THE EFFECTS OF PARTICIPATION IN FARMER ORGANIZATIONS ON PRODUCTION EFFICIENCY: EVIDENCE FROM COARSE GRAIN FARMERS IN MALI

By

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ABSTRACT

THE EFFECTS OF PARTICIPATION IN FARMER ORGANIZATIONS ON PRODUCTION EFFICIENCY: EVIDENCE FROM COARSE GRAIN FARMERS IN MALI

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Increasing agricultural productivity is at the core of the Government of Mali's strategies to reduce poverty and achieve food security. Dry cereals, such as maize, sorghum, and millet, support the livelihoods of more than 60 percent of the Malian population. Public interventions to boost dry cereal productivity have mostly focused on investments to develop and promote farm intensification strategies. Historical data shows that yields have not responded proportionally. This study looks at an alternative approach on how to address the problem of low production performance. It emphasizes efficiency gains in the farm resource allocations, as a sustainable way to achieve productivity gain. Following a parametric approach, stochastic frontier Cobb-Douglas production functions for sorghum and maize are estimated. The levels of technical and allocative inefficiency in the production of these cereals are derived. Furthermore, the role of farmer organizations, as potential drivers to enhancing production efficiency, is investigated. Using a Propensity Score Matching approach, the marginal effects of membership in farmer organizations (FOs) and under different participation regimes are estimated. The results show that overall, membership in farmer organizations improves technical efficiency and reduces the costs of technical and allocative inefficiencies. Moreover, the results corroborate the fact that farmers who participate more actively in their FOs (e.g., group purchase of inputs, group sale or both) are more efficient. These findings suggest that addressing market imperfections and covering the market-related risks could incentivize farmers to adopt efficiency-increasing production decisions.

I dedicate this work to my parents Mamadou Sissoko and M'Madama Sylla for the education I received and for being a model of courage and integrity. I am grateful for your trust, blessings, and love. To my sister Tounko and brothers Moussa and Fousseyni, I am humbled by your respect and affection. To my friend and confidant, Mahmud Dicko, I thank you for standing with me in all circumstances.

In your love, I took ground and found the strength to persevere on the path that has led me here.

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KEY TO ABBREVIATIONS

GOM	Government of Mali
FO	Farmer Organization
GRPSM	Rural Associations of Producers and Mutual Supports
OPAM	Office of Malian Agricultural Products
SOMIEX	Malian Import and Export Company
CMDT	Malian Company for Textile Development
NGO	Non-Governmental Organization
ON	Office of Niger
OPA	Professional Agricultural Organizations
PAPAM	Agricultural Productivity Growth Project of Mali
PNISA	National Plan of Investment in the Agricultural Sector
ULPC	local union of cereal producers

1. INTRODUCTION

1.1. Motivation

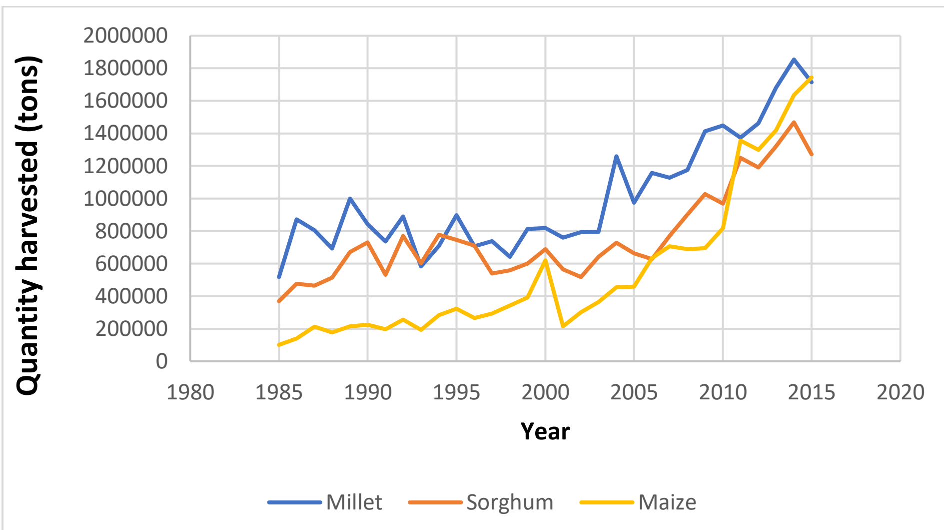
Agriculture is the backbone of Mali’s economy, accounting for 40% of its GDP. Agricultural exports represent more than half of the Total Malian exports (World Bank 2016). Over two-thirds of the country’s labor force is involved in agricultural activities (INSTAT 2017). About 60% of the 17 million Malians live in rural areas, where agriculture is the primary source of income and employment (Lazarus 2013). Yet, poverty is still high among rural people. For these reasons, the agricultural sector remains at the heart of the national strategies aimed at reducing poverty and promoting economic growth in Mali.

Cereals are the most important agricultural commodities in Mali, both regarding food security and cropland use. About 90% of farmers produce cereals for subsistence purposes (Chauvin, Mulangu and Porto 2012). Cereals, such as rice, maize, millet, and sorghum, covered 77% of the total cultivated area (CountrySTAT 2008). These crops provide approximately 65% of the total food supply (kcal/capita/day) in Mali compared to an average of approximately 45% in West Africa (FAOSTAT 2013).

Coarse grains, which include maize, millet, and sorghum, are the main staple crops grown by rural farmers. Millet and sorghum are particularly well-adapted to the harsh agro-ecological conditions of Mali. They are less demanding of water and other inputs than many other crops, making them accessible to poor smallholder farmers (CGIAR 2014). Coarse grains account for about 85% of the total land devoted to cereal crops (CPS/SDR 2016). Current per capita consumption of coarse grains in Mali is about 168 kg/year compared to approximately 83kg/year and 14kg/year for rice and wheat, respectively (FAO/GIEWS 2016).

Over the last 20 years, maize, millet, and sorghum production have been increasing (Figure 1). During the same period, the cultivated areas have notably increased while yields have remained stagnant[1] (Figures 2 and 3). A Pearson correlation test between the total production of coarse grains and areas cultivated gives an average correlation coefficient of 0.87, while the average correlation coefficient between production and yields is 0.59. Thus, the increase of the production of coarse grains over the last two decades has been a result of land extensification. Overall, the coarse grain sector has poorly performed regarding productivity gains.

Figure 1: Production of coarse grains in Mali, from 1985 to 2015



[1] The spike observed in maize yields in 2011 can partially be explained by the cotton sector crisis between 2005 and 2010, which led to a drastic decline in cotton prices and areas cultivated (MAFAP 2013). Maize is cultivated in the main cotton production zones. It is the second most important cash crop after cotton. Anecdotal stories report that the drop in cotton prices has led some cotton growers to deviate subsidized inputs destined to cotton to their maize plots.

Figure 2: Areas cultivated of coarse grains, from 1985 to 2015

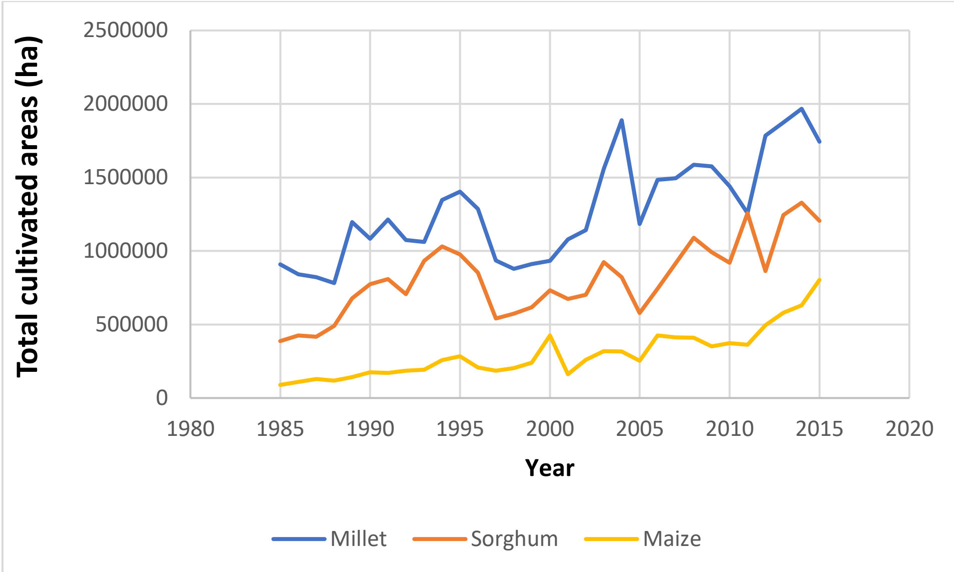
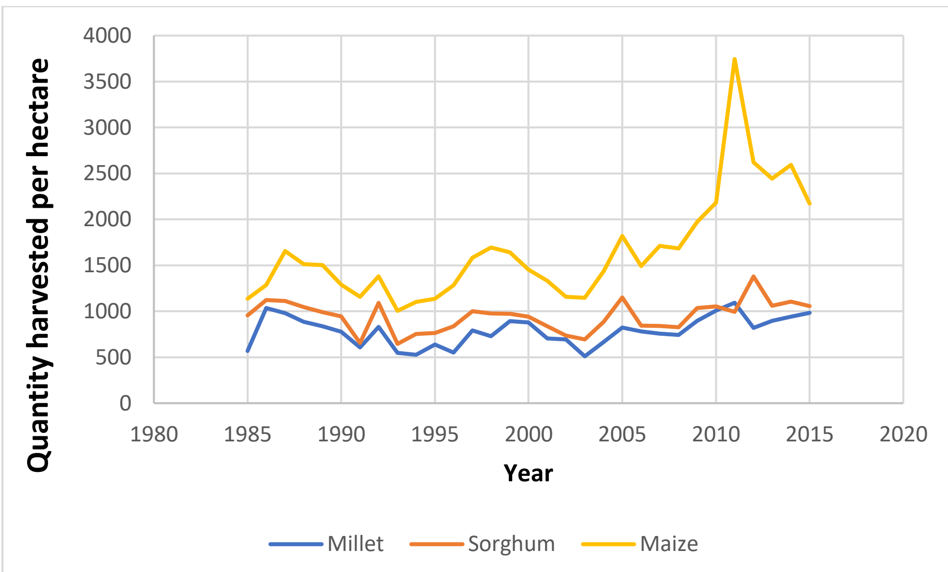


Figure 3: Yields of coarse grains in Mali, from 1985 to 2015



Source: (INSTAT 2014)

Mali is self-sufficient in producing coarse grains. However, in the long run, the land-intensive production of those crops cannot be sustained, first, because "extensification" can be a driver of natural resource degradation and deforestation. Second, the Malian population is expected to more than double by 2050. Over half of the population will be urban and per capita income is also expected to grow (Hollinger and Staatz 2015). With population growth and expansion of cities, the agricultural sector would be in direct competition with other sectors of the economy to access whatever land remains available. Note that most of the fertile land has already been exploited. Within the agricultural sector, the limited fertile land available would have to be competitively allocated across agricultural activities. On the one hand, rice, wheat, meat and milk products are highly demanded, mainly by urban consumers, as evidenced by their high-income elasticity (Hollinger and Staatz 2015). On the other hand, coarse grains are pivotal to rural food security and often seen as the food of the poor. It is thus imperative to increase agricultural productivity, especially for coarse grains, to ensure that the supply of the staple food meets the demand for the low-income segment of the population.

As highlighted by Christiaensen, Punam and Aly (2013), poverty alleviation in Africa depends on increasing productivity of staple crops. They claim that 1% growth in agriculture, induced by cereals and tubers productivity gains, reduces national poverty by more than 1 % and generates a higher poverty reduction than if export crops drove the growth. Their claim is consistent with the fact that most poor smallholder farmers rely on staple crops for their livelihoods.

Increasing agricultural productivity is at the core of the Government of Mali's (GOM) strategies to reduce poverty and achieve food security. The PAPAM[2] and PNISA[3] are two national programs that translate the political will and commitment to support agricultural productivity growth in Mali (GOM 2015, GOM 2010). These programs allocate considerable funding to develop and promote agricultural intensification, including modernization strategies. They support investments in large irrigation infrastructures, inputs subsidies as well as research and development

[2] PAPAM: Agricultural productivity growth project in Mali initiated in 2010 and funded for a period of 7 years
[3] PNISA: National Plan for Priority Investment in the Agricultural Sector

of new crop technologies (i.e., improved seeds). For instance, through the PNISA, about USD 119 million is budgeted to encourage intensification and modernization of the coarse grain production. However, given their high costs, these policy interventions are unlikely to be sustained over more extended periods of time.

Moreover, adoption of agricultural intensification technologies by smallholder farmers in developing countries continues to be highly constrained. According to Kaminski, Elbehri and Samake (2013), the persistent low sorghum and millet yields in Mali can be attributed to the lack of input use as smallholder farmers face difficulties in accessing inputs due to liquidity and credit constraints. Despite the existence of improved seed varieties and management techniques, constraints linked to technology adoption, market failures and lack of public and private support to extension services are significant drivers of the poor performance in the coarse grain sector (Kaminski, Elbehri and Samake 2013, Staatz, et al. 2011).

Efficiency gains could be a cost-effective way to achieve productivity gains in the Malian agriculture. Following Farrell (1957), efficiency is defined as the success of a firm in producing the maximum possible outputs given a set of inputs (this refers to technical efficiency) or as the success in choosing the optimal cost-minimizing set of inputs given a level of outputs (this refers to allocative efficiency). In Fried, Schmidt and Lovell (1993), Grosskoft defines factor productivity growth as the net change in output due to changes in efficiency and technical change. While technical change captures output growth resulting from the shift in production technology between two periods of time, efficiency reflects output gains due to the changes in inputs utilization. Latruffe (2010) identifies three sources of productivity growth: 1) increase in efficiency, 2) economies of scale, and 3) technological progress. In the context of this study, smallholder farmers use their inputs in an efficient way when they can produce more outputs with the same level of inputs. Efficiency, thus, implies the possibility of achieving higher results with the resources already available. It is an indicator of production performance.

Provision of technical assistance and support services, such as credit, can be crucial for efficiency gains since they facilitate farmers'access to inputs as well as information on better farm management practices. Bokusheva and Kumbhakar (2008) argue that non-optimal use of production inputs may result from financial constraints that limit their purchase. Abdallah (2016) investigated the link between access to agricultural credit and technical efficiency in Ghana and found that access to credit increases farmers'efficiency by 4%. Furthermore, exposure to extension services has been found to improve efficiency. Nordin and Sören (2017) found that extension visits contributed to more efficient uses of fertilizer and, thereby, to increased production in Sweden.

Following the liberalization of cereals markets in the 1990s, the GOM has withdrawn from providing support services to smallholder farmers and has transferred much of its responsibility to farmer organizations (Staatz, et al. 2011). Farmer organizations (FOs) have played a key role in providing smallholder farmers with information, technical assistance, and support services. Here, an FO refers to an "*autonomous association of men or women who unit voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise* " (FAO 2012).

Farmer organizations provide their members with a package of services that can induce productivity and efficiency gains. For instance, dissemination and exchange of knowledge is a core component of the activities undertaken by FOs and, as discussed above, are efficiency-enhancing factors. Through their membership to FOs, smallholder farmers can share their farming experience and learn about new management techniques and technologies from their peers as well as from external experts. Moreover, farmer organizations can facilitate access to input credits and input subsidies, which relax the financial constraints faced by smallholder farmers and in turn, encourage input use. They can also provide farmers with input and output price and market information, which contributes to reducing transaction costs (Verhofstadt and Maertens 2014).

In Mali, farmer organizations have served as an interface with buyers, by grouping production and negotiating the terms of exchange (Vroegindewey, Theriault and Staatz Forthcoming). Some FOs with stronger organizational capacity have even been able to negotiate input loans for their members, make a bulk purchase of inputs, and acquire subsidized fertilizer. Others have provided farm equipment loans, rental services, crop insurance, and literacy training to their members (Vroegindewey, Theriault and Staatz Forthcoming). The provision of such supports services confers to the organizations the capacity to enhance production efficiency of their members.

1.2. Objectives of the study

The broad objective of this study is to investigate whether participation in farmer organizations (including cooperatives and farmer associations) improves technical and allocative efficiency on maize and sorghum cultivated plots in Mali. The study aims to identify the effect of membership, as well as the effect of different types of membership, referred to as "participation regimes." Four participation regimes are defined: 1) members who use the FO channel for input provision service only, 2) members who use the FO channel for group marketing service only; 3) members who use the FO as a channel for both input and marketing services and, 4) members who do not use any input or marketing services.

To achieve this objective, the study addresses the following research questions:

- Q1: What is the average technical efficiency among sorghum and maize smallholder farmers?
- Q2: How are inputs of these crops (i.e., labor, fertilizer, herbicides, and seeds) allocated *vis a vis* the optimal use?
- Q3: What are the costs associated with technical and allocative inefficiency?
- Q4: Does membership in farmer organizations influence technical and allocative efficiency as well as their related costs?
- Q5: Does efficiency differ across different participation regimes?

The hypotheses underlying those research questions are:

- H1: The Malian maize and sorghum farmers are operating at a low level of efficiency.
- H2: Inputs are non-optimally allocated
- H3: There are high costs associated with low efficiency
- H4: Being a member of an FO improves both technical and allocative efficiency and reduces the costs of productive inefficiency.
- H5: Farmers who participate in input provision and/or output marketing services are, on average, more efficient than non-participants.

Answering those questions will shed light on the types of services offered by FOs that sorghum and maize smallholder farmers most value. It will also inform on the channels through which membership affects efficiency. This information is valuable to formulate policy interventions tailored to the needs of the organizations and their members. The ultimate goal is to find ways to improve the productivity of coarse grains to reduce poverty and achieve food security in Mali.

1.3. Contributions from the study

This study makes several contributions to the literature. First, studies on farmers' decisions to patronage their organizations (referring to the participation regimes) have not been examined from an efficiency 's point of view. So far, previous studies have explained the motivating reasons behind the choice of the participation regimes. However, these studies have overlooked the relationship between the participation regimes and technical and allocative efficiency (Fischer and Qaim 2014, Mujawamariya, D'Haese and Speelman 2013, Cechin, et al. 2013, Pascucci, Gardebroek and Dries 2012, Bhuyan 2007).

Second, studies that estimated agricultural production efficiency show only evidence of membership effect on efficiency scores (Abate, Gian Nicola and Kindie 2014, Addai, Victor and Gideon 2014, Boubacar, et al. 2016, Debebe, et al. 2015). To our knowledge, none of them have analyzed the individual effects of different participation regimes on technical and allocative efficiency.

Third, this study describes in detail the different pathways through which participation in farmer organizations can influence farm productivity and efficiency. It does so by drawing on institutional economics theories.

The rest of the thesis is organized as follows: Chapter 2 reviews the relevant literature and outlines the gap that this thesis aims to fill. Chapter 3 presents the conceptual framework describing how farmer organizations affect production efficiency. The theoretical and empirical frameworks for measuring production inefficiency and its costs, as well as the effects of FO membership, are discussed in Chapter 4. Chapter 5 describes the contextual background, including the historical evolution of cooperative movements in Mali. Chapter 6 presents the dataset. The empirical estimation models are specified in Chapter 7. Results of the analysis are discussed in Chapter 8. Main conclusions and key recommendations are drawn in Chapter 9.

2. LITERATURE REVIEW

2.1. Farmer organizations and farm performance

The literature widely covers the role of farmer organizations in improving farm performance. One strand of the literature has analyzed factors that confer those organizations the capacity to mitigate high transactions costs and market imperfections (Verhofstadt and Maertens 2014, Fischer and Qaim 2012a, Shiferaw, Hellin and Muricho 2011, B. Shiferaw, G. Obare and G. Muricho, et al. 2009, Markelova, et al. 2009, Bernard and Spielman 2009, Vroegindewey, Theriault and Staatz Forthcoming). For instance, Verhofstadt and Maertens (2014) mentioned that participation in cooperatives with joint input purchase and collective marketing could improve small farmers' bargaining power *vis-a-vis* input suppliers and output buyers and can reduce transaction costs on input and output markets. This has been supported by Shiferaw, Hellin and Muricho (2011) who pointed out that through the range of services provided by the FOs (such as, marketing, financial, education, advocacy, resources pooling) members are in a better position to reduce their transaction costs. Moreover, members can better access information and new technologies and compete with larger farms and agribusinesses.

Moreover, collective marketing can reduce buyers' transaction costs considerably, by aggregating products of homogenous quality, which in turn allows FOs to negotiate better prices for their members. Vroegindewey, Theriault and Staatz (Forthcoming) developed a framework that built upon transaction cost economics to analyze market coordination choice among cereal producers in Mali. Their findings show that transaction characteristics, which determine the presence of high transaction costs, play a significant role in predicting the choice of a horizontal coordination structure (e.g., marketing cooperatives, bargaining associations or service provider cooperatives) over other types of market coordination structure. Shiferaw et al. (2009) reported that farmer organizations have the potential to mitigate the effects of imperfect markets by enabling contractual linkages to input and output markets and by promoting economic coordination in liberalized markets. According to Bernard and Spielman (2009), group inclusiveness is a major determinant explaining FOs' success to providing services to their members effectively. Group inclusiveness can be determined by the degree of openness to all interested individual farmers, the extent to which participatory decision-making is conducted and to which all individuals in the locality benefit from the activities of the organizations.

Another strand of the literature has assessed the effect of FOs on farm productivity. Findings from these studies indicated that the portfolio of services offered by the organizations to their members is a significant driver of productivity gain. By offering financial services, FOs can induce productivity-enhancing investments (Verhofstadt and Maertens 2014). Moreover, knowledge dissemination through training and extension activities may have a significant and positive impact on technology adoption and farm management practices, which ultimately result in higher productivity.

The impact of FOs on production efficiency has also been investigated. For instance, cooperative membership and exposure to extension services have been found to affect technical efficiency gains among smallholder farmers positively (Boubacar, et al. 2016, Kelemu and Workneh 2016, Debebe, et al. 2015, Hailu, Alfons and Bart 2015, Addai, Victor and Gideon 2014, Abate, Gian Nicola and Kindie 2014, Theriault and Serra 2014, Jaime and César A. 2011). In their study on rice farms in South-Western Niger, Boubacar et al. (2016) used a data envelopment analysis approach and a Tobit regression to estimate technical efficiency and identify its determinants. Their results showed an average technical inefficiency of 0.52, meaning that rice producers could decrease their inputs use by 52% while keeping their outputs at the same level. Their results also showed evidence of the mitigating effect of a cooperative on inefficiency.

Debebe et al. (2015) used a parametric approach to estimate technical and allocative efficiency among maize farmers in Ethiopia. Assuming a Cobb-Douglas production function, their stochastic frontier and dual cost frontier estimates indicated an average technical and allocative inefficiency of 38% and 43%, respectively. The results from the Tobit regression model, in the second stage of their estimation, also suggest that cooperative membership significantly affects both technical and allocative efficiency. In line with these studies, Addai, Victor and Gideon (2014) and Abate et al. (2014) used a propensity score matching approach, to draw similar conclusions regarding the effects of FOs on production efficiency. Likewise, Theriault and Serra (2013) conducted a parametric estimation of technical efficiency and its determinants using a Cobb-Douglas frontier production function for Malian cotton growers. They estimated an average technical efficiency score of 72% and found that services provided by cotton cooperatives, such as access to credit, extension services, and timely payment, are significant determinants of efficiency. They concluded that policies aiming at reducing farmers' financial stress and improving access to input-credit markets should be encouraged to improve technical efficiency in West Africa.

The differential effects of different types of organizations on the farms' performance have also been addressed in the literature. Verhofstadt and Maertens, (2014) identified a broad typology of cooperatives. These include 1) marketing cooperatives, in which farm outputs are sold collectively; 2) production cooperatives, in which production resources are pooled and; 3) supply cooperatives, in which production inputs are collectively acquired. The diversity of the organizational forms and thereby, the activities were cooperatively undertaken, may lead to different effects of FOs on farm performance. As highlighted by the authors, the effects of different organizational forms on the farms' performance have not been sufficiently covered in the literature. The study carried out by Vroegindewey, Theriault, and Staatz (Forthcoming) in the context of the Malian cereal sector also pointed out the existence of different types of FOs regarding their roles and activities undertaken at the village-level. For instance, the authors distinguished between bargaining associations, marketing cooperatives, and service provider cooperatives. While the first two types intervene as an interface between producers and potential buyers to facilitate the linkages to downstream markets, the latter primarily assume the provision of training, education and credit services. Francesconi and Heerink (2011) examined the differential impact of Ethiopian cooperatives on the marketed share of outputs across different types of organizations and found that members of marketing cooperatives exhibited significantly higher marketed share as compared to non-members.

However, when farmers belong to livelihood organizations (or service provider organizations), the membership effect on the marketed share was insignificant, or even negative, in some instances. In meso-America, Hellin, Lundy and Meijer (2009) analyzed whether forming an organization is beneficial to producers of undifferentiated crops, such as maize, compared to high-value crops, such as vegetables. The authors argued that because of low transaction costs in the maize sector, FOs have a greater impact in facilitating access to inputs (e.g., improved seeds) than access to output market. In contrast to maize, tomato production is more subject to volume and price volatility due to its high level of perishability, which contributes to higher transaction costs. As such, only medium to large producers with high capital endowment can operate in the sector. For these reasons, the authors considered farmer organizations to be more beneficial to the vegetable sector than the staple crop sector regarding output market access.

One of the main threats that weaken farmer organizations and jeopardize their long-term sustainability is the low level of active participation in the organization's activities, which we refer to as "patronage decision." This leads to another strand of literature, which looks at factors that affect the decision of the members to patronize the services provided by their organizations (Wollni and Fischer 2015, Mujawamariya, D'Haese and Speelman 2013, Cechin, et al. 2013, Pascucci, Gardebroek and Dries 2012, Bhuyan 2007, Fulton and Giannakas 2001, Klein, Richards and Walburger 1997, Fulton and Adamowicz 1993). The word "patronage" is used in this literature to refer to members' participation in the activities of the organization or the actual use of the services offered by the organization. Bhuyan (2007) analyzed the determinants of the patronage behavior and found that members' socioeconomic characteristics (such as farm size, off-farm income, farm income, duration of membership) and their attitude toward the cooperative management system have a significant effect. On the other hand, Klein, Richards and Walburger (1997) found that older Albertan farmers with more landholding are more likely to patronage their cooperatives. Higher prices for farm outputs and refunds (rebates) have also been found to positively influence farmers' decisions to patronize their cooperatives (Fulton and Adamowicz 1993, Fulton and Giannakas 2001). Recently, Wollni and Fisher (2015) have argued that liquidity constraint, and the discounted value of late payments from collective marketed output are strong determinants of the patronage decision.

While previous studies on the patronage decision have focused on analyzing its determinants both as a discrete and continuous decision-making, none of them has investigated its impact on farm performance indicators, such as technical and allocative efficiency. Moreover, previous studies on its determinants have not disaggregated between different levels of patronage decisions (a.k.a participation regimes). First, some members may find it more advantageous to use the input provision services offered by the FOs only while relying on other marketing channels for their outputs. For instance, for farmers with diversified crops, collective marketing may result in higher opportunity costs if their FOs focus on specific crops or if better marketing alternatives are accessible to them (Fischer and Qaim 2014). Second, some members may be interested in collective marketing services only because they face high transaction costs in selling their outputs.

Third, some farmers may face market failures in both input and output markets and thus, patronaging the FO for both input provision, and collective marketing may be an optimal decision. Fourth, some farmers may only value the information and education services offered by the FOs and therefore, do not patronage either for input provision or access to output markets. Perhaps those members are wealthier farmers with a stronger social network, less liquidity-constrained, more entrepreneurial and thereby, the reasons for their membership to FOs are to enhance their knowledge. Alternatively, they may keep their membership status for non-economic reasons, such as conformity to social norms or loyalty to the organization. How these decisions translate into economic performance, such as technical and allocative efficiency, have been overlooked in the literature.

One exception is Klein, Richards and Walburger (1997) who analyzed discrete and continuous decisions to patronage cooperatives for both inputs (e.g., seed, fertilizer, fuel) and marketing (e.g., grain sales) services. They analyzed factors that determine the decision to use the cooperative channel for input procurement and output sale as well as factors that explain the amount of inputs and outputs transacted through the cooperative channel. Their results show that older farmers with large farms tend to patronage more the cooperatives both intensively and extensively. Farmers 'perception about the cooperatives' performance and competitive prices that they offered have also been found to be major determinants of the intensity of the patronage behavior. However, their analysis was limited to only identifying farmers' socioeconomic characteristics and attitudes that predict the different levels of the patronage decision. The effects of such behavior on production performance were not explored.

2.2. Cooperative movements in the Malian context: history, opportunities, and challenges

Current rural organizations in Mali are the legacy of post-colonial cooperative movements initiated by the government to structure the rural economy. The first forms of cooperatives emerged under the socialist government regime of the first Republic (1960-1968) with the creation of the GRPSM ("Groupements Ruraux de Producteurs et de Secours Mutuels") at the villages level. The GRPSM reflected the government ideology of a modernized agriculture following the collectivist socialism ideals. Participation in the GRPSM was mandatory, and each village possessed a "collective field" managed by the members of the GRPSM (Tag 1994). Surplus generated from the "collective fields" were invested in public services (e.g., roads, schools and hospitals).

Another function of the GRPSM was the provision of consumption goods to both urban and rural population in coordination with parastatal agencies such as OPAM[4] (Office of Malian Agricultural Products), SOMIEX[5] (Malian Import and Export Company), CMDT[6] (Malian Company for Textile Development) (Traore 1993). Before the liberalization of markets, OPAM was the parastatal agency controlling the cereal markets and possessed a legal monopoly over cereals trade. The CMDT was the equivalent of OPAM operating in the cotton sector. SOMIEX was a state company in charge of the imports and exports of agricultural and manufacturing goods. The undemocratic nature of the GRPSM management and the strict control over prices by

[4] OPAM: Office des Produits Agricoles du Mali
[5] SOMIEX: Societe Malienne Import Export
[6] CMDT: Compagnie Malienne du Development des Textiles

parastatal agencies led to the disengagement of rural producers, causing poor production performance on fields managed by GRPSM compared to collective and individual fields managed by the household's head and household members.

In 1982, the government of the second Republic instituted the "Tons Villageois," a village level association, to represent the primary legal, organizational unit of rural communities (Traore 1993). They were instituted as a new model of "cooperative development" with a more democratic character and intended to correct the weaknesses of the previous GRPSM models. The "Tons Villageois" were then used as an institutional tool to promote and manage economic, social and cultural development in rural areas. The main objectives assigned to these organizations were to 1) increase the productivity of rural farms by facilitating individual or group access to production inputs; 2) the organization of the bulking, storage, and commercialization of farm products; 3) the provision to members of consumption goods, equipment, and services; 4) the organization of collective savings to enable access to credits supporting production and consumption. The activities of the "Tons Villageois" were kept inscribed in the political agenda and closely related to the operations of parastatal agencies that had a legal monopoly on production and trade of the main agricultural products (such as cereals and cotton). The parastatal agencies were at the same time the only buyers of agricultural products and the main suppliers of services to the "Tons Villageois"- private operations were restricted. To accommodate the "Tons Villageois" to the democratic principles, the government allowed the creation of voluntary rural organizations in the form of "Village Associations" as transitory institutions to the establishment of the Ton Villageois.

The "Village Associations" have existed since the 1970's. In contrast to "Tons Villageois," they have been created on a voluntary basis. They are informal associations of people with no legal status. The initial goal of the creation of the "Village Associations" was to let them mature and acquire enough credentials in cooperative practices to upgrade to the status of a “Ton Villageois” (Bélières, et al. 2008). Thus, the Village Associations” before 1990, were pre-cooperative organizations with a transitory status. The first forms of these types of organizations were promoted by CMDT in the mid-1970s in the cotton production area (including the Southern Mali zone). Their functions were centered on the commercialization of cotton, especially the grading, weighing and transportation of cottonseed (Theriault and Sterns 2012). They also stood as the primary channel for farmers to access inputs and technical assistance provided by CMDT (Bélières, et al. 2008, Theriault and Sterns 2012). At that time, very few of them adopted the legal status of “Ton Villageois,” mainly to avoid the heavy administrative and legal requirements expected from such cooperative movements during the State interventionism period.

The early 1990’s experienced the reform and restructuration of state-interventionism policies with the liberalization of cereal markets. These reforms translated into the retreat of the State from production and marketing activities in the Malian cereal sector and the transfer of the market functions to the private sector. The roles of OPAM became limited to managing the national security stock and providing market information services to the private sector. The implications of these market reforms became the necessity to empower the rural organizations to take over the functions previously fulfilled by the State Agencies (Mercoiret 2006). These contextual changes led to the emergence of multiple forms of organizational movements and the engagement of NGOs (Non-Governmental Organizations) to support and defend the interests of rural producers. The Village Associations, primarily established to support cotton production, evolved into several specialized organizations (including village-level cooperatives and regional and national unions and federations) around different agricultural value chains (including coarse grain, rice, livestock, and cotton). Given their strategic and economic importance for the country, as main export crops, cotton and rice farmer organizations continue to benefit from direct government supports through inputs subsidies, credit and technical assistance provided by the CMDT and ON[7]. For cereal farmer organizations, such supports are mainly obtained from NGOs or research and development projects with the resulting downside of a dependence of some FOs lifespan on the duration of the projects supporting their activities.

In 2001, the government reformed the status of cooperative movements and established a legal framework that promotes autonomy for producers in the realization of their collective economic and social needs. The term “OPA”(Professional Agricultural Organizations) is the actual terminology used to refer to any groups of people with an agricultural vocation, who voluntarily unite to advocate their interests before public authorities and ensure the provision of goods and services to the members (CRA n.d.). The “OPAs” can assume different functions: production (e.g., inputs services), marketing (e.g., storage, group sale, and market information), credit and financial assistance, representation and advocacy of members ‘interests. From the article 27 of the Malian agricultural policy (LOA 2006), the “OPA” denomination includes cooperatives, village associations, unions of cooperatives, federations, confederations, and syndicates. Village associations, cooperatives, and their unions are the types of “OPA” concerned in this study. The difference between these types of organizations depends on the jurisdiction that defines their legal status and the scope of their activities. Unlike village associations, cooperatives have a legal status, a more sophisticated governance structure and are financially autonomous (Vroegindewey, Theriault and Staatz Forthcoming, Theriault and Sterns 2012).

[7] The ON (Office du Niger) is a government agency in Mali that manages a large irrigation scheme supporting rice production in Segou region

The rapid changes occurring in the agri-food system of developing countries, including the consolidation in the downstream sector into supermarket chains and the emergence of many modern mini retail stores and processing factories create new challenges to the rural food production systems. For instance, farmers must meet the quality and quantity requirements of a downstream sector characterized by an increasing market power, which can be costly (Reardon, et al. 2000). While some of these costs come as threshold investment costs, others are transaction costs. In this context, it is essential to identify institutions and modes of rural organizations that should govern the food production activities while mitigating these challenges (Ménard and Valceschini 2005). Since the retreat of the government from cereal markets, farmer organizations have been the main (if not the only) institutional support available to coarse grain growers, who continue to face issues of high transaction costs and inefficiency in production.

These organizations have considerable potential to scale up production in the coarse grain value chain while minimizing transaction costs (Kaminski, Elbehri and Samake 2013). Take for instance the three cases of the local union of cereal producers (ULPC), Faso Jigi, and the Cereal Banks in the Malian cereal production zone. The local union of cereal producers (ULPC) in the Dioila district, offers inputs (e.g., fertilizers, pesticides, seeds) to its members at the beginning of the cropping season, bought from its own funds. It sets a reference price, which is an average output price from three villages plus a premium (Kaminski, Elbehri and Samake 2013). After harvest, farmers deliver part of their production to the union to repay their credits. The union borrows money from banks or micro-credit institutions to purchase cereals from members and organizes grouped sales with higher prices provided to the supplying farmers. Beyond the input credit repayment scheme, members can sell their grains to the union, which organize the collective marketing.

Faso Jigi in Koutiala is another producer organization providing input credits to farmers in the form of payment advances on the quantity they committed to deliver, based on a fixed base price at the beginning of the season. The payment advances allow farmers to make investments to procure inputs for the cropping season. The remaining payment is made after harvest with deductions of interests. Collective outputs are sold to local retailers and processors, sometimes under marketing contracts with premium prices. This type of grouped marketing can be a source of income improvement and stability for farmers (Kaminski, Elbehri and Samake 2013).

The “Cereal Banks” are local development instruments used by rural organizations to address the issue of food insecurity collectively. The “Cereal Banks” act as a sort of village-level cereal warehouses, which is managed by the village associations. After the harvest period, the banks purchase grains from producers (members and non-members of village associations), collect and store them in the warehouses. The grains kept until the food shortage period are then sold to the local population at non-speculative prices (lower than market price) (AfriqueVerte n.d.). Priority is given to members of the associations managing the banks for the purchase of the grain. While the primary objective of the “Cereals Banks” is food security, a crucial implicit role of this type of collective action is to smoothen consumption risks. For most smallholder farmers in developing countries who are both buyers and sellers of staple crops, the needs to smoothen consumption can be a considerable obstacle to investing in the production activities. Therefore, participation in cereal banks can decrease farmers’ risk averseness toward consumption and increase their willingness to make productivity and efficiency increasing investments.

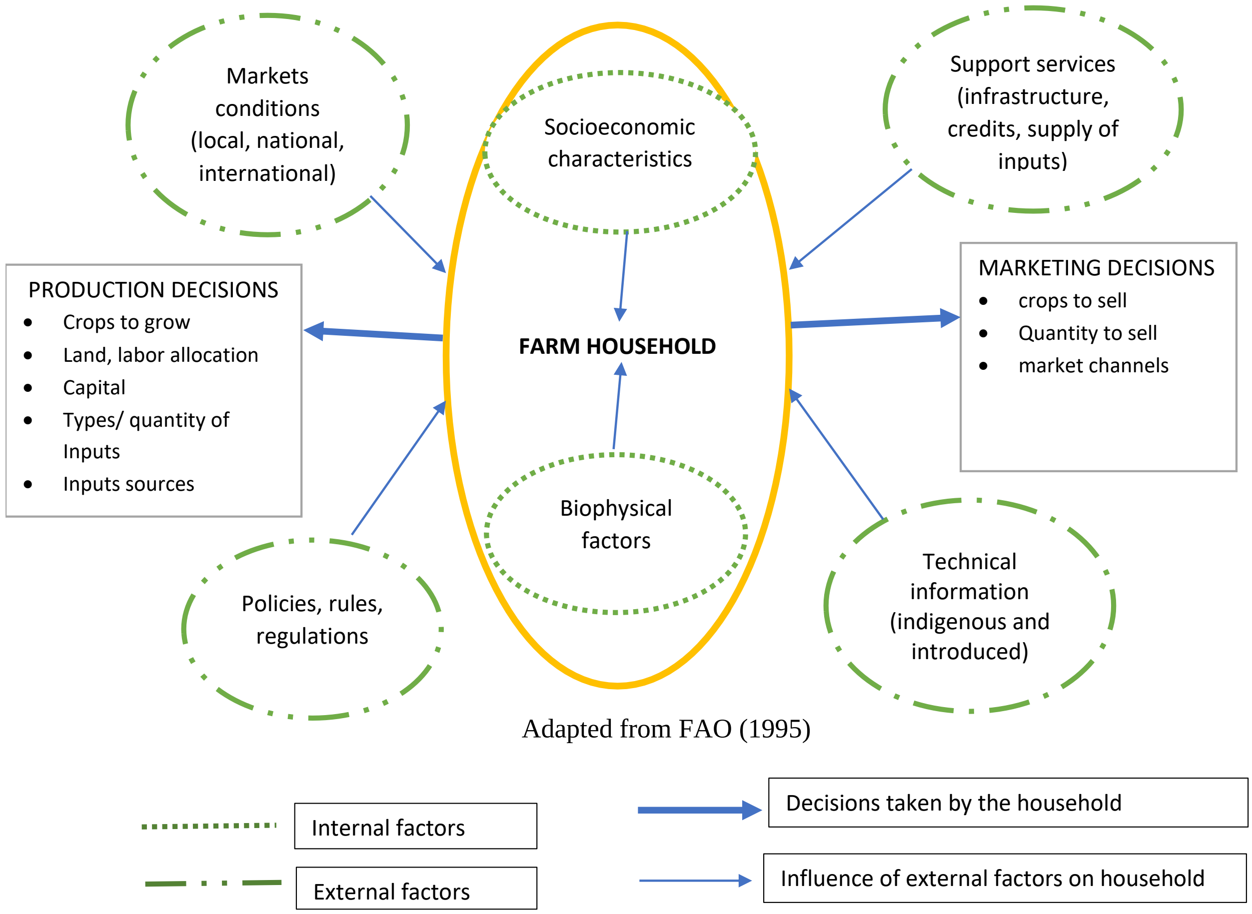
The diversity in rural organizations as well as in their functions (input provisions, group sale, food security, resources pooling) raises the question of how these organizations address the needs of smallholder farmers in this “market economy” environment. Addressing this question requires an analysis of the effects of farmers' participation in FOs on their farming activities. Since efficiency gains can be an important determinant of performance in a market economy, the focus of this study is to examine, to which extent participation in FOs can induce technical and allocative efficiency gains and reduce the costs of inefficiencies.

3. CONCEPTUAL FRAMEWORK

Technical efficiency refers to the capacity of the farm household to achieve the maximum possible output (the frontier output) with a minimum use of inputs. Alternatively, a technically efficient firm maximizes output with a given level of inputs. Allocative efficiency refers to the ability to choose the optimal input quantities that minimize costs, given the level of output and the relative factor prices. A firm's ability to achieve higher efficiency is conditioned on the decision on its input utilization.

Here, the framework of farm household-level decision making developed by FAO (1995) is adapted to illustrate the potential links between input allocation decisions and participation in farmer organizations. As seen in Figure 2, the economic activity of a farm household involves two main types of management decisions: 1) investment and marketing decisions and 2) production and conservation decisions. The first type of decisions focuses on farm product marketing decisions. The second type of decisions is related to the adoption of farm management practices, such as soil conservation and crop management practices as well as resource allocation decisions, such as labor, land, capital, and input acquisition. These two types of management decisions are influenced by both internal (e.g., farmers' socioeconomic characteristics, biophysical characteristics of the farm) and external factors to the farm household (e.g., markets, policies, support services, technical information).

Figure 4: Framework of farm household-level decision making



Adapted from FAO (1995)

Following this framework, FOs can affect production efficiency through their ability to create an enabling environment for optimal decision- making regarding both farm inputs investment and utilization. For instance, Falkowski and Ciaian (2016) explained that when farmer organizations succeed in insuring against the risks of contract hold up faced by farmers, they can indirectly contribute to moving farm investments closer to the optimum. The FOs can affect farm productivity or efficiency by reducing the investment risks on productive resources. When farmers expect that their investments will leave them vulnerable, they are unlikely to make these investments in an efficient way (Falkowski and Ciaian 2016). As farmer organizations reinforce the bargaining power of individual members, they mitigate the market risks faced by farmers and, hence, promote optimal investments and allocation of farm resources. Besides the influence of FOs on market-related factors, the provision of support services and the dissemination of technical information by FOs constitute other factors that can lead to efficiency gains.

As mentioned previously, this study hypothesizes that farmers' participation in farmer organizations, among other factors, has a positive effect on their productive efficiency by reducing output losses due to both technical and allocative inefficiencies. Drawing from the literature, there are three pathways through which the effect of FOS on efficiency can be seen: 1) knowledge and information dissemination; 2) increased access to farm inputs and; 3) reduction of transaction costs. The next sections elaborate on those pathways and how they can increase technical and allocative efficiency.

3.1. Enhanced knowledge of farm management practices

Membership in farmer organizations provides a setting for learning. As such, it influences members' productive efficiency by facilitating their access to technical and market information. Indeed, improving farmers' access to technical training and advisory services is a function that FOs aim to perform. Farmer organizations have made key contributions to the provision and enhancement of extension services by facilitating linkages between extension providers and smallholder farmers (FAO 2010). These advisory or extension services might originate from external providers (such as government extension officers, NGOs or development projects) who are more willing to work with groups of farmers than individuals (Shiferaw, Hellin and Muricho 2011).

Farmer organizations have bridged the gap between local agricultural knowledge and technical research knowledge. The flows of information received through either extension services or from other members, enhance learning about optimal input combinations that maximize the farm outputs. Farmers may learn about the optimal timing for applying inputs, which all contribute to better production outcomes. Exposure to the extension services may also make them aware of and more willing to adopt, for instance, new cropping practices, including soil fertility management practices, that improve land productivity (Junge, et al. 2009, Somda, et al. 2002).

Previous studies have identified two sources of uncertainty that constraint farmers' willingness to adopt new farm technologies (e.g., soil conservation practices and improved seeds):1) their knowledge about the optimal input mix needed to realize the maximum output level and; 2) their expectations about the profitability of the new technologies. Learning can be a crucial determinant of adoption (Foster and Rosenzweig 1995, Conley and Udry 2010, Bandiera and Rasul 2006, Besley and Case 1993, Ma and Shi 2015, Munshi 2014). Members of farmer organizations can learn from the experiences of their peers (social learning) on the optimal ways to utilize a given farm technology. By reducing the risks perceived in the adoption process of a new farming practice and by improving farmers' own experience, the learning dynamic within FOs can be an important contributor to members' production performance. As a platform for social learning, information sharing, and capacity building, farmer organizations can be a source of improvement in technical and allocative efficiency.

3.2. Improved access to inputs

Production efficiency is built upon input decisions. Thus, improved access to inputs, both physically and economically, is critical to achieving higher allocative efficiency. Indeed, *ceteris paribus*, farmers with better access to inputs are expected to have higher allocative efficiency than farmers with more limited access. Everything else equal, farmers with limited access to farm inputs are more likely to underinvest in those resources than peers whose access are less constrained. Two factors may constrain farmers' access to inputs: 1) liquidity constraint and; 2) transaction costs. While the effect of the former on access to inputs is obvious and straightforward, the effect of the latter will be explained more in details in the next section. Participation in farmer organizations can mitigate both constraints. However, in contrast to the learning benefits procured by the membership status, here members must decide to use the FO as a channel for input procurement and/or output sale to overcome liquidity constraint and transaction costs.

Most FOs distribute inputs, such as chemical fertilizers, pesticides or seeds to their members under different procurement systems. Input credit is a type of input procurement systems that some FOs make available to their members. Another procurement system offered by FOs is the provision of subsidized inputs. The FOs usually have facilitated access to input subsidies through their collaboration with NGOs, government extension services, and local development projects. However, while enhancing members' access to inputs, subsidies may lead to undesirable effects on productive efficiency. Subsidies create distortions to the free-market economy and as such, affect the relative factor prices that inform optimal input decisions.

Therefore, farmers with access to input subsidies may report higher allocative inefficiency than others, assuming the subsidies affect relative prices. Nevertheless, input credits and subsidies are mechanisms through which FOs may relax the liquidity constraint faced by members. Consequently, organizations can help improve members' access to productivity-increasing inputs. Considering the criterion of improved access to inputs, membership to FOs can be a source of improvement in productive efficiency, particularly the allocative efficiency.

3.3. Reduced transaction costs

Transaction costs incurred by farmers on both output and input markets can be another potential source of inefficiency for similar reasons (accessibility criterion) discussed above. A good understanding of the effects of transaction cost on inefficiency and of the way participation in FOs can mitigate those effects depend on knowing first what transaction costs are.

The theory of transaction costs is anchored in the seminal work of Coase, "The Nature of the Firm". Coase (1937) was the first to recognize that market exchange is not costless and that the rationale of the existence of a firm is to internalize some of its activities (through vertical integration), which would otherwise generate higher costs if transacted through the open market system. Firms seek to minimize their costs. Following the New Institutional Economics (NIE), transaction costs are the costs associated with the use of market institutions for the transfer of property rights between parties (Garfamy 2012, Ménard and Valceschini 2005). Since market transactions are costly, the firm arises as an alternative institution, which internalizes the organization of transfers.

Any exchange of goods and services under the open market is subject to costs shared by both parties involved in the exchange. Here, the definition of transaction costs adopted by Coase (1937) and later summarized in Hobbs (1996) and Hobbs (1997) is used. Coase defined transaction costs as the costs of discovering what prices should be, the costs of negotiating individual contracts for each transaction and the costs of accurately specifying the details of a transaction in a long-term contract (contract enforcement). Hobbs (1996, 1997) provided three main classifications of these costs:

- Information costs: costs of searching information about products, prices, inputs, buyers, and sellers. The price discovery costs depend on the extent to which there are easily accessible sources of market price information.
- Negotiation costs: costs incurred from the physical act of the transaction. These costs include transportation costs, both the monetary value and the opportunity costs of the

producer time and effort of organizing the transportation of the goods to the market (or buyers). Other coordination costs include assembling the output and storage costs.

- Monitoring and enforcement costs: arise after the exchange has been negotiated and may include the monitoring of the quality of goods from a supplier and the monitoring of the buyer behavior to ensure that all the pre-agreed terms of the contract are met.

Although the transaction cost literature has focused mostly on the output market side, all three types of transaction costs (as defined above) can be observed in input markets.

Williamson (1981) defined three transaction attributes that influence costs: i) the frequency to which transactions occur, ii) the uncertainty surrounding the transactions, and iii) the degree to which transaction-specific investments are required to realize least costs supply (a.k.a. asset specificity). Menard (2007) and Garfamy (2012) explained that relative costs of using markets for exchange depend on these attributes of the transaction. Asset specificity can arise in three different ways: site specificity (characterized by the degree of immobility of resources invested), physical asset specificity (technological advantage) and human asset specificity (arises from learning by doing, the know-how advantage). In general asset's specificity is reinforced when the resources invested in a specific production sector generate low alternative values when invested in a different sector.

Coase (1937) attributed the existence of transaction costs to the limitations of the neoclassical theory, which assumes perfect competition in a frictionless economy. Hobbs (1996) grouped these limitations under what he called the key concepts supporting transaction cost analysis: bounded rationality, opportunism, asset specificity (as defined by Williamson), and information asymmetry. Bounded rationality implies that, although individuals intend to take rational decisions, their capacity or ability to explore all possible decision options is limited.

Opportunism refers to the risk that some individuals or firms involved in transactions will seek to exploit the situation to their advantages (for instance, when few alternative suppliers are available to buyers or vice versa). Finally, the asymmetrical distribution of information among parties of an exchange arises when all parties to the transaction do not possess the same level of information. Parties might all have access to public information, but access to private information is limited to a selected group of people. Information asymmetry creates a situation of uncertainty which may lead to opportunistic behavior. Garfamy (2012) extended the list of factors explaining the costs of using market for exchanges by adding the following: low bargaining power (or the degree to which a firm has alternative suppliers or buyers to meet its needs) and loss of resource control (when a firm outsources a product it should naturally own or produce). Following the author, transaction costs can be conceptualized as a function of the cost-determining attributes of the transaction (frequency, uncertainty, asset specificity) and factors creating transactional difficulties (bounded rationality, opportunism, information asymmetry, bargaining power, and resource control).

With this theoretical review in mind, we now turn to how transaction costs may affect the allocative efficiency and how membership to FOs can mitigate their effects. The optimal condition defining allocative efficiency in production is an input quantity choice, such that the marginal value product equals the marginal cost of the inputs ($pf_1 = w_{1;}\ pf_2 = w_2$), alternatively the ratio of the marginal products equals the ratio of the prices ($f_1/f_2 = w_1/w_2$). Transaction costs may affect allocative efficiency through their distortion effects on output prices, p, or on the relative factor prices, leading to market failures. In rural economies of developing countries, transaction costs are the principal drivers of market failures (Alene 2008, Key, Sadoulet and De Janvry 2000). When a farm household participates in markets to sell and buy a given food crop or service, the difference between the sale price and buying price of the commodity determines a "price band" within which it can be advantageous for the household to participate. If within the price band, the household's shadow price (its valuation of the good or service) is less than the purchase price and higher than the sale price of the good on markets, the household will not participate. Market failures arise when the shadow price of a commodity or service falls within the price band (De Janvry, Fafchamps and Sadoulet 1991). Transaction costs can lead to market failures by enlarging the width of this price band in such a way that farmer's supply price of a commodity is higher than the prevailing market price, and his/her demand price is lower than the market price. Transaction costs thus reduce the price of a commodity or service sold by the farmer and increase the purchase price of the same goods relative to the market price. Consequently, exchange becomes disadvantageous for the farmer in either case.

Market failures can apply to both output and input goods. For instance, most of the farm households in developing countries purchase on markets (especially during the period of food shortage) the same food crops that they grow on their farms. In this case, high transaction costs will affect output prices. On the other hand, households may participate in the labor market by supplying their labor force or by hiring external labor force. For this latter case, the differences between earned wages from supplying the labor force and the costs of hiring external labor force determine the transaction costs that may create failures in this input market. Thus, through these distortion effects on prices and given that costs are household- specific, high unobserved transaction costs incurred by the farm households can be responsible for the observed allocative inefficiency.

Due to unobserved transaction costs, farmers can look inefficient in their input decisions, even though their decisions might reflect a rational choice. The mode of operation of FOs can reduce the distortion effects on input decisions due to the presence of high unobserved transaction costs.

The reason is that; FOs are more capable than individual farmers to address some of the issues regarding the transaction attributes inherent to market exchanges (i.e., the seven transaction attributes beforehand mentioned) that lead to higher costs. Membership and participation in different activities of the organizations (e.g., input procurement and group marketing) may reduce uncertainty and opportunism behavior surrounding transactions. By bulking outputs, pooling resources, organizing group sales, offering guaranteed output prices, and ensuring access to inputs, participation can lower uncertainty and risk for members.

Such collective activities can also contribute to addressing the bargaining power and the issues of control over the resources (Verhofstadt and Maertens 2014). The learning dynamic that takes place within the organizations, as well as the education services, can address the information asymmetry and bounded rationality problems when it comes to looking for low costs or high-quality inputs and better market opportunities for outputs (Shiferaw, Hellin and Muricho 2011).

The effect of membership and participation in FO's activities on asset specificity and frequency of transactions can be nuanced. For instance, when production is highly diversified for a given farmer, collective marketing may result in high opportunity costs, especially if the organization concentrates on some specific crops only or better alternatives are available to farmers (Fischer and Qaim 2014). In this case, dealing with FOs can increase members' asset specificity and inflate the transaction costs incurred. On the other hand, when members are isolated or located in remote villages, participating in group activities can reduce the costs related to the location specificity since FOs can help to bulk and coordinate the transport of members' outputs, generally a village level warehouse. In this case, the location specificity effect on transaction costs is attenuated.

4. MEASUREMENT OF FARM EFFICIENCY

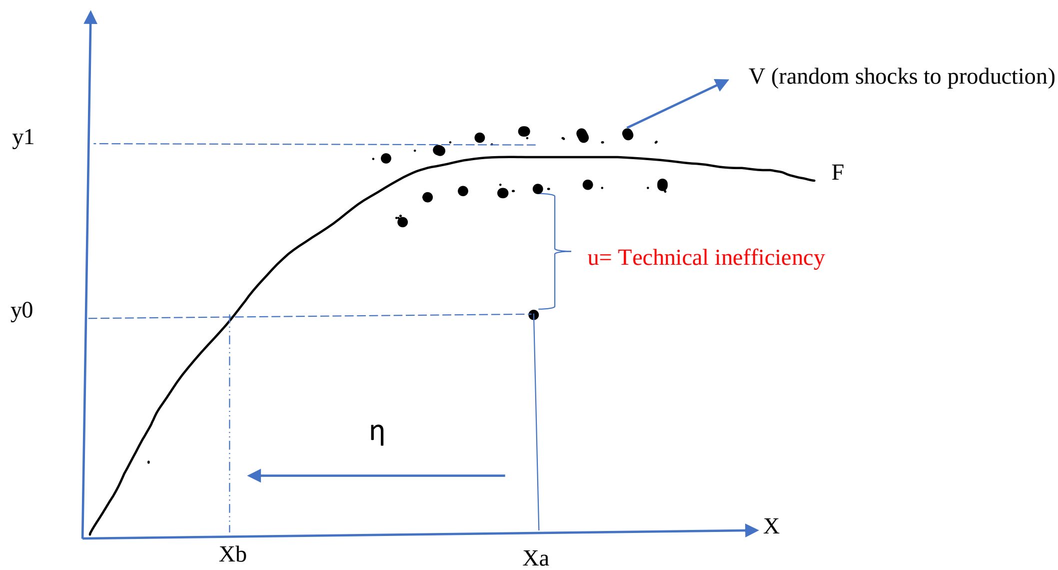
4.1. Theoretical approach

The standard producer theory provides the basic framework for production efficiency measures. Farrell (1957) has been the first to introduce the concept of productive efficiency. He distinguished two components of productive efficiency: technical efficiency (TE) and allocative efficiency (AE). In the attempt to provide a theoretical representation of these two concepts, let us assume that the farm household produces a single output, Y, using a bundle of inputs X (x_1, x_2). A theoretical representation of the farm production function is given by its production possibility frontier, F, which delineates the set of all possible outputs the farm can realize with the production technology available for a different level of the input bundle X (Schmidt 1985).

In Figure 5, each level of X represents a combination of inputs x_1 and x_2 used to produce output Y. The production frontier, F, determines the output of a fully technically efficient farm household, meaning the set of maximum possible output levels for each level of input bundle X. The set of points represented by, v, reflect any random shocks to the production; any deviation from the frontier output caused by factors outside of farmer's control (e.g., weather and economic shocks). If at input bundle level, Xa, the farmer produces output level, Y_0, his/her technical inefficiency, u, is represented by the deviation from the production frontier function while taking into account random shocks (v) to the production. At the input level, Xa, the fully efficient output level would have been to produce the amount Y_1. The term, u, measures the Output-Oriented (OO) technical inefficiency of the production given the technology available to the farmer. The OO technical inefficiency is interpreted as the proportion by which outputs can be increased, holding the level of inputs constant or the losses of outputs due to inefficiency.

Alternatively, the level of inputs can be reduced from X_a to X_b while holding the output at the same level Y_0 and moving to the frontier function, F. The proportion by which the level of inputs can be reduced holding outputs constant at its efficient level represents the Input-Oriented (IO) technical inefficiency. In Figure 5, the IO technical inefficiency is represented by, η, and expresses the overuse of inputs due to inefficiency or the increase in input costs resulting from technical inefficiency.

Figure 5: Frontier production function and technical inefficiency



There is no significant distinction between OO and IO technical inefficiency measures, except that they represent alternative perspectives of technical inefficiency. As pointed out by Kumbhakar, Wang and Horncastle (2015), the choice of examining IO or OO technical inefficiency depends on whether outputs or inputs are considered exogenous. For instance, in a sector where the output level that each firm can produce is regulated (e.g., production quota), the firm optimization decision-making will be reduced to choosing the level of inputs that maximize outputs or reduce the costs of production. In this case, estimating IO-technical inefficiency becomes more suited. In the framework of this study, the level of outputs that each farm can produce is not restricted or regulated, therefore estimating the OO technical inefficiency makes more sense. However, since the estimation of the costs of inefficiency is one of the objectives of this study, the IO technical inefficiency will also be estimated as it offers a more straightforward interpretation of the costs induced by technical inefficiency.

One can also assume either a heteroscedastic or a homoscedastic technical inefficiency. A homoscedastic technical inefficiency implies that the variance of the firm's inefficiency (δu) is constant. In contrast, a heteroscedastic inefficiency assumption implies that the variance of u varies in function of some variables. For this study, the output-oriented heteroscedastic technical inefficiency is assumed. Following Kumbhakar, Wang and Horncastle (2015), a production function with OO technical inefficiency can be mathematically written as:

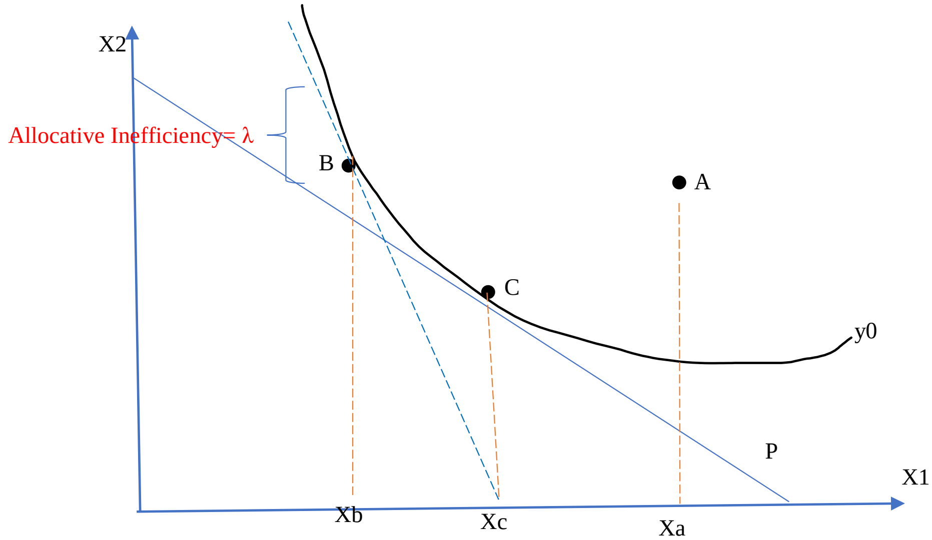
$$Y = F(X).e^{v-u}, \quad u \geq 0$$

Where u measures the OO technical inefficiency, e^{-u} is the measure of OO technical efficiency (TE) and $0 \leq (e^{-u}) \leq 1$. A fully efficient farmer has a value of e^{-u} equals to 1.

Regarding the allocative inefficiency, let us consider Figure 6, where the curve y0 represents the efficient isoquant of the firm or the isoquant of its production frontier. On the curve y0, each combination of the bundle of inputs X(x1, x2) yields the output level, y0, which is the maximum feasible outputs given the technology available. Note that, while the efficient isoquant can be conceptualized in theory, in practice, it is not observed and can only be estimated.

Now, let us assume that the slope of the line, P, represents the input price ratio (w_1 / w_2), so that line P gives us the isocost curve of the production. Following the producer theory, the optimal quantities of inputs to use are given at point C, at the tangency of the isoquant and isocost lines.

Figure 6: The efficient isoquant and allocative inefficiency



At point C, the farmer allocates the inputs in a way that minimizes its costs, while producing a technically efficient output. Therefore, the farmer is both technically and allocatively efficient at point C. The ratio of the marginal product of the two inputs is equal to the ratio of the prices of the inputs, $f_1/f_2 = w_1/w_2$ (optimality condition). At point B, this equality is not satisfied, and the departure from the optimality condition (cost-wise) is represented by the allocative inefficiency λ (Kumbhakar and Wang 2006). The difference between the slope of line P and the slope of the line tangent to y0 at point B (dotted line) measures the firm allocative inefficiency. Following Kumbhakar and Wang (2006), the input quantities at point B, are optimal with respect to the price ratio given by $(w_1/w_2)e^{\lambda}$. The term e^{λ} captures the distortion effect induced by the allocation inefficiency that creates a deviation from the optimal condition. Notice that at point B, the farmer is technical efficient since it produces on his/her efficient isoquant.

If at the point A the combination of the input bundle X (x1, x2) yields the output level y0 then the farmer will be both technically and allocatively inefficient. Indeed, if the technology used was technically efficient, the combination of inputs at point A should yield an output level y1 higher than y0. Allocative inefficiency is the possible reduction (point A to C) or increase (point B to C) in input costs to move to the optimal input use condition.

The estimation of production efficiency requires a few assumptions regarding the characteristics of the underlying efficient isoquant. The isoquant must be convex at the origin and must display a non-positive slope at every point. The convexity assumption ensures the most conservative estimates of the efficient isoquant and the non-positive slope ensures that outputs do not decrease from increasing inputs level (M. J. Farrell 1957). Details on the estimation procedure of u (OO technical inefficiency) and λ (allocative efficiency) are given in section 4.2.1 below. For each input J, λj can take both positive and negative values. A positive value means that the input pair (J, 1) is being used at a level above the cost minimizing and a negative value means that the input pair is being used at a level below the cost-minimizing (Kumbhakar, Wang and Horncastle 2015). For instance, at point B, the bundle of inputs (x1, x2) is above the least cost curve. Therefore, λ should take a non-zero positive value.

4.2. Empirical approach

When it comes to specifying an empirical strategy for estimating productive efficiency, two distinctions can be made. The first distinction is between the deterministic and stochastic frontier models. Deterministic models are nonparametric; they attribute any deviations from the frontier output to inefficiency. In other words, deterministic models force the error term of the frontier production estimation to represent inefficiency only; there is no white (or random) noise. In addition to the restriction imposed on the error term, another limitation of the deterministic models is their high sensitivity to extreme observations or outliers in the data. Deterministic models, however, exhibit more flexibility in the estimation since they do not impose a specific functional form to the data (Bravo-Ureta and Rieger 1991).

In contrast, the stochastic frontier model better handles extreme observations and decompose the disturbance term into two components: a symmetric normal component, v, referring to random shocks to production and a one-sided distributed error term, u, referring to the OO inefficiency term (Aigner, Lovell and Schmidt (1977) and Meeusen and van Den Broeck (1977)). Another key advantage of stochastic frontier models is that they allow each firm to be inefficient relative to their own frontier rather than to a sample norm (Schmidt and Lovell 1979). Stochastic frontier models also have a weakness worth noting. Being heavily parameterized, estimates from such models may be biased and inconsistent if the models are misspecified and/or the distributional assumption about the error term breaks down (Bravo-Ureta and Pinheiro 1993).

A second distinction is made between models that assume exact cost minimization (measuring technical inefficiency only) and models with inexact cost minimization. Inexact cost minimization models disaggregate the measure of firm's total efficiency (or inefficiency) into its technical and allocative components. Early stochastic frontier studies such as Aigner, Lovell and Schmidt (1977), Meeusen and van Den Broeck (1977) are based on exact cost minimization. Schmidt and Lovell (1979) extended the model built by Aigner, Lovell and Schmidt (1977) to allow for the estimation of allocative inefficiency considering the duality between stochastic frontier production and cost functions. Other examples of inexact cost minimization studies, which have decomposed total efficiency measure into its different components are: Greene (1980); Kopp and Diewert (1982) ; Jondrow, et al. (1982); Bravo-Ureta and Rieger (1991); S. C. Kumbhakar (1987); Kumbhakar and Wang (2006); Kumbhakar and Tsionas (2005); Kumbhakar, Wang and Horncastle (2015).

The empirical estimation model in this study capitalizes on the historical evolution of the state of knowledge on modeling technical and allocative efficiency. Following the inexact cost minimization approach, the duality between the stochastic frontier production function and the cost function is used to estimate farm technical inefficiency, allocative inefficiency and the cost associated with each inefficiency measure. A propensity score matching approach will be used to estimate the effects of the participation regimes on inefficiency measures and the induced costs. Acknowledging the sensitivity of the stochastic frontier model to the misspecification problem, robustness check will be conducted using an exponential functional form of the inefficiency term u (Table A15 in the appendix).

4.2.1 Estimating technical and allocative efficiency

It is assumed that the farmers aim to minimize their costs subject to a stochastic production frontier. Given the duality between the production frontier and cost functions, this assumption can alternatively be stated as the maximization of output level subject to given input levels. Technical inefficiency occurs when the farm operates below its stochastic frontier production function. The firm is allocatively inefficient if it operates off the least cost curve (Schmidt and Lovell 1979).

Following Kumbakhar and Wang (2006) and Kumbhakar,Wang and Horncastle (2015), a derivation of the technical inefficiency and allocative inefficiency starts with a system of equations including a standard production function that relates output to inputs and the FOCs (first-order conditions) of cost minimization:

$$Y_i = F(x_{ik}, \beta_k, z_1, z_2)e^{(v-u)} \qquad k = 1, 2, 3, 4 \ldots L^{th} \text{ input} \qquad i = 1, 2, \ldots m^{th} \text{ plot} \qquad \textbf{(1)}$$

$$\text{FOCs: } \frac{\frac{\partial y}{\partial x_J}}{\frac{\partial y}{\partial x_1}} = \frac{f_J}{f1} = \frac{wj}{w1} e^{\lambda j} \qquad J = 2, 3, 4 \ldots L^{th} \text{ input} \qquad \textbf{(2)}$$

Where F(.) represents the technology used by plot manager (i), which transforms the vector of variable inputs and quasi-fixed factors x, into a quantity of outputs Y. Quasi-fixed factors are variables such as land or capital. The other variables included in x are fertilizer, labor, seed, and herbicide. The vector z_1 captures differences in soil quality and input quality (e.g., local seed vs. improved seed). The vector z_2 represents plot manager, and farm characteristics assumed to influence the variance of the technical inefficiency. These characteristic variables include farm size, household size, education and gender of the plot manager, assets owned and distances from the household's house to markets. β_k is the vector of parameters to be estimated.

A Cobb-Douglas functional form is assumed for the production technology F(.), because it allows the analytical derivation of the costs associated with technical and allocative inefficiencies. Also, the Cobb-Douglas offers a dual property which is more suited to the models that account for both technical and allocative inefficiency. Moreover, this functional form has been used in many studies from developing countries, facilitating comparisons.

u_i is the measure of technical inefficiency for the plot (i), which is explained by the vector of factors z_2.

v_i, captures the random shocks to production (or the white noise).

The ratio fj/f1 is the relative factor productivity, with factor X_1 taken as a numeraire.

The ratio (wj /w_1) is the relative factor prices, where λ_j is the measure of allocative inefficiency for the input pair (j, 1).

Taking the input elasticity of output, equation (2) can be transformed to obtain:

$$\frac{\frac{\partial y}{\partial X_J}}{\frac{\partial y}{\partial X_1}} = \frac{\frac{\partial lny}{\partial lnx_j} * \frac{y}{X_J}}{\frac{\partial lny}{\partial lnx_1} * \frac{y}{X_1}} = \frac{wj}{w1} e^{\lambda} \qquad \textbf{(3)}$$

$$\frac{\frac{\partial lny}{\partial lnx_j}}{\frac{\partial lny}{\partial lnx_1}} \Leftrightarrow \frac{S_j}{S1} = \frac{wjxj}{w1x1} e^{\lambda} \quad J = k+1 \ldots\ldots L \qquad \textbf{(4)}$$

Where: $S_j = \frac{\partial lny}{\partial lnx_j} = \beta j$; $S1 = \frac{\partial lny}{\partial lnx_1} = \beta 1$

Assuming a Cobb-Douglas production technology, the estimation form of the model given by the system of equations (1) and (4) is:

$$lny_i = \beta 0 + \sum_{k=1}^{L} \beta_k * lnx_{ik} + v - u \qquad \textbf{(5)}$$

$$\ln(\frac{\beta j}{\beta 1}) - \ln(\frac{wj}{w1}) - lnxj + lnx1 = \lambda j \ , \qquad j = 2,3\ldots..L \qquad \textbf{(6)}$$

$u \sim N^+(0, \delta_u(z_2))$

$v \sim N\ (0, \delta_v)$

$\lambda j \sim MVN\ (0, \Omega)$

The parameters of the production frontier model are estimated following the maximum likelihood estimation method. The estimation of the model requires some distributional assumption on the error terms v, u and λ. The error term v is assumed to follow a normal distribution with mean zero and a constant variance δ_v. The inefficiency term u is assumed to follow a half-normal distribution with mean zero and a heteroscedastic variance $\delta_u(z_2)$. The variance of inefficiency is expected to vary with farm characteristics z_2. The allocative inefficiency term λ, is distributed with no systematic error (mean zero) and variance Ω.

After estimating the Cobb-Douglas production function, equations (6) is followed to compute the allocative inefficiency term λj of each input pair (j,1). A positive value of λj indicates that input j is being underutilized relative to the numeraire input 1 and a negative value indicates that input j is being overused relative to the numeraire input 1 (Kumbhakar, Wang and Horncastle 2015).

The notion of the underutilization or overutilization of inputs does not tell much about the extent of the farm household's allocative inefficiency. A measure of the extent of allocative inefficiency can be the cost incurred from deviating from the optimal input choice condition. The next section provides the framework to estimate the costs of allocative and technical inefficiency.

4.2.2 Estimating the costs of allocative and technical inefficiency

Inefficiency is costly to producers; the presence of technical inefficiency implies an excess cost resulting from the overuse of inputs. This excess cost is directly captured by the IO technical inefficiency term, η_i, discussed earlier. Indeed η_i represents the proportion by which inputs can be reduced while keeping outputs constant; it represents the cost index of being technically inefficient. A relationship can be established between IO inefficiency and OO inefficiency applying the formula: $u_i = (\sum \beta_k)*\eta_i$) (Kumbhakar, Wang and Horncastle 2015). The production frontier model specified in equation (5) will directly estimate u_i and the relationship above can be used to recover η_i.

Allocative inefficiency also creates an excess cost due to resource overuse or underuse. The quantification of the excess costs related to allocative inefficiency requires a preliminary estimation of a frontier cost function corresponding to the minimum level of input costs to produce the efficient level of outputs. Input quantity decisions deviate from the frontier cost due to technical and allocative inefficiency.

Given the self-dual property of the Cobb-Douglas production function, a dual cost frontier function can be derived analytically by using the parameters estimated from equation (6) only. Following Schmidt and Lovell (1979) and Kumbhakar, Wang and Horncastle (2015), the dual cost function takes the form:

$$LnC = K + \frac{1}{r}\, lny + \sum_{k=1}^{L} \frac{\beta_k}{r} * lnw_k - \frac{1}{r}(v - u) + (E - lnr) \qquad \textbf{(7)}$$

Where:

$r = \sum_{k=1}^{L} \beta_k$;

$E = \sum_{j=2}^{L} \frac{\beta_j}{r} * \lambda_j + ln\left[\beta_1 + \sum_{j=2}^{L} \beta_j * e^{-\lambda_j}\right]$;

$$K = lnr - \frac{1}{r} * \beta_0 - \frac{1}{r} * ln\left[\prod_{k=1}^{L} \beta_k{}^{\beta_k}\right]$$

The minimum or stochastic cost frontier component of the cost function is

$$LnC = K + \frac{1}{r}\, lny + \sum_{k=1}^{L} \frac{\beta_k}{r} * lnw_k - \frac{1}{r}(v)$$

Observed cost exceeds the frontier cost by two factors: 1) excess cost due to technical inefficiency captured by the term, $\frac{1}{r}(u)$ and 2) excess cost due to allocative inefficiency captured by the term (E-lnr). Note that the term, $\frac{1}{r}(u)$, corresponds to the IO technical inefficiency, η, beforehand defined. Once equation (6) is estimated the costs associated to technical and allocative inefficiency are then computed following equation (7).

4.2.3 Modeling the impact of participating in farmer organizations on efficiency

4.2.3.1. Modeling group membership’s effect on efficiency outcomes

To estimate the effects of membership in farmer organizations on technical and allocative efficiency, a propensity score matching (PSM) approach is used.

The PSM is a non-experimental method used to address the issue of counterfactual in impact evaluation studies. The PSM approach consists of constructing a comparison group using non-members, who can approximate the characteristics of members. Non-members of FOs represent the control group, and members of FOs form the treatment group. The method, first, looks for a common support region, where the control and treatment group are matched based on their propensity scores. Then the average treatment effect (ATE) is derived by taking the difference of the outcomes between the two groups. The propensity scores represent the probability distribution of being a member of an FO. This probability distribution is constructed based on a set of observed characteristics that predict the membership.

Under the Conditional Independence Assumption (CIA), there exists a vector of observable covariates, X, such that after controlling for these covariates, the potential outcomes are independent of treatment status. The CIA is an important assumption for the identification of the treatment effect (Caliendo and Kopeinig 2008).

Coming back to the framework of this study, we are interested in estimating the effects of membership in farmer organizations on technical efficiency (TE= e^{-u}), costs of technical inefficiency (η) and costs of allocative inefficiency (E-lnr). A look at the history of cooperative movements in Mali indicates that current organizations are legacies of government-led initiatives to further develop the rural economy. Note that NGOs have also played a crucial role in encouraging the establishment of FOs and supporting their activities. Given that most FOs were established decades ago, membership is assumed to be independent of the outcomes analyzed in this study.

To identify the treatment effect, time-invariant covariates are included in the propensity score matching of non-members (i.e., control group) and members (i.e., treatment group) based on the probability distribution of membership decision. Such covariates are specified in equation (10) below, and include farmer socio-economic characteristics (e.g., age, and gender) and household characteristics (e.g., farm size and household size) among other things. A logit model of membership decision is first estimated (as specified below).

The Nearest-Neighbor matching strategy is used to produce statistically comparable groups. To ensure that a match is found for each treated subject, the matching procedure with replacement will be adopted. It is worth noting that the PSM approach rules out selection bias on observable characteristics only. There may still be unobservable characteristics that influence the membership decision (unobserved heterogeneity) and may confound the relationship between membership of FOs and observed efficiency scores. The sensitivity of the results to potential unobserved heterogeneity bias is evaluated using the Rosenbaum bounds analysis (Table A8-A11 in the appendix).

Using matched observations, the ATE of the membership decision is calculated by taking the difference between the treatment group's outcomes (members 'outcomes) and the control group's outcomes (non-members' outcomes).

If Π_c (d) is the vector of outcome variables such that:

- c = refers to technical efficiency (TE), cost of technical inefficiency (η), or cost of allocative inefficiency (E-lnr),
- d= denotes the membership status (yes=member; no= non-member)

Then the PSM estimator of the ATE on the outcome c is identified as follows:

$ATE_c^{PSM} = \{[E (\Pi_c(d)| d= yes, P(d=yes)] - [E (\Pi_c(d)| d = no, P(d=no)]\}$,

Where P(d=yes) is the propensity score of the members and P (d= no) is the propensity score of non-members. E represents the expectation operator.

The logit model of group membership decision

To identify the effect of FO's membership on farm inefficiency measures, factors that predict the membership decision need to be controlled upfront to avoid selection bias. As hypothesized, enhanced learning, reduction in transaction costs and improved access to inputs are the main channels through which FO's membership mitigates production inefficiencies. The choice of variables used to proxy these channels will be emphasized.

An individual farmer i aims to maximize his/her utility U_i of participating in an FO, subject to his/her resource constraints. The observable utility function is expressed as a function of observable characteristics, X_i, and parameters, α, to be estimated, such that:

$U_i = F(\alpha X_i) + \varepsilon_i$. **(8)**

The probability (Prob) of a farmer i to be a member of an FO is given by:

Prob ($grp_i = 1$) = Prob($\varepsilon_i < \alpha X_i$) = $\alpha X_i + \varepsilon_i$. **(9)**

The unobservable part of the utility is given by μi which is assumed to be independently and identically distributed with mean zero. If U_m is the utility derived from membership and U_{-m} the utility derived from non-membership in an FO, then the membership decision represented by grp_i is such that:

$grp_i = 1$ if $U_m > U_{-m}$;

$grp_i = 0$ if $U_{-m} > U_m$.

The observable characteristics, X_i, include proxied variables for transaction costs, access to inputs, and knowledge of farming practices along with other plot manager and household characteristics that are expected to influence farmer's likelihood to participate in FOs.

Prob ($grp_i = 1$) **= F (X_i, α) = F (L, TC, A, H, α)** **(10)**

α: is the vector of parameters to be estimated

TC: is a vector of variables used to proxy transaction costs. TC includes distance of the household' house to a paved road, to markets and travel costs to the nearest markets

L: is a vector of variables used to capture the likelihood for a given farm household to benefit from the learning dynamic that takes place within the organizations. Components of vector L are communication assets (such as TV, radio, cell phones), transport assets (motorcycle, bicycle, car) and the education of plot manager.

A: is a vector of variables used to capture both the physical and economical access to inputs. Vector A includes distance to input sources and off-farm incomes.

H: is a vector of household and plot manager characteristics and includes plot manger age and gender as well as farm size, household size, and the number of adults in the household.

4.2.3.2. Modelling the effects of the participation regimes

Four participation regimes are identified: 1) farmers who do not use any services; 2) farmers who use the input provision service only; 3) farmers who use the marketing services only; and 4) farmers who use both input and marketing services. The first regime is used as the comparison group to the remaining three treatment groups. To isolate the effect of each of these regimes, a series of logit models for the participation decisions are estimated (equation 12), and common support regions between participants and non-participants are found. The average treatment effect of the participation regimes on efficiency outcomes is then estimated following the procedure described in the previous section.

Logit model of the participation regime decision

A farmer's decision to deliver outputs to, and/or buy inputs from FOs (referred to as the participation regimes) is modeled as in section (4.2.3.1). Let's Pin denotes the patronage decision of the farmer i for services n, where n= 1 if no service is used, n= 2 if uses input service only, n= 3 if uses marketing services only, and n= 4 if uses both input and marketing services.

The farmer uses the FO channel for a given service n if the utility U_{in} associated with this decision is greater than the utility associated with the alternative participation regimes U_{i-n}. If U_{in} is the utility function derived from choosing service n, such that:

$$U_{in} = F(\theta Y_{in}) + \xi_i \quad \textbf{(11)}$$

The probability of a farmer i to patronize the service n is:

$$\text{Prob } (P_{in}= 1) = \text{Prob}(\xi_{in}< \theta Y_{in}) = \theta Y_{in} + \xi_{in} \quad \textbf{(12)}$$

$P_{in} = 1$ if $U_{in} > U_{i-n}$

$P_{in} = 0$ if $U_{in} < U_{i-n}$

Table 1 illustrates the decision space of farmer's patronage behavior, where four participation regimes in FOs' activities are defined.

Table 1: The decision space defining the participation regimes

		Does the farmer sell outputs through the FO channel	
Does the farmer obtained inputs from the FO		YES	NO
	YES	U_{i4}: (P_{i4}=1| θY_{i4})	U_{i2}: (P_{i2}=1| θY_{i2})
	NO	U_{i3}: (P_{i3}=1| θY_{i3})	U_{i1}: (P_{i1}=1| θY_{i1})

Adapted from *Pascucci, Gardebroek and Dries* (2012)

From the data available, the vector of observable characteristics Y_{in} is defined (in equation 13 below) to predict the four participation regimes. It includes variables capturing farmers' characteristics, transaction costs, knowledge on farm management practices, access to inputs and other potential predictors of the patronage behavior such as members' commitment to their FOs and the extent of involvement in cotton cultivation.

Bhuyan (2007) and Cechin et al. (2013) proxied commitment to FOs with variables such as frequency of meeting, attendance, participation in training sessions, and frequency of exchange with the management committee of the organization. The higher the values of those variables are, the higher the commitment and probability of participating in group's activities. In our analysis, commitment to FOs is proxied by the ownership of transport assets (considered in the vector L). It is assumed that farmers who have limited access to transport are less likely to participate in meetings and training sessions than others.

Cereal farmers who also grow cotton have long benefited from a highly institutionalized and cooperative-led cotton sector. Therefore, through their involvement in cotton cultivation, they are more inclined to acquire their farm inputs, for both cotton and cereal crops, through a cotton cooperative (more patronage behavior). The involvement in cotton cultivation is captured by the number of hectares devoted to cotton at the household level.

$$\text{Prob}\ (P_{in}= 1) = F\ (Y_{in}, \theta) = F\ (\mathbf{L, TC, H, A, C}, \theta,) \qquad \textbf{(13)}$$

L, TC, A, and H are defined following equation (10). Variable C measures the extent of cotton cultivation (cotton areas cultivated), and θ represents the vector of parameters to be estimated.

5. STUDY AREA AND DATA

5.1. Study area:

Sorghum and maize are mostly produced within the cereal belt production zone in southern Mali. The zone also represents a major production zone of cotton. The Koulikoro and Sikasso regions within the southern Mali are the main production zones of those crops. Those two regions account for approximately 60% and 90% of the national sorghum and maize production (Table 2) and half of the national agricultural population (CPS/SDR 2016).

Table 2: Total cereal production per region, 2015/2016

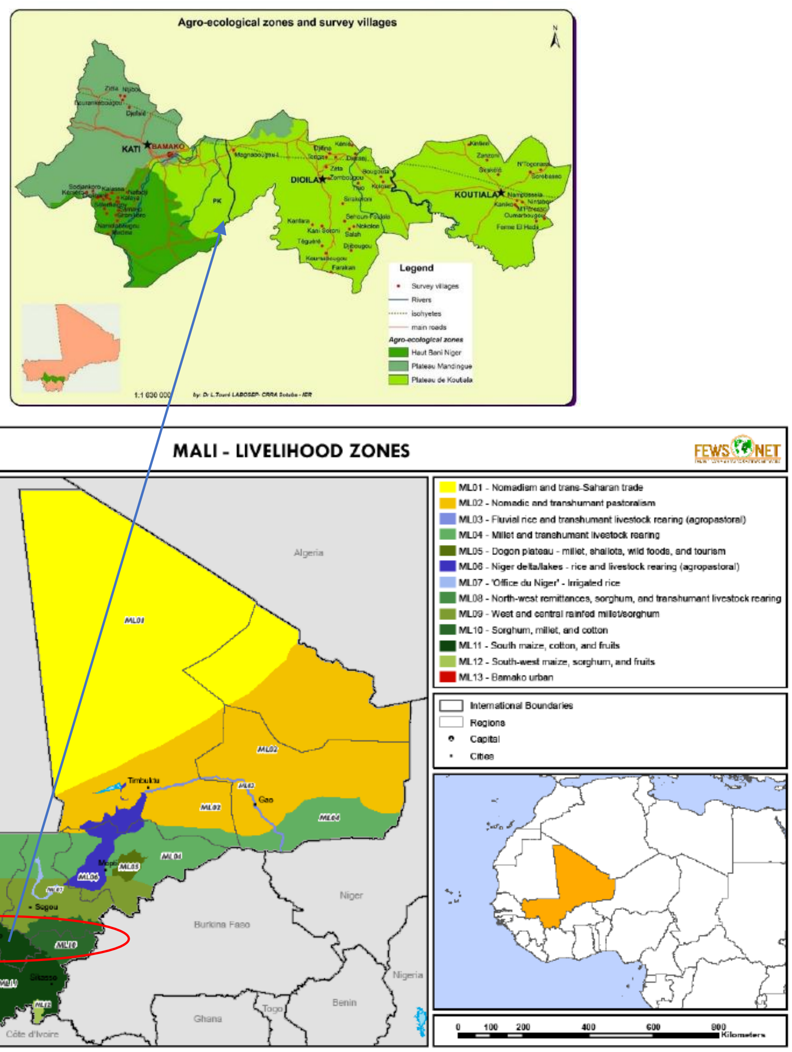
	Millet	Sorghum	Rice	Maize	Wheat	Fonio	Total	Unit: (ton)
Région	**Mil**	**Sorgho**	**Riz**	**Mais**	**Blé/Orge**	**Fonio**	**Total**	**%**
Kayes	70 735	304 600	44 226	196 595		3 016	**619 173**	7,69
Koulikoro	260 436	541 921	124 956	465 234		2 388	**1 394 934**	17,32
Sikasso	210 022	345 312	279 046	1 532 964		1 614	**2 368 959**	29,41
Ségou	606 019	261 914	941 748	72 295	6 546	10 596	**1 899 118**	23,58
Mopti	618 108	54 646	537 656	6 569		2 680	**1 219 659**	15,14
Tombouctou	82 419	18 923	265 039	2 379	28 395		**397 155**	4,93
Gao	16 562	139	138 382		815		**155 899**	1,94
Kidal	-	-	-	-	-	-	**-**	-
Bamako	-	-	-	-	-	-	**-**	-
Total	**1 864 301**	**1 527 456**	**2 331 053**	**2 276 036**	**35 756**	**20 294**	**8 054 896**	100,00

Source : CPS/SDR (Rapport de l'Enquête Agricole de Conjoncture EAC 2015/2016)

This study covers farm households selected in the districts of Kati and Dioila in the Koulikoro region and the district of Koutiala in the Sikasso region. Based on FewsNet's report on livelihood zoning and profiling in Mali, the study area is in livelihood Zones 10 and 11 respectively, where sorghum, millet, cotton, maize, and fruits are the primary sources of subsistence to farm households (Figure 7).

The Koutiala district is part of zone 10. It is characterized by rain-fed agriculture and sedentary livestock rearing. It is the most populous district and the second industrial city in the country. The population is estimated at 575, 235 with a density of 66 inhabitant/sq km. The zone is relatively productive due in part to its more favorable agroecological conditions, with annual precipitation ranging from 700 to 1300 mm. The vegetation is the type Sudano-Sahelian and soils are classified as sandy clay, sandy loam (FEWSNET 2010). Soils are degraded and deficient in phosphorus, especially in the higher reaches of the topo sequence (Smale, Assima and Weltzien, et al. 2014)). Soils in the lower reaches are more likely to be fertilized since it is where cotton and maize are cultivated (Smale, Assima and Weltzien, et al. 2014). Given that they are well-adapted to harsh conditions, farmers grow sorghum and millet on the more degraded and marginal soils, which receive tiny fertilizer amendment.

Figure 7: The study area



Source: Adapted from FewsNet ((2010) (FEWSNET 2010)*)*

Historically, cotton has been the major cash crop in the zone. Cotton growers are organized in cooperatives and receive inputs on credit, farm equipment, and technical assistance from the CMDT- the public company supporting cotton production and textile development in Mali. Sorghum and maize are often cultivated in rotation with cotton. Farmers do not directly receive government assistance for growing these cereals. Maize has benefited from the fertilizer residuals on fields previously grown with cotton (FEWSNET 2010). Due to the recent crisis in the cotton sector (e.g., falling prices, late payments) and recent talks about the privatization of the CMDT, farmers have been diversifying their production out of cotton and more toward cereal-based production systems (FEWSNET 2010).

The districts of Kati and Dioila are in the livelihood zone 11 of the country, where the average annual rainfall ranges from 1000 to 1300 mm, allowing a rainfed cultivation of maize, sorghum, millet, and cotton. Soils are clay, loam, lateritic and the vegetation is Sudano-Sahelian with a flat topography. Cotton and maize are the main cash crops within the zone with similar production characteristics as in zone 10. Other cash crops include fruits, groundnut, cowpeas, sesame and vegetables (FEWSNET 2010). Kati is home to 948,128 people (56 inhabitant/sq km) and Dioila, the least populated district, counts 249 403 people (19 inhabitant/sq km).

With the decline of cotton production, the cereal-based production system so-called the “traditional sector” is confronted to the constraints of low access to inputs, farm equipment and technical supports (Staatz, et al. 2011, Kaminski, Elbehri and Samake 2013).

5.2. The Data

The data for this study come from a cross-sectional farm household survey conducted under the Guiding Investments in Sustainable Agricultural Intensification in Africa (GISAIA) project by the

Food Security team of MSU. More information about the data, including the strategy of sampling, is available in the Survey Report (2015).

The villages are from the Koutiala district in the Sikasso region and Kati and Dioila districts in the Koulikoro region. The objective of the survey was to address research questions related to sustainable intensification of sorghum cropping in the Malian agriculture. The sampling frame was drawn from a village census previously undertaken, that enumerated all sorghum and maize growers in each village. The village census was conducted to evaluate the adoption rates of improved seed varieties of sorghum. The data that include information at the household and plot levels were collected in four rounds. At the household level, a simple random sampling was used to determine the sample size needed based on the village census frame. The formula used to calculate the sample size is as follow:

$N= t^2 (1-p) *p / e^2$

Where N is the total sample size, p (=22%) is the proportion of households that adopt the improved sorghum seed from the census frame, t (= 1.96) is the statistic representing 95% confidence interval and e (= 3.5%) is the marginal error tolerated.

A sample size of 538 households is derived from this formula. To account for non-response rate, 5% additional observations were considered for a rounded sample size of 580 households. Then, 48 hybrid-variety growers were added to generate a total sample size of 628 households. In each 58 villages, ten sorghum-cropping households were randomly selected, and 48 hybrid producers in the three districts were also surveyed. All cultivated plots by these farm households were inventoried during the first round of data collection. The plots level information collected during the first round was used as the sampling frame for the rounds 2, 3, and 4. Considering only the plots where maize and sorghum were grown, collective and individual plots were randomly selected and used for the survey in the other rounds. A total number of 1382 plots were randomly selected from the frame elaborated during the first round of data collection.

The sampling design did not allow detailed information to be collected on all the crops (plots) grown by the households. Detailed data were collected for sampled maize and sorghum plots only during the second round. Since the sample did not include all maize and sorghum plots grown by each household, a household level analysis is not feasible. The analysis is therefore done at the plot level considering maize and sorghum plots.

5.3. Descriptive statistics

The analysis of the productive efficiency is done at the plot level and includes observations from 964 maize and sorghum plots after deleting for non-matched plots across survey rounds. The plots belong to 575 farm households. Summary statistics of farm and plot manager characteristics are presented in Table 3. Plot managers in the sample are almost exclusively male (94%), and most belong to an organization (78%), whether a cooperative or a village association. Only 19% of them attended a formal school, but 48% are literate. They average 49 years old. Plot size averages 2 hectares. The plot managers travel, on average, about 3 kilometers to access farm inputs. The mean of household size is 16 people, who get their livelihood from an average farm size of 11 ha.

The households supplement their farming activities with external income sources as well as from remittance or off-farm employment. The farm households surveyed receive, on average, an annual amount of 52,500FCFA (about 100$) in remittances and 32,600FCFA (about 50$) from off-farm economic activities. Farm and plot characteristics disaggregated between maize and sorghum crops are presented in columns 2 and 3.

Table 3: Summary statistics of farm and plot characteristics (N= 964)

Variable	All Plots		Maize Plots		Sorghum Plots	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	49.3	13.8	49.7	13.6	17.0	85.0
Household size	15.6	8.1	15.8	8.1	3.0	57.0
Farm size (hectare)	11.2	6.5	11.1	6.4	2.0	35.0
Asset value (FCFA)	1,347,204.0	1,085,593.0	1,383,857.0	1,096,505.0	58,000.0	7,890,000.0
Herd size (TLU)	11.3	15.8	11.7	16.0	0	119.1
Oxen (TLU)	2.6	2.2	2.6	2.2	0	13.8
Plot area (hectare)	1.9	1.7	1.7	1.6	0.1	10.0
Off-farm workers(Number)	0.4	0.8	0.5	0.9	0	6.0
Off-farm income (FCFA)	32,663.9	116,282.7	36,347.5	125,433.0	0	1,500,000.0
Remittance (FCFA)	52,541.8	133,137.6	57,893.1	137,806.0	0	1,015,000.0
Distance to input source (km)	3.2	2.9	3.4	3.0	0	13.8
Distance to market (km)	12.1	10.3	11.7	9.9	0	60.0
Distance to paved road (km)	27.1	26.1	25.0	25.9	0	93.0
Village level wage (FCFA)	1,334.5	405.5	1,382.6	423.9	750.0	2,500.0
Number of Bikes	2.4	1.4	2.4	1.4	0	6.0
Number of Motorbikes	1.1	1.1	1.1	1.1	0	5.0
Number of Tv	0.4	0.6	0.4	0.6	0	2.0
Number of Phones	3.1	2.1	3.2	2.1	0	9.0

Key characteristics of members and non-members of FOs are compared in Table 4, using t-test statistics. Members of FOs live in households with more landholding (farm size), assets, oxen, and bicycles. They are significantly closer to input sources than non-members and reside in villages whith lower average wage rate of a male labor.

Table 4: T-Test statistics comparing farm and plot characteristics of members and non-members of the FOs

	Member=1 Non-Member = 0	
Variables	**diff =Mean (0) - Mean (1)**	**SD**
Age (years)	-0.533	(-0.49)
Household size	-0.662	(-1.04)
Number of adults	-0.522	(-1.36)
Farm size (hectare)	-1.185*	(-2.32)
Asset value (FCFA)	-173923*	(-2.05)
Herd size (TLU)	-0.787	(-0.64)
Oxen (TLU)	-0.471**	(-2.79)

Table 4 (cont'd)

Plot area (hectare)	-0.236	(-1.80)
Off-farm workers	0.059	(-0.9)
Off-farm income (FCFA)	36.220	0
Remittance (FCFA)	5158	(-0.49)
Distance to input source (km)	0.525*	(-2.34)
Distance to market (km)	-0.740	(-0.92)
Distance to paved road (km)	-2.799	(-1.37)
Village level wage (FCFA)	160***	-5.12
Number of Bikes	-0.241*	(-2.19)
Number of Motorbikes	0.046	(-0.54)
Number of Tv	0.053	(-1.15)
Number of Phones	-0.159	(-0.99)

The summary statistics on maize and sorghum production and input use are reported in Table 5. The average total quantity of fertilizer applied on maize plots (274 kg) is by far higher than on sorghum plots (36 kg). On average, sorghum plots are more labor intensive (about 342 hours of labor force used), which may compensate for the low level of fertilizer use. Land size is, overall, comparable; 1.8 ha for sorghum compared to 1.5 ha for maize. Maize yields average three tons per hectare whereas sorghum yields average about 2 tons per hectare. Although the use of agricultural equipment is higher on sorghum plots, the difference in hourly cost of farm machinery used suggests that more sophisticated equipment might be allocated to maize plots. The unit cost (price) of each input is obtained by dividing total expenditures by total quantity used.

Table 5: Summary statistics of production and input use at the plot level

	SORGHUM (N=423)			
Variables	Mean	Std. Dev.	Min	Max
Production(kg)	1,874.6	3,309.6	40.0	60,000.0
Seed (kg)	17.4	18.4	1.0	161.0
Herbicide (kg)	2.9	20.7	0	375.0
Fertilizer (kg)	34.9	108.3	0	1,750.0
Labor (hours)	341.7	236.1	32.0	1,579.0
Land (hectares)	1.8	1.5	0.1	8.9
Seed price (FCFA/Kg)	200.7	215.7	6.0	2,000.0
Herbicide price (FCFA/Kg)	4,565.8	2,009.2	7.5	16,250.0
Fertilizer price (FCFA/Kg)	204.5	52.4	73.3	944.2

Table 5 (cont'd)

Variables	Mean	Std. Dev.	Min	Max
Hourly labor cost (FCFA/hour)	1,347.1	1,218.8	78.1	8,083.3
	MAIZE (N=541)			
Variables	Mean	Std. Dev.	Min	Max
Production(kg)	3013.8	5338.2	7.0	100000.0
Seed (kg)	22.0	39.4	0.5	751.0
Herbicide (kg)	2.8	5.2	0	100.0
Fertilizer (kg)	274.2	309.0	0	2200.0
Labor (hours)	267.6	193.0	10.0	1512.0
Land (hectares)	1.5	1.3	0.03	8.8
Seed price (FCFA/Kg)	202.5	245.2	5.0	2666.7
Herbicide price (FCFA/Kg)	5164.3	3559.5	40.0	50750.0
Fertilizer price (FCFA/kg)	211.8	182.1	26.5	4333.3
Hourly labor cost (FCFA/hour)	1517.9	3868.5	20.8	85575.0

Table 6 compares members to non-members regarding their production characteristics. The results of the t-test statistics show that members of FOs produce significantly more of sorghum and maize than non-members. They use a higher amount of fertilizer and face a significantly lower price of fertilizer compared to non-members. The members also allocate more land to sorghum and maize than non-members.

Table 6: T-test statistics comparing the production and inputs used by members and non-members of the FO

	Member=1 Non-Member = 0	
Variables	**diff =Mean (0) - Mean (1)**	**SD**
Production(kg)	-772*	(-2.15)
Seed (kg)	-7.047**	(-2.82)
Herbicide (kg)	1.173	(-1.06)
Machinery (hours)	-12.760	(-0.86)
Fertilizer (kg)	-68.860**	(-3.28)
Labor (hours)	7.331	(-0.43)
Land (hectares)	-0.392***	(-3.58)
Seed price (FCFA)	-22.120	(-1.22)
Fertilizer price (FCFA)	2.493	(-0.23)
Hourly labor cost (FCFA)	-106	(-0.45)

6. ECONOMETRIC MODELS

6.1. Group membership decision model:

The first stage in the propensity score matching method consists of matching non-members to members of FOs based on relevant covariates that predict membership decision. The probability distribution of membership decision is modeled following the specification below (equation 14) where C_m is a vector of explanatory variables. The CIA assumption imposes that C_m includes all variables that can influence the probability of treatment, such that after controlling for them, the assignment into treatment is random. The squared term of age and farm size are also included in the model to account for a potential U-inverted shape distribution of the effects of these variables on membership. The logistic regression method is used to estimate the equation.

$$\text{Prob}(grp_i=1) = \alpha_0 + \sum_{m=1}^{19} \alpha_m * C_m + \varepsilon_i \qquad \textbf{(14)}$$

C_1 = age of plot manager (years)

C_2 = if plot manager is male =1; Otherwise=0

C_3 = if plot manager attended formal school=1; Otherwise=0

C_4 = if plot manager is literate =1; Otherwise=0

C_5 = farm size (hectare)

C_6= household size (persons)

C_7 = average distance to inputs sources (km)

C_8 = number of mobile phones used in the household (number phones)

C_9 = number of TVs used in the household (number of TVs)

C_{10} = number of motorcycle used in the household (number of motorcycles)

C_{11} = number of bicycles used in the household (number of bicycles)

C_{12} = wage level in the village (FCFA/hour)

C_{13} = distance to the paved road (km)

C_{14} = age squared

C_{15} = farm size squared

6.2. Participation decision model:

Similarly, to identify the effects of the participation regimes, the users of the regimes 2, 3, 4 (defined beforehand) are first paired with non-users (regime 1) based on relevant covariates that predict the participation decision. The probability distribution of these decisions is modeled following the specification below. The logistic regression method is used to estimate the equation.

Prob (P_{in}=1) = $\theta_0 + \sum_{m=1}^{19} \theta_m * D_m + \xi_i$ **(15)**

n= 1, 2, 3, 4 corresponds to the four regimes

D_1 = age of plot manager (years)

D2 = if plot manager is male =1; Otherwise=0

D_3 = if plot manager attended formal school=1; Otherwise=0

D_4 = if plot manager is literate =1; Otherwise=0

D_5 = farm size (hectare)

D_6= household size (persons)

D_7 = number of mobile phones used in the household (number of phones)

D_8 = number of TVs used in the household (number of TVs)

D_9 = number of motorcycle used in the household (number of motorcycles)

D_{10} = number of bicycles used in the household (number of bicycles)

D_{11} = wage level in the village (FCFA/hour)

D_{12} = distance to the paved road (km)

D_{13}= areas of cotton cultivated (hectare)

D_{14} = age squared

D_{15} = farm size squared

6.3. The Cobb-Douglas frontier production model

The estimation form of the Cobb-Douglas frontier production function is specified below. A frontier production function is estimated for maize and sorghum separately. In addition to the standard inputs of production, dummy variables are also included in the models to control for zero values of some inputs, type of seeds, and whether anti-erosion practices are used. First, we observe zero values for inputs variables such as fertilizer and herbicide. Not accounting for these zero values may result in biased estimates of the production parameters (Battese 1997).

To address the zero input values, the method suggested by Battese (1997) is followed, where a dummy variable DX_k of the input X_k is included in the model to address the issue. DX_k is equal to 1 if the observed quantity of the input X_k is zero and equals 0 otherwise. Then, the value of the corresponding input variable is replaced by the maximum of (X_k, DX_k). While some authors address the "zero observation" problem by excluding the zero values from the analysis or replacing them by small arbitrary values, Battese (1997) points out to the fact that these approaches may result in biased estimates. As robustness checks, results using the method of replacement by a small value (0.1) are reported in the appendix.

Second, since the plot managers in the sample are not using the same seed varieties of crops especially for sorghum, a dummy variable of the seed varieties is included. Dummy variables are also included to account for the presence of anti-erosion practices.

$$lnyi=\beta 0 + \beta 1lnx1 + \beta 2lnx2 + \beta 3lnx3 + \beta 4lnx4 + \beta 5lnx5 + \beta 6lnx6+ \beta 7D1+\beta 8D2+ \beta 9D\mathrm{X}1+\beta 10D\mathrm{X}2+ vi- \mathrm{u}(Z2) \quad \textbf{(16)}$$

$$\ln(\frac{\beta j}{\beta 1}) - \ln(\frac{wj}{w1}) - lnxj + lnx1 = \lambda j \quad \textbf{(17)}$$

y = quantity of cereals produced (kg)

x1 = quantity of fertilizer applied (max (X1, DX1)) (kg)

x2 =quantity of seeds applied (kg)

x3 = labor force used on each plot (hours)

X4 = plot area allocated to the crop (ha)

X5 = quantity of herbicide applied (max (X6, DX6)) (kg)

D1= dummy variable=1 if anti-erosion practices are adopted, Otherwise= 0

D2 = dummy variable =1 if hybrid seeds are used; Otherwise=0

DX1 = dummy variable = 1 for zero value of fertilizer; Otherwise =0

DX2 = dummy variable =1 for zero value of herbicide; Otherwise =0

Z2= Factors affecting inefficiency, including membership to FO, age, gender, farm size, education, assets owned.

7. RESULTS

7.1. Estimates of the stochastic frontier functions and Technical Efficiency scores

a) Maize

Table 7 presents the parameter estimates of the stochastic production frontier for maize. Column (1) displays the estimates of the production function, and Column (2) presents the determinants of technical inefficiency. All the inputs considered are significant determinants of maize production (Column (1)). Non-application of fertilizer on maize reduces the quantity of maize produced as suggested by the negative coefficient of the fertilizer application dummy variable. The use of anti-erosion practices appeared to be negatively associated with the production. The positive coefficient of the herbicide application dummy variable indicates that non-utilization of herbicide is associated with higher maize outputs. These results may reflect the fact that anti-erosion measures and herbicide are intended to mitigate losses of production due to weed infestation or poor soil quality. The primary purpose of their utilization is not to increase the production per se but to minimize the losses observed firsthand. Therefore, the sign of the estimated coefficients is not unusual.

The result corroborates the hypothesis of the study – membership is highly significant and negative, meaning that it reduces technical inefficiency in maize production. This result may be sensitive to potential bias from unobserved heterogeneity. The presence of those biases is tested applying Rosenbaum bounds test and are discussed in subsequent sections. Technical inefficiency in maize production is reduced with larger households owning telecommunication devices such as TV.

Table 7: Maximum Likelihood Estimates of a Cobb-Douglas Production function with heteroscedastic inefficiency (half-normal distribution of δu) for Maize

Maize (N=541)			
(1)		**(2)**	
Determinants of production	Mean (SE)	Determinants of inefficiency	Mean (SE)
Fertilizer (kg)	0.185***	Group membership	-0.993***
	(0.0631)		(0.219)
Seed (kg)	0.120**	Age (years)	-0.000316
	(0.0501)		(0.00675)
Herbicide (kg)	0.142**	Farm size (hectare)	-0.0188
	(0.0631)		(0.0176)
Labour (hours)	0.105*	Dummy education	-0.380
	(0.0597)		(0.261)
Land (hectare)	0.371***	Dummy literacy	0.265
	(0.0608)		(0.201)
Dummy herbicide	0.00957	Tv	-0.515***
	(0.0939)		(0.175)
Dummy fertilizer	-0.907***	Phone	0.0315
	(0.321)		(0.0553)
Dummy soil fertility	-0.172**	Motorcycle	-0.121
	(0.0864)		(0.108)
Constant	7.427***	Bicycle	-0.0343
	(0.396)		(0.0828)
		Dist.input source (km)	-0.00223
			(0.0336)
		Household size	-0.0458***
			(0.0152)
		Constant	1.906***
			(0.457)
Variance of random error			
constant	-1.040**		
	(0.128)		

Note: Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1
The inputs are expressed in logarithmic values

The likelihood ratio test (sigma_u=0: chibar2(01) = 38.41. Prob >= chibar2 = 0.000) rejects the null hypothesis of a fully efficient maize production asserting that farmers operate with some level of technical inefficiency (Table A1 in the appendix). The average technical efficiency (TE) score in maize production is 51%, which is lower than the efficiency score estimated by Theriault and Serra (2014) from cotton farmers in Mali. A preliminary report by Mansur, Gaskell and Gautam (2017) on coarse grain productivity across different agro-ecological zones in Mali estimated an average technical efficiency ranging from 53% to 57%. Thus, the TE score found is closely in line with findings based on a nationally representative dataset (i.e., LSMS). About 75% of the sample have a technical efficiency score below 65%, and none of them is fully efficient. The highest efficiency score is about 86%. Indeed, the TE score ranges from 0.6% to 86%. The cost of technical inefficiency averages 68%.

Table 8: Summary statistics of technical efficiency and cost of technical inefficiency

MAIZE (N=541)									
	TE					**η_i**			
	Percentiles	Smallest				Percentiles	Smallest		
1%	0.020	0.006			1%	0.195	0.168		
5%	0.189	0.012			5%	0.275	0.168		
10%	0.252	0.013	Obs	541	10%	0.330	0.182	Obs	541
25%	0.369	0.015	Sum of Wgt.	541	25%	0.465	0.193	Sum of Wgt.	541
50%	**0.533**		**Mean**	**0.507**	**50%**	**0.683**		**Mean**	**0.858**
		Largest	**Std. Dev.**	**0.186**			Largest	**Std. Dev.**	**0.633**
75%	0.651	0.837			75%	1.082	4.531		
90%	0.738	0.845	Variance	0.035	90%	1.498	4.754	Variance	0.401
95%	0.776	0.857	Skewness	-0.376	95%	1.807	4.809	Skewness	3.146
99%	0.835	0.857	Kurtosis	2.477	99%	4.237	5.579	Kurtosis	18.506

The robustness of these results is evaluated against an alternative approach to dealing with the zero values observed in herbicide and fertilizer inputs. Table A2 and A3 in Appendix report the Maximum Likelihood estimates of the Cobb-Douglas production function for maize when zero input values are replaced by an arbitrary value close to zero (a value of 0.1 is used). No significant differences in the frontier estimates are found between the two approaches. The average technical efficiency and the cost of technical inefficiency are also consistent between the two approaches.

A T-Test statistic for differences in the mean scores of technical efficiencies and its cost is estimated (Table 11). Results show that, on average, members of FOs achieve higher technical efficiency than non-members and lower costs induced by inefficiency for maize production. The mean differences in the efficiency scores between members and non-members are strongly significant. These results reflect the findings of previous studies relative to FO's membership effect on farm's technical efficiency (Abate, Gian Nicola and Kindie 2014, Addai, Victor and Gideon 2014, Boubacar, et al. 2016, Debebe, et al. 2015). Participation in the group's activities- inputs acquisition, group marketing or both- is associated with higher average technical efficiency compared to non-participation.

While these results give a descriptive overview of the effects of the collective action on farm technical efficiency, the statistical estimation of the marginal effects is obtained from the results of the PSM analysis (Table 15).

b) Sorghum

Estimates of the frontier production function for sorghum are presented in Table 9. Except for fertilizer, the coefficients of all input variables are significant. The non-significant coefficient of fertilizer may reflect the meager amount used as sorghum is primarily produced for household's consumption needs and is agronomically less responsive to fertilizer than maize. The coefficient of herbicide is negative as often expected since this input is used to minimize the losses of output and not necessarily to increase productivity.

The likelihood ratio test (sigma_u=0: chibar2(01) = 0.000. Prob >= chibar2 = 1.000) fails to reject the null hypothesis of a fully efficient sorghum production indicating the absence of technical inefficiency in sorghum cultivation (Table A4, appendix). The stochastic frontier model can thus be reduced to a standard OLS model with all errors forced into the white noise. For these reasons, only results related to allocative inefficiency are reported for sorghum in the next sections.

Note that these results remain consistent even when zero inputs values are replaced by a small arbitrary value (0.1), as reported in the appendix (Tables A5, A6). These results may reflect the limitation of our model specification, in adequately representing the underlying production function of sorghum. Sorghum is a staple crop like maize, but in contrast with maize, it is primarily produced for domestic consumption and is rarely marketed. Therefore, the use of inputs such as fertilizer, for instance, is marginal given the low value to costs ratio and this type of input may be excluded from the model.

Table 9: Maximum Likelihood Estimates of a Cobb-Douglas Production function with heteroscedastic inefficiency (half-normal distribution of δu) for sorghum

Sorghum (N=423)			
(1)		**(3)**	
Determinants of production	Mean (SE)	Determinants of inefficiency	Mean (SE)
Fertilizer (kg)	0.137 (0.0842)	Group membership	-0.0513 (0.374)
Seed (kg)	0.154*** (0.0531)	Age (years)	-0.00278 (0.0112)
Herbicide (kg)	-0.145* (0.0801)	Farm size (hectare)	-0.138*** (0.0532)
Labour (hours)	0.265*** (0.0660)	Dummy education	-0.617 (0.442)
Land (hectare)	0.171*** (0.0546)	Dummy literacy	0.471 (0.364)
Dummy herbicide	0.164 (0.122)	Tv	-0.587 (0.387)
Dummy fertilizer	-0.563 (0.379)	Phone	0.268** (0.110)
Dummy soil fertility	0.126 (0.104)	Motorcycle	-0.367 (0.243)
Constant	5.616*** (0.376)	Bicycle	-0.0611 (0.154)
		Dist. input source (km)	0.128** (0.0561)
		Household size	-0.0344 (0.0289)
		Gender	0.233 (0.715)
		Constant	0.188 (0.952)
Variance of random error			
Constant	-0.661*** (0.118)		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
The inputs are expressed in logarithmic values

7.2. Allocative inefficiency scores:

a) Maize

The computed inefficiency in resources allocation is summarized in Table 10. The positive non-zero values, first, indicate the presence of allocative inefficiency and second, that the different input pairs are, on average, allocated above their cost minimizing level. The positive values also indicate that labor is overutilized on average compared to the other inputs used in production, (Kumbhakar, Wang and Horncastle 2015). Labor is more easily accessible than modern inputs.

As these results do not indicate the extent of allocative inefficiency, the proportional increase/decrease in input costs imputable to allocative inefficiency (E-lnr) is estimated. As seen in Table 10, the average cost of resource allocation inefficiency for maize is about (-17%). Meaning, the actual maize production cost is below the minimum cost by 17%. More quantity of maize can be produced by using more inputs while moving to the efficient frontier function.

Table 10: Resources allocation inefficiency in maize production

Variables	Mean	SD	Min	Max
Seed/Labor	3.48	1.16	0.27	9.04
Herbicide/labor	2.83	1.85	-0.73	8.77
Fertilizer/labor	4.74	1.34	0.36	9.73
E-lnr	-0.17	0.40	-0.75	1.94

Following Table 11, members of FOs display a significantly lower cost of allocative inefficiency, on average, compared to non-members. Also, participation in group activities for the inputs provision service and/or marketing service reduces the cost of allocative inefficiency, on average, for maize. The difference in the allocative inefficiency costs between participants and non-participants is highly significant considering the participation regime 2 (inputs provision only). However, no significant differences are found in the allocative inefficiency costs between participants and non-participants of the regimes 3 (marketing service).

Table 11: T-test for differences in technical efficiency and costs of inefficiency across participation regimes in maize production

Participation regimes	diff = Mean (no) - Mean (yes)	SD	Frequency
Membership in FOs			
TE	-0.0910***	(-4.67)	No =110
η_i	0.357***	(5.23)	Yes = 431
E_Lnr	0.143***	(3.36)	Total= 541
Use inputs service only			
TE	-0.0527**	(-3.09)	No =235
η_i	0.179**	(3.15)	Yes= 223
E_Lnr	0.131**	(3.55)	Total= 458
Use marketing service only			
TE	-0.0823*	(-2.31)	No =235
η_i	0.183	(1.42)	Yes = 34
E_Lnr	0.136	(1.70)	Total= 269
Use both input & marketing services			
TE	-0.106***	(-3.59)	No =235
η_i	0.245*	(2.22)	Yes = 49
E_Lnr	0.151*	(2.17)	Total= 284

t statistics in parentheses
*** p<0.05, ** p<0.01, *** p<0.001**

b) Sorghum

Allocative inefficiency in sorghum production has been computed considering three variable inputs: seed, fertilizer, and labor. The computation of inefficiency is based upon the assumption of a well-behaved production function with positive elasticities of production (such as the Cobb-Douglas). As this assumption is violated in the case of herbicide, the model could not derive a value for allocative inefficiency associated with herbicide.

Considering only the three variable inputs - with positive elasticities, the average increase in inputs costs due to allocative inefficiency is 96% (Table 12). This finding indicates that given the current level of output, the observed input costs are almost double the value of the minimum optimal cost. Sorghum production cost can be reduced by 96% while keeping the current quantity produced as constant. As in maize production, seed and fertilizer are underutilized compared to labor.

Table 12: Resources allocation inefficiency in Sorghum production

Variable	Mean	Std. Dev.	Min	Max
Seed/Labor	4.47	1.17	1.74	7.70
Fertilizer/labor	5.21	2.33	-2.00	9.52
E-lnr	0.96	0.50	-0.10	2.26

The cost of allocative inefficiency is significantly lower for members of FOs and those who participate in the inputs provision service (Table 13). Farmers who use the inputs provision service only or both input and marketing services of the organization have lower costs imputable to allocative inefficiency. However, farmers who use the marketing service only have higher costs of allocative inefficiency than farmers who do not participate in this regime, although the difference is not significant.

The marginal effects of the participation regimes on the costs associated with allocative inefficiency are analyzed in section 7.3.

Table 13: t-test for differences in allocative inefficiency cost across participation regimes in Sorghum production

Participation regimes	**diff = Mean (no)- Mean yes)**	**SD**	**Frequency**
Membership of an FO			
E_Lnr	0.168**	(2.85)	No= 91 Yes =332 Total = 423
Use Inputs service only			
E_Lnr	0.202***	(3.95)	No= 187 Yes = 175 Total = 362

Table 13 (cont'd)

Use marketing service only			
E_Lnr	-0.140	(-1.49)	No= 187 Yes= 27 Total= 214
Use both input & marketing services			
E_Lnr	0.006	(0.07)	No= 187 Yes = 34 Total= 221

t statistics in parentheses
*** p<0.05, ** p<0.01, *** p<0.001**

7.3. Marginal effects of Farmer Organizations on the production efficiency:

a) Maize

The propensity score matching approach is used to determine the marginal effects of group membership and four participation regimes on three efficiency outcomes: technical efficiency score (TE), cost of technical inefficiency (η_i) and cost of allocative inefficiency (E-lnr). The average treatment effects (ATE) is estimated using the 1:1 Nearest Neighbor (NN) matching approach. To improve the matching quality and covariates balance, a caliper of 0.15 is imposed on the data indicating the maximum range within which the propensity scores of the treatment and control group observations can be dissimilar (Caliendo and Kopeinig 2008). For the membership effect, the logistic regression model is employed (default STATA command) to predict the propensity scores using the covariates defined in equation (7). For each of the participation regime, the propensity scores are determined using covariates in equation (9). Results of the logistic model displaying the determinants of FO's membership are reported in Appendix Table A7.

Under the 1:1 NN matching approach of the PSM model, covariate balance is achieved for the variables that appear in Table 14. As can be seen in Table 14, the standardized differences in mean between members and non-members for the covariates considered are minimized with the matching in contrast to the raw data. Also, the variance ratio is closer to 1 for the matched observations compared to the raw data, together with the mean differences, this attests a reasonable level of covariates balance and a large region of common support. A formal covariates balance test undertaken with the Inverse Probability Weight (IPW) model fails to reject the null hypothesis that covariates are balanced. Thus, the matching approach followed is reliable.

Table 14: Covariates balance summary for maize

	Standardized differences		**Variance ratio**	
	Raw	Matched	Raw	Matched
Age (years)	0.094607	-0.10939	0.798272	0.937595
Age squared (years)	0.062126	-0.11521	0.887756	0.952738
Dummy education (0/1)	0.225906	0.004612	1.460073	1.006928
Dummy literacy (0/1)	0.180758	-0.03694	1.013452	1.000684
Farm size (hectares)	0.242197	0.068245	1.123334	0.943766
Farm size squared (hectares)	0.189481	0.033721	1.212132	0.814895
Household size (persons)	0.068192	0.148161	1.488582	1.359076
Distance to inputs source (km)	-0.25486	0.046475	1.276053	1.736365
Number phone (units)	0.012886	0.086191	0.966145	1.044769
Number TV (units)	-0.10281	0.089022	1.20218	1.476307
Number motorcycle (units)	-0.06644	-0.05292	0.842534	0.939508
Number bicycle (units)	0.1196	0.073391	1.274507	1.359348
Village Wage level (FCFA)	-0.4988	0.069145	0.704034	0.91589
Distance to paved road (km)	0.292528	-0.00835	1.424689	1.188297
Overidentification test*	H0: Covariates are balanced: chi2(15) = 7.865 Prob > chi2 =0.9291			

The PSM results for maize confirm the hypothesis of the study that membership in farmer organizations reduces productive inefficiencies (Table 15). The average technical efficiency of members is 9% higher than non-members. Membership also significantly reduces the costs related to technical and allocative inefficiency by 32% and 16%, respectively. To check for the sensitivity of these results to potential biases from unobserved heterogeneity, a Rosenbaum bounds analysis is performed (Appendix, TableA8). Selection into FO's membership is robust to unobserved variables for two of three outcomes (TE and n_i). For technical efficiency and cost of technical inefficiency outcomes, the lowest value of Gamma (Γ) generating a 95% confidence interval that includes zero is 2.2. Moreover, considering the Hodges-Lehmann point estimates (the upper and lower bounds), the lowest value of Gamma for which the upper and lower bounds interval encompasses zero is 2.8. Since these minimum values of Gamma are higher than 2, the treatment effect estimates are robust to hidden biases for these two outcomes (Mirrlees, et al. 2011, Duvendack and Palmer-Jones 2012, Rosenbaum 2002). However, the cost of allocative inefficiency outcome (E-lnr) is sensitive to potential biases.

The results also support the hypothesis that engaging in FO's activities is beneficial to farmers in general. Members who patronage their FO for either input and/or marketing services have significantly higher technical efficiency and lower cost of technical and allocative inefficiency than non-participants. Overall, the PSM's findings corroborate the positive effects of membership and the patronage behavior on the efficiency scores.

Specifically, when allocative inefficiency is concerned, participation in the input provision service is the most beneficial as it strongly reduces the cost of allocative inefficiency. This result aligned with the idea carried that improved access to inputs can address the underutilization. The effect of using both the input and marketing services on the costs of allocative inefficiency, albeit positive, is not as strong compared to the other regimes.

When technical efficiency is concerned, participation in group marketing service appears to be the most beneficial as it yields the highest positive significant effect compared to the other regimes. Using the input provision service has no significant impact on technical efficiency. This finding is of great interest as it suggests that farmers tend to get the most of their productive resources when they are ensured of the availability of a market for their outputs. In other words, reduced market risks and unobserved transaction costs enabled by the FOs induce more efficient utilization of farm inputs. To promote agricultural productivity gains, research and public supports have traditionally focused on getting the upstream segment of farm business right, through investments in input subsidy programs and research programs on crop seed variety improvement. This result calls for a broader perspective, as it shows that getting the downstream segment of the farm business right can also play a significant role in stimulating production behaviors that promote productivity gain.

The treatment effects of the participation regimes must be interpreted with some reserve as the Rosenbaum sensitivity analysis fails to reject the presence of hidden biases that confound outcomes and the treatment assignment (Appendices Table A9-A11)

Table 15: Marginal effects of membership and the participation regimes on maize production efficiency using the PSM

Participation regimes	**TE**	**η_i**	**E_Lnr**	N
	Mean (SE)	Mean (SE)	Mean (SE)	
Group membership	0.089*** (0.0244)	-0.319*** (0.0920)	-0.157*** (0.055)	No =110 Yes = 431 **Total= 541**
Input service only	0.031 (0.0206)	-0.108* (0.0586)	-0.170*** (0.0605)	No =235 Yes= 223 **Total= 458**
Marketing service only	0.190*** (0.0198)	-0.444*** (0.0617)	-0.150*** (0.0262)	No =235 Yes = 34 **Total= 269**
Input & marketing	0.080*** (0.0200)	-0.215*** (0.0724)	-0.136* (0.0742)	No =235 Yes = 49 **Total= 284**

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
TE = technical efficiency; η_i= cost of technical inefficiency; E_Lnr = cost of allocative inefficiency

b) Sorghum

Regarding the sorghum production, as indicated earlier, the LR test fails to reject the null hypothesis of the absence of technical inefficiency. Therefore, only results on allocative inefficiency are interpreted. For the treatment models, covariates balance is achieved for variables presented in Table 16. A formal covariates balance test fails to reject the null hypothesis that covariates are balanced. Thus, the matching approach followed is reliable.

Table 16: Covariates balance summary for sorghum

	Standardized differences		**Variance ratio**	
	Raw	Matched	Raw	Matched
Age	0.067918	0.072961	0.731757	1.029672
Age squared	0.021632	0.075108	0.800651	1.136755
Dummy education	0.213167	-0.04253	1.486828	0.93341
Dummy literacy	0.302419	-0.14204	1.087757	1.003376
Farm size (hectare)	0.069623	0.09404	0.668408	1.000596
Farm size squared (hectare)	-0.0371	0.063809	0.56159	0.97395
Dummy gender	0.312418	-0.0774	0.545574	1.223691
Distance to inputs source (km)	-0.0122	-0.07308	0.947964	1.200375
Number Phone	0.177204	-0.01669	0.931938	1.016611
Number TV	0.016195	0.136809	1.335417	1.534663
Number motorcycle	-0.0498	0.075268	0.823092	1.038816
Number bicycle	0.182422	0.014953	1.033362	1.238146
Wage (FCFA)	-0.20102	-0.07424	0.675379	0.760481
Distance to paved road (km)	-0.12351	-0.01001	1.031185	1.160453
Overidentification test	H0: Covariates are balanced: chi2(15) = 7.85449 Prob > chi2 =0.9295			

As seen in Table 17, the findings on the cost of allocative inefficiency for sorghum are aligned with those of maize, except for two of the participation regimes. As found in the case of maize, group membership and participation in the input provision service significantly reduce the cost incurred due to the presence of allocative inefficiency. In contrast, participation in the marketing service only has an adverse effect on the costs of allocative inefficiency in sorghum production, but this result is weakly significant. Unlike maize, the effect of using both the input and marketing services, albeit positive, is statistically non-significant on sorghum production.

Table 17: Marginal effects of membership and the participation regimes on sorghum production efficiency using the PSM

Participation regimes	E_Lnr Mean (SE)	N
Group membership	-0.205*** (0.0605)	No= 91 Yes =332 Total = 423
Input service only	-0.189*** (0.056)	No= 187 Yes = 175 Total = 362
Marketing service only	0.196* (0.119)	No= 187 Yes= 27 Total= 214
Input & marketing	-0.094 (0.0575)	No= 187 Yes = 34 Total= 221

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

8. CONCLUSION

Cereal production is the main source of livelihoods for a large segment of the Malian rural population and remains an important component of the Malians' diet in general. A parametric estimation approach is used to examine the productive efficiency of maize and sorghum farmers in Mali, and particularly the role played by farmer organizations. A Cobb-Douglas frontier production function with inefficiency is estimated using a 2015 cross-sectional farm household data. Both technical and allocative efficiency estimates are derived. The study aimed to address five research questions: Q1. What is the average technical efficiency among sorghum and maize smallholder farmers? Q2: How are inputs of these crops (i.e., labor, capital, fertilizer, herbicides, and seeds) allocated with respect to the optimal use? Q3: What are the costs associated with technical and allocative inefficiency? Q4: Does membership of farmer organizations influence technical and allocative efficiency as well as their related costs? Q5: Does efficiency differ across different participation regimes?

An average technical efficiency of 51% is found on maize, which suggests that there is considerable room to achieve higher productivity gain. Our model specification could not identify the presence of technical inefficiency on sorghum as the Likelihood Ratio test from the frontier production estimation fails to reject the null hypothesis of the absence of inefficiency.

Inefficient allocation of farm resources is a driver of low productivity. Indeed, the results show that input costs can be reduced by 96% from their current level to move to the efficient output level in the case of sorghum and increased by 17% in the case of maize. Consequently, the levels of inputs used on these crops are non-optimal. There is a relatively high technical and allocative inefficiency in the production of maize and sorghum.

While the GOM's concerns about agricultural productivity have primary been translated into substantial investment funds to support input subsidy programs or crop seed improvement, historical data show that dry cereal production has not responded proportionally regarding yield improvement. The results of this study emphasize the necessity to couple these interventions with assistance services on farm management practices to maximize production performance and induce the optimal use of resources. Attention must be paid to some socio-economic characteristics of farm households and plot managers, given their influence on the technical inefficiency. For instance, membership in farmer organizations, farm size, education, gender, assets owned, especially communication assets, are potential avenues for policy interventions as they significantly affect technical inefficiency.

To deeper insights on the determinants of production inefficiency, the role of farmer organizations is further investigated. A treatment effect model, namely a propensity score matching technique (PSM), is used to, first, estimate the marginal effect of FO's membership on efficiency/inefficiency scores. Then, the membership effect is disentangled from the effects of different participation levels into FO's activities. This is a key contribution of this study to the literature. The PSM model finds that FO's membership improves farmers' technical efficiency while reducing the incremental costs induced by technical and allocative inefficiency. Members achieve a 9% technical efficiency gain over non-members and members incurred on average 24% lower costs of productive inefficiencies than non-members in maize production. For sorghum production, members of farmer organizations are 20.5% more efficient in allocating their farm inputs than non-members.

Similarly, farmers who participate in FO's activities do better when compared to non-participants regarding the optimal allocation of their resources. Participation in the input provision service of FOs significantly reduces allocative inefficiency in both sorghum and maize production. When it comes to technical efficiency, participation in group sale has the most significant positive impact. This result shows that, when market-related risks faced by farmers are attenuated (as it is the case with the group sale), they tend to adopt a production behavior that promotes efficiency and productivity gain.

While research efforts and agricultural development supports have traditionally focused on the upstream farm segment, this study argues that it also matters to correct for output market imperfections to improve production performance among smallholder farmers. Farmer organizations can provide a compelling institutional setting for facilitating linkages to markets. Thus, their organizational capacity must be strengthened in such a way that their activities are sustained beyond the lifespan of the NGOs or development projects which often provide them with supports. There are many pathways to productivity enhancement, but increased productive efficiency can be a costless and sustainable way to achieve it.

In addition to promoting access to productive resources, policy interventions in the agricultural sector of developing countries should facilitate farmers' access to training and advisory services for a more efficient utilization of resources. Investments in transport and communication infrastructures should be promoted along with marketing strategies, such as contract farming and/or organized group sale, since they all contribute to mitigating transaction costs and market-related risks faced by farmers. Insuring against market-related risks could lead to efficiency-increasing decision-making among farmers.

Some limitations of this study are worth mentioning. The analysis involves cross-sectional data, which cannot control for some potential bias due to unobserved heterogeneity in the treatment model. Such an issue can be effectively corrected with panel data. This constitutes a limitation with cross-sectional data analysis. The study attempts to account for the potential biases induced by running a Rosenbaum bounds analysis. While some treatment effects estimates are found to be robust to hidden biases, such as the effects of group membership on technical efficiency and the cost of technical inefficiency, other results need to be interpreted with reserve. Another limitation is that of the use of a Cobb-Douglas production function, which is not the most flexible functional form, but its compelling duality property makes it appropriate for this analysis. Other functional forms such as the translog may be more flexible, but they are costly regarding the degrees of freedom, especially for a small dataset.

An interesting follow-up research topic would be to investigate the effects of different contractual links to output or input markets on farmers' production efficiency. Examples of these contractual links are the "warrantage" system and contract farming. The analysis did not disaggregate between different types of FOs (e.g., cooperatives versus village associations). A comparative analysis of the effects of these different types of organization is another research avenue that would be interesting to explore in future works.

APPENDIX

APPENDIX

Table A1

Likelihood ratio test of the presence of technical inefficiency in maize production

		Maize (N=541)			
(1)		(2)		(3)	
Determinants of production	Mean (SE)	Variance of Random Error	Mean (SE)	Technical inefficiency	Mean (SE)
Fertilizer (kg)	0.178***	Constant	-0.987***	Constant	0.168
	(0.0652)		(0.138)		(0.148)
Seed (kg)	0.184***				
	(0.0520)				
Herbicide (kg)	0.156**				
	(0.0671)				
Labour (hours)	0.110*				
	(0.0622)				
Land (hectare)	0.396***				
	(0.0633)				
Dummy herbicide	0.0261				
	(0.0974)				
Dummy fertilizer	-0.831**				
	(0.329)				
Dummy soil fertility	-0.196**				
	(0.0931)				
Constant	7.288***				
	(0.414)				

LR test of sigma_u=0: chibar2(01) = 38.41. Prob >= chibar2 = 0.000

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A2
Maximum likelihood estimates of a Cobb-Douglas production function for maize with zero input values replaced by 0.**1**

	Maize (N=541)		
(1)		(2)	
Determinants of production	Mean (SE)	Determinants of inefficiency	Mean (SE)
Fertilizer (kg)	0.185***	Group membership	-0.993***
	(0.0631)		(0.219)
Seed (kg)	0.120**	Age (years)	-0.000316
	(0.0501)		(0.00675)
Herbicide (kg)	0.142**	Farm size (hectare)	-0.0188
	(0.0631)		(0.0176)
Labor (hours)	0.105*	Dummy education	-0.380
	(0.0597)		(0.261)
Land (hectare)	0.371***	Dummy literacy	0.265
	(0.0608)		(0.201)
Dummy herbicide	-0.317	Tv	-0.515***
	(0.209)		(0.175)
Dummy fertilizer	-1.333***	Phone	0.0315
	(0.459)		(0.0553)
Dummy soil fertility	0.172**	Motorcycle	-0.121
	(0.0864)		(0.108)
Constant	7.837***	Bicycle	-0.0343
	(0.431)		(0.0828)
		Dist. input source (km)	-0.00223
			(0.0336)
		Household size	-0.0458***
			(0.0152)
		Constant	1.906***
			(0.457)
Variance of random error			
Constant	-1.040***		
	(0.128)		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3

Summary statistics of technical efficiency and cost of technical inefficiency for maize with zero input values replaced by 0.1

MAIZE (N=541)									
	TE					η_i			
	Percentiles	Smallest				Percentiles	Smallest		
1%	0.020	0.005			1%	0.197	0.170		
5%	0.194	0.012			5%	0.276	0.171		
10%	0.254	0.012	Obs	541	10%	0.320	0.176	Obs	541
25%	0.370	0.016	Sum of Wgt.	541	25%	0.465	0.193	Sum of Wgt.	541
50%	**0.537**		**Mean**	**0.508**	**50%**	**0.675**		**Mean**	**0.854**
		Largest	**Std. Dev.**	**0.186**			Largest	**Std. Dev.**	**0.632**
75%	0.651	0.837			75%	1.078	4.463964		
90%	0.744	0.851	Variance	0.034	90%	1.487	4.779667	Variance	0.399
95%	0.775	0.854	Skewness	-0.390	95%	1.778	4.782262	Skewness	3.187
99%	0.834	0.855	Kurtosis	2.493	99%	4.237	5.705907	Kurtosis	18.991

Table A4
Likelihood ratio test of the presence of technical inefficiency in sorghum production

Sorghum (N=423)					
(1)		(2)		(3)	
Determinants of production	Mean (SE)	Variance of Random Error	Mean (SE)	Technical inefficiency	Mean (SE)
Fertilizer (kg)	0.159*	Constant	-0.290***	Constant	-7.991
	(0.0914)		(0.0697)		(68.59)
Seed (kg)	0.216***				
	(0.0524)				
Herbicide (kg)	-0.175**				
	(0.0790)				
Labour (hours)	0.270***				
	(0.0694)				
Land (hectare)	0.217***				
	(0.0563)				
Dummy herbicide	0.171				
	(0.120)				
Dummy fertilizer	-0.622				
	(0.406)				
Dummy soil fertility	0.0758				
	(0.106)				
Constant	4.944***				
	(0.630)				

LR test of sigma_u=0: chibar2(01) = 0.000. Prob >= chibar2 = 1.000
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A5
Maximum likelihood estimates of a Cobb-Douglas production function for sorghum with zero input values replaced by 0.1

Sorghum (N=423)			
(1)		**(2)**	
Determinants of production	Mean (SE)	Determinants of inefficiency	Mean (SE)
Fertilizer (kg)	0.137	Group membership	-0.0512
	(0.0842)		(0.375)
Seed (kg)	0.154***	Age (years)	-0.00279
	(0.0531)		(0.0112)
Herbicide (kg)	-0.145*	Farm size (hectare)	-0.138***
	(0.0801)		(0.0533)
Labour (hours)	0.265***	Dummy education	-0.617
	(0.0660)		(0.442)
Land (hectare)	0.171***	Dummy literacy	0.472
	(0.0546)		(0.364)
Dummy herbicide	0.497*	Tv	-0.587
	(0.283)		(0.387)
Dummy fertilizer	-0.878	Phone	0.269**
	(0.569)		(0.110)
Dummy soil fertility	0.126	Motorcycle	-0.367
	(0.104)		(0.243)
Constant	5.598***	Bicycle	-0.0611
	(0.476)		(0.154)
		Dist.input source (km)	0.129**
			(0.0561)
		Household size	-0.0345
			(0.0289)
		Gender	0.233
			(0.716)
		Constant	0.187
			(0.953)
Variance of random error			
Constant	-0.661***		
	(0.118)		

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Note: The inputs are expressed in logarithmic values

Table A6
Likelihood ratio test of the presence of technical inefficiency in sorghum production when zero input values are replaced by 0.1

		Sorghum (N=423)			
(1)		**(2)**		**(3)**	
Determinants of production	Mean (SE)	Variance of Random Error	Mean (SE)	Technical inefficiency	Mean (SE)
Fertilizer (kg)	0.159*	Constant	-0.290***	Constant	-7.991
	(0.0914)		(0.0697)		(68.24)
Seed (kg)	0.216***				
	(0.0524)				
Herbicide (kg)	-0.175**				
	(0.0790)				
Labour (hours)	0.270***				
	(0.0694)				
Land (hectare)	0.217***				
	(0.0563)				
Dummy herbicide	0.574**				
	(0.278)				
Dummy fertilizer	-0.989				
	(0.613)				
Dummy soil fertility	0.0758				
	(0.106)				
Constant	4.908***				
	(0.702)				

LR test of sigma_u=0: chibar2(01) = 0.000. Prob >= chibar2 = 1.000
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A7
Determinants of FO membership

	Member =1 Non-member =0	
Variables	**Mean**	**SD**
Age (years)	0.0132**	(0.00518)
Age square (years)	-0.000136***	(5.06e-05)
Gender (0/1)	-0.0916*	(0.0528)
Education (dummy)	0.0940**	(0.0419)
Literacy (dummy	0.0222	(0.0304)
Farm size (hectare)	0.0244***	(0.00732)
Farm size square	-0.000653***	(0.000211)
Household size	-0.00191	(0.00198)
Remittances	-0.0342	(0.0284)
Number of off-farm workers	-0.00221	(0.0162)
Asset value(FCFA)	5.49e-08***	(1.94e-08)
Distance to input source (km)	-0.00684	(0.00526)
Phone (number)	0.00606	(0.00816)
Tv (number)	-0.0450*	(0.0255)
Motorcycle (number)	-0.0327*	(0.0169)
Bicycle (number)	0.00778	(0.0123)
Herd size (TLU)	-0.000266	(0.00108)
Village wage level (FCFA)	-0.000145***	(3.28e-05)
Distance to paved road (km)	-0.000623	(0.000639)
Observations	964	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A8
Rosenbaum bounds analysis for group membership effect(Maize)

Outcomes		Hodges-Lehmann point estimates		95% confidence interval	
		Upper bound	Lower bound	Upper bound	Lower bound
	Γ				
TE					
	1	0.107237	1.07E-01	0.083314	0.131467
	1.2	0.087624	0.127066	0.063683	0.150943
	1.4	0.071145	0.14329	0.047081	0.167682
	1.6	0.057247	0.15763	0.032699	0.183005
	1.8	0.044939	0.169881	0.019483	0.196281
	2	0.034031	0.181579	0.008259	0.208174
	2.2	0.023787	0.191776	**-0.00226**	**0.218906**
	2.4	0.01476	0.20116	-0.0115	0.228679
	2.6	0.006489	0.209907	-0.02031	0.237547
	2.8	**-0.00105**	**0.217779**	-0.02828	0.24566
	3	-0.00786	0.224801	-0.03589	0.253451
η_i					
	1	-0.25601	-0.25601	-0.31838	-0.19611
	1.2	-0.30718	-0.20705	-0.37229	-0.14664
	1.4	-0.35151	-0.16614	-0.4192	-0.10426
	1.6	-0.38966	-0.13057	-0.46105	-0.0675
	1.8	-0.42516	-0.09853	-0.50004	-0.0348
	2	-0.45694	-0.07054	-0.53768	-0.0064
	2.2	-0.48722	-0.0462	**-0.57177**	**0.019415**
	2.4	-0.51521	-0.02254	-0.60626	0.043441
	2.6	-0.54276	-0.00262	-0.638	0.065765
	2.8	**-0.56774**	**0.016293**	-0.66908	0.086596
	3	-0.5933	0.033961	-0.70027	0.106521
E_Lnr					
	1	-0.12642	-0.12642	-0.18978	-0.06329
	1.2	-0.17835	-0.07454	-0.24197	-0.01
	1.4	-0.22169	-0.03142	**-0.28555**	**0.034871**
	1.6	**-0.25881**	**0.007365**	-0.32414	0.074164
	1.8	-0.29138	0.040342	-0.3574	0.107797
	2	-0.32011	0.070539	-0.38821	0.138924
	2.2	-0.34622	0.096112	-0.41364	0.165849
	2.4	-0.37003	0.121047	-0.43936	0.191935
	2.6	-0.39168	0.142711	-0.46172	0.21499
	2.8	-0.41066	0.162586	-0.48262	0.235814
	3	-0.42943	0.182259	-0.50298	0.256456

Table A9
Rosenbaum bounds analysis for the effect of participation in inputs provision service (Maize)

Outcomes		**Hodges-Lehmann point estimates**		**95% confidence interval**	
		Upper bound	Lower bound	Upper bound	Lower bound
	Γ				
TE					
	1	0.06415	0.06415	0.026487	0.100665
	1.2	0.041319	0.086286	0.003677	0.122137
	1.4	0.023312	0.103545	**-0.01589**	**0.139843**
	1.6	0.006824	0.119158	-0.03284	0.155164
	1.8	**-0.00726**	**0.132055**	-0.04843	0.169468
	2	-0.01984	0.143466	-0.06262	0.180783
	2.2	-0.03124	0.153933	-0.07438	0.191334
	2.4	-0.04267	0.163868	-0.08613	0.201228
	2.6	-0.0522	0.172154	-0.09705	0.20981
	2.8	-0.06079	0.179855	-0.10661	0.217889
	3	-0.06933	0.186665	-0.11538	0.224868
η_i					
	1	-0.16538	-0.16538	-0.2586	-0.07508
	1.2	-0.22189	-0.11115	-0.31011	-0.01614
	1.4	-0.26651	-0.06597	**-0.35967**	**0.030696**
	1.6	-0.303	-0.02387	-0.40107	0.072042
	1.8	**-0.33763**	**0.010144**	-0.43568	0.110373
	2	-0.36942	0.042056	-0.46692	0.145081
	2.2	-0.39706	0.06798	-0.49563	0.17932
	2.4	-0.42176	0.094485	-0.52121	0.207376
	2.6	-0.44251	0.118623	-0.54627	0.234081
	2.8	-0.46305	0.14184	-0.56729	0.260065
	3	-0.48196	0.164347	-0.58647	0.284056
E_Lnr					
	1	-0.17611	-0.17611	-0.26179	-0.09538
	1.2	-0.22846	-1.26E-01	-0.31772	-0.04609
	1.4	-2.70E-01	-8.79E-02	-0.36445	-0.00603
	1.6	-3.10E-01	-5.21E-02	**-4.07E-01**	**0.029008**
	1.8	-3.44E-01	-2.35E-02	-4.45E-01	0.06001
	2	**-0.37376**	**1.22E-03**	-4.80E-01	0.086042
	2.2	-0.40286	0.025577	-0.51149	0.111469
	2.4	-0.43067	0.046658	-0.54171	0.131519
	2.6	-0.45408	0.066767	-0.56973	0.151832
	2.8	-0.47689	0.08329	-0.5939	0.170195
	3	-0.49777	0.100436	-0.61537	0.189518

Table A10
Rosenbaum bounds analysis for the effect of participation in marketing service (Maize)

Outcomes	Γ	Hodges-Lehmann point estimates		95% confidence interval	
		Upper bound	Lower bound	Upper bound	Lower bound
TE					
	1	0.084063	0.084063	-0.01005	0.156053
	1.2	0.060263	1.03E-01	-0.02675	0.189231
	1.4	3.86E-02	1.16E-01	-0.04786	0.215938
	1.6	2.08E-02	1.24E-01	-6.68E-02	0.232954
	1.8	1.07E-02	1.35E-01	-8.76E-02	0.244301
	2	0.004166	1.44E-01	-9.96E-02	0.254142
	2.2	**-0.00803**	**0.152984**	-0.1142	0.260303
	2.4	-0.0118	0.162816	-0.12425	0.277533
	2.6	-0.02108	0.174893	-0.13118	0.289507
	2.8	-0.02395	0.187846	-0.13693	0.313153
	3	-0.03027	0.194247	-0.14999	0.328943
η_i					
	1	-0.22774	-0.22774	-0.43073	0.012347
	1.2	-0.25182	-0.17723	-0.49529	0.054679
	1.4	-0.28716	-0.14044	-0.52512	0.098193
	1.6	-0.30584	-0.07204	-0.54726	0.121209
	1.8	-0.343	-0.03882	-0.57276	0.169421
	2	-0.3919	-0.02131	-0.65201	0.206379
	2.2	-0.41878	-0.00397	-0.68481	0.233981
	2.4	**-0.44224**	**0.015682**	-0.72987	0.25715
	2.6	-0.45442	0.033001	-0.75829	0.273255
	2.8	-0.48741	0.052609	-0.7809	0.299961
	3	-0.49723	0.060018	-0.79158	0.310789
E_Lnr					
	1	-0.00872	-0.00872	-0.28682	0.185835
	1.2	**-0.07019**	**0.026451**	-0.34328	0.254378
	1.4	-0.11969	0.052464	-0.41188	0.313656
	1.6	-0.16429	0.08738	-0.43129	0.389
	1.8	-0.22656	0.122804	-0.44462	0.431459
	2	-0.25401	0.153592	-0.47438	0.462043
	2.2	-0.27364	0.171686	-0.54083	0.51228
	2.4	-0.29566	0.198508	-0.55496	0.537215
	2.6	-0.31226	0.218867	-0.57396	0.558976
	2.8	-0.33332	0.249735	-0.62069	0.592366
	3	-0.36591	0.26751	-0.67428	0.633279

Table 11
Rosenbaum bounds analysis for the effect of participation in both inputs and marketing services (Maize)

Outcomes	Γ	Hodges-Lehmann point estimates		95% confidence interval	
		Upper bound	Lower bound	Upper bound	Lower bound
TE					
	1	0.06014	0.06014	-0.00983	0.130145
	1.2	0.041936	0.077559	-0.03119	0.148553
	1.4	0.024171	0.094189	-0.04473	0.161251
	1.6	0.012793	0.105973	-0.061	0.177992
	1.8	0.000647	0.11853	-0.0766	0.190338
	2	**-0.00932**	**0.128483**	-0.08727	0.20758
	2.2	-0.01652	0.136072	-0.10291	0.216655
	2.4	-0.02668	0.143281	-0.1108	0.230682
	2.6	-0.03299	0.151122	-0.1266	0.239684
	2.8	-0.03969	0.157178	-0.13283	0.249567
	3	-0.04456	0.160897	-0.13832	0.263624
η_i					
	1	-0.1295	-0.1295	-0.28969	0.036904
	1.2	-0.17137	-0.08249	-0.33739	0.07514
	1.4	-0.20685	-0.04712	-0.38404	0.114116
	1.6	-0.23501	-0.01553	-0.424	0.155849
	1.8	**-0.26659**	**0.009556**	-0.46568	0.201589
	2	-0.2864	0.035938	-0.50178	0.244059
	2.2	-0.31368	0.049589	-0.52581	0.283958
	2.4	-0.32733	0.066558	-0.55321	0.316765
	2.6	-0.34788	0.080702	-0.57309	0.367852
	2.8	-0.3646	0.096283	-0.60906	0.460832
	3	-0.38206	0.112758	-0.63316	0.530614
E_Lnr					
	1	-0.10672	-0.10672	-0.30673	0.099324
	1.2	-0.16183	-0.06192	-0.37578	0.170867
	1.4	-0.2096	0.000128	-0.43369	0.237005
	1.6	-0.23874	0.04054	-0.48063	0.295365
	1.8	-0.27064	0.067986	-0.51448	0.331686
	2	-0.30447	0.095088	-0.54034	0.369726
	2.2	-0.32918	0.12053	-0.56932	0.401492
	2.4	-0.36412	0.157856	-0.58966	0.439669
	2.6	-0.38404	0.18254	-0.6179	0.486197
	2.8	-0.40988	0.20696	-0.64922	0.538071
	3	-0.43287	0.233623	-0.66877	0.591898

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