). Coefficients of 0.318 and 0.891 in model (1) and (2) mean that increase of the income per capita by 10% increase the HDDS and the FCS by 10% increases the HDDS and the FCS by 0.03 (0.318*log [1.1]) food groups and 0.084 (0.891*log [1.1]) points, respectively. Likewise, an increase of the commercialization by 10% increase HDDS and the FCS by 0.009 food groups and 0.063 points, respectively.

To compare this result with the effect of the wife's share of farm revenue we estimate the magnitude of these effects (table 6.3). A hypothetical shift from a zero level of wife's share of farm revenue to 50% – relative to the sample mean- would cause the HDDS and FCS to increase by 13.25 and 8.2%, respectively relative to the sample mean. First, these effects are low in the sense that for example to meet the requirements of 6 food groups and the 35 for the FCS would require a shift of the farm revenue share towards the wife of about 98 and 61 percentage points, respectively. Secondly and interestingly, the result of Table 6.3 suggests that the effect size of the wife's share of farm revenue is greater than those of the household commercialization index and income per capita. A shift from a zero level of income per capita (commercialization) to 50% would only increase the HDDS and the FCS by 2.5 (2.7) and 3.25% (1.13%) respectively. This result is consistent with the findings in Table 6.2. An important implication of this finding is that even though the effect size of the wife's share of farm revenue remains low, it constitutes the fastest mean of improving household nutrition diversity.

Table 6.2: Effect wives' share of farm revenue on nutrition outcomes (Household-fixed effect)

Dependent variables	HDDS		VAD		FCS	
	(1)		(2)		(3)	
Variables	Coeff.	S. E	Coeff.	S. E	Coeff.	S. E
Wives' farm revenue share (0-100)	0.083***	0.006	0.024***	0.007	0.345***	0.048
Wives' farm revenue share squared	-0.000***	0.000	0.000	0.000	0.003***	0.000
Income per capita (log)	0.318***	0.036	0.16***	0.003	0.891***	0.283
Commercialization index (0-100)	0.009***	0.001	0.002***	0.001	0.063***	0.008
Proportion of adult female (%)	-0.002	0.002	-0.001	0.004	-0.020	0.012
Proportion of educated female (%)	0.001	0.001	0.000	0.000	0.014	0.012
Wife age (Average age for polygamy)	0.009**	0.004	0.005**	0.002	0.076***	0.025
Proportion of wives (%)	0.010***	0.002	0.001***	0.000	0.066***	0.021
Wife membership to F. O (1/0)	-0.010	0.013	-0.312	0.377	-0.050	0.106
Wife access to credit (1/0)	0.095	0.090	0.062	0.608	0.469	0.670
Wife contact with extension agent (1/0)	0.138**	0.067	0.138**	0.067	0.4895	0.470
Wife earns non-farm income Non-farm (%)	0.003*	0.002	0.004	0.019	0.018	0.013
Household head's age (years)	0.005**	0.002	0.000	0.001	0.027	0.017
Household size	-0.06***	0.008	-0.090***	0.020	-0.39***	0.060
Proportion of children 0-5 years old (%)	-0.002	0.002	-0.015	0.006	-0.017	0.017
Proportion of children 6-15 years old (%)	-0.000	0.002	-0.029	0.025	-0.018	0.015
Crops diversification	-0.010	0.020	0.017**	0.008	0.100	0.137
TLU (Tropical Livestock Units)	0.001	0.006	0.000	0.002	0.040	0.047
Farmland size (log)	-0.243**	0.109	-0.011**	0.005	-0.943	0.710
Farmland size squared (log)	0.027**	0.012	0.007***	0.002	0.127	0.083
Year-Province dummy	YES		YES		YES	
Observations	15571		15571		15571	
R-squared	0.206		0.172		0.332	
Test of endogeneity (F-statistic)	75.98***		45.56***		144.34***	

The wife's share of farm revenue is defined as the ratio between the farm revenue owned by the wife (or wives) and the total farm revenue (multiplied by 100). The commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). F.O: Farmers Organization. SE: Standard errors bootstrapped with 1000 replications *** p<0.01, ** p<0.05, * p<0.1. Coeff. are the estimated coefficients. The endogeneity test is performed as a joint Wald test for the equality to zero of all coefficients in the polynomial of the first-stage residuals for wives' farm revenue share and its square. The number of groups is 5011.

Table 6.3: Magnitude of the estimated effects (When the variable of interest increases by 50%)

	Increase in the nutrition outcome in percentage		
variables	HDDS	VAD	FCS
Wife's share of farm revenue	13.25	22.40	8.2
Commercialization index	2.50	8.00	3.125
Income per capita	2.70	7.90	1.13

Note: The magnitude is estimated at the 50% increase relative to the sample mean for each independent variable. We use the estimated coefficients in table 6.2. For example, an increase of S by a one-half standard deviation (17.64:2=8.82) which correspond to 58% (8.82:14.76) increase relative to the sample mean will cause HDDS to rise by 0.734 (8.82*0.083) in food groups, which represents 15.37% (0.734:4.76) increase relative to the sample mean of HDDS. If a 58% increase in S causes an increase of HDDS by 15.37%, then 50% will cause 13.25%. Note that for income per capita, the expected increase in y is: $\widehat{\delta_{inc}} * \log(1.5)$.

To understand the transmission channel, we look at the effect of the wife's share of farm revenue on the food expenditure (Table 6.4). First, model (1) of Table (1) shows that the wife's share of farm revenue has a positive and significant effect on total food per capita. Raising the wife's share of farm revenue by 10% is associated with a 12% ($[e^{10*0.011}-1]$*100) increase in total food consumption per capita (model (1) of table 6.4). This effect becomes higher when we split food consumption into staple and non-staple food. More specially, the consumption per capita of staple food and non-staple food increase by 46 and 14%, respectively when the wife relative farm revenue increases by 10% (model (2) and (3) of table 6.4). These results confirm our hypothesis that household food expenditure per capita increases with an increase in the wife's share of farm revenue. Moreover, consistent with the above results, the effect of the wife's share of farm revenue is higher than the effect of the overall commercialization level of the household and the income per capita. For example, an increase of the income per capita (household commercialization) by 10% is associated with an increase in the total food expenditure by 3% ($[e^{0.318*\log(1.1)}-1]*100$). This result is in accordance with the findings by Radchenko and Corral (2018) and Dillon et al., (2015) that the income generated through crop sales does not necessarily translate into a higher food expenditure. Furthermore, this result associated with the higher effect of the wives' share farm revenue on the nutrition outcomes in Table 6.3 suggests that the identity of income earner plays an important role in the allocation of income to alternative utilizations, more specifically for food purchase. The results remain consistent when use only the subsample of the households who commercialize the farm output (Table A6.7).

Table 6.4: Effect of wives' share of the farm revenue on food expenditure (Household-fixed effect)

Dependent variables	Food		Staple		Non-Staple	
	(1)		(2)		(3)	
Variables	Coeff.	S. E	Coeff.	S. E	Coeff.	S. E
Wives' farm revenue share (0-100)	0.011***	0.002	0.038***	0.007	0.013***	0.002
Wives' farm revenue share squared	-0.000**	0.000	-0.000***	0.000	-0.000***	0.000
Income per capita (log)	0.318***	0.016	0.421***	0.047	0.262***	0.015
Commercialization index (0-100)	0.003***	0.000	0.020***	0.001	0.002***	0.000
Proportion of adult female (%)	-0.000	0.000	0.000	0.002	-0.001*	0.000
Proportion of educated female (%)	0.000	0.000	0.002	0.002	0.000	0.000
Wife age (Average age for polygamy)	0.001	0.001	0.002	0.004	0.001	0.001
Proportion of wives (%)	0.005***	0.001	0.000	0.003	0.005***	0.001
Wife membership to F. O (1/0)	-0.007	0.005	-0.022	0.016	-0.001	0.005
Wife access to credit (1/0)	0.069**	0.027	0.055	0.093	0.047*	0.028
Wife contact with extension agent (1/0)	0.025	0.020	0.086	0.068	0.010	0.020
Wife earns non-farm income Non-farm (%)	0.000	0.000	0.003*	0.002	0.000	0.000
Household head's age (years)	-0.000	0.000	0.004	0.002	-0.000	0.000
Household size	-0.06***	0.003	-0.04***	0.008	-0.06***	0.003
Proportion of children 0-5 years old (%)	-0.002**	0.000	0.001	0.003	-0.003***	0.000
Proportion of children 6-15 years old (%)	-0.002**	0.000	-0.002	0.002	-0.002***	0.000
Crops diversification	0.011*	0.000	0.002	0.023	0.005	0.006
TLU (Tropical Livestock Units)	0.000	0.002	-0.010**	0.005	0.002	0.002
Farmland size (log)	-0.036	0.034	-0.064	0.128	-0.033	0.028
Farmland size squared (log)	0.002	0.004	0.000	0.014	0.002	0.003
Year-Province dummy	YES		YES		YES	
Observations	15571		15571		15571	
R-squared	0.317		0.183		0.300	
Endogeneity test (F-statistic)	3.35		11.10**		4.31	

Note: The dependent variable is the log of the food (1), staple food (2), and non-staple food (3) per capita. S.E: Standard errors bootstrapped with 1000 replications. Wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). The commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). F.O: Farmers Organization. *** p<0.01, ** p<0.05, * p<0.1. Coeff. are the estimated coefficients .The endogeneity test is performed as a joint Wald test for the equality to zero of all coefficients in the polynomial of the first-stage residuals for wives' farm revenue share and its square. The number of groups is 5011.

The wife's share of farm revenue and budget share on non-staple foods

To analyze the effect of the wife's share of farm revenue on the household budget allocation, we estimate equation (6.5). There is a strong rejection of the exogeneity of both wife's share of farm revenue and the total expenditure (see Table A6.5 for the regression output). First, in line with Engel's law, food is a necessity: the share of the household budget allocated to food decreases as total expenditure increases (table 6.5). An increase of 10% in total expenditure is associated with a decrease of 2.3 percentage points in the food budget share. This corresponds to an expenditure elasticity[27] of food demand (at the mean values in the sample) of 0.521.

Second, the budget share on the staple food decreases with an increase in the total expenditure while the share of the budget allocated to non-staple food items in the food basket (except for vegetable and fruits) increase as the total expenditure increases. This result suggests that at the higher level of income (wealthier households), household substitutes staple foods (mainly home-produced) for non-staple foods (purchased foods). This finding is consistent with a recent study by Armand et al.(2020) in Mexico.

Now, we turn to the coefficients of the wife's share of farm revenue (For full regression output see Table A6.6). First, the results show that the wife's share of farm revenue has a positive and significant effect on the share of the budget allocated to food. Raising the wife's share of farm revenue by 1% will increase the budget share on food by 0.213 percent points (column 3 of Table 6.5). This is consistent with our hypothesis (3). This result is also in line with the findings from conditional cash transfer studies which target mothers (Angelucci & Attanasio, 2013; Armand et al., 2020; Attanasio & Lechene, 2010; Tommasi, 2019). This contributes also to explain why the increase in the income may be translated into an unexpected increase in the budget share on food due to the counterbalancing effect of the wife's relative control on the additional income. For this study, the estimates show that compensating for the reduction in the food budget share induced by a 10% increase in total expenditure would require a shift of the farm revenue share towards wives of about 1 percentage point. This counterbalancing effect is stronger than the case of Mexico's CCT by Armand et., al (2020). One explanation is that in the case of the CCT program, husband may appropriate a large part of the transfer (considered as a gift to the whole family) as compared to our case where revenue is gained through farming activities.

[27] The expenditure elasticity of food demand at mean values (assuming an AIDS specification) is equal to $(1 + \delta/w^F)$, where δ is estimated using equation (2) and w^F is the average food budget share.

Table 6.5: Effect of wife's share of farm revenue on the budget share on food

Dependent variable: Budget share of food category					
	Descriptive statistics		Results from equation (6.5)		
	Mean (%)	Standard deviation	Coefficients	S. E	Effect size (%)
	(1)	(2)	(3)	(4)	(5)
Food budget share*	**46.67**	**19.63**			
Wife's share of farm revenue			0.230***	0.052	24.64
Total expenditure (log)			-24.00*	6.781	-19.38
Staple food items (cereals, legumes, roots, and tubers)	**29.60**	**20.77**			
Wife's share of farm revenue			-0.265***	0.056	-44.76
Total expenditure (log)			-47.703***	7.154	-65
Non-Staple food items	**70.40**	**20.77**			
Meat and fish	**21.20**	**15.61**			
Wife's share of farm revenue			0.292***	0.042	69.00
Total expenditure (log)			59.94***	6.020	114.60
Dairy products	**5.14**	**6.85**			
Wife's share of farm revenue			0.173***	0.018	168
Total expenditure (log)			11.970***	3.177	94.42
Vegetables and Fruits	**7.04**	**7.80**			
Wife's share of farm revenue			0.141***	-1.212	100
Total expenditure (log)			-7.077	3.364	40.75
Drinks and other sugars	**25.05**	**16.38**			
Wife's share of farm revenue			-0.149***	0.043	-26.85
Total expenditure (log)			33.098***	7.147	75.73
Salt and other condiments	**11.97**	**14.33**			
Wife's share of farm revenue			-0.184***	0.035	-77.00
Total expenditure (log)			57.982***	6.521	196.00

* The *food budget share* is defined as the ratio between the expenditure on food and the total household expenditure (multiplied by 100). The *staple (non-staple) food budget share* is defined as the ratio between the expenditure on staple food (non-staple food) and the total household food expenditure (multiplied by 100). The wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). The *effect size* is the increase in budget share on food relative to sample mean as a result of a hypothetical increase of the wife's share of farm revenue and total food expenditure by from 0 to 50 %.S.E are the standard errors bootstrapped with 500 replications. Note that for the total expenditure, the expected increase in *w* is: $\widehat{\gamma_1} * \log(1.5)$.

Secondly, the results in columns (3) and (5) of Table 6.5 show that the wife's share of farm revenue affects significantly both the budget shares staple food and non-staple food. More specifically, raising wife's share of farm revenue by 1% reduces the budget share on staple food by 0.265 percentage points. More importantly, the result shows that raising wife's share of farm revenue induces a move away from salt and sugars, and towards meat, fish, and dairy. For example, a hypothetical increase in wife's share of farm revenue from 0 to 50% would increase the budget share on micronutrient-rich foods by at least 70% and reduces the budget share on high caloric food by 26% (column (5) of table 6.5). These results are in line with the previous study that an increase of the wife's relative income induces a re-allocation of the household budget towards more nutritious food (Armand et al., 2020; Attanasio & Lechene, 2010; Thomas, 1990). The results remain consistent when using only the subsample of the households who commercialize the farm output (Table A6.8).To check the consistency of the results, we also estimate the probability that the main source of consumption of a given food group is the market. The results are presented in Table 6.6. Except for eggs, the coefficients of the non-staple food are positive and significant. More importantly, the share of the farm revenue controlled by the wives increases the probability of purchasing Vitamin A rich food groups such as vegetables, fruits, meat, and dairy products, which comfort the result shown in Table 6.4. This result is in line with the highly significant coefficient of vitamin A diversity in Table 6.2. The share of revenue controlled by wives not only increases the household per capita food expenditure but also improves the nutrition quality through the purchase of more nutritious foods in the market.

The overall results of this study are consistent with the non-cooperative model of expenditures and the anthropological literature on household expenditures in sub-Saharan Africa (Guyer, 1980; Guyer & Peters, 1987). Adult women are usually responsible for acquiring and preparing food for the household. This in turn reflects 'gender ideologies 'which attach great importance to 'good mothering', of which the provision of food is an important component (Hoddinott & Haddad, 1995). By contrast, these ideologies support the notion that adult males have a right to personal spending money(Bruce, 1989). Moreover, consistent with the collective model of Chiappori (1988, 1992), the intra-household distribution of farm revenue affects the demand for foods, and more specifically the budget allocation toward more nutritious foods.

Table 6.6: Effect of wives' share of farm revenue sale on food groups purchase (Linear probability model)

Food group	Coefficients	Standard errors	R-squared adjusted
Cereals	0.012	0.015	0.237
Roots and tubers	0.032*	0.020	0.140
Legumes and nuts	0.026*	0.017	0.030
Vegetables	0.073***	0.026	0.183
Fruits	0.033*	0.012	0.088
Red meat	0.103***	0.013	0.268
Organ meat	0.073***	0.015	0.132
Fish and sea foods	0.047*	0.026	0.065
Egg	0.018	0.011	0.022
Milk and dairy products	0.064**	0.022	0.091
Oil and fats	-0.030	0.024	0.053
Sweets and sugar	-0.022***	0.008	0.083

Note: *, **, *** statistical significance at 10%, 5% and 1% respectively. Standard errors (SE) in parentheses are bootstrapped with 1000 replications. Number of the observations: 15571. Group (1) is split into 2 subgroups: Cereals and Roots and Tubers. Group (3) is also spilt into 3 sub-groups: red meat, organ meat, and fish and sea foods. Group (10) (spices, condiments, and beverages) is omitted because are consumed in small quantity and are always paid. Coefficients of the covariates omitted are. The estimates are obtained using a control function approach describe in section 6.4.3

6.6. Conclusion

This paper has focused on the impact of the share of farm revenue controlled by wives on household nutrition. We used panel data of farm households in Burkina Faso covering four annual survey rounds from 2014 to 2017 to assess the effect of spouses' share of farm revenue on the dietary diversity, Vitamin A diversity, and food consumption score. Our study contributes to the literature by providing empirical evidence of the impact of the intra-household distribution of farm income on the household nutrition. Furthermore, as opposed to the previous works, we used panel data to obtain more consistent estimates.

The results show that raising wives' share of farm revenue increases the household dietary diversity and food consumption score. Moreover, the effect is stronger when we reduce food groups to food groups rich in Vitamin A. The results also suggest that the effect of wives' share of farm revenue on household nutrition is greater than the effect of the overall level of household income. These results imply that intra-household distribution of farm income affects household nutritional status. Furthermore, we have shown that in the increase in the wife relative farm revenue induces a reallocation of the household budget toward the purchase of highly nutritious foods, which could represent the channel through which the control of farm revenue by wives improves the household nutrition outcomes. Our findings are consistent with the previous studies supporting that gender control of the farm income plays an important role in the household nutrition improvement (Fischer & Qaim, 2012; Ogutu et al., 2019; Yimer & Tadesse, 2016). We were able to control for a wide range of economic and social factors and self-selection of households based on time-invariant characteristics. Furthermore, we used a CF approach to control for potential time-variant unobservable variables. This suggests that a causal relationship between wife's share of the farm revenue and household nutrition could be plausible.

While several tests confirmed the robustness of our findings, there are few limitations to our study. First, like the previous studies that used the 7-day food consumption recall data, we were not able to account for seasonality and intra-household food distribution (Brown et al., 2018; Sibhatu & Qaim, 2017). Secondly, the use of 12-months recall data for farm production and marketing activities is likely to be associated with certain levels of imprecision. Third, data limitation makes impossible to take an account home consumption and prices of food items in the analysis. Hence, causal interpretation should be made with some caution, although the effects described are plausible.

Previous studies have shown that male-controlled revenue has negative or at best has no impact on household nutrition quality. Our findings complement the previous studies by showing that raising women’s share of farm revenue could help improving household food security and nutrition. Thus, one implication is that agricultural interventions in developing countries may be more likely to succeed if they are targeted towards women. In addition, women's empowerment initiatives should focus more on women's access to productive resources such as land and labor-saving technologies, through which they can increase their incomes and therefore improve household food and nutrition security without compromising the well-being of children. This is also important since it not only contributes to repairing social inequality by reducing the gender gap in agriculture, but also improving the household revenue allocation efficiency.

6.7. Appendix of chapter 6

Table A 6.1:: Summary statistics of spouse and household level covariates

	2014	2015	2016	2017	All	
Variables	Mean	Mean	Mean	Mean	Mean	SD
Proportion of adult female (%)	53.70	53.34	53.50	53.87	53.60	15.53
Proportion of educated female (%)	6.56	6.05	6.58	6.53	6.43	13.14
Wife age (Average age for polygamy)	36.36	36.81	37.48	37.82	37.12	10.80
Proportion of wives (%)	16.04	18.42	17.90	17.66	17.52	11.68
Wife membership to F. O (1/0)	0.34	0.27	0.28	0.34	0.31	0.65
Wife access to credit (1/0)	0.037	0.028	0.035	0.054	0.04	0.20
Wife contact with extension agent (1/0)	0.09	0.067	0.092	0.091	0.085	0.28
Wife earns non-farm income Non-farm (%)	1.88	1.54	1.75	3.02	2.04	9.52
Land cultivated by wives (ha)	0.257	0.260	0.276	0.32	0.27	0.48
Household head's age (years)	50.22	50.25	50.75	50.13	50.34	15.22
Household size	11.07	10.78	11.09	11.24	11.04	6.61
Proportion of children 0-5 years old (%)	20.19	19.17	18.10	17.57	18.75	12.61
Proportion of children 6-15 years old (%)	29.33	29.59	30.70	31.26	30.22	15.20
TLU (Tropical Livestock Units)	3.23	3.60	3.54	3.56	3.51	6.20
Crops diversification	2.80	3.55	3.60	3.75	3.42	1.45
Farmland size (ha)	2.42	2.22	2.41	2.60	2.41	2.52
Observations	3,942	3,926	3,830	3,873		
Note: F.O: Farmers Organization. S. D is the standard deviation						

Table A 6.2: The weights for food groups to construct the food consumption score

	Food items (examples)	Food groups	Weight
1	Maize , maize porridge, rice, sorghum, millet pasta, bread and other cereals	Main staples	2
	Cassava, potatoes and sweet potatoes, other tubers, plantains		
2	Beans, peas, groundnuts and cashew nuts	Pulses	3
3	Vegetables, leaves	Vegetables	1
4	Fruits	Fruit	1
5	Beef, goat, poultry, pork, eggs and fish	Meat and fish	4
6	Milk yogurt and other diary products	Milk	4
7	Sugar and sugar products, honey	Sugar	0.5
8	Oils, fats and butter	Oil	0.5
9	spices, tea, coffee, salt, fish power, small amounts of milk for tea.	Condiments	0

Source: WFP(2008)

Table A 6.3: Determinant of wife's share of farm revenue (OLS regression)

	First stage for equation (6.4)		First stage for equation (6.5)	
VARIABLES	share	share2	share	share2
	(1)	(2)	(3)	(4)
Land cultivated by wives (log)	4.2094***	74.7115***	4.1816***	73.3025***
	(0.3239)	(24.1666)	(0.3225)	(24.0688)
Land cultivated by wives squared (log)	-0.0604	29.1005***	-0.0560	29.3068***
	(0.0768)	(6.4654)	(0.0765)	(6.4514)
Income per capita (log)	2.0694***	49.3167***	1.9908	226.5731
	(0.1923)	(14.6116)	(5.3856)	(442.5479)
Income per capita squared (log)			-0.0822	-13.7268
			(0.2557)	(20.9077)
Female cultivated plot characteristics				
(1) Proportion of land in uppermost plot	-2.6293**	-192.9283**	-2.6226**	-192.6193**
	(1.2200)	(86.8240)	(1.2200)	(86.7267)
(2) Proportion of land in bottom plot	-0.8798	-86.4650	-0.8570	-83.2570
	(1.4942)	(106.5075)	(1.4883)	(106.0908)
(3) Proportion of land in mid-sloped plot	-0.9699	-60.4550	-0.9732	-60.1118
	(0.6577)	(51.2796)	(0.6580)	(51.2610)
(4) Proportion of land in newly restored plot	1.1938	69.7631	1.1717	69.2230
	(2.0257)	(153.4571)	(2.0260)	(153.8466)
(5) Proportion of land with Anti-erosive	-0.1003	3.5001	-0.1037	2.8814
	(1.0235)	(76.0061)	(1.0220)	(75.9559)
(6) Proportion of land located in bush	-1.2654*	-46.8398	-1.2786*	-47.2851
	(0.7308)	(57.4746)	(0.7302)	(57.4139)
(7) Proportion of land located in a camp	-0.8607	5.8361	-0.8370	7.3470
	(1.3561)	(111.1576)	(1.3528)	(110.8492)
Wife covariates	YES	YES	YES	YES
Household covariates	YES	YES	YES	YES
Year-commune dummy	YES	YES	YES	YES
Observations	15,571	15,571	15,571	15,571
R-squared	0.3711	0.2675	0.3723	0.2684
F-test for excluded instruments	324.11	290.68	60.78	24.44

Share and share2 are wives' farm revenue share and its square, respectively. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. (1)-(3) indicate the plot slope with lowland as the base category. (6)-(7) indicate plots location with "located at a nearby house" as the base category.

Table A 6.4: Determinants of total expenditure and Food expenditure (OLS regression)

	First stage for equation (6.5)			
VARIABLES	Expenditure	Expenditure2	ExpendH	ExpendH2
	(1)	(2)	(3)	(4)
Land cultivated by wives (log)	0.0336***	0.8323***	0.0368***	0.8566***
	(0.0095)	(0.2276)	(0.0110)	(0.2486)
Land cultivated by wives squared (log)	-0.0038*	-0.0950**	-0.0008	-0.0245
	(0.0019)	(0.0465)	(0.0023)	(0.0523)
Income per capita (log)	0.8670***	15.9054***	0.6609***	11.0812**
	(0.1704)	(4.0233)	(0.2087)	(4.6162)
Income per capita squared (log)	-0.0203**	-0.2585	-0.0148	-0.1572
	(0.0080)	(0.1889)	(0.0098)	(0.2177)
Female cultivated plot characteristics	YES	YES	YES	YES
Wife covariates	YES	YES	YES	YES
Household covariates	YES	YES	YES	YES
Year-commune dummy	YES	YES	YES	YES
Observations	15,571	15,571	15,571	15,571
R-squared	0.7119	0.7132	0.5732	0.5738
F-test for excluded instruments	98.98	98.76	44.12***	44.25***
Expenditure and Expenditure2 are the total expenditure and its square, respectively. ExpendH and ExpendH2 are the total expenditure on food and its square, respectively. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. (1)-(3) indicate the plot slope with lowland as the base category. (6)-(7) indicate plots location with "located at a nearby house" as the base category.				

Table A 6.5: Effect of wife' s share of farm revenue on non-durable goods (full regression output)

VARIABLES	Food	Energy	Clothing and ceremonies	Transpor-tation	Commu-nication	Health	Edu-cation	Alcohol and tobacco
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wife's share of farm revenue (0-100)	0.23***	-0.07***	-0.04*	-0.02	-0.02	0.02	-0.07***	0.00
	(0.04)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.03)	(0.00)
Wife's share of farm revenue squared	-0.00	0.00***	0.00	0.00	-0.00	-0.00	0.00*	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Log of the total food expenditure	- 23.90***	3.60	-4.04	-5.22**	15.59***	5.45*	32.24***	- 0.67***
	(6.79)	(2.29)	(3.45)	(2.18)	(2.92)	(3.02)	(4.03)	(0.15)
Log of the total food expenditure	0.69**	-0.11	0.14	0.26***	-0.64***	-0.23*	-1.30***	0.03***
	(0.28)	(0.09)	(0.14)	(0.09)	(0.12)	(0.12)	(0.17)	(0.01)
Commercialization index (0-100)	0.04***	-0.01**	0.01*	0.00	-0.01***	-0.01	-0.01	-0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Proportion of female adults (%)	-0.02**	0.01*	0.02***	0.00	-0.00	0.01**	0.01**	-0.00**
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Proportion of educated female (%)	-0.04***	-0.00	-0.02***	-0.00	0.02***	-0.01**	0.08***	-0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Wife Age (average age for polygamy)	-0.03*	-0.00	0.00	-0.02***	-0.03***	-0.01	0.07***	0.00***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
proportion of wives (%)	0.07***	-0.00	-0.02**	-0.02***	-0.01	-0.00	-0.03***	0.00***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Wife membership to F.O	-0.26**	0.03	-0.00	-0.07*	-0.04	-0.16***	0.30***	-0.00
	(0.13)	(0.04)	(0.07)	(0.04)	(0.06)	(0.06)	(0.08)	(0.00)
Wife access to credit	0.05	0.66**	-0.95**	-0.05	-0.39	-0.34	0.29	0.02
	(0.77)	(0.26)	(0.39)	(0.25)	(0.33)	(0.34)	(0.46)	(0.02)
Wife access to extension service	-0.17	0.17	0.51*	-0.12	0.35	-0.23	0.35	0.01
	(0.54)	(0.18)	(0.27)	(0.17)	(0.23)	(0.24)	(0.32)	(0.01)
Females who earn non-farm income (%)	0.03**	-0.01	-0.00	-0.01	-0.00	-0.02***	-0.01*	-0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)
Age of the household's head	-0.02	0.01	0.01	0.01	-0.01	0.02***	-0.01	-0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)

Size of the household	-0.12***	-0.02	0.04**	-0.01	0.05***	0.01	0.21***	-0.00**
	(0.03)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.00)
Proportion of children 0-5 years old (%)	0.01	-0.01***	0.01	0.02***	0.01**	0.00	-0.06***	-0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)
Proportion of children 6-15 years old (%)	-0.02	-0.01	-0.00	-0.00	-0.01***	-0.02***	0.06***	-0.00*
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Crops diversification	-0.01	0.03	0.11*	-0.14***	-0.14***	0.12**	0.19***	0.01***
	(0.12)	(0.04)	(0.06)	(0.04)	(0.05)	(0.05)	(0.07)	(0.00)
TLU (Tropical Livestock Units)	-0.10***	-0.03***	0.04***	0.02**	0.02**	0.02*	-0.07***	-0.00***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Farmland size (log)	-1.49**	0.24	1.39***	0.16	0.45	-0.76**	-0.47	-0.04***
	(0.72)	(0.24)	(0.37)	(0.23)	(0.31)	(0.32)	(0.43)	(0.02)
Farmland size squared (log)	0.05	-0.06**	-0.14***	0.01	-0.01	0.08**	0.10**	0.00*
	(0.08)	(0.03)	(0.04)	(0.02)	(0.03)	(0.03)	(0.05)	(0.00)
Endogeneity 1 (chi2)	20.79***	14.69***	1.07	8.19*	5.06	10.61**	1.50	4.81
Endogeneity 2 (chi2)	49.88***	36.73***	119.44***	122.73***	51.02***	36.31***	58.78***	11.12**
Observations	15,571	15,571	15,571	15,571	15,571	15,571	15,571	15,571
R-squared	0.236	0.058	0.085	0.082	0.072	0.066	0.174	0.126

Note: Standard errors in parentheses (Bootstrapped with 1000 replications) *** p<0.01, ** p<0.05, * p<0.1. Wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). Commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). F.O: Farmers Organization. The endogeneity 1 (endogeneity 2) test is performed as a joint Wald test for the equality to zero of all coefficients in the polynomial of the first-stage residuals for wives' farm revenue share (total expenditure) and its square. Number of groups is 5011. Inconsistence in the number observations with Table 6.1 is due the exclusion of female headed household and household in which in wife does not own plots.

Table A 6.6: Wife 's share of farm revenue and budget share on food (full regression output)

VARIABLES	Staple food	Meat and Fish	Vegetables and fruits	Dairy products	Sugar and drinks	Salt and condiments
	(1)	(2)	(3)	(4)	(5)	(6)
Wife's share of farm revenue (0-100)	-0.2651***	0.2920***	0.1415***	0.1730***	-0.1491***	-0.1838***
	(0.0500)	(0.0421)	(0.0218)	(0.0186)	(0.0432)	(0.0354)
Wife's share of farm revenue squared	0.0024***	-0.0042***	-0.0006*	-0.0007**	0.0010	0.0022***
	(0.0008)	(0.0006)	(0.0003)	(0.0003)	(0.0006)	(0.0005)
Log of the total food expenditure	-47.7030***	59.9406***	-1.2120	11.9677***	33.0981***	-57.982***
	(7.1440)	(6.0202)	(3.3642)	(3.1775)	(7.1474)	(6.5214)
Log of the total food expenditure	2.8672***	-2.7126***	-0.0241	-0.5933***	-1.7455***	2.2880***
	(0.3164)	(0.2650)	(0.1473)	(0.1381)	(0.3147)	(0.2825)
Commercialization index (0-100)	0.0158	-0.0027	0.0057	-0.0177***	0.0200*	-0.0161*
	(0.0131)	(0.0113)	(0.0062)	(0.0048)	(0.0111)	(0.0095)
Proportion of female adults (%)	-0.0013	0.0065	0.0008	-0.0012	-0.0094	-0.0016
	(0.0191)	(0.0163)	(0.0084)	(0.0065)	(0.0172)	(0.0131)
Proportion of educated female (%)	0.0048	0.0173	-0.0029	-0.0000	-0.0084	-0.0083
	(0.0188)	(0.0154)	(0.0083)	(0.0059)	(0.0143)	(0.0121)
Wife Age (average age for polygamy)	0.0060	0.0241	-0.0146	0.0048	-0.0501	0.0186
	(0.0391)	(0.0307)	(0.0156)	(0.0141)	(0.0357)	(0.0292)
proportion of wives (%)	0.0378	0.0067	-0.0075	0.0100	-0.0186	-0.0295
	(0.0287)	(0.0226)	(0.0132)	(0.0217)	(0.0225)	(0.0226)
Wife membership to F.O	-0.4076***	-0.0747	0.0674	-0.0773*	0.1074	0.2760***
	(0.1314)	(0.1129)	(0.0588)	(0.0453)	(0.1189)	(0.1061)
Wife access to credit	-0.7082	1.0462	-0.4245	-0.1948	0.7169	-0.3924
	(0.7781)	(0.6935)	(0.2980)	(0.2177)	(0.6470)	(0.5585)
Wife access to extension service	-1.1946**	0.4565	-0.0523	-0.0884	0.4995	0.5657
	(0.5436)	(0.4472)	(0.2346)	(0.1646)	(0.4779)	(0.3694)
Females who earn non-farm income (%)	0.0342*	-0.0123	-0.0010	-0.0004	-0.0007	-0.0198
	(0.0196)	(0.0149)	(0.0079)	(0.0064)	(0.0185)	(0.0129)
Age of the household's head	0.0243	0.0128	0.0004	0.0129	-0.0127	-0.0371**
	(0.0264)	(0.0233)	(0.0100)	(0.0092)	(0.0238)	(0.0165)

Size of the household	-0.1498	-0.0602	-0.0155	0.0050	0.1370*	0.0731
	(0.0926)	(0.0820)	(0.0377)	(0.0354)	(0.0772)	(0.0626)
Proportion of children 0-5 years old (%)	0.0326	0.0013	-0.0007	-0.0009	-0.0257	-0.0033
	(0.0272)	(0.0248)	(0.0123)	(0.0104)	(0.0235)	(0.0177)
Proportion of children 6-15 years old (%)	0.0110	-0.0045	-0.0025	0.0055	-0.0009	-0.0033
	(0.0237)	(0.0204)	(0.0106)	(0.0094)	(0.0198)	(0.0166)
Crops diversification	-0.0574	0.1680	-0.0844	0.0333	0.0282	-0.0635
	(0.2173)	(0.1871)	(0.0953)	(0.0772)	(0.1905)	(0.1474)
TLU (Tropical Livestock Units)	-0.0949**	0.0471	0.0033	0.0040	-0.0114	0.0594
	(0.0474)	(0.0467)	(0.0238)	(0.0241)	(0.0566)	(0.0523)
Farmland size (log)	0.1667	0.0222	0.3429	0.3022	-0.1569	-0.9124
	(1.1431)	(0.9774)	(0.4740)	(0.3874)	(0.9830)	(0.8128)
Farmland size squared (log)	-0.0153	0.0084	-0.0179	-0.0187	-0.0390	0.1008
	(0.1286)	(0.1092)	(0.0534)	(0.0432)	(0.1097)	(0.0888)
Year-Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Endogeneity 1 (chi 2)	3.96	32.13***	2.22	25***	21.67***	10.27**
Endogeneity 2 (chi 2)	45.54***	38.05***	34.07***	9.76**	30.48***	56.78***
Observations	15,564	15,564	15,564	15,564	15,564	15,564
R-squared	0.1447	0.1447	0.1381	0.2145	0.2015	0.3278

Note: Standard errors in parentheses (Bootstrapped with 1000 replications) *** p<0.01, ** p<0.05, * p<0.1. Wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). Commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). F.O: Farmers Organization. The endogeneity 1 (endogeneity 2) test is performed as a joint Wald test for the equality to zero of all coefficients in the polynomial of the first-stage residuals for wives' farm revenue share (total expenditure) and its square. Number of groups is 5011. Inconsistence in the number observations with Table 6.1 is due missing outcome variable.

Table A 6.7: Effect of wife's share of farm revenue on nutrition and food expenditure for only the subsample of households who have commercialized

VARIABLES	Non-food good	food	Staple food	Non-staple food	HDDS	FCS
Wife's share of farm revenue (0-100)	0.0084***	0.0121***	0.0422***	0.0135***	0.0901***	0.3719***
	(0.0027)	(0.0020)	(0.0070)	(0.0019)	(0.0065)	(0.0495)
Wife's share of farm revenue squared	-0.0001**	-0.0001**	-0.0005***	-0.0001***	-0.0008***	0.0024***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0008)
Income per capita (log)	0.4982***	0.2900***	0.3682***	0.2448***	0.3587***	1.0924***
	(0.0227)	(0.0174)	(0.0508)	(0.0168)	(0.0410)	(0.3464)
Commercialization index (0-100)	0.0037***	0.0042***	0.0235***	0.0032***	0.0150***	0.0660***
	(0.0007)	(0.0005)	(0.0016)	(0.0005)	(0.0014)	(0.0095)
Proportion of female adults (%)	-0.0003	-0.0007	0.0002	-0.0007	-0.0012	-0.0118
	(0.0008)	(0.0006)	(0.0021)	(0.0006)	(0.0017)	(0.0139)
Proportion of educated female (%)	-0.0000	0.0009*	0.0030*	0.0004	0.0007	0.0138
	(0.0006)	(0.0005)	(0.0018)	(0.0005)	(0.0016)	(0.0120)
Wife Age (average age for polygamy)	0.0022	0.0022*	0.0037	0.0018	0.0089**	0.0732***
	(0.0018)	(0.0013)	(0.0042)	(0.0011)	(0.0039)	(0.0275)
proportion of wives (%)	0.0037**	0.0060***	0.0005	0.0067***	0.0131***	0.0709***
	(0.0016)	(0.0013)	(0.0035)	(0.0014)	(0.0031)	(0.0246)
Wife membership to F.O	-0.0001	-0.0050	-0.0133	0.0008	-0.0090	-0.0602
	(0.0057)	(0.0053)	(0.0181)	(0.0048)	(0.0155)	(0.1056)
Wife access to credit	0.0765**	0.0488*	0.0383	0.0369	0.0890	0.4729
	(0.0361)	(0.0295)	(0.0940)	(0.0283)	(0.0911)	(0.6780)
Wife access to extension service	0.0106	0.0263	0.0780	0.0167	0.1479**	0.3220
	(0.0254)	(0.0203)	(0.0693)	(0.0191)	(0.0691)	(0.4832)
Females who earn non-farm income (%)	-0.0001	0.0008	0.0024	0.0002	0.0027	0.0181
	(0.0007)	(0.0005)	(0.0021)	(0.0005)	(0.0018)	(0.0135)
Age of the household's head	0.0019*	-0.0005	0.0030	-0.0009	0.0047*	0.0244
	(0.0011)	(0.0007)	(0.0029)	(0.0007)	(0.0025)	(0.0175)
Size of the household	-0.0413***	-0.0579***	-0.0383***	-0.0576***	-0.0662***	-0.4121***
	(0.0046)	(0.0031)	(0.0097)	(0.0031)	(0.0087)	(0.0643)
Proportion of children 0-5 years old (%)	-0.0028***	-0.0011	0.0012	-0.0019***	-0.0021	-0.0129
	(0.0011)	(0.0008)	(0.0031)	(0.0008)	(0.0025)	(0.0198)

Proportion of children 6-15 years old (%)	-0.0022**	-0.0018**	-0.0015	-0.0021***	-0.0002	-0.0122
	(0.0010)	(0.0007)	(0.0026)	(0.0007)	(0.0022)	(0.0173)
Crops diversification	-0.0103	0.0089	-0.0043	0.0056	-0.0048	0.1392
	(0.0090)	(0.0065)	(0.0211)	(0.0066)	(0.0205)	(0.1446)
TLU (Tropical Livestock Units)	-0.0006	0.0008	-0.0125**	0.0015	0.0104*	0.1045***
	(0.0020)	(0.0022)	(0.0058)	(0.0021)	(0.0058)	(0.0387)
Farmland size (log)	-0.0598	-0.0602*	-0.1793	-0.0245	-0.2581**	-0.6302
	(0.0462)	(0.0343)	(0.1265)	(0.0306)	(0.1138)	(0.7737)
Farmland size squared (log)	0.0094*	0.0050	0.0135	0.0020	0.0292**	0.0930
	(0.0051)	(0.0039)	(0.0139)	(0.0034)	(0.0126)	(0.0875)
Year-Province	Yes	Yes	Yes	Yes	Yes	Yes
Endogeneity (chi-squared)	5.13	3.10	14.27***	4.41	67.68***	125.72***
Observations	14,660	14,653	14,660	14,660	14,660	14,660
R-squared	0.3053	0.3261	0.1882	0.3073	0.2108	0.3409
Number of HH_id	4,957	4,956	4,957	4,957	4,957	4,957

Note: The dependent variable is the log of the food (1), staple food (2), and non-staple food (3) per capita. Standard errors in parentheses are bootstrapped with 1000 replications. Wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). Commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). F.O: Farmers Organization. *** p<0.01, ** p<0.05, * p<0.1. The endogeneity test is performed as a joint Wald test for the equality to zero of all coefficients in the polynomial of the first-stage residuals for wives' farm revenue share and its square. Number of groups is 5011. Inconsistence in the number observations with Table 6.1 is due the exclusion of female headed household and household in which in wife does not own plots.

Table A 6.8: Effect of wife's share of farm revenue on budget share on food for the subsample of households who have commercialized

VARIABLES	Staple food	Meat and Fish	Vegetables and fruits	Dairy products	Sugar and drinks	Salt and condiments
	(1)	(2)	(3)	(4)	(5)	(6)
Wife's share of farm revenue (0-100)	-0.2837***	0.3060***	0.1478***	0.1680***	-0.1426***	-0.1853***
	(0.0524)	(0.0436)	(0.0218)	(0.0184)	(0.0441)	(0.0351)
Wife's share of farm revenue squared	0.0026***	-0.0044***	-0.0006*	-0.0007**	0.0008	0.0022***
	(0.0008)	(0.0007)	(0.0003)	(0.0003)	(0.0007)	(0.0005)
Log of the total food expenditure	-49.6343***	60.7124***	-6.0467*	9.0359***	40.6658***	-56.7849***
	(7.5398)	(6.2712)	(3.1365)	(2.6463)	(6.3502)	(5.0501)
Log of the total food expenditure	2.9425***	-2.7387***	0.1788	-0.4683***	-2.0624***	2.2345***
	(0.3335)	(0.2774)	(0.1387)	(0.1171)	(0.2809)	(0.2234)
Commercialization index (0-100)	0.0080	0.0157	0.0114*	-0.0180***	0.0122	-0.0212**
	(0.0149)	(0.0124)	(0.0062)	(0.0052)	(0.0126)	(0.0100)
Proportion of female adults (%)	-0.0125	0.0094	-0.0023	0.0037	-0.0047	-0.0011
	(0.0199)	(0.0166)	(0.0083)	(0.0070)	(0.0168)	(0.0133)
Proportion of educated female (%)	0.0036	0.0155	-0.0008	0.0038	-0.0064	-0.0114
	(0.0193)	(0.0161)	(0.0080)	(0.0068)	(0.0163)	(0.0129)
Wife Age (average age for polygamy)	0.0221	0.0094	-0.0067	0.0077	-0.0709**	0.0260
	(0.0405)	(0.0337)	(0.0169)	(0.0142)	(0.0341)	(0.0271)
proportion of wives (%)	0.0261	0.0052	0.0075	-0.0035	-0.0171	-0.0180
	(0.0319)	(0.0265)	(0.0133)	(0.0112)	(0.0269)	(0.0214)
Wife membership to F.O	-0.3938***	-0.0600	0.0848	-0.1048**	0.1281	0.2284**
	(0.1342)	(0.1116)	(0.0558)	(0.0471)	(0.1130)	(0.0899)
Wife access to credit	-0.7794	1.2375*	-0.5267	-0.1282	0.6038	-0.2992
	(0.7938)	(0.6602)	(0.3302)	(0.2786)	(0.6685)	(0.5317)
Wife access to extension service	-1.2628**	0.3221	-0.0404	-0.1268	0.6900	0.6170*
	(0.5532)	(0.4601)	(0.2301)	(0.1941)	(0.4659)	(0.3705)
Females who earn non-farm income (%)	0.0344*	-0.0021	0.0031	-0.0015	-0.0149	-0.0189
	(0.0203)	(0.0169)	(0.0085)	(0.0071)	(0.0171)	(0.0136)
Age of the household's head	0.0215	0.0176	-0.0059	0.0145	-0.0035	-0.0435**
	(0.0273)	(0.0227)	(0.0114)	(0.0096)	(0.0230)	(0.0183)
Size of the household	-0.1621*	-0.0452	-0.0063	-0.0121	0.1342*	0.0797
	(0.0951)	(0.0791)	(0.0396)	(0.0334)	(0.0801)	(0.0637)

Proportion of children 0-5 years old (%)	0.0406	-0.0120	0.0094	-0.0029	-0.0294	-0.0020
	(0.0285)	(0.0237)	(0.0118)	(0.0100)	(0.0240)	(0.0191)
Proportion of children 6-15 years old (%)	0.0151	-0.0014	0.0036	0.0019	-0.0097	-0.0051
	(0.0248)	(0.0206)	(0.0103)	(0.0087)	(0.0209)	(0.0166)
Crops diversification	-0.0699	0.1271	-0.0496	0.0342	0.0617	-0.0912
	(0.2242)	(0.1865)	(0.0933)	(0.0787)	(0.1888)	(0.1502)
TLU (Tropical Livestock Units)	-0.1223**	0.1045**	0.0108	-0.0172	0.0442	-0.0085
	(0.0588)	(0.0489)	(0.0245)	(0.0206)	(0.0496)	(0.0394)
Farmland size (log)	-0.5508	0.6920	0.0230	0.1524	0.2960	-0.6601
	(1.2242)	(1.0182)	(0.5092)	(0.4297)	(1.0310)	(0.8199)
Farmland size squared (log)	0.0510	-0.0664	0.0147	-0.0018	-0.0745	0.0757
	(0.1364)	(0.1135)	(0.0568)	(0.0479)	(0.1149)	(0.0914)
Year-Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Endogeneity WS (Chi-squared)	4.32	45.94***	2.90	37.57***	18.95***	6.33
Endogeneity Exp (Chi-squared)	43.58***	40.29***	49.41***	214.61***	45.71***	75.38***
Observations	14,653	14,653	14,653	14,653	14,653	14,653
R-squared	0.3044	0.1435	0.1427	0.2236	0.1993	0.3189

Note: Standard errors in parentheses are bootstrapped with 1000 replications. *** p<0.01, ** p<0.05, * p<0.1. Wife's share of farm revenue is defined as the ratio between the farm revenue owned by wife (or wives) and the total farm revenue (multiplied by 100). Commercialization index is the ratio between the value of the output sold by the household and the total output value (multiplied by 100). F.O: Farmers Organization. The endogeneity 1 (endogeneity 2) test is performed as a joint Wald test for the equality to zero of all coefficients in the polynomial of the first-stage residuals for wives' farm revenue share (total expenditure) and its square. Number of groups is 5011. Inconsistence in the number observations with Table 6.1 is due the exclusion of female headed household and household in which in wife does not own plots.

7. CONCLUSION

It is widely recognized that the commercialization of agriculture is an important part of the agrarian transformation of low-income economies. However, to achieve this goal, the coordination of economic activities by market institutions should necessarily contribute to minimize the transaction costs and facilitate exchange between economic agents. This dissertation analyzed the role rural markets functioning has on the use of modern inputs and the welfare gain from crops commercialization for small farm household in Burkina Faso.

To achieve its objectives, in chapter 3, this research consisted in evaluating price transmission between local grain markets focusing in the case of cowpea. The results suggest that transaction costs between central market and secondary markets are asymmetric. This asymmetry is higher for trade between central market and markets located in rural producing areas. Also, there is a strong association between transaction costs and distance. Furthermore, the sign and the amplitude of adjustment parameters are consistent with the spatial equilibrium even though prices respond quickly to positive shocks than negative shocks. Finally, the results show that there are few violations of competitive spatial equilibrium, which, associated with the consistency in the adjustments parameters suggest that the local market of cowpea is performing well.

However, low performance of grain markets due the transaction cost may negatively affect the economic return of yield-increasing technologies. As a result, farmers can get discourage from adopt them. This phenomenon is tested in Chapter 4 .To achieve this, this chapter combines price data and a five years panel data of farm households of Burkina Faso. The results suggest a strong association between crop output market integration and farmer decision to adopt modern inputs. More specifically, increase in price gap between central market and secondary markets during the last 12 months preceding the planting season reduces the likelihood of adopting modern inputs. Moreover, the results suggest that this association is stronger for farmers who previously adopted these yield-increasing inputs.

Chapter 5 interested in the factors that affect smallholder farmers market participation in Burkina Faso with a special focus on the role played by farmer comparative advantage in the production. The data used in this chapter comes from the nationally representative household cross-section survey collected in 2014 in Burkina Faso under the Living Standards Measurement Study – Integrated Surveys in Agriculture (LSMS-ISA). First, the results suggest that farmer marketing behavior is guided by their comparative advantage. More specifically, farmers who hold a comparative advantage in the production of specific crop are more likely to be net sellers of that crop. Second, after controlling the individual farmer's comparative advantage, the net selling decision is made regardless of market access factors.

However, how the intra-household distribution of commercialization revenue affects household welfare is not well understood. Therefore, in chapter 6, this dissertation analyzed the impact of wives' share of farm revenue on the nutrition. It used the households four years panel data from the farm continuous survey of Burkina Faso. The results show that raising spouses' share of farm revenue increases household nutrition diversity and quantity demanded for food. The findings suggest also that the effect of the wives share of farm revenue on the household nutrition is greater than the effect of the overall level of household commercialization and income per capita, which supports that intra-household distribution of farm commercialization revenue affects household nutritional status. Finally, this chapter has shown that raising the wife's relative farm revenue induces the re-allocation of the household food budget toward more nutritious foods.

The findings of this dissertation provide some policy recommendations to improve the commercialization of agriculture and its impact on farm households' welfare in Burkina Faso. First, at macro level, investment in transportation infrastructures could help to reduce transportation cost between producing regions and consumption centers. As discussed in chapter 2, most of the rural producing areas become inaccessible during the rainy season which hinders surplus farmers to sell their crops even in the neighboring villages. For some cases, simple rural tracks or/ small bridges may create a big difference in integrating a whole locality into the commune market. Also, at farmers and traders' level, credit systems that target specifically the commercialization of agricultural products may be developed. Access to formal credit by traders will help to realise economies of scale and storage opportunities. These measures could contribute not only to increase the share of the farm output that is commercialized, but also the revenue earned from commercialization. Second, agricultural interventions that target the adoption of modern inputs should be accompanied by market development measures. One of the major limitations in the agricultural policies in developing countries including Burkina Faso is that a lot of effort has been made to increase the yield per hectare while less is done to facilitate the commercialization of crops. Specific measures such as contract farming could help to improve smallholder farm household's integration in the marketing channel and then improve the economic returns to their investment in yield-increasing technologies. Also, the warehouse receipt system can help the poor farmers to smooth the crops supply the yearlong and then avoid selling crops at low product during harvest time, these may compensate for the negative effect of the low market integration. Third, promoting access to land and labor-saving technologies by women may help to increase the share of farm revenue they owned and then contribute to improving the household nutrition outcomes. This is particularly important since it not only contributes to repairing social inequality by reducing the gender gap in agriculture, but also improving household revenue allocation efficiency.

8. REFERENCES

Abdul-Hanan, A. (2016). Does credit market inefficiency affect technology adoption? Evidence from Sub-Saharan Africa. *Agricultural Finance Review*, *76*(4), 494–511. https://doi.org/10.1108/AFR-05-2016-0052

Abdulai, A. (2000). Spatial price transmission and asymmetry in the Ghanaian maize market. *Journal of Development Economics*, *63*(2), 327–349. https://doi.org/10.1016/S0304-3878(00)00115-2

Akerlof, G. A. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, *84*(3), 488–500. https://doi.org/10.2307/1879431

Alene, A. D., Manyong, V. M., Omanya, G., Mignouna, H. D., Bokanga, M., & Odhiambo, G. (2008). Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya. *Food Policy*, *33*(4), 318–328. https://doi.org/10.1016/j.foodpol.2007.12.001

Alpha, A., & Pemou, B. (2019). *Articuler stocks publics et stocks de proximité pour améliorer la sécurité alimentaire au Burkina Faso*. CIRAD. Working Paper #3.

Angelucci, M., & Attanasio, O. (2013). The Demand for Food of Poor Urban Mexican Households: Understanding Policy Impacts Using Structural Models. *American Economic Journal: Economic Policy*, *5*(1), 146–178.

Armand, A., Attanasio, O., Carneiro, P., & Lechene, V. (2020). The Effect of Gender-Targeted Conditional Cash Transfers on Household Expenditures: Evidence from a Randomized Experiment. *The Economic Journal*, *130*(631), 1875–1897. https://doi.org/10.1093/ej/ueaa056

Attanasio, O., & Lechene, V. (2010). Conditional cash transfers, women and the demand for food. *Institute for Fiscal Studies, IFS Working Papers: W10/17, 2010*.

Attanasio, O., & Lechene, V. (2014). Efficient responses to targeted cash transfers. *Journal of Political Economy*, *122*(1), 178–222. https://doi.org/10.1086/674968

Baquedano, F. G., & Liefert, W. M. (2014). Market integration and price transmission in consumer markets of developing countries. *Food Policy*, *44*, 103–114. https://doi.org/10.1016/j.foodpol.2013.11.001

Bardhan, P. (1989). The new institutional economics and development theory: A brief critical assessment. *World Development*, *17*(9), 1389–1395. https://doi.org/10.1016/0305-750X(89)90080-6

Barrett, C. B. (2008). Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food Policy*, *33*(4), 299–317. https://doi.org/10.1016/j.foodpol.2007.10.005

Barrett, C. B., & Li, J. R. (2002). Distinguishing between equilibrium and integration in spatial price analysis. *American Journal of Agricultural Economics*, *84*(2), 292–307. https://doi.org/10.1111/1467-8276.00298

Bassolet, B. (2000). *Libhiisation du March6 Cirialier au Burkina Faso: une Analyse Neo-institutionelle de son Organisation et de son Efficacite Temporelle et Spatiale*. PhD thesis. University of Groningen, The Netherlands.

Bassolet, B., & Lutz, C. (1999). Information service and integration of cereal markets in Burkina Faso. *Journal of African Economics*, *8*(1), 31–51. https://doi.org/10.1093/jae/8.1.31

Baulch, B. (1997). Transfer Costs, Spatial Arbitrage, and Testing for Food Market Integration. *American Journal of Agricultural Economics*, *79*(2), 477–487.

Beaman, L. A., BenYishay, A., Magruder, J., & Mobarak, A. M. (2018). Can Network Theory-Based Targeting Increase Technology Adoption? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3225815

Bekkers, E., Brockmeier, M., Francois, J., & Yang, F. (2017). Local Food Prices and International Price Transmission. *World Development*, *96*, 216–230. https://doi.org/10.1016/j.worlddev.2017.03.008

Bellemare, Marc F; Barrett, C. B. (2006). An ordered tobit model of market participation : evidence from kenya and ethiopia. *American Journal of Agricultural Economics*, *88(2)*(May), 324–337.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., … Uauy, R. (2013).

Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, *382*(9890), 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Botosaru, I., & Muris, C. (2020). Intertemporal Collective Household Models: Identification in Short Panels with Unobserved Heterogeneity in Resource Shares. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3642893

Boughton, D., Mather, D., Barrett, C. B., Benfica S, R., Abdula, D., Tschirley, D., & Cunguara, B. (2007). Market Participation by Rural Households in a Low-Income Country: An Asset Based Approach Applied to Mozambique. *Faith and Economics*, *50*, 64–101.

Bourguignon, F., Browning, M., & Chiappori, P. A. (2009). Efficient intra-household allocations and distribution factors: Implications and identification. *Review of Economic Studies*, *76*(2), 503–528. https://doi.org/10.1111/j.1467-937X.2008.00525.x

Brown, C., Calvi, R., & Penglase, J. (2018). Sharing the Pie: Undernutrition, Intra-Household Allocation, and Poverty. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3199129

Bruce, J. (1989). Homes divided. *World Development*, *17*(7), 979–991. https://doi.org/10.1016/0305-750X(89)90162-9

Burke, M., Falcao Bergquist, L., & Miguel, E. (2017). *Selling low and buying high: An arbitrage puzzle in Kenyan villages*. Retrieved from https://web.stanford.edu/~mburke/papers/MaizeStorage.pdf

Burke, W. J., Myers, R. J., & Jayne, T. S. (2015). A triple-hurdle model of production and market participation in Kenya's dairy market. *American Journal of Agricultural Economics*, *97*(4), 1227–1246. https://doi.org/10.1093/ajae/aav009

Carletto, C., Corral, P., & Guelfi, A. (2017). Agricultural commercialization and nutrition revisited: Empirical evidence from three African countries. *Food Policy*, *67*, 106–118. https://doi.org/10.1016/j.foodpol.2016.09.020

Chamberlin, J., & Jayne, T. S. (2013). Unpacking the Meaning of "Market Access": Evidence from Rural Kenya. *World Development*, *41*(1), 245–264. https://doi.org/10.1016/j.worlddev.2012.06.004

Chege, C. G. K., Andersson, C. I. M., & Qaim, M. (2015). Impacts of Supermarkets on Farm Household Nutrition in Kenya. *World Development*, *72*, 394–407. https://doi.org/10.1016/j.worlddev.2015.03.016

Chiappori, P. (1988). Rational Household Labor Supply. *Econometrica*, *56*(1), 63–90.

Chiappori, P. (1992). Collective Labor Supply and Welfare. *Journal of Political Economy*, *100*(3), 437–467.

Chowdhury, S., Negassa, A., & Torero, M. (2005). Market Institutions : Enhancing the Value of Rural-Urban Links. In *International Food Policy Research Institute (IFPRI) Discussion Paper BRIEFS*. Retrieved from http://www.ifpri.org/sites/default/files/publications/fcnbr195.pdf

Cochrane, W. W. (1958). *Farm Prices: Myth and Reality.* Minneapolis. University of Minnesota Press.

Coelli, T., Rao, P., O'Donnell, C., & Battesse, G. (2005). *An Introduction to Efficiency and Productivity Analysis* (Second). New York: Springer.

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

Coulter, J. (2012). *Révision du warrantage (crédit de stockage) au Burkina Faso*. Préparé pour Université de Greenwich, Natural Resources Institute, Royaume Uni, 58p.

Croppenstedt, A., Demeke, M., & Meschi, M. M. (2003). Technology adoption in the presence of constraints: The case of fertilizer demand in Ethiopia. *Review of Development Economics*, *7*(1), 58–70. https://doi.org/10.1111/1467-9361.00175

Cunningham, K., Ploubidis, G. B., Menon, P., Ruel, M., Kadiyala, S., Uauy, R., & Ferguson, E. (2015). Women's empowerment in agriculture and child nutritional status in rural Nepal. *Public Health Nutrition*, *18*(17), 3134–3145. https://doi.org/10.1017/S1368980015000683

DGESS/MAAH. (2017). *Rapport General Des Resultats Definitifs De La Campagne Agricole 2017/2018 Et Des Perspectives Alimentaire Et Nutritionnelle*. Ouagadougou, Burkina Faso.

DGESS/MAAH. (2020). *Annuaire des statistiques agricoles 2018*. Ouagadougou, Burkina Faso.

DGESS/MASA. (2014). *Resultats Definitifs De La Campagne Agricole 2013/2014 Et Perspectives De La Situation Alimentaire Et Nutritionnelle*. Ouagadougou, Burkina Faso.

DGPER/DPSAA/MAAH. (2011). *Recensement general de l'agriculture. Rapport general du module tronc commun*. Retrieved from http://www.cns.bf/IMG/pdf/rapport_module_tronc_commun_def.pdf

DGPER/MASA. (2012). *Enquete sur la commercialisation des produits agricoles*. Rapport d'analyse. Ouagadougou, Burkina Faso.

Dillon, A., McGee, K., & Oseni, G. (2015). Agricultural Production, Dietary Diversity and Climate Variability. *Journal of Development Studies*, *51*(8), 976–995. https://doi.org/10.1080/00220388.2015.1018902

Dorosh, P. A., Rashid, S., & van Asselt, J. (2016). Enhancing food security in South Sudan: the role of markets and regional trade. *Agricultural Economics (United Kingdom)*, *47*(6), 697–707. https://doi.org/10.1111/agec.12266

Duflo, E., & Udry, C. (2004). Intrahousehold Resource Allocation in Côte D'Ivoire: Social Norms, Separate Accounts and Consumption Choices. In *NBER Working Paper* (No. w10498; Vol. 1542). https://doi.org/10.1017/CBO9781107415324.004

Enke, S. (1951). Equilibrium among Spatially Separated Markets : Solution by Electric Analogue. *Econometrica*, *19*(1), 40–47.

Fackler, P. L., & Goodwin, B. K. (2001). Chapter 17 Spatial price analysis. *Handbook of Agricultural Economics*, *1*(PART B), 971–1024. https://doi.org/10.1016/S1574-0072(01)10025-3

Fafchamps, M. (2004). *Market Institutions in Sub-Saharan Africa*. MIT Press, Cambridge, MA.

FAO, IFAD, UNICEF, WFP, W. (2019). *The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns.* https://doi.org/10.26596/wn.201910395-97

FAO & FHI 360. (2016). *Minimum Dietary Diversity for Women- A Guide to Measurement*. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0306919217301902

FEWS Net. (2017a). *Burkina Faso: Staple Food an Livestock Market Fundamentals*. Retrieved from http://www.fews.net/west-africa/burkina-faso/market-fundamentals/october-2017

FEWS Net. (2017b). *Production and Trade Flow Map, Cowpea, Normal Year*. Retrieved from http://fews.net/west-africa/burkina-faso/production-and-trade-flo w-map/october-2017

Fischer, E., & Qaim, M. (2012). Gender, agricultural commercialization, and collective action in Kenya. *Food Security*, *4*(3), 441–453. https://doi.org/10.1007/s12571-012-0199-7

Fongar, A., Gödecke, T., Aseta, A., & Qaim, M. (2019). How well do different dietary and nutrition assessment tools match? Insights from rural Kenya. *Public Health Nutrition*, *22*(3), 391–403. https://doi.org/10.1017/S1368980018002756

Gabre-Madhin, E. (2001). Market institutions, transaction costs, and social capital in the Ethiopian grain market. In *Research Report of the International Food Policy Research Institute*. https://doi.org/10.2499/089629126xrr124

Gabre-Madhin, E. (2009). *A market for all farmers: Market institutions and smallholder participation*. CEGA Working Paper Series No. AfD-0903. University of California, Berkeley.

Gabre-Madhin, E., Barrett, C. B., & Dorosch, P. (2003). *Technological Change and Price Effects in Agriculture: Conceptual and Comparative Perspectives*. IFPRI/MTID Discussion Paper No.62.Washington, D.C.

Galtier, F., David-Benz, H., Subervie, J., & Egg, J. (2014). Les systèmes d'information sur les Marchés agricoles dans les pays en développement: nouveaux modèles, nouveaux impacts. *Cahiers Agricultures*, *23*(4–5), 245–258. https://doi.org/10.1684/agr.2014.0715

Galtier, F., & Egg, J. (2003). Le "paradoxe" des systèmes d'information de marché (SIM) : une clef de lecture issue de l'économie institutionnelle et de la théorie de la communication. *Economies et*

Sociétés, *41*, 1227-1260.

Goodwin, B. K., & Piggott, N. E. (2001). Spatial market integration in the presence of threshold effects. *American Journal of Agricultural Economics*, *83*(2), 302–317. https://doi.org/10.1111/0002-9092.00157

Govereh, J., Jayne, T. S., & James, N. (1999). Smallholder Commercialization, Interlinked Markets And Food Crop Productivity: Cross-Country Evidence In Eastern And Southern Africa. *Department of Agricultural Economics and the Department of Economics*, *Michigan State University (MSU)*, 39–50. https://doi.org/10.1111/j.1574-0862.2003.tb00133.x

Greb, F., Krivobokova, T., Munk, A., & von Cramon-Taubadel, S. (2014). Regularized Bayesian estimation of generalized threshold regression models. *Bayesian Analysis*, *9*(1), 171–196. https://doi.org/10.1214/13-BA850

Greb, F., Von Cramon-Taubadel, S., Krivobokova, T., & Munk, A. (2013). The estimation of threshold models in price transmission analysis. *American Journal of Agricultural Economics*, *95*(4), 900–916. https://doi.org/10.1093/ajae/aat006

Guyer, J. I. (1980). Household Budgets and Women's Incomes. In *ASC Working Papers (28) in African Studies Series. Boston University*. Retrieved from http://www.bu.edu/africa/

Guyer, J. I., & Peters, P. E. (1987). Conceptualizing the household: issues of theory and policy in Africa: introduction. *Development & Change*, *18*(2), 197–213.

Haider, H., Smale, M., & Theriault, V. (2018). Intensification and intrahousehold decisions: Fertilizer adoption in Burkina Faso. *World Development*, *105*, 310–320. https://doi.org/10.1016/j.worlddev.2017.11.012

Hansen, B. E., & Seo, B. (2002). Testing for two-regime threshold cointegration in vector error-correction models. *Journal of Econometrics*, *110*(2), 293–318. https://doi.org/10.1016/S0304-4076(02)00097-0

Hayami, Y., & Herdt, R. W. (1977). Market price effects of technological change on income distribution in semi-subsistence agriculture. *American Journal of Agricultural Economics*, *59*(2), 245-56.

Headey, D., Hirvonen, K., Hoddinott, J., & Stifel, D. (2019). Rural Food Markets and Child Nutrition. *American Journal of Agricultural Economics*, *101*(5), 1311–1327. https://doi.org/10.1093/ajae/aaz032

Hirvonen, K., Hoddinott, J., Minten, B., & Stifel, D. (2017). Children's Diets, Nutrition Knowledge, and Access to Markets. *World Development*, *95*, 303–315. https://doi.org/10.1016/j.worlddev.2017.02.031

Hoddinott, J., & Haddad, L. (1995). Does Female Income Share Influence Household Expenditures? Evidence From Côte D'Ivoire. *Oxford Bulletin of Economics and Statistics*, *57*(1), 77–96. https://doi.org/10.1111/j.1468-0084.1995.tb00028.x

INSD. (2017). *ANNUAIRE STATISTIQUE 2016*. Retrieved from http://www.insd.bf/n/index.php/component/content/article/12-le-burkina/28-geographie

Jamora, N., & von Cramon-Taubadel, S. (2016). Transaction Cost Thresholds in International Rice Markets. *Journal of Agricultural Economics*, *67*(2), 292–307. https://doi.org/10.1111/1477-9552.12152

Joffe, S., & Jones, S. (2004). *Stimulating Private Investment and Market Development for Agriculture: New Approaches and Experience.* Oxford Policy Management.

Johnston, D., Stevano, S., Malapit, H. J., Hull, E., & Kadiyala, S. (2018). Review: Time Use as an Explanation for the Agri-Nutrition Disconnect: Evidence from Rural Areas in Low and Middle-Income Countries. *Food Policy*, *76*(December 2017), 8–18. https://doi.org/10.1016/j.foodpol.2017.12.011

Jones, A. D., Shrinivas, A., & Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy*, *46*, 1–12. https://doi.org/10.1016/j.foodpol.2014.02.001

Judge, G., & Takayama, T. (1971). Spatial and temporal price allocation models. *Journal of International*

Economics, *3*(3), 304. https://doi.org/10.1016/0022-1996(73)90024-X

Kadiyala, S., Harris, J., Headey, D., Yosef, S., & Gillespie, S. (2014). Agriculture and nutrition in India: Mapping evidence to pathways. *Annals of the New York Academy of Sciences*, *1331*(1), 43–56. https://doi.org/10.1111/nyas.12477

Karlan, D., Knight, R., & Udry, C. (2015). Consulting and capital experiments with microenterprise tailors in Ghana. *Journal of Economic Behavior and Organization*, *118*, 281–302. https://doi.org/10.1016/j.jebo.2015.04.005

Kazianga, H., & Wahhaj, Z. (2013). Gender, social norms, and household production in Burkina Faso. *Economic Development and Cultural Change*, *61*(3), 539–576. https://doi.org/10.1086/669258

Komatsu, H., Malapit, H. J. L., & Theis, S. (2018). Does women's time in domestic work and agriculture affect women's and children's dietary diversity? Evidence from Bangladesh, Nepal, Cambodia, Ghana, and Mozambique. *Food Policy*, *79*(February), 256–270. https://doi.org/10.1016/j.foodpol.2018.07.002

Koussoubé, E., & Nauges, C. (2017). Returns to fertiliser use: Does it pay enough? Some new evidence from Sub-Saharan Africa. *European Review of Agricultural Economics*, *44*(2), 183–210. https://doi.org/10.1093/erae/jbw018

Krivonos, E. (2004). The Impact Of Coffee Market Reforms On Producer Prices And Price Transmission. *American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005*, (202), 44. Retrieved from https://ageconsearch.umn.edu/record/19315/files/sp05kr02.pdf

Kurosaki, T. (2003). Specialization and diversification in agricultural transformation: The case of West Punjab, 1903-92. *American Journal of Agricultural Economics*, *85*(2), 372–386. https://doi.org/10.1111/1467-8276.00126

Langyintuo, A. S., Lowenberg-DeBoer, J., Faye, M., Lambert, D., Ibro, G., Moussa, B., … Ntoukam, G. (2003). Cowpea supply and demand in West and Central Africa. *Field Crops Research*, *82*(2–3), 215–231. https://doi.org/10.1016/S0378-4290(03)00039-X

Lo, M. C., & Zivot, E. (2001). Threshold cointegration and nonlinear adjustment to the law of one price. *Macroeconomic Dynamics*, *5*(4), 533–576.

Low, J. W., Mwanga, R. O. M., Andrade, M., Carey, E., & Ball, A. M. (2017). Tackling vitamin A deficiency with biofortified sweetpotato in sub-Saharan Africa. *Global Food Security*, *14*(January), 23–30. https://doi.org/10.1016/j.gfs.2017.01.004

MAFAP/FAO. (2013). *Analyse Des Incitations et Penalisations Pour Le Sorgho Au Burkina Faso*. Rome, Italy: FAO.

Malapit, H. J. L., Kadiyala, S., Quisumbing, A. R., Cunningham, K., & Tyagi, P. (2015). Women's Empowerment Mitigates the Negative Effects of Low Production Diversity on Maternal and Child Nutrition in Nepal. *Journal of Development Studies*, *51*(8), 1097–1123. https://doi.org/10.1080/00220388.2015.1018904

Mather, D., Boughton, D., & Jayne, T. S. (2013). Explaining smallholder maize marketing in southern and eastern Africa: The roles of market access, technology and household resource endowments. *Food Policy*, *43*, 248–266. https://doi.org/10.1016/j.foodpol.2013.09.008

Mcintosh, C., Sarris, A., & Papadopoulos, F. (2013). Productivity, credit, risk, and the demand for weather index insurance in smallholder agriculture in Ethiopia. *Agricultural Economics (United Kingdom)*, *44*(4–5), 399–417. https://doi.org/10.1111/agec.12024

Meyer, J., & von Cramon-Taubadel, S. (2004). Asymmetric price transmission: A survey. *Journal of Agricultural Economics*, *55*(3), 581–611. https://doi.org/10.1111/j.1477-9552.2004.tb00116.x

Michler, J., Tjernstrom, E., Verkaart, S., & Mausch, K. (2018). Money Matters: The Role of Yields and Profits in Agricultural Technology Adoption. In *SSRN*. https://doi.org/10.2139/ssrn.3174824

MIDT. (2015). *Tableau de bord 2013 du Ministère des infrastructures , du désenclavement et des transports*. Ouagadougou, Burkina Faso.

Ministry of Health of Burkina Faso. (2016). *Enquêtes nutritionnelles nationale. SMART survey Burkina Faso*. 53. Retrieved from https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/smart_2016.pdf

Montalbano, P., Pietrelli, R., & Salvatici, L. (2018a). Participation in the market chain and food security: The case of the Ugandan maize farmers. *Food Policy*, *76*, 81–98. https://doi.org/10.1016/j.foodpol.2018.03.008

Montalbano, P., Pietrelli, R., & Salvatici, L. (2018b). Participation in the market chain and food security: The case of the Ugandan maize farmers. *Food Policy*, *76*, 81–98. https://doi.org/10.1016/j.foodpol.2018.03.008

Nakelse, T., Dalton, T. J., Hendricks, N. P., & Hodjo, M. (2018). Are smallholder farmers better or worse off from an increase in the international price of cereals? *Food Policy*, *79*, 213–223. https://doi.org/10.1016/j.foodpol.2018.07.006

Njuki, J., Kaaria, S., Chamunorwa, A., & Chiuri, W. (2011). Linking smallholder farmers to markets, gender and intra-household dynamics: Does the choice of commodity matter? *European Journal of Development Research*, *23*(3), 426–443. https://doi.org/10.1057/ejdr.2011.8

North, D. C. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge University Press.

Obstfeld, M., & Taylor, A. M. (1997). Nonlinear aspects of goods-market arbitrage and adjustment: Heckscher's commodity points revisited. *Journal of the Japanese and International Economies*, *11*(4), 441–479. https://doi.org/10.1006/jjie.1997.0385

Ogutu, S. O., Gödecke, T., & Qaim, M. (2019). Agricultural Commercialisation and Nutrition in Smallholder Farm Households. *Journal of Agricultural Economics*. https://doi.org/10.1111/1477-9552.12359

Ogutu, S. O., & Qaim, M. (2019). Commercialization of the small farm sector and multidimensional poverty. *World Development*, *114*, 281–293. https://doi.org/10.1016/j.worlddev.2018.10.012

Olwande, J., Smale, M., Mathenge, M. K., Place, F., & Mithöfer, D. (2015). Agricultural marketing by smallholders in Kenya: A comparison of maize, kale and dairy. *Food Policy*, *52*, 22–32. https://doi.org/10.1016/j.foodpol.2015.02.002

Papke, L. E., & Wooldridge, J. M. (2008). Panel data methods for fractional response variables with an application to test pass rates. *Journal of Econometrics*, *145*(1–2), 121–133. https://doi.org/10.1016/j.jeconom.2008.05.009

Parlasca, M. C., Mußhoff, O., & Qaim, M. (2020). Can mobile phones improve nutrition among pastoral communities? Panel data evidence from Northern Kenya. *Agricultural Economics (United Kingdom)*, (November 2019), 1–14. https://doi.org/10.1111/agec.12566

Pemou, B. (2016). *Etude Pour l'etablissement d'une Situation De Reference Des Stocks Commerçants Et Des Stocks Institutionnels Au Burkina Faso*. ECOAGRIS /CILSS. Centre Régional AGRHYMET, Niamey, Niger.

Pingali, P. L. (1997). From Subsistence to Commercial Production Systems: The Transformation of Asian Agriculture. *American Journal of Agricultural Economics*, *79*(2), 628–634. https://doi.org/10.2307/1244162

Porteous, O. (2020). Trade and agricultural technology adoption: Evidence from Africa. *Journal of Development Economics*, *144*(February 2019), 102440. https://doi.org/10.1016/j.jdeveco.2020.102440

Poussart-Vannier, M. (2006). *eux d'acteurs dans le système alimentaire Burkinabé. Normes, conflits et compromis dans le marché céréalier et la gestion de l'aide alimentaire d'urgence*. Thèse de doctorat en sociologie, IEDES-Université Paris I Panthéon-Sorbonne, décembre 2006.

Radchenko, N., & Corral, P. (2018). Agricultural Commercialisation and Food Security in Rural Economies: Malawian Experience. *Journal of Development Studies*, *54*(2), 256–270. https://doi.org/10.1080/00220388.2017.1283014

Rao, N., Gazdar, H., Chanchani, D., & Ibrahim, M. (2019). Women's agricultural work and nutrition in South Asia: From pathways to a cross-disciplinary, grounded analytical framework. *Food Policy*, *82*(November 2018), 50–62. https://doi.org/10.1016/j.foodpol.2018.10.014

Remans, R., DeClerck, F. A. J., Kennedy, G., & Fanzo, J. (2015). Expanding the view on the production and dietary diversity link: Scale, function, and change over time. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(45), E6082. https://doi.org/10.1073/pnas.1518531112

Renkow, M., Hallstrom, D. G., & Karanja, D. D. (2004). Rural infrastructure, transactions costs and market participation in Kenya. *Journal of Development Economics*, *73*(1), 349–367. https://doi.org/10.1016/j.jdeveco.2003.02.003

Rios, R. A., William, A. M., & Gerald, E. S. (2008). Linkages between Market Participation and Productivity : Results from a Multi-Country Farm Household Sample. *Prepared for Presentation at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27-29, 2008*.

Ruel, M. T., Quisumbing, A. R., & Balagamwala, M. (2018). Nutrition-sensitive agriculture: What have we learned so far? *Global Food Security*, *17*(January), 128–153. https://doi.org/10.1016/j.gfs.2018.01.002

Ruijs, A. (2005). *Cereal Trade in Developing Countries : A Stochastic Equilibrium Analysis and Institutional Changes in Burkina Faso*. Environmental Economics and Natural Resources Group, Wageningen University,Wageningen, The Netherlands.

Sadoulet, E., & de Janvry, A. (1995). Quantitative development policy analysis. In *Baltimore MD: The Johns Hopkins University Press* (Vol. 19). https://doi.org/10.1111/j.1574-0862.1998.tb00540.x

Salazar, C., Ayalew, H., & Fisker, P. (2019). Weather Shocks and Spatial Market Efficiency: Evidence from Mozambique. *Journal of Development Studies*, *55*(9), 1967–1982. https://doi.org/10.1080/00220388.2018.1528352

Samuelson, P. A. (1952). Spatial Price Equilibrium and Linear Programming. *American Economic Review*, *42*, 283–303.

Shikuku, K. M., Okello, J. J., Wambugu, S., Sindi, K., Low, J. W., & McEwan, M. (2019). Nutrition and food security impacts of quality seeds of biofortified orange-fleshed sweetpotato: Quasi-experimental evidence from Tanzania. *World Development*, *124*, 104646. https://doi.org/10.1016/j.worlddev.2019.104646

Sibhatu, K. T., & Qaim, M. (2017). Rural food security, subsistence agriculture, and seasonality. *PLoS ONE*, *12*(10), 1–15. https://doi.org/10.1371/journal.pone.0186406

SP/CPSA/MASA. (2013). *Situation de référence des principales filières agricoles au Burkina Faso : Rapport final*. Ouagadougou, Burkina Faso.

Sraboni, E., Malapit, H. J., Quisumbing, A. R., & Ahmed, A. U. (2014). Women's empowerment in agriculture: What role for food security in Bangladesh? *World Development*, *61*, 11–52. https://doi.org/10.1016/j.worlddev.2014.03.025

Staatz, J. M., Dioné, J., & Dembélé, N. N. (1989). Cereals market liberalization in Mali. *World Development*, *17*(5), 703–718. https://doi.org/https://doi.org/10.1016/0305-750X(89)90069-7

Stifel, D., & Minten, B. (2017). Market Access, Well-being, and Nutrition: Evidence from Ethiopia. *World Development*, *90*(Essp Ii), 229–241. https://doi.org/10.1016/j.worlddev.2016.09.009

Stiglitz, J. E. (1989). *American Economic Association Markets , Market Failures , and Development Author (s): Joseph E . Stiglitz Source : The American Economic Review , Vol . 79 , No . 2 , Papers and Proceedings of the Hundred and First Annual Meeting of the American Economic*. *79*(2), 197–203.

Strasberg, P. J., Jayne, T. S., Yamano, T., Nyoro, J., Karanja, D., & Strauss, J. (1999). *Effects Of Agricultural Commercialization On Food Crop Input Use And Productivity In Kenya*. MSU International Development Working Paper No. 71.

Suri, T. (2011). Selection and Comparative Advantage in Technology Adoption. *Econometrica*, *79*(1), 159–209. https://doi.org/10.3982/ECTA7749

Theriault, V., Smale, M., & Haider, H. (2018). Economic incentives to use fertilizer on maize under differing agro-ecological conditions in Burkina Faso. *Food Security*, *10*(5), 1263–1277. https://doi.org/10.1007/s12571-018-0842-z

Thomas, D. (1990). Intra-Household Resource Allocation: An Inferential Approach. *The Journal of Human Resources*, *25*(4), 635–664.

Timmer, C. P. (1997). Farmers and Markets: The Political Economy of New Paradigms. *American Journal of Agricultural Economics*, *79*(2), 621–627. https://doi.org/10.2307/1244161

Tirkaso, W., & Hess, S. (2018). Does commercialisation drive technical efficiency improvements in Ethiopian subsistence agriculture? *African Journal of Agricultural and Resource Economics*, *13*(1), 44–57.

Todorova, T. (2016). Transaction Costs, Market Failure and Economic Development. *Journal of Advanced Research in Law and Economics*, *7*(3(17)). Retrieved from http://hdl.handle.net/10419/157218%0A

Tommasi, D. (2019). Control of resources, bargaining power and the demand of food: Evidence from PROGRESA. *Journal of Economic Behavior and Organization*, *161*, 265–286. https://doi.org/10.1016/j.jebo.2019.04.008

Verger, E. O., Ballard, T. J., Dop, M. C., & Martin-Prevel, Y. (2019). Systematic review of use and interpretation of dietary diversity indicators in nutrition-sensitive agriculture literature. *Global Food Security*, *20*(November 2018), 156–169. https://doi.org/10.1016/j.gfs.2019.02.004

von Braun, J. (1995). Agricultural commercialization: impacts on income and nutrition and implications for policy. *Food Policy*, *20*(3), 187–202. https://doi.org/10.1016/0306-9192(95)00013-5

Von Braun, J., & Kennedy, E. (1994). Agricultural commercialization, economic development, and nutrition. In *The Johns Hopkins University Press Baltimore and London*. https://doi.org/10.1016/0306-9192(95)90037-3

West, C. T. (2010). Household extension and fragmentation: Investigating the socio-environmental dynamics of Mossi domestic transitions. *Human Ecology*, *38*(3), 363–376. https://doi.org/10.1007/s10745-010-9317-3

WFP. (2008). *Food Consumption analysis Calculation and use of the food consumption score in food security analysis.* Rome,Italy.

World Bank. (2016). Burkina Faso Poverty and Vulnerability ,and Income Source. In *Washington DC. Report No. 115122*. https://doi.org/10.1596/27943

Wu, W., Chien, H., Sakurai, T., & Muranaka, S. (2019). Vertical price transmission in the Nigerian cowpea market. *British Food Journal*, *121*(11), 2730–2745. https://doi.org/10.1108/BFJ-09-2018-0591

Yameogo, S. F. (2014). *Impact de la gestion des stocks publics des produits vivriers sur le warrantage au Burkina Faso*. Mémoire de fin d'étude, Diplôme de Mastère en Sécurité Alimentaire et Nutritionnelle du Centre Régional AGRHYMET, Niamey, Niger.

Yimer, F., & Tadesse, F. (2016). Synopsis: Women's empowerment in agriculture and dietary diversity in Ethiopia. In *ESSP research note 55. International Food Policy Research Institute (IFPRI).* Retrieved from https://ideas.repec.org/p/fpr/essprn/55.html