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Technical efficiency, adoption and impact of organic farming practic-es: a case study of organic cotton farming in Burkina Faso

Thèse de Doctorat

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Declaration

This thesis is the result of research work undertaken by Abdoulaye KOUDOUGOU in the Department of Economics, University Cheikh Anta Diop of Dakar, under the supervision of Prof. Adama Diaw.

It has never been submitted in whole or part for any degree in this university or elsewhere.

References to other people have been duly acknowledged.

Dedication

This thesis is dedicated to my parents for all the support they gave me throughout my education.

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Table of contents

List of tables

Liste of figures

List of abbreviations

ATT*: Average Treatment on the Treated*

ATU*: Average Treatment on the Untreated*

CNAbio *: Conseil National pour l'agriculture biologique*

CDE*: Centre for Development and Environment (Switzerland)*

DDC *: Direction du Développement et de la Coopération*

DEA*: Data Envelopment Analysis*

EU*: European Union*

ESR*: Endogenous Switching Regression*

FIBL*: Research Institute of Organic Agriculture*

GHG*: Greenhouse Gaze*

IFOAM*: International Federation of Organic Agriculture Movements*

IPCC*: International Panel on Climate Change*

MECV*: Ministère de l'Environnement et du Cadre de Vie*

UNCTAD*: United Nations Conference on Trade and Development*

UK*: United Kingdom*

UNEP*: United Nations Environment Programme*

UNPCB*: Union Nationale des Producteurs de Coton du Burkina Faso*

USA*: United States of America*

SDG*: Sustainable Development Goal*

SECO*: Secrétariat d'Etat à l'économie (Switzerland)*

SOCOMA*: Société COtoniere du gourMA*

SOFITEX*: Société des Fibres TEXtiles*

PSM*: Propensity Score Matching*

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Abstract

Organic farming sector is presented today as an alternative to limit the numerous environmental challenges caused by conventional farming practices. Essentially based on farm biota for fertilization and the control of pests, this type of farming practice reduce considerably external contributions on the farm such as agricultural chemicals. Though its environmental efficiency have been well established, organic farming still poorly adopted all over the world. The potential of organic methods (crop rotation, natural enemies, and organic pesticides) to provide nutrients and insure pests and weed control is an important issue of the acceptance of organic farming. Given that organic farming practices are constrained in terms of inputs use, their ability to provide acceptable yields is questioned. Potential adopters wonder about the capacity of organic farming practices to derive productive inputs through only soil biological processes. In addition, the question of the economic impact of organic farming practices on farm household livelihoods is also a subject of debates. Based on these questionings, this study aims to examine the technical efficiency, the adoption and the impact of organic farming in the specific case of organic cotton production in Burkina Faso. Given that the adoption and diffusion of innovations is essentially an informational process, a merged framework of the theory of diffusion of innovations and the theory of planned behaviour serves as conceptual framework for this study. The adoption and impact of organic cotton production is investigated through an endogenous switching regression model to control for the endogeniety of the adoption decision while stochastic frontier analysis are applied to determine the technical efficiency of organic cotton farming and its exogenous determinants. The results of the study revealed that factors such as the experience in cotton farming, the education of the head of household, the household size, the gender of the head of household and the knowledge provided to cotton farmers through radio emissions affect negatively the decision to grow organic cotton. While the age of the head of household has a positive impact on the decision to grow organic cotton. Moreover the adoption of organic cotton farming has a significant positive impact on the returns on cotton production of organic cotton farmers but affect negatively their capacity to grow non-cotton crops. The analysis of the technical efficiency of organic cotton farmers revealed that the mean technical efficiency of organic cotton farmers is about 0.6538323 with a confidence interval of [0.026201; 0.9998788] at 95%. Farm size is an efficiency enhancing factor while the experience in cotton production, the distance from household to cotton farm and the soil fertility status are efficiency reducing factors.

Résumé

Le secteur de l'agriculture biologique est présenté aujourd'hui comme une alternative pour limiter les nombreux défis environnementaux liés aux pratiques agricoles conventionnelles. Essentiellement basé sur les éléments internes à la ferme pour la fertilisation et la lutte contre les parasites, ce type de pratique agricole réduit considérablement les contributions externes à la ferme telles que les engrais minéraux et les pesticides chimiques. Bien que son efficacité environnementale soit bien établie, l'agriculture biologique reste encore faiblement adoptée dans le monde entier. Le potentiel des pratiques agricoles biologiques (rotation des cultures, ennemis naturels et pesticides biologiques) à fournir les éléments nutritifs nécessaires à la croissance de la plante et à assurer la lutte contre les ravageurs et les mauvaises herbes est une importante question qui limite leur l'acceptation. Étant donné que les pratiques agricoles biologiques sont limitées en termes d'utilisation des intrants chimiques, leur capacité à fournir des rendements acceptables est constamment remise en cause. Les utilisateurs potentiels s'interrogent sur la capacité des pratiques agricoles biologiques à fournir des intrants productifs uniquement par le biais des processus biologiques du sol. En outre, la question de l'impact économique des pratiques agricoles biologiques sur les moyens de subsistance des ménages agricoles fait également l'objet de débats. A partir de ces questionnements, cette étude vise à examiner l'efficacité technique, l'adoption et l'impact de l'agriculture biologique sur les moyens de subsistance des ménages agricoles dans le cas spécifique de la production de coton biologique au Burkina Faso. Étant donné que l'adoption et la diffusion des innovations est un processus essentiellement informationnel, un cadre théorique qui fusionne la théorie de la diffusion des innovations et la théorie du comportement planifié sera utilisé dans la présente étude. L'adoption et l'impact de la production de coton biologique est analysé au moyen d'un modèle de régression à commutation endogène afin de contrôler l'endogénéité liée à la décision d'adoption, tandis qu'un modèle frontière stochastique est appliqué pour déterminer l'efficacité technique de la culture du coton biologique et les déterminants exogènes de l'inefficacité technique. Les résultats de l'étude ont révélé que des facteurs tels que l'expérience dans la culture du coton, le niveau d'éducation du chef de ménage, la taille du ménage, le sexe du chef de ménage et les connaissances fournies aux producteurs de coton par le biais d'émissions radiophoniques ont une incidence négative sur la décision d'adoption de la culture du coton biologique tandis que que l'âge du chef de ménage a un impact positif sur la décision d'adoption de la culture du coton biologique. De plus, l'adoption de la culture du coton biologique a un impact positif sur les revenus de la production de coton des producteurs de coton biologique, mais affecte négativement leur capacité à produire d'autres cultures telles que les céréales. L'analyse de l'efficacité technique des producteurs de coton biologique a révélé que l'efficacité technique moyenne des producteurs de coton biologique est d'environ 0,6538323 avec un intervalle de confiance de [0,026201; 0,9998788] à 95%. La taille de la ferme est un facteur d'amélioration de l'efficacité technique, tandis que l'expérience dans la production de coton, la distance qui sépare les ménages des exploitations cotonnières et l'état de la fertilité des sols réduisent l'efficacité technique.

Chapter I: Introduction

1.1 General context of the study

1.1.1 Some issues related to organic farming

The increasing public consciousness of the environmental detrimental effects of conventional agricultural production systems has raised during these last years the debate about finding new production systems able to limit the ecological footprint of agriculture. The Sustainable Development Goal 12 (SDG 12) related to the issues of sustainable production and consumption, emphasized the need to limit the generation of toxic materials, waste and pollutants as a precondition to a long term growth. The agricultural sector considered to be the major source of livelihoods especially in developing countries present a great potential for the transition to an alternative economy. Indeed the massive use of chemical inputs-based production processes in conventional farming led to serious toxic waste pollution issues (Chakrabarty et al. 2014). The (pesticide action network, 2009)1 revealed that the conventional farming behaviour accumulate more than 2 million tonnes of toxins per year in the ecosystems. The issue of pesticides use in agriculture still a question of great importance (Ajayi et al. 2011). Based on data from 291 households in Nepal, (Atreya 2008) showed that the predicted probability of falling sick from pesticides related symptoms is higher within farmers that are applying pesticides than those who are not. The health costs of pesticides adopters is revealed to be height times more important than non-adopters. Aside of humans and animals health effects, pesticide pollution is also impacting negatively environmental factors such as soil, surface and groundwater, crop productivity, fauna and flora (Pimentel 2005). Following (Fantke et al. 2012) assessment of the health impacts and related damage costs from pesticides exposure in 24 European countries, 33 substances are now banned from the European market. Organic agriculture is presented today as an alternative to limit the issues associated with conventional farming such as biodiversity loss, animal welfare concerns, nitrate pollution, food safety, etc. (Läpple & Rensburg 2011). The Organic agriculture movement arose first with pioneers farmers and consumers who were aware of the need to preserve ecosystems around farmlands and to improve the health-giving benefits of food (Reed & Holt 2006). The development of

[1] Retrieved from http://pesticideinfo.org/

organic farming today is interpreted within two main theories: the ecological modernisation theory and the treadmill of production theory. While ecological modernisation theorists (Zimmerman, 1990), (Hubert, 1991) emphasised the role of the environmental consciousness of social entrepreneurs in the development of organic farming, treadmill of production theorists centre the analysis on a profit maximisation view. The organic farming movement cannot be dissociated from regulation and labelling schemes (through auditing and certification processes) which played a crucial role in the expansion of the sector by insuring reliability and trust among market actors (Lockie 2006). The regulation system of organic agriculture currently in application in the European Union (EU) define organic agriculture as any type of farming system that prohibit the use of synthetic fertilisers and chemical pesticides and associate several agronomic practices that are sustainable2. As (Läpple & Rensburg 2011) mentioned, organic farming constitute today an essential element of the European common agricultural policy and member states are continuously increasing their shares of organic lands. Organic agriculture emphasise the use of management practices (agronomic, biological, mechanical methods) rather than the use of chemical inputs to fulfil any specific function within the farming system (Eyhorn et al. 2005). By its nature, organic farming constitute an adaptation option that can be targeted at reducing the vulnerability of rural populations to the adverse effects of climate change and variability (Wani et al. 2013). It's a farming system that reduced inputs costs and lower the risks of partial or total crop failure (Wani et al. 2013). (Uematsu & Mishra 2012) argued that organic farming eliminate agricultural chemicals and other external inputs to improve farm economics. For (Kilcher 2007) organic farming is a cost effective farming system that present the potential to reduce poverty and contribute to sustainable agricultural development. The potential of organic farming in terms of climate change mitigation have also been considered. Organic farming allows to recycle wastes from plants and animals in order to return nutrients to the land and minimise the use of non-renewable resources. It is an alternative farming system that has the potential to both reduce Greenhouse Gases (GHG) emissions and enhance carbon sequestration in the soil (Wani et al. 2013). Despite its mitigation and adaptation potentials described above, the organic farming sector still in its infancy and represent a small portion of the total of utilizable agriculture lands especial-

[2] Council Regulation (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural product.

ly in Africa3. Organic agriculture currently represent 0.3% of the total of agricultural lands worldwide and is more adopted in developed countries (Connor 2008). The question of the productivity of organic agriculture and the potential of organic methods (crop rotation, natural enemies, and organic pesticides, etc.) to provide the required nutrients and insure pests and weed control are important barriers to a widespread adoption of organic farming (Connor 2008). In organic farming practices, soil fertility issues, weed management, pest and disease control depend on the combination of physical, cultural and biological practices (Baker & Gian 2012). Though these methods have been described to be sustainable and environmentally friendly, sceptics continue to consider organic agriculture to be ideologically driven and inefficient as a farming system (Reganold & Wachter 2016). For sceptics organic farming is a land intensive farming system and by this way represents a threat to the world's forest, wetlands and grasslands (Reganold & Wachter 2016). A former US secretary of agriculture Earl Butz in 1971 was showing his pessimism about the development of organic agriculture in these terms: "**Before we go back to organic agriculture in this country, somebody must decide which 50 million americans we are going to let starve or go hungry**" (Reganold & Wachter 2016). Organic farming is perceived as an economically and technically inefficient practice (Acs et al. 2005). As (Kumbhakar et al, 2009) argued, organic farming is less productive than the conventionnal one because the organic production process is based on the use of restricted specific inputs. For the organic production to be profitable, the price differential should be high enough to compensate the loss of productivity due to the conversion. It is commonly accepted that conventional farming practices which associate the use of chemicals provide better yields than organic farming system (Offermann & Nieberg 2010). Conversely, other authors found these comparisons incomplete and missing to account for the quality of the outputs and the negative environmental impact of conventional agriculture (Lotter 2014). Among the scarce and growing literature that applies production economics to compare the

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[3] Share of organic agricultural land worldwide in 2015, by region extracted from www.statista.com: Oceania (45 percent of the global organic farmland), Europe (25 percent of the global organic farmland) and Latin America (13 percent of the global organic farmland), Asia (8% of the global organic farmland), North America (6% of the global organic farmland), Africa (3% of the global organic farmland)

performances of organic and conventional farming practices is (Tzouvelekas et al. 2001). Based on two samples of organic and conventional growing olives and cotton farms, the authors find out mixed results. In the case of olive farms, the results showed that the organic growing system, is less technically efficient than the conventional system due to structural problems like the lack of scientific research and extension services. In contrast to the olive farms considered in the study, organic cotton farmers were found to be technically efficient with respect to their own frontier. These results are essentially explained by some measures put in place by organic cotton farmers such as the prudent choice of inputs in terms of quantity and quality to compensate the effect of lower margins. (Lansink et al, 2002) in their study on Finnish crop and livestock farms, provide evidence that organic farmers are more efficient than conventional ones when distance is measured with respect to the transformation curve of each production system. But their efficiency becomes lower when the distance is considered with respect to the envelope of the frontiers of both production systems. The potential of organic farming practices to provide sustainable livelihoods to small scale farmers is also a question of debate. Even though the advantages of organic agriculture have been found to be enormous in terms of climate change adaptation and mitigation, many production challenges coupled with the lack of governments' interest in organic agriculture continue to limit widespread adoption of organic agriculture (Arah & Kumah 2015). The high costs of organic certification, the non-availability of large volume of organic inputs and the lack of regional markets for organic products are seen to be some challenges limiting the profitability of organic farming (Jouzi et al. 2017). Activists in favour of the development of organic agriculture in contrast consider organic agriculture as the panacea to reach food security in developing countries (Baker & Gian 2012). In sub-Saharan Africa, organic agriculture is perceived by the (Africa Development Bank Group 2012) as a viable sustainable agricultural development option that can strengthen farmers' resilience to weather shocks and contribute to poverty alleviation. Local NGOs, development agencies and farmers' groups are increasingly emphasizing that a full adoption of organic farming practices can contribute to improve productivity and address the problems of food security all around Africa. The third African organic agriculture conference which hold in Lagos in 2015 came out with the common declaration that ecological organic agriculture has a significant role to play in Africa in addressing issues like land degradation, market access, food insecurity, and climate change4.

[4] The Lagos Declaration on Achieving Social and Economic Development through Ecological and Organic Agricultural Alternatives

1.1.2 Organic cotton farming in Burkina Faso

The situation of the cotton sector in Burkina Faso is a perfect illustration of the controversies described above between the necessity to increase agricultural productivity and the need to preserve soils fertility in the long run. Indeed one of the earliest and well-structured organic farming sector in West Africa in general and in Burkina Faso in particular is the organic cotton sector. The cotton economy in Burkina Faso has been qualified as a success story (Coulter 2011). Between 2006 and 2007, Burkina Faso was the leading cotton producer and exporter in Africa (Kaminski 2009). The cotton sector constitute a major economic growth leading factor and a major cash crop for small scale farmers in Burkina Faso (Azam & Djimtoingar 2004). Before the gold mining boom in 2008, cotton was the main commodity exported and was accounting for about 60 percent of export revenues (Meda 2016). Along with the expansion of the mining sector the last years, the cotton sector constitute now the second contributor to the export revenues in Burkina Faso (Meda 2016). Even though the contribution of the cotton sector to export revenues is decreasing, the cotton economy remain a major source of income for small scale farmers and continue to support 1.5 to 2 million people (Kaminski 2009) all around the country. Before the introduction of the organic cotton in the early 2000s, cotton production in Burkina Faso was dominated by conventional cotton production which rely heavily on costly agrochemical inputs. Cotton is considered to consume the most important part of agrochemicals in agriculture and account for 60% of all fertilisers and 80% of pesticides use in West Africa (Meda 2016). In Burkina Faso, though cotton represent 5% of crop areas, it consumes more than 90 percent of the total of pesticides used (Ouédraogo et al. 2011). The contribution of the conventional cotton production to the economies in many developing countries has not been cost free for farmers. Synthetic inputs are provided to farmers on credit by cotton companies and farmers sometimes are struggling to achieve sufficient yields in other to make profits and reimburse the credits contracted with cotton companies. (Sanfilippo & Perschau 2008) argued that pesticides account for up to 60% of production costs in conventional cotton production in West Africa. In Burkina Faso, the aggregate costs of insecticides exceed annually US $ 60 million (Pertry et al. 2016) . The increasing price of agrochemical synthetic inputs combined with the declining price of grain cotton have been threatening the economic viability of the conventional cotton farming sector since 2000 (Bassett 2010); (Vitale et al. 2008). In addition pests resistance to insecticides has emerged leading to an intensive use of insecticides that pose significant health hazards to farmers

(Pertry et al. 2016). The decreasing efficiency of the green revolution technologies (synthetic insecticides and pesticides) for pest control accentuated the interest of the government of Burkina Faso to find new pest control options such as biotechnological applications (Pertry et al. 2016). The National Biosafety Agency authorized in 2008 the production and commercialization of two Bt cotton varieties after several years of field trials (2003-2007) (Pertry et al. 2016). The experience with Genetically Modified (GM) cotton in Burkina Faso has not been long since cotton companies decided during the 2016/2017 cropping season to abandon it due the low quality of GM cotton fiber (Meda 2016). The organic and fair trade cotton program in Burkina Faso has been launched since 2004 with the technical assistance of Helvetas, an independent Swiss development organisation (CDE 2009). This program covers 7 organic cotton production zones, including the Banfora production zone in the Comoé province, the Ioba production zone in the Bougouriba province, the Oubrittenga production zone in the province of Oubrittenga, the Nayala production Zone in the Nayala province, the Ziro Production zone in the Ziro Province, the Fada N'gourma production zone in the province of Gourma and the Tenkodogo production zone in the Central-Eastern region (CDE 2009). In 2014/2015, only 0.75% of the total of cotton land was under organic cultivation while conventional and genetically modified cotton farming systems were representing respectively 29.74% and 69.51% of the total of cotton land (Meda 2016). With less than 100 producers for a total production of 12.5 tons in 2004, the production of organic cotton reached the level of 750 tons in 2007 for a total number of 1800 producers tons (Konaté, 2012)[5]. The 2010-2011 season recorded a satisfactory level of production of 1,600 tons with regard to production targets of 1,900 tons (Konaté, 2012). During the 2011-2012 campaign, the production of organic cotton fell by about 500 tons and was evaluated at 1390 tons (Konaté, 2012). Yields per hectare also rose rapidly from 412 to 540 kg per hectare between the 2004/2005 and 2008/2009 cropping seasons (CDE 2009). The steady increase in the number of organic cotton producers since the launch of the organic and fair trade cotton program testifies to the interest that organic cotton has aroused among cotton producers, (CDE 2009). Between the 2008/2009 and 2015/2016 cropping seasons, the number of organic cotton producers has not stopped increasing overall, sometimes exceeding 5000 producers (UNPCB data). The double certification of organic and

[5] (Konaté, 2012), baisse de la production du coton bio-équitable, campagne 2012-2013 au Burkina Faso, cas de la zone du Ziro : diagnostic et propositions de solutions.

fair trade allows organic cotton farmers to benefit from prices above the conventional cotton price (Coulter 2011). The organic Fairtrade cotton program in Burkina Faso promote Fairtrade standards (equal representation of women, the implementation of an integrated crop and pest management, democratic management of producers' groups, prohibition of child labour, etc.) (Coulter 2011). The potential benefits of organic cotton farming include improved rural livelihoods through higher income, the reduction of the dependence in harmful expensive chemical inputs and improved health and environment (Coulter 2011). (Coulter 2011) showed that cotton incomes per hectare in Burkina Faso are nearly three times higher in organic cotton than in conventional cotton.

1.2 Problem statement

Despite initiatives from NGOs to promote the organic farming sector and the strong interest of farmers for organic production especially in the cotton sector in Burkina Faso, the organic cotton sector expansion still limited. (Coulter 2011) consider the institutional organization of the cotton sector as the main constraint to the expansion of the organic cotton sector in Burkina Faso. For the author the monopsonistic governance structure of the cotton sector, in which three companies control cotton production and marketing is not in favour of the organic cotton sector. Since these companies generate their profits from conventional cotton production, there is a low interest to support the lower-yielding organic cotton sector. (Meda 2016) also argued that some institutional factors such as the provision of chemical fertilizers by cotton companies to conventional and Bt cotton producers for non-cotton crops production, such as maize, tends to discourage the adoption of the organic production method which he described as the most sustainable cotton farming practice. The low yields observed in organic cotton farming and the doubts that sceptics have about its ability to provide sustainable livelihoods and alleviate poverty in rural areas hinder its expansion. In the context of Burkina Faso few studies have investigated the performance of organic cotton farming system in terms of its productive efficiency and also in terms of its impact on farm household's livelihoods. The existing impact analysis is the one conducted by the NGO Helvetas in 2008 (CDE, 2008). Through descriptive statistics and based on a sample of 53 organic cotton farmers and 48 conventional cotton farmers, this analysis revealed that in average the value of the output per acre is the same for organic and conventional farmers. This is mainly linked to the fact that organic cotton farmers benefit from higher prices compare to conventional cotton farmers. Organic cotton farmers are spending 90% less in inputs endowment. In contrast to past ideas received which are presenting organic farming as a labour intensive farming technology due to inputs restrictions, this study revealed that organic cotton farmers need 23% less of labour compare to conventional cotton farmers. The net reduction of cotton inputs costs in the organic sector have been found to improve farmers mental health who are free of any credit constraint with cotton companies. (Meda 2016) used a green economics perspective to compare organic, conventional and genetically modified cotton farming in Burkina Faso. This analysis was done based on an aggregated green economic performance indicator built by taking into account the economic, environmental and social performances of each cotton farming technology. The study revealed that the organic farming system is the most sustainable cotton farming system in Burkina Faso and provide more potential for greening agriculture compared to conventional and genetically modified cotton farming systems. Organic cotton farming impact studies compared to conventional cotton farming are rare in the context of Burkina Faso and the existing study cited above is based on descriptive statistics which can hide a lot of selection bias. These methods are not relevant to control for selection bias due to observable and unobservable factors that can occur in the decision of farmers to grow organic cotton. Moreover, the existing impact study do not explicitly examine the counterfactual case and the differential gain of adoption when comparing organic and conventional cotton farming systems. Efficiency analysis in the context of organic cotton farming in Burkina Faso are almost inexistent and there is no evidence of the productive efficiency of organic cotton farming and the factors responsible of its inefficiencies.

1.3 Research questions

In light of the issues described above regarding the context and the literature of organic cotton farming practice in Burkina Faso, the main question remain: Could the low interest of the government and cotton companies for the development of the organic cotton sector be explained by the productive inefficiency of this farming system and its limited impact on farm households' livelihoods?

The study will address the following specific questions:

- What are the drivers that influence the adoption of organic certification by rural smallholder cotton farmers?

- Are organic cotton farmers economically better off than conventional farmers?
- Can productive inputs be derived efficiently from biological processes in the case of organic cotton farming?

1.4 Research objectives

In terms of objectives, the main goal of this study is to evaluate the productive efficiency of organic cotton farming and its impact on farm households' livelihoods in Burkina Faso.

Specifically, it will consists to:

- Determine the factors influencing farmers decision to adopt organic cotton farming;
- To evaluate the average treatment effect of the adoption of organic cotton farming practices on farm household's return on cotton production and on farm household's non-cotton crops production value for both organic and conventional cotton farmers.
- To analyse the influence of the organic label on cotton farms' technical efficiency.

1.5 Research hypothesis

The following hypothesis will be tested in this research:

- There are technical, economic and social factors affecting the decision of cotton farmers to adopt organic cotton farming;
- Organic cotton farmers are not economically better off than conventional cotton farmers in terms of farm household's return on cotton production and in terms of farm household's non-cotton crops production value.
- Organic cotton farming is technically inefficient as a farming system;

The thesis defended in this research is that: though organic cotton farming can be technically inefficient as a farming system due to restricted conditions in input use and the gradual learning of the organic production technology by organic cotton farmers, organic cotton farming provide an alternative to limit cotton farmer's dependence to inputs credit and to improve their livelihoods.

1.6 Justification of the study

In light of a changing climate and given the need to promote sustainable patterns of production and consumption especially in developing countries, where livelihoods rely essentially on agriculture and natural resources, it is critical today to understand the supply side factors influencing the adoption of organic agriculture. Basically applied to the case of the organic cotton sector in Burkina Faso, this study will contribute to understand the behaviour of cotton farmers towards organic farming system. The computation of organic cotton farm inefficiencies and the factors affecting these inefficiencies will provide valuable information to avoid the sources of inefficiencies and improve organic farming management practices. The measurement and analysis of inefficiencies will emphasize the factors responsible of efficiency differentials and allow to eliminate the causes of inefficiencies. Evaluating the impact of organic farming on farm household livelihoods can provide evidence of the social inclusiveness of organic farming compare to conventional farming system.

1.7 Outline of the thesis

The present thesis will be organised as follows:

Following the introductory Chapter, the second chapter will be dedicated to the literature review. The third and fourth chapters will respectively address the methodological part and the results and discussions. Finally the conclusion and recommendations part will follow.

Chapter II: Review of the literature

This Chapter is composed by two main parts: the theoretical literature on the one hand and the empirical literature on the other. The theoretical literature aims to describe the concepts and theories on which are based the present research. The empirical literature provide an extensive review of the empirical methods applied in the fields of the efficiency analysis of organic farming and the impact of organic farming on farm household livelihoods.

2.1 Theoretical literature

The theoretical literature focused on the description of the concepts of sustainable agriculture and organic farming, the description of theories such as the ecological modernization theory and the treadmill of production theory which are considered to provide the theoretical interpretations of the growth in organic farming. The theory of the diffusion of innovations and the theory of planned behaviour are also presented here as the main theories providing a comprehensive framework explaining farmers' behaviour toward organic farming practices.

2.1.1 Environmental Economics versus Ecological Economics perspective of environmental issues.

There are two different economic approaches to environmental issues: the neo-classical environmental economics approach and the ecological economics approach. While environmental economics utilize the basic principles of neoclassical economics to analyse environmental issues, ecological economics use an interdisciplinary approach including ecological modelling and energy/entropy analysis (Proops and Safonov 2004). Environmental economics became a sub discipline of economics following (Pigou, 1920)'s analysis of externalities (Verhoef 1999). Environmental economics assume that environmental issues as part of the overall economic issues could be solved by extending the basic principles of neoclassical economics. At the micro level, neoclassical economic-based models such as the random utility model (Domencich and McFadden 1975) or household production function approach (Becker 1965a) are used to understand how environmental goods are managed by individuals and households to improve economic welfare. Similarly macro models developed by (Hotelling 1931) and (Hartwick 2007) based on neoclassical economics principles (individual rationality) have been proposed to analyse the long term relationship between the economy and the environment. A number of authors (Heyes 2000) have even made efforts to incorporate the environment into the neoclassical IS-LM models. On the contrary, ecological economics consider that neoclassical welfare economics does not provide a convenient framework to deal with environmental and social issues faced by the humanity in the twentieth century (Gowdy & Erickson 2005). For ecological economists, neoclassical welfare economics principles embodied in the axioms of consumer choices and production theory are capable of addressing very few environmental issues but are inadequate when it comes to deal with the variety of environmental issues currently faced by the world (Gowdy & Erickson 2005). Neoclassical models ignores the natural limits to growth while ecological economics considers the economy as a subsystem of a global ecosystem. The ecological economics perspective of environmental issues instead of prescribing a single approach like in environmental economics, rely on a methodological pluralism in which a variety of conceptual frameworks such as macroeconomic scale, ecological footprint, long-term sustainability, and ecological complexity are used to widen the scope of analysis of environmental issues. The above discussions suggests that though environmental economics and ecological economics have the same goal of dealing with environmental issues, they present a number of differences from the theoretical point of view.

2.1.2 Genesis of the concept of sustainable development

The 1970s has been characterised by a major change in development thinking with the appearance of new concepts such as the concept of sustainable development (Barbier 1987). The 1972 Book limits to growth (Meadows et al. 2005) provoked at this time a general debate related to both population and economic growth. The Book limits to growth raised the issue of the limits of the ecosystem to continually supply raw materials and absorbed waste. The human economy is considered here to be a subsystem of a finite and non-growing larger ecosystem. Therefore in a biophysical point of view there are clearly limits to the expansion of an economy. For (Daly 1990) economy growth cannot be sustained over long period of time. (Daly 1990) marked a clear difference between growth which is a quantitative increase in physical scale and development which is a more qualitative concept that refer to the ability to realize potentialities and move to a better state. (Daly 1990) argued that an economy can grow without developing or develop without growing. Therefore he rejects the concept of sustainable growth because economic growth is limited by the finite and non-growing ecosystem in which this economy is located. In contrast economic development which doesn’t imply necessarily economic growth can be sustained over long period of time. The Brundtland Commission Report (World Commission on Environment and Development 1987) also made a great contribution to sustainable development thinking by emphasising the need for sustainable development and bringing it to the top of the agendas of the United Nations and development banks. The 1972 United Nations Conference on the Human Environment, held in Stockholm is considered by (Barbier 1987) to be the meeting that popularised the concept of sustainable development. Whereas (Caldwell 1984) argued that the concept of sustainable development originates from the Paris Biosphere Conference and the Washington DC conference on the Ecological Aspects of International Development which both held in 1968. (Pearce et al. 1994) refer to the term sustainable to define sustainable development. To these authors the term sustainable has a clear meaning and is not opened to speculations. Sustainable means simply enduring and lasting (Pearce et al. 1994). So Sustainable development is development that lasts (Pearce et al. 1994). The 1987 report of the world commission on environment and development define sustainable development as development that meets the needs of current generation without compromising the ability of future generation to meet their own needs. (Munda 1997) considers the issue of distributional equity both within the same generation (intra-generational equity) and between different generations (inter-generational equity) and the economic-ecological integration in terms of resource use and pollution emissions as the main features of sustainable development. In a situation where current generations integrate future concerns in their current choices, the problem of sustainability is automatically solved (Pearce et al. 1994). But in the real life what we observed is far from this situation. The well-being W_0 of an individual i at the current time t_0 depends on his current consumption C_0 and consumption of future generations over time horizon. What some authors qualified as selfish altruism (Pearce et al. 1994). Mathematically this relation can be resumed as:$W_0 = f(C_0, C_1, C_2, \ldots\ldots C_T)$. But a unit of consumption going to generations 1,2 ... T is less valued than a unit of consumption going to generation 0 because generation 0 is at the present time in control of value (Pearce et al. 1994). The definition of sustainable development gave by (Barbier 1987) points out that sustainable development is a multicriteria concept. For this authors sustainable development implies to maximise simultaneously the biological system goals (genetic diversity, resilience, biological productivity), economic system goals (satisfaction of basic needs, enhancement of equity, increasing useful goods and services), and social system goals (cultural diversity, institutional sustainability, social justice, participation). This definition is closed to the definition gave by environmental organizations such as the UNEP which consider that sustainable development seeks to achieve, in a balanced manner, economic development, social development and environmental protection. Sustainable development has been institutionalised by the Rio Earth Summit' in 1992 where the world leaders adopted Agenda 21, with specific action plans to realize sustainable development at national, regional and international levels (Dresner 2008). Sustainable development remains today the framework of international environmental policymaking, and of national environmental planning.

2.13 Environmental Economics, Ecological Economics and the Concept of Sustainable Development

The interpretation of the concept of sustainable development from the environmental economics point of view is also different from its interpretation viewed from an ecological economics perspective. The debate on sustainability between environmental economics and ecological economics is all about the question of the substitutability or the complementarity between man-made capital and the natural capital. In the environmental economics perspective of sustainable development, the goal is to maintain the utility of future generations non-declining. The assumption of neoclassical environmental economics has been that man-made capital is a perfect substitute of natural capital. Neoclassical economists have an optimistic view of the role of technological progress to break the natural barriers to economic growth. Even though they recognised that economic growth can be limited by the endowment in natural resources, neoclassical environmental economists believe that technical progress can push the natural limits to economic growth. Technical progress can offset the decline in natural capital and keep the output per worker non-declining (Venkatachalam 2007). In contrast, the point of view of ecological economists concerning the role of technology is completely different. For ecological economists the ultimate goal of sustainability is to maintain the natural capital intact (Daly 2007). Capital and natural resources present different qualitative roles in the production process and cannot be considered as substitutes. Natural capital as provider of raw materials and energy is complementary to manmade capital. Economic growth is more constrained by the availability of natural capital than man-made capital (Daly 1990). (Daly 1990) established some basic principles regarding the sustainable or quasi sustainable management of renewable and non-renewable resources. For renewable resources two basic principles should be followed according to (Daly 1990). The first principle states that the harvest rate of renewable resources should equal their regeneration rate. The second principle related to the sustainable management of renewable resources is about the natural assimilative capacities of the ecosystem in which these resources are located. Production process generates waste. The waste generated though the production of goods should not exceed the accumulative capacity of the ecosystem. Non-renewable resources which by definition exist in limited stocks can be managed in a quasi-sustainable manner according to (Daly 1990). A quasi-sustainable management of non-renewables impose that the receipts from non-renewables be divided into an income component that can be currently consumed and a capital component that can be reinvested in the form of compensating renewable substitutes. The aim is to reduce the rate of depletion of the non-renewable resource.

In ecological economics, all the ecological resources has the same value irrespective of their scarcity. While in environmental economics, economic treatment is given only to environmental resources that are scare and also contribute to improve individuals' welfare (Daily & Townsend 1993). Environmental economics and ecological economics all aims to understand the human-environment relationship in order to redirect economies towards sustainability. Though environmental economics has been criticized to prescribe a single approach for the analysis of environmental issues, it has been considered to be analytically rigour and to influence policy making. The multi-disciplinary approach adopted however in ecological economics is found to be challenging because of its vast scope due to its focus on too many areas.

2.1.4 Relationship between Climate Change and Agriculture

It is commonly accepted that climate change constitute a major threat to human and natural systems and adversely affect agricultural productivity. Climate change poses a serious threat to farmers in terms of yields reduction, lower farm income and welfare (Jalloh et al. 2013). Based on projections, it has been established that changes in temperature, rainfall and the frequency of extreme events will affect agricultural systems by reducing crops yields in many regions across the world especially in sub-Saharan Africa and parts of Asia (Jalloh et al. 2013). Although agriculture is most often viewed as a victim of climate change, agriculture is also an essential contributor to greenhouse gases emissions. Various studies provided evidence that our current agricultural practices are also source of greenhouse emissions and consequently drive climate change (Yohannes 2016).

2.1.4.1 The impact of climate change on agriculture

Agricultural production is highly dependent on climatic conditions as it involves natural processes that are strongly affected by the conditions of temperature, precipitation, nutrients supply, changes in growing season, changes in pests and diseases, ect (Nastis et al. 2012). Climate change affect agriculture through the changes in rainfall patterns and the occurrence of extreme events such as floods and droughts (Nastis et al. 2012). The rise in temperature coupled with the reduction of precipitation is expected to affect negatively agricultural productivity (Nastis et al. 2012). Climate change according to projections will significantly reduce the yields of some commodities such as maize, rice, wheat, potatoes and vegetables by 2050 (Ludi & Stevens 2007). The livestock sector as well is not excluded from the adverse effects of climate change through the effects of extreme events like floods and droughts on the availability of resources for animals feeding (Sejian et al. 2016). Climate change regional impacts presents however a number of disparities (Rosenzweig & Parry 1994). Its effects on crops yields is expected to be less harmful in middle and high latitude regions compare to low latitudes regions (Rosenzweig & Parry 1994). In subtropical and tropical areas, crop production is likely to decline while in developed countries, agriculture may benefit from climate change (Rosenzweig & Parry 1994). In the middle and high latitude regions where temperatures are low compare to tropical and subtropical regions, crop productivity is likely to increase for local means temperatures increase up to 1-3 °C (Rosenzweig & Parry 1994). In contrast to mid and high latitude regions, crop productivity in tropical regions is projected to decrease in response to even small temperatures increases (Rosenzweig & Parry 1994). As (Padgham 2009) argued, climate change could significantly impact agricultural production and food security up to 2030 particularly for sub-Saharan Africa and South Asia due to both changes in mean temperature and rainfall.

2.1.4.2 The contribution of agricultural production activities to climate change

Though agriculture is considered to be the sector that is the most exposed to climate change adverse effects, agriculture is also an important contributor to anthropogenic greenhouse gases emissions (Reganold & Wachter 2016). Agriculture contribute to 30-35% of anthropogenic greenhouse emissions largely from tropical deforestation, methane emissions from livestock and rice cultivation, and nitrous oxide emissions from fertilized soils (Foley et al. 2011). The emissions of greenhouse gases from agriculture (Carbone dioxide, methane, nitrous oxide) account for one-fifth of the annual increase in radiative forcing of climate change (Cole et al.

1997). The FAO's recent estimates of greenhouse gases data show that emissions from agriculture, forestry and fisheries have nearly doubled over the past fifty years and could increase an additional 30 percent by 2050 if any effort is made to reduce them6. Developing countries are considered to be the main drivers of greenhouse gases emissions in the agricultural sector (Olander et al. 2013). The contribution of developing countries to greenhouse gases emissions from agriculture is estimated to be three-quarter of global agricultural greenhouse emissions (Olander et al. 2013). The sources of agricultural greenhouse emissions are both direct and indirect (Olivier et al. 2005). The direct sources referred to enteric fermentation by animals, rice cultivation, animals waste, crop production, savannah burning, the use of synthetic fertilisers, animal manure, traditional land use practices such as tillage which have the potential to cause CO2 emissions by provoking the decomposition of the soil organic matter, ect (Olivier et al. 2005). The indirect sources of agriculture greenhouse gases emissions are linked to the atmospheric deposition of nitrogen in ammonia (NH3) and nitrous oxide (N2O) as well as from the leaching and run-off of nitrogen in soils. The use of fossil fuels for mechanization and for the production of fertilizers and agrochemicals constitute also a major indirect source of agriculture greenhouse gases emissions (Olivier et al. 2005). Agricultural emissions are still increasing with different rates regarding agricultural emissions sources (Tubiello et al. 2013). For instance emissions from synthetic fertilisers application are growing faster than those from animal manure and emissions from deforestation are considered to be declining (Tubiello et al. 2013). In terms of the regional trends of agricultural greenhouse emissions, emissions from developing countries are growing at a faster rate than emissions in developed countries (Tubiello et al. 2013).

2.1.5 The concept of sustainable agriculture

Some of the issues in modern agriculture have raised a number of doubts regarding the sustainability of conventional production processes. The high reliance of modern agriculture in agrochemicals and its external costs in terms of environmental pollution, in terms of threat to other species and in terms of risks to human and animal health are serious concerns of sustainability in the modern world. (Francis & Hildebrand, 1989) mentioned that there is no general agreement about the definition of the concept of sustainable agriculture. For (Youngberg

[6] Extracted from http://www.fao.org/news/story/en/item/216137/icode/

& Harwood 1989) the complex interrelationship between agriculture and the environment do not allow a clear identification and definition of sustainable farming practices per geographic zone. (Hansen & Jones 1996) considered that most of the studies that tried to set the principles of sustainable agriculture suffered from conceptual considerations and practical issues. First the concept of sustainability is an alternative development approach that is not only specific to agriculture. As sustainability deals with the future, characterising, observing and quantifying sustainability in agriculture appear to be complex. The characterisation of sustainable agriculture based on management practices is considered by the authors to not reflect accurately the concept of sustainability in Agriculture. According to (Weil 1990), the term sustainable agriculture refers to the concepts of ecological, biological, alternative, low input and regenerative agriculture. The authors identified tree areas of concerns that underlie the concept of sustainable agriculture. These are economic concerns that deals with the long term profitability of agriculture, environmental concerns taking into account the effect of agriculture on water, lands and wildlife resources and also public concerns that are related to food quality and human exposure to toxic chemicals. (Weil, 1990) also argued that it is not possible to define sustainable agriculture in terms of a set of practices because the process of agricultural production is specific to the special conditions of the area that is concerned. The concept of sustainability in agriculture goes beyond agricultural practices and integrate also economic and political factors that cannot be separated from it. The annual meeting of the soil science society of America in December 1998 defined sustainable agriculture as a system of farming that improve environmental quality and is economically and socially viable. (Weil, 1990) proposed a set of criteria that can be used to evaluate the direction of agricultural programs, policies or practices towards sustainability. These criteria consist to: i) to strengthen the economic viability of agribusiness opportunities; ii) to ensure the long-term productivity and diversity of agricultural and natural ecosystems; iii) to limit the health hazards of agricultural production activities on producers and consumers.

2.1.7 The concept of organic farming

The concept of organic farming is subjected to various definitions in the literature. (Mannion 1995) associate organic farming with any view of agricultural practice that aims to enhance the interrelationships between farm biota, its production and the overall environment. The concerns (environmental risks in agriculture, its impact on soil fertility and human health) that motivated the appearance and the development of the concept of organic agriculture are part of the overall debate of sustainable agricultural systems. (Northbourne, 1940) who is considered to be the first one to use the concept of organic farming advocate a world with small scale and self-contained units where people and the nature will not be the subordinates of machines (Rigby & Caceres 2001). This view has various implications in terms of the environmental impact of human activities. The concentration of the production in large scale specialised units is at the basis of environmental concerns of production systems. The view of (Northbourne, 1940) has been famously articulated in recent years by (Schumacher 1973) in a paper titled small is Beautiful. As (Lampkin 1999) stated, the aim of organic farming is to create integrated environmentally and economically sustainable production systems. (Rigby & Caceres, 2001) in the same way define organic agriculture as both a philosophy and a system of farming based on values that reflect the awareness of ecological and social realities and the ability of the individual to take effective actions. Internationally, organic farming is regulated by the codex "alimentarius guidelines" conjointly defined by the United Nations Food and Agriculture Organization (FAO), the International Federation of Organic Agriculture Movements (IFOAM) and the world health organization (Tuomisto et al. 2012). IFOAM basic standards and the Codex alimentarius Guidelines provide a baseline for national and regional standards for organic certification (Tuomisto et al. 2012). National standards are set based on local conditions and take into account the requirements of farmers, local buyers and the government (Tuomisto et al. 2012). Apart from national standards, private certification bodies exist and have they own standards that may be more constraining than national standards (Tuomisto et al. 2012). The IFOAM basic principles for organic agriculture can be summarised in the table below (IFOAM, 1998)7.

Table 1: Principles of organic farming

The principles of organic production and processing
To ensure production in quantity and quality
To interact constructively not in a destructive way with natural systems and cycles
To account for the social and ecological aspects of the production and processing system
To take advantage of the biological cycles within the farming system including microorganism, fauna and flora, plants and soils

7 International Federation of Organic Agriculture Movements (IFOAM) - Organics International

To ensure a sustainable aquatic ecosystem
To ensure soils productivity over time
To ensure the genetic diversity of the production system and its surroundings
To ensure a safe and sustainable use of water resources
To accentuate the use of renewable resources in locally organised production systems
To find an harmonious balance between animal husbandry and crop production
To limit environmental risks
To use renewable resources for food processing.
To provide biodegradable products.
To produce good quality and lasting fibres.
To ensure good quality of life, provide a safe working environment and cover the basic needs of producers and consumers.
To provide a socially just and responsible production, processing and distribution chain

Source: Author

These principles essentially seek to develop a type of farming that reduce health risks by minimising the use of mineral fertilisers, synthetic pesticides, animal drugs and food additives that could have adverse health effects (Tuomisto et al. 2012). Organic agriculture also seeks to ensure ecological sustainability (Tuomisto et al. 2012). This necessarily passes through the use of local resources, the recycling of waste, the efficient management of materials and energy (Tuomisto et al. 2012). The search for fairness constitute an essential element in organic farming. Organic farming in this point of view seeks to provide good quality of life, reduce poverty, enhance animal well-being, contribute to food sovereignty and ensure good quality of life for future generation (Tuomisto et al. 2012). Organic farming is not only based on the biophysical aspects of the production but it also include other aspects such as economic justice and environmental responsibility. Farmers are converting to organic agriculture for a variety of reasons including the awareness of environmental and health concerns in light with the intensive use of synthetic agrochemicals and expectations that organic agriculture may be more profitable than the conventional one. Consumers in their side care about the contamination of agriculture by chemicals which can be damageable to their health conditions.

2.1.8 Potential and challenges of organic farming

Considered to be a sustainable agricultural practice, organic farming is viewed today as an alternative to tackle the challenges related to the green revolution technologies (Das et al. 2017). Many authors considered organic farming as a holistic production system that emphasize the long term environmental sustainability of farming (Tu et al. 2006); (Pulleman et al. 2003); (Patel et al. 2014); (Gopinath et al. 2008). Organic farming according to these authors provide some environmental benefits such as better quality of soils, biodiversity conservation, water harvesting, the reduction of evaporation, the reduction of greenhouse gases emissions and the improvement of energy efficiency in agricultural production. It also has some social and economic benefits such as the reduction of inputs costs, the access to organic markets with higher prices, the improvement of smallholder livelihoods, a better access to credit market and the exchange of knowledge and experience (Tuomisto et al. 2012). Organic farming practices present also some drawbacks that have been highlighted in the literature. These drawbacks consist of the low yields observed in organic production, the management of risks during the transition period, the lack of organic nutrients (compost and green manure) and the complexity to control pests and diseases in organic farming (Tuomisto et al. 2012).

2.1.8.1 Main potentials of organic farming

2.1.8.1.1 Environmental benefits

Rural poor are more concerned by environmental degradation since their livelihoods greatly depend on natural resources. The environmental dependence of rural livelihoods can eventually lead to a cycle of poverty and environmental degradation that can worsen environmental issues (Dasgupta et al. 2003). The organic production approach should fit the natural ecological approaches and cycles. (Tuomisto et al. 2012) analysing a large set of research papers focussing on the environmental impact of organic agriculture come to the conclusion that the environmental impact of organic farming is low per area unit but high when it is measured per product unit. The authors argued that the differences of the magnitude of the environmental impacts of organic farming when it is measured per area unit and when it is measured per product unit is related first to the lower yields observed in organic farming and also to the variability of environmental impact methods. In organic production systems, nitrogen leaching, ammonia and nitrous oxide emissions are lower per area unit but higher per product unit (Tuomisto et al. 2012). Due to the fact that agricultural chemicals are not allowed in OF, the risk of water, soil and air contaminations by chemical inputs is much lower than in conventional systems (Shepherd et al. 2003). Biodiversity conservation and management is an essential element of the organic production system. (Meyling et al. 2010) argued that crop resistance in organic farming is improved by the enriched biodiversity which enhance the diversity of natural enemies. For (Birkhofer et al. 2008), pests resistance is generally more pronounced in organic farming than in conventional farming due to increased soil quality and enhance microbial biomass. The enriched biodiversity in organic farming allow the diversity of natural enemies that contribute to protect plants from pests attack. (Rahmann 2011) in a meta-analysis revealed that biodiversity in organic farming is more pronounced than in conventional farming. For (Bengtsson et al. 2005) the diversity of species is increased by 30% in organic farming and the abundance of micro-organisms is 50% higher in organic farming than in conventional farming. The positive effects of organic farming on biodiversity is linked to the low use of external inputs on farm and the promotion of agro-ecological practices that contribute to limit the risks of the loss of species (Bengtsson et al. 2005). Improving soil fertility is considered to be a serious challenge to overcome the problem of agricultural productivity and food insecurity in developing countries (Lal 2009). Organic farming practices such as balanced rotation, organic amendments, minimum tillage or no tillage of the land, terraces, soil bunds, mulching, planting cover crops and agroforestry, contour cultivation are agricultural practices that have the advantage to protect agricultural soils and minimise the loss of soil nutrients (Lal 2009). (Gattinger et al. 2012) argued that soils under organic cultivation have higher organic matter than soils under conventional cultivation. Water efficiency, drought resilience and energy efficiency are increased in organic farming (Gattinger et al. 2012). The higher content in organic matter of soils under organic cultivation allow to retain water for a long time (Gattinger et al. 2012). So organic production is less dependent on freshwater and water for irrigation compared to conventional farming practices (Gattinger et al. 2012). By the same channel, the energy used in organic farming for irrigation purposes is also reduced compare to conventional farming practices (Gattinger et al. 2012). For (Azadi et al. 2011), organic farming contribute to climatic resilience through building flexible food farming systems that reduce the risks of crop losses (diversification) and enhance soil fertility. The resilience of organic production systems to stress (drought, flood, erratic rainfall, temperature variations) due to higher organic matters content, assist farmers in adapting to climate change (Azadi et al. 2011). Organic farming is also considered to be a viable climate change mitigation option (Azadi et al. 2011). The reduction of the use of agrochemicals in organic farming reduce the emission of some greenhouse gases such as nitrous oxide and methane. The higher organic matter content of soils in organic farming also enhance carbon sequestration and by the same channel reduced energy demand and CO2 emissions (Azadi et al. 2011).

2.1.8.1.2 Economic benefits

In addition to the wide range of environmental benefits that have been cited above, organic farming also contribute to improve farmers' revenue through various channels. For (De Ponti et al. 2012), the financial performance of organic farming is a precondition to its long term growth. (Uematsu & Mishra 2012) considered factors like crops yields, labour and total costs, price premium for organic products, costs saving from reduced reliance on non-renewable resources as the main determinants of the financial performance of organic farming. The low requirement of external inputs in organic farming contribute to reduce significantly input costs which is an important component of the production costs in farming (Uematsu & Mishra 2012). Organic farming eliminate agricultural chemicals and other external inputs to improve farm economics (Uematsu & Mishra 2012). According to (Kilcher 2007) organic farming as a cost effective farming system has the potential to reduce poverty and contribute to sustainable development. (Crowder & Reganold 2015) in a meta-analysis of the financial performance of organic farming combines different findings from 40 years of studies covering 55 crops grown on five continents. The results of this meta-analysis revealed that despite its low yields organic farming is 22-35% more profitable with a benefits/costs ratio 20 to 24% higher than conventional farming. Regarding, the production costs, the meta-analysis found that total production costs in organic and conventional farming practices are strongly similar except labour costs which is significantly 7 to 8% higher in organic farming. The extra labour in organic farming has been considered by some authors as an opportunity for rural employment and development (Mendoza 2008); (Prihtanti et al. 2014). For (Nemes 2009) organic farming in developing countries provide higher profitability through higher yields, reduced costs and price premium for organic products. Successful organic projects (Kleemann 2016); (Jouzi et al. 2017) conducted all over the world provide the evidence of the economic potential of organic farming. Most of the economic studies comparing the economic performance of organic and conventional farming do not take into account the potential of organic farming to reduce production external costs. Putting a monetary value on the positive externalities provided by organic farming in terms of the limitation of soil erosion, nitrogen leaching into groundwater, eutrophication, ammonia and nitrous oxide emissions, carbon sequestration could make organic farming more economically viable than conventional farming.

2.1.8.1.3 Social benefits

The social benefits of organic farming are also of different dimensions. Organic farming is considered to be an inclusive farming system. In developing countries small scale farmers are generally excluded from the conventional production system due to expensive inputs, the lack of capital and the low access to credit market. Organic farming is considered to strengthen the social interactions between farmers and consumers (Macrae et al. 2008); (Gruère et al. 2009) and to provide employment opportunities for farm workers (Mendoza 2008); (Prihtanti et al. 2014). Organic farming increase the social capital of rural communities through a higher bargaining power, contribute to the exchange of knowledge of experience between farmers and increase the employment opportunities for rural farmers (UNEP & UNCTAD 2008); (Elzakker & Eyhorn 2010). Although organic farming require extra labour compare to conventional farming, the limitation of chemical inputs use in organic farming reduce farmers' exposure to the toxicity of chemicals since most of them do not have access to safety equipment (Eddleston et al. 2002); (Thundiyil et al. 2008). Some studies (Baker et al. 2002) revealed that most of the fatalities related to the exposure to agricultural chemicals mostly occurred in developing countries where illiteracy and poverty in rural populations are such that farmers ignore the safety protocols of agro-chemicals utilization and lack safety equipment. Moreover, regarding food safety and quality issues, organic foods are supposed to contain less chemical residues than conventional foods (Baker et al. 2002). The diversification of crop operations in organic farming through rotations and the use of leguminous crops for nitrogen fixation reduced the risks of crop failure and improve variety in diets (Halberg et al. 2006).

2.1.8.2 Main challenges of organic farming

The major challenges raised in organic farming are the issues of lower yields, nutrient management, certification, access to markets, education and research, ect. The lower yields observed in the context of organic farming is an issue of concern and is the main argument used by sceptics to reject organic farming practices. (Kirchmann et al. 2008) considered that a large scale shift to organic farming could lead to a reduction of crops yields by 40% and create serious food shortages. In a meta-analysis of 362 papers comparing organic and conventional farming systems (De Ponti et al. 2012) concluded that organic farming yields are around 80% of conventional farming yields. In the same order of ideas (Seufert et al. 2012) in a meta-analysis of 66 studies concluded that organic farming is 25% less productive than conventional farming. This study also revealed some differences between developing and developed countries in terms of the productivity of organic farming. Whereas in developing countries organic farming is supposed to be 43% less productive than conventional farming, in developed countries the loss of productivity in organic farming is around 20%. (Aune 2012) estimated that organic farming is 30 to 50% less productive than conventionnal farming. Some authors (Ponisio et al. 2015) considered that under improved management practices, the loss of yields in organic farming can be reduced to 19.2%. Sceptics argued that organic agriculture is an extensive agricultural systems and by this way represent a major threat to world's forests, wetlands and grasslands (Trewavas 2001); (Emsley 2001). Some considered that organic farming has too many shortcomings (Trewavas 2001); (Kirchmann & Thorvaldsson 2000) and is an inefficient approach to food security (Connor & Mínguez 2012); (Pickett 2013). For critics, a large-scale shift to organic agriculture could cause serious food issues because of the net reduction in crop yields that will consequently follow. Organic farming is seen as a production technology that is not enough productive to provide sufficient food to meet the needs of a growing world's population (Aune 2012). The limited options to enrich the soil and to control pests, diseases and weed are the main reasons of low yields in organic farming. Authors like (Connor 2008) wonder about the ability of organic practices to provide sufficient nutrients to support the high productivity required to feed a growing world population. Aside of low yields issues, there are many other challenges that limit a widespread expansion of organic farming. These challenges include the lack of interest of public policy to promote organic farming, the lack of knowledge and information about organic farming and the lack appropriate infrastructures (Reganold & Wachter 2016). The concentration of market power and the current agricultural policies on the conventional farming system have limited the options for the development of organic agriculture (Reganold & Wachter 2016). Less public and private funding has been dedicated to research and development in organic farming systems resulting in a lack of knowledge and information supporting organic farmers (Reganold & Wachter 2016). Organic farmers also face some infrastructural and economic barriers such as certification costs, access to market for organic products, access to credit, limited access to additional labour, infrastructure for storage and distribution, appropriate certification requirements (Reganold & Wachter 2016). Finally cultural biases against the philosophy (individual or collective) of organic farming are not in favour of its development (Reganold & Wachter 2016).

2.1.9 Organic farming current statistics around the world

Organic industry is one of the fastest growing sectors of the food market as the global market for organic food has increased from 15.2 billion USD in 1999 to 72 billion USD in 2013. The main organic markets are the United States and the EU (together 90%) while developing countries have very small organic markets (FiBL & IFOAM 2015). 90% of the sales of organic products are concentrated in United States of America and Europa (FiBL & IFOAM 2018). The United States alone control 47% of the global organic market, followed by the European Union (37%) and China (6%) (FiBL & IFOAM 2018). According to the FiBL data, organic farmland area is about 58 million hectares worldwide and represent 1.2% of global farmland (FiBL & IFOAM 2018). The repartition of organic farmland across regions show disparities and testify to the interest that each region gives to the development of the organic sector (FiBL & IFOAM 2018). Oceania with 27.3 million of organic farmland occupies almost 50% of organic farmland worldwide and is followed by Europe 23%, Latin America 12%, Asia 9%, North America 6% and Africa 3% (FiBL & IFOAM 2018). By region, the highest organic shares of the total agricultural land are also located in Oceania (6.5%) and Europe (2.7%) (FiBL & IFOAM 2018). The European Union taken separately present an organic share of 6.7% of the total agricultural area. Some countries like the Liechtenstein and French Polynesia have respectively converted 37.7% and 31.3% of their total agricultural land into organic (FiBL & IFOAM 2018). While the largest organic areas are located in Oceania and in Europe, developing countries have the highest number of organic farmers (FiBL & IFOAM 2018). Estimated to be at least 2.7 million in 2016, forty per cent of the world organic producers are located in Asia followed by Africa 27% and Latin America 17% (FiBL & IFOAM 2018). Developing countries represent a quarter of the organic area but more than 87% of the organic producers worldwide. Arable land constitute 18% of the agricultural land and is essentially use for cereals, oilseeds, green fodder, dry pulses and textile crops. Permanent crops account for eight per cent of organic farmland. Over two-thirds of the organic agriculture land worldwide are grassland/grazing areas (FiBL & IFOAM 2018). In Africa the number of organic farmers had not stop increasing over the years and was estimated to be more than 741000 organic farmers in 2016 for a total of 1.8 million of organic agriculture land during the same year (FiBL & IFOAM 2018). Tanzania and Uganda have the lead in terms of organic production in Africa (FiBL & IFOAM 2018). Whereas Tanzania is the country with the largest organic area in Africa (270000 hectare, 15% of global organic area in Africa), Uganda appears to be the country with the largest number of organic producers (more than 210000 organic producers, more than 28% of global organic farmers in Africa) (FiBL & IFOAM 2018). The island state Sao Tomé et Principe is considered as the country presenting the highest share of organic agricultural land in Africa (13%) (FiBL & IFOAM 2018). Regarding organic cotton production, 107980 metric tons of organic cotton fibre was produced globally by 219947 farmers on 302562 hectares of land in the 2015/2016 growing season (FiBL & IFOAM 2018). Eighteen countries are globally involved in organic cotton production worldwide but 97% of the organic cotton is supplied by just seven countries (FiBL & IFOAM 2018). India which is the largest producer of organic cotton account for 55.7% of the total production followed by China (13.7%), Kyrgyzstan (7.4%), Turkey (7%), Tajikistan (6.1%), the United States (4.2%) and Tanzania (2.99%) (FiBL & IFOAM 2018). The remaining 3% of the global organic cotton production is distributed among Egypt (0.95%), Burkina Faso (0.4%), Benin (0.3%), Pakistan (0.3%), Peru (0.3%), Uganda (0.3%), Mali (0.1%), Brazil (0.02%), Israel (0.01%), Thailand (0.003%), Senegal (0.001%) (FiBL & IFOAM 2018). In Burkina Faso, the total organic farmland is about 27268 hectares and represent 0.2% of agricultural land (FiBL & IFOAM 2018). Between 2013 and 2016, the organic agriculture land has increased by 3345 hectares. The number of organic producers in Burkina Faso are estimated to be around 9036 and 8382 (92%) are employed in the organic cotton sector (FiBL & IFOAM 2018). Organic cotton land area in Burkina Faso is around 4928 hectares and represent 18% of the total organic land (FiBL & IFOAM 2018).

2.1.10 Theoretical interpretations of the growth in organic farming

(Obach 2007) identifies two theoretical approaches within which can be framed the development and institutionalization of organic farming. The ecological modernization theory which offer an optimistic prediction and the treadmill of production theory which emphasise conflicts between capital accumulation and environmental concerns. Within the ecological modernization framework, organic agriculture is interpreted as a social movement involving environmental minded entrepreneurs (private business), the State, movement actors and the consumers which are all interested in achieving ecological sustainability. Environmental free minded entrepreneurs acting in a free market in concert with the state, movement actors and consumers are likely to develop more environmental sound technologies and social practices which enhance the progress towards ecological sustainability and at the same time allowing to seek for increased prosperity (Boström 2003); (Mol 1997); (Mol 2002). In contrast the treadmill of production theory rejects the possible compatibility of the competitive quest of profits and environmental protection (Gould et al. 1996); (Buttel et al. 1994). The central social actors within capitalist democracies are all motivated by profit seeking and there is no way to redirect production means towards environmental sustainable practices. Organic farming occurs here as a result of a market driven process where profit seeking entrepreneurs in concert with the state co-opted a movement seeking institutional change.

2.1.10.1 Ecological Modernization Theory and organic farming development

(Mol 1997) is considered to be one of the founding theorists of the ecological modernization theory. Ecological modernisation theory as described by (Mol 1997) is a theory of social transformation. It's a theoretical approach to understanding the dynamics of the social transformation of industrial economies to deal with ecological challenges. The basic idea of the ecological modernisation theory is that, in a free market, environmental minded entrepreneurs working in synergy with the state and under the control of consumers organisations and environmental movements will develop technologies that are environmental friendly while remaining economically viable. (Zimmerman, 1990), (Hubert, 1991) considered ecological modernisation as a concept dealing with the market economy, the institutions of modern technology ant the State intervention. The ecological modernization theory rejects the opposition between economic development and environmental concerns. This theory emphasises the importance of the market, the role of social entrepreneurs and the state intervention for the transition to an alternative economy. The ecological modernization theory presents four main aspects (Mol 1997). The first one is related to the role of science and technology in sustainable development. Unlike previous environmental analysis which considered technological development to be a source of ecological disturbances, the ecological modernisation theory places technological development at the centre of sustainable development. Science and technology are viewed here as the central elements for ecological reforms. Environmental sounded technologies could contribute to make production processes more sustainable. Second, in ecological modernization theory, the market forces are not opposed to the goal of sustainable development and are fully supportive of the progress towards sustainability. The market dynamics associated with ecological reforms create such a competition between innovators on the basis of their environmental performances. These actors will seek to meet the market demand of ecological products by developing standards and certification bodies and creating their own niche markets. Through this competition the private actors become the central elements of environmental restructuring. Third, the ecological modernization theory provide another interpretation of the role of the state in terms of environmental regulation. Although it recognizes the role of the State in environmental management, this theory rejects strong bureaucracy in transforming production and consumption patterns into more sustainable ones. The role of the state need to be preventive and participative rather than curative. Instead of raising rigid regulation, targets and penalties, the State should motivate private actors to promote environmentally sound practices. The fourth and last feature of the ecological modernization theory is related to the role of environmental movement organisations in environmental protection. Their capacity to propose innovative and alternative ideas, to mobilize consumers and to support or disapprove public policies should be used to develop environmental sound strategies. These organisations should be more active and participative in the process by working with governments and private actors to develop environmental policies instead of being simple critical commentators. The ecological modernisation theory has been applied to interpret the development of some phenomena such as the improvement of industrial energy efficiency (Enevoldsen et al, 2007).

The progressive institutionalisation of organic agriculture is considered to reflect the different aspects of the ecological modernisation theory. (Obach 2007) based on the case of the US provide a comprehensive description of the process of institutionalisation of organic farming following the ecological modernization theory. The concept of organic agriculture took place in the 1970s following health and environmental movements. It was a time during which many environmental actors emphasised the need for a deep social transformation to achieve ecological sustainability (Brulle 1996). Environmental movements' organisations, more than being simple critics outside of the system participate in it through environmental and health movements which increase consumers' interest to organic products. The increasing profitability of the organic business pushed social entrepreneurs to develop the sale of organic products and expand organic agriculture. Public policies have been of great importance for the development of organic agriculture. In opposite to the environmental strategies adopted in the 1970s which were essentially based on command and control, public environmental agencies focused on the development of standards for organic certification which allow consumers and producers to have a unique understanding of the organic label. Producers are free to adopt organic farming or not, depending on their business interests (Boström 2003). Public agencies also played another critical role in the development of science and technology related to organic farming. Important research founding has been provided by governmental agencies to support research related to the development of organic agriculture.

2.1.10.2 Treadmill of production theory and organic farming development

The treadmill of production theory is a theory of ecological disorganisation introduced by (Schnaiberg 1980) in his book titled '**The environment: From Surplus to Scarcity**'. It is a political economic approach to understand the ecological disorganisation in the post-World war II era. The treadmill of production theory is centred on the idea that capitalistic system is an ecological destructive way of production. These ecological disorganizations are observed in the process of ecological withdrawals and ecological additions. Ecological withdrawals are related to resource withdrawal processes essentially the process of raw materials extraction. In the post-World War II era, the process of raw material extraction have been essentially driven by a chemically intensive segment of the treadmill of production. These chemical and technological innovations in resources withdrawal reduced labour inputs needs, accelerate resources withdrawal and increase the destruction of the nature. Capitalistic production and consumption systems also cause ecological disorganization through ecological additions. Ecological additions refer to the emission of pollutants in the ecosystem as a result of the acceleration of the treadmill of production. In short, the treadmill of production theory gives an explanation of how profit seeking capitalistic societies along with the chemical/technological innovations contribute to accentuate ecological disorganization following the post-world war II. The treadmill of production theory emphasise the role of the state, the private sector and the labour in accelerating ecological disorganisation. An examination of the main interests of these forces allow to understand the logic of production expansion behind the treadmill of production theory. The capital is subjected to production expansion because investors seek to continually reinvest in order to be profitable in a competitive market. This can be achieved by generating surplus through production expansion or finding more efficient ways of production. Labour is also motivated by production expansion. One can argue that greater productivity is not a condition sine qua non to greater return to labour because investors can use the existing wealth for reinvestment or take it away for their personal use instead of redistributing. But increased productivity still a sufficient condition for workers to improve their living conditions. The state in its side need resources to implement public policies. These resources are obtained through taxing investor's wealth or workers' wages. The government revenue can therefore increase when the production is expanding and investors and workers are respectively gaining better profits and salaries. So the united forces of capital, labour and the state are all motivated by the economic expansion regardless of environmental concerns. In contrast to the ecological modernization theory, profit seeking here is at the centre of decision making concerning production and consumption regardless of environmental challenges (Schnaiberg, & Gould, 1994). As (Obach 2007) argued, the treadmill of production theory is highly problematic for creating the conditions for sustainability and ecological responsibility. Entrepreneurs are supposed to exploit any profitable social transformation and organic farming is an example of a potentially profitable social transformation. The increasing demand for organic products by consumers in response to environmental and health issues provide new markets for organic products where new profits can be generated. On this basis, entrepreneurs begin to produce and distribute organic products. Within the treadmill of production theory, sustainable production practices are used only for their cost effectiveness regardless of the environmental awareness of entrepreneurs. Compare to the ecological modernisation theory where environmental benefits are achieved through the environmental consciousness of social entrepreneurs, the only logic behind the treadmill of production theory related to organic farming is the opportunity to take advantage of an alternative agricultural movement. Organic producers are less concerned with the ecological sustainability of organic farming. Organic agriculture appears as a social change movement co-opted by the dominant treadmill forces (Capital, labour and the State), in order to increase profits, wages revenue and public resources (Obach 2007).

2.1.11 Farmers' motives of adoption of organic farming

Various factors are influencing farmers' decisions to convert to organic farming. In a theoretical perspective, two main approaches are used in the literature to investigate the adoption behaviour: the theory of diffusion of innovations and the theory of planned behaviour.

2.1.11.1 Diffusion of innovations theory and organic farming adoption

The diffusion theory initially developed in the 1940s by rural sociologists in the US aims to capture the process of change occurring in a community. Innovation is described here as a new idea, product or process that is new to an individual, society or simply an adoption unit. (Rogers 1983) interpreted diffusion of innovation as a kind of social change that involve interpersonal communications, communications in which participants create and share information in order to reach the same level of understanding. From this point of view, diffusion of innovations theory seeks essentially to explain how, why, and at what rate new ideas and technology spread. Four main elements are considered by (Rogers 1983) to influence the process of diffusion of a new idea. These are: the innovation itself, communication channels, time and a social system. Communication as it is defined by (Rogers 1983) is a process by which participants create and share information with one to another in order to reach a homogeneous level of understanding. Diffusion is a particular type of communication in which the information shared are totally related to new ideas. For a new idea to be recognized and accepted as an innovation, it has to be done within a social system. An innovation takes place when the social system as a whole recognised it and information about this innovation are shared within that social system or with other systems. The diffusion of an innovation include also a time aspect. It requires that potential adopters analysed the main characteristics of this innovation before any decision making. (Rogers and Shoemaker,1971) observed that five attributes of an innovation can influence its adoption rate: its **relative advantage** (the degree at which the innovation is perceived to be a better option than the one in practice), **compatibility** (the extent to which the innovation is compatible with adopters needs, beliefs, ideas and past experience), **complexity** (the degree at which the innovation is relatively difficult to understand and use), **triability** (the extent to which the innovation can be tested before adoption), and **observability** (how easy the results of an innovation can be visible). Five main stages are then identified by (Rogers 1983) in the innovation decision process. These are: the knowledge stage, the persuasion stage, the decision stage, the implementation stage and the confirmation stage. According to (Padel 2001), the diffusion theory could be used to understand the process of adoption of organic agriculture in a given community and the way to improve it. The changing characteristics of organic farmers and the way they are perceived by other farmers correspond to a process of diffusion of innovation. To understand organic agriculture as an innovation and its adoption as an example of diffusion of innovation, one has to go back to the context within which the concept of organic agriculture took place. Indeed, after the 2nd world war, enormous quantities of chemicals which were produced for military purposes faced the loss of market and then was turned to agricultural use. Chemicals companies that were producing synthetic chemicals for the military sector began to introduce in the market, various forms of fertilisers, pesticides, growth hormones, basically composed by toxic chemicals. The application of these heavy chemicals associated with the improvement of the technology allow a net increase in agricultural yields. These technologies have been massively exported in the developing world in order to fight against hunger. This period of fast development of agriculture is the so called green revolution. In recent years, some concerns about the environmental and health effects of the massive use of synthetic agrochemicals raised the question of agricultural sustainability. Organic agriculture is a social, environmental and technological alternative to conventional agriculture which relies on synthetic agrochemicals. It should not be interpreted as peasant agriculture or a conservative concept. In light with the diffusion theory, organic agriculture is interpreted as a social innovation which seeks to change the relationship between the community and the environment. It is an agricultural practice that is close to the principles of sustainable development. (Padel 2001) have initially considered factors such as the connexion with the nature, the desire to develop another production system and a holistic approach of life as the main motives of the conversion to organic farming. For (Offermann & Nieberg 2010), the adoption of organic farming practices are more guided by economic benefits associated to organic agriculture such as price premium. In many countries around the world, organic agriculture is supported by subsidies and organic farmers' benefit from number of facilities such as price premium, the assistance for the certification process, etc. (Padel, 2001) concluded that although the diffusion theory can be used to describe the process of adoption of organic farming, it has to be done with caution regarding the specificities of organic farming which is a complex set of innovations.

2.1.11.2 Theory of planned behaviour and organic farming adoption

For (Ajzen & Fishbein 1980) the individual nature and the perceived social pressure are two main factors that contribute to explain an individual behaviour. The individual specific factor is his negative or positive evaluation of performing a given behaviour. As an individual feeling, the individual evaluation of the opportunity to perform a behaviour is termed his attitude towards this behaviour. Another factor to take into account is the individual perception of the social pressure put on him to perform or not perform an innovation. This factor is termed by (Ajzen & Fishbein 1980) the subjective norm. Combining both factors, that means to say, the individual attitude towards a behaviour and the perceived social pressure, (Ajzen & Fishbein 1980) draw the conclusion that people will be willing to adopt a behaviour when they have a favourable evaluation of performing that behaviour and also believe that a number of people in their community wish they will perform it. Both factors are also emphasised in the diffusion of innovations theory where (Rogers 1983) argued that an innovation take place given potential adopters evaluation of its relative advantage and its acceptance within a social system. Based on these arguments, (Ajzen & Fishbein 1980) developed the theory of reasoned action which state that individuals are rational and make their decisions by taking into account the available information and the implications of their actions. The main critics addressed to the theory of reasoned action is its applicability only in situations where the behaviour is under individual volitional control. Skills, resources or opportunities which are not freely available or not under individual control are not predicted by the theory of reasoned action. External factors not under individual control could limit the rate of adoption of an innovation. (Rogers 1983) in the diffusion theory considers the complexity and triability of an innovation as part of its main attributes. To complete the theory of reasoned action an extra construct called the perceived behavioural control was added to better predict individual behaviours. This third factor is related to the individual perception of the ease or difficulty to perform a behaviour. Under the theory of planned behaviour, an individual's behaviour results from his intentions, attitude, social norms and perceived behavioural control (Bergevoet 2005). In light with the theory of planned behaviour, farmers' adoption of organic farming can be explained by tree main group of factors: farmers' attitude towards organic farming, social values and control factors that encourage or discourage organic farming adoption. The attitude of farmers towards organic farming refers to their knowledge of organic farming, their personal characteristics and their perception of environmental issues. The social factor refers to the perceived social pressure such as traditions and the control factors refer to the benefits costs aspects of the adoption of organic farming (investment costs of conversion, organic farming gross margin, and risk associated to conversion).

2.1.12 Standard theories of farm household production choices

Three alternative economic theories have been developed to understand the behaviour of peasant household's decision making. These are profit maximisation theories, utility maximisation theories and risk adverse theories. All of these theories are based on the assumption that farm household maximise an objective function under a set of constraints.

2.1.12.1 Profit maximisation theories

In the profit maximising approach, the peasant households are viewed as profit maximisers in a perfectly competitive market (Kello 1992). Profit maximisation theories are based on Schultz's hypothesis that the allocation of resources in traditional agriculture is efficient and there is no additional profit to gain by reallocating resources. Before Schultz Peasants were considered as non-rational economic agents who based their economic decisions on traditions or conservatism instead of maximizing Profit (Lundahl 2011). Schultz hypothesis on the efficiency of peasant household implies explicitly the allocative efficiency of peasant households in the sense that inputs are optimally combined to maximise profits (Marginal value Product=

Marginal Factor Costs) and implicitly technical efficiency as the output is produced with the minimum level of inputs. This reference to economic efficiency is similar to a profit-maximising behaviour because economic efficiency in the context of perfect competition is realised when Profit maximisation coincide with the maximisation of satisfaction (Kello 1992). Several empirical studies have been conducted to test the validity of Schultz's hypothesis that peasant households are profit maximisers. Unfortunately no general consensus have emerged among these empirical studies. Authors like (Hopper 1965) who tested Indian peasant farms reach the conclusion that peasant households are efficient. However others like (Farmer 1984) found that peasants are not efficient. These contradictory results in the empirical investigation of Shultz hypothesis have been explained by two main reasons. The first reason is related to methodological issues where the method of calculation of the allocative efficiency used in empirical studies have been questioned (Shapiro 1983). The calculation of efficiency scores using production function approach based on ordinary least square have been criticized in the sense that contrary to the ''best practice'' firms approach based on linear programming, the average production function approach does not show the different levels of technical competence between farmers (Ellis 1987). The second reason is related to direct criticisms of the profit maximisation theory as a theory of farm household behaviour. Profit maximisation theory ignore the presence of risk and uncertainty in agricultural production (Lipton 1968); (Mcpherson 1986).

2.1.12.2 Utility maximising theories

Utility maximising theories are built based on Chayanov's seminal work (Chayanov 1966). From Chayanov peasant household model, a variety of farm household models have been developed. Labour and income are the two key elements in Chayanov's peasant household model. In this model income is defined as a function of labour and labour has a disutility while income has a utility. The model also assume the non-existence of a labour market. A part of farm's outputs valuated at market price is consumed by the household and the rest is sold. Land is unlimitedly available for cultivation and the acceptable level of income for a household is determined by social norms. Formally the Chayanov's peasant household model can be expressed as:

$$\textit{Maximise}$$
$$U = u(L, Y)$$
$$\partial U / \partial L \leq 0; \partial U / \partial Y \geq 0 \; \textit{This condition ensures that indifference curves are convex towards the origin where the } \max\textit{imum } L \textit{ is reached}$$
$$\textit{Where } U \textit{ is utility}$$
$$L \textit{ is labour time}$$
$$Y \textit{ is income}$$
$$\textit{Subject to}$$
$$Y = f(L, P);\; Y \geq Y \min\textit{imum subsistence};\; L \leq L \max\textit{imum labor time};\; P \textit{ the price}$$

This model reached the conclusion that assuming that the production function is the main constraint faced by the farm household, the solution will be where the marginal rate of technical substitution of leisure for income equals the marginal value product of labour. By reconsidering the hypotheses emitted in the chayanov's household model, neoclassical economists in the 1960s developed new household's models to explain the duality of farm household production and consumption decisions. New farm household models looked further than the Chayanov's peasant model by incorporating the notion of full income. Thus the analysis is no more only based on farm household own production like in the Chayanovian peasant household model but now incorporate household purchased goods and services as well as well as its domestic resources. Household is now considered to maximise utility by consuming purchased goods and services as well as its own resources and leisure under full income constraints (Becker 1965). Based on these hypotheses, two types of farm household models can be distinguished: recursive (or separable) and non-recursive farm households models (Singh 1986). In recursive farm household models, Production and consumption decisions are considered to be separable. Recursive models are based on the hypothesis that markets exist and function perfectly in contrast to the chayanov's farm household model where the nonexistence of labour market is assumed. In such conditions, farmers are price takers and the time dedicated to leisure is fully independent of the time going to production activities. These conditions hold because there is a well-functioning labour market and then the utilization of family labour is determined by market wage. Income is here the only link between production and consumption decisions (Singh 1986). In contrast to recursive farm household models, non-recursive farm household models assume that markets are imperfect. Thus due to the non-existence of a well-functioning labour market, production and consumption (leisure) decisions are not separable. Farmers have to decide themselves about the percentage of their total available time that will be affected to leisure and the share going to production activities. The decision process becomes circular in this condition since consumption affects income and income affects consumption (Singh 1986). Further developments have tried to propose farm household models that integrate missing or imperfect markets (De Janvry et al. 1991) in order to take into account the specificities of developing countries where markets are missing or highly imperfect. So farm household objective function is now to maximise the utility derived from the consumption of a list of goods (home-produced goods, purchased goods, and leisure) under a large set of constraints including missing markets. Similar to profit maximisation theories, the main critic addressed to utility maximisation theories is the non-integration of risk and uncertainty to explain farm household behaviour.

2.1.12.3 Risk adverse household theories

Farmers produce under very high level of uncertainty induced by climatic hazards, pests attacks, conflicts, natural disasters, market fluctuations, conflicts, state interventions, ect (Ellis 1987). This uncertainty cause peasants to be cautious in their decision making since the objective is no more to maximise profit but to ensure a minimum level of subsistence to their households (Walker & Jodha 1986). (Lipton 1968) argued that peasants are of necessity risk adverse because production decisions at higher risk levels does not necessarily guarantee their households needs. The expected utility theory and the disaster avoidance approach are the two main theories used to conceptualise farm household risk aversion. In the expected utility approach farm household chose among risky alternatives based on their preferences and the probability of occurrence of the possible outcome. Thus they are utility maximisers constrained by risk in the sense that they are willing to choose the low risk–high utility productive activities (Mas-colell et al. 1995). Under the disaster-avoidance model the first objective of a decision maker facing risky income streams is to guarantee a minimum subsistence level. So the decision maker first evaluate alternatives in order to isolate safe alternatives or alternatives ensuring at least the subsistence level. The alternative to adopt is now chosen among safe alternatives based on its expected utility (Mendola 2007). However authors such as (Conklin, S. et al. 1980) reject the theory of risk adverse household and assume that peasant households are not risk adverse at all and are ready to take risks. The risk adverse peasant theory faced some critics in the sense that the theory ignore the role of peasant social relations and other non-market forms of economic interactions that are helpful to reduce extreme hardship during unfavourable periods (Scott 1976). (Scott 1976) reconsidered the question of risk mitigation strategies by emphasising an approach based on the collective action of peasants instead of an isolated peasant household framework. In this way two aspects of the system are emphasised. The production made by the peasant himself to ensure a subsistence level for his household and the social interactions in the community that could also help the peasant to face unfavourable periods.

2.2 Empirical literature review

The empirical review provide a review of empirical studies focusing on the determinants of the adoption of organic farming, the efficiency analysis in organic farming systems and the Impact of the adoption of organic farming on farm household' livelihoods.

2.2.1 Determinants of the adoption of organic farming

2.2.1.1 Farms' technical characteristics and socioeconomic determinants

(Khaledi et al. 2010) consider that the decision to adopt organic farming follow a lengthy process. These authors identified three main stages in the process of adoption of organic farming practices. In the first stage, the producer makes his own evaluation of the opportunities that can bring this new form of farming. This stage is in line with the theory of planned behaviour (Ajzen 1991) and the diffusion of innovations theory (Rogers 1983) which both consider the individual own evaluation of an innovation as the early stage towards the adoption of this innovation. At this stage, potential adopters of organic farming practices are aware of the technology and seek to understand more. The second stage of the process of adoption is essentially information-seeking and processing. Potential adopters gather information about the technology through public related agencies or through people already engaged in the process of organic production. Potential adopters in this stage seek to inform themselves about the nature of organic agriculture, its potential impact on farm household livelihoods, the market opportunities for organic products and the activities involved in a conversion to organic management. The third stage of the process is related to the technology evaluation stage where the producers compare the costs and benefits of the technology to other alternatives. After comparing the anticipated costs and benefits of the organic technology to that of alternatives, the producer will develop a preference for organic agriculture if the costs benefit analysis reveal that organic agriculture ranks more than these alternatives. To be fully considered as an organic farmer, the adopter should be accepted by certification bodies based on a system of certification. (López et al 2005) using the theoretical approach of the diffusion of innovations analysed the diffusion of organic agriculture in olive production in the south of Spain. This study indicated that organic olive production spread among producers in an autonomous way and is also influenced by external factors. Information and knowledge are fundamental factors in the decision to adopt organic farming practices. (Padel 2001) emphasised the importance of knowledge network in the process of diffusion of organic agriculture. Beyond economic and information issues, other authors raised social issues and argued that social factors can also influence conversion decisions (Lobley et al. 2005). Some studies used econometric models to examine the conversion behaviour of organic farmers. Three main methods are applied in these studies: discrete choice models, Bayesian averaging models and duration analysis. The most common models used in the empirical literature to analyse the determinants of organic farming adoption are discrete choice models. (Tiffin & Balcombe 2011) using a sample of 237 horticultural producers (151 conventional, 86 organic) in the UK applied a Bayesian model averaging to identify the determinants of farmers' adoption of organic horticulture. This analysis showed that the age of the farmer did not have any significant influence on his willingness to adopt organic horticulture farming. The decision to adopt organic farming or not is more influenced by the farmer beliefs about the potential of organic farming to meet the needs of the society in terms of food and fibre. When farmers believe that organic farming is sustainable, its rate of adoption is increased by 15 points of percentage. In the opposite case, the probability of adoption of organic practices is reduced by 25 points of percentage. (Mzoughi 2011) analysed the role of moral and social concerns in farmers' decisions to adopt integrated crop protection and organic farming in the case of French fruit and vegetable producers. Having initially targeted 1286 fruit-growers and vegetable producers located in the French areas of Alpes de Haute Provence, Hautes-Alpes and Vaucluse, this analysis finally considered 243 individual responses. Although economic concerns have been found to play an important role in the decision to adopt each type of farming system, a significant number of farmers also raised moral and social concerns. Building on a multinomial logistic regression, the results of this study revealed that social concerns (showing to others one's environmental commitment) affect both the decision to adopt integrated crop protection and organic farming while moral concerns (do not feel guilty about one's choices) increase the probability of adoption of organic farming only. (Genius et al, 2006) in the case of Greece proposed an empirical framework to analyse farmers joint decision to adopt organic farming practices and to seek farming technical information from various sources. By estimating a trivariate ordered probit model, the authors came to the conclusion that the decision of information acquisition and organic land conversion are strongly related. (Kassie et al. 2009) used plot-level data from the semi-arid Tigray region of Ethiopia to investigate the determinants of farmers' decision to adopt sustainable agricultural practices focusing particularly on conservation tillage and compost. Based on a multinomial logit analysis, this study underscored the role of both plots and household characteristics in the decision of adoption. In contrast factors such as poverty and access to information are revealed to play a strong role in the decision to adopt sustainable agricultural practices. The adoption of technologies has been found to be location-specific while the effect of gender on adoption decision was found to be technology-specific. Applying a stochastic dominance analysis, the authors furthermore concluded that sustainable agricultural practices enhance productivity and can even perform better than conventional farming practices. (Sodjinou et al. 2015) drawing from the case of cotton producers from the centre and northern parts of Benin investigate the socioeconomic and institutional factors affecting the adoption of organic cotton farming practice. For that purpose, the authors applied a probit model on a set of data collected from 242 cotton farmers. The empirical findings show that farmers' socioeconomic characteristics, the contact with extension and advisory services and the physical distance between the farm and the household play a crucial role in the decision to adopt organic cotton farming in Benin. Women are found to be more attractive to organic farming than conventional farming. Older, less educated and low income farmers who are revealed to be concerned by environmental issues are also likely to adopt organic cotton farming. Organic farming can therefore be used as a poverty alleviation strategy while contributing to preserve the environment and natural resources' at the same time. (Méda et al. 2018) who also focused on cotton production analysed the effects of institutional factors on farmers' adoption of organic, conventional and genetically modified cotton farming in the western cotton zone of Burkina Faso. According to these authors, the institutional arrangements made by the government, cotton companies, farmers and other partners in the cotton sector (in terms of the provision of subsidized inputs on credit to conventional and genetically modified cotton farmers for both cotton and cereals production and in terms of the influence of cotton companies and cotton producers organisation) are likely to promote conventional and genetically modified cotton farming and inhibit the development of the organic cotton sector. Building on institutional theory and a random utility framework, the authors applied a multinomial logistic regression on a set of primary data collected from 429 cotton farmers including 171 conventional cotton farmers, 61 organic cotton farmers and 197 genetically modified cotton farmers. The results of the analysis confirmed that institutional factors play a crucial role in the decision to adopt each type of cotton farming system. Whereas subsidies on fertilizers and credit for cereal production are found to be negatively associated to the adoption of organic cotton farming, they have no effect on genetically modified cotton farming adoption compared to conventional cotton farming. For the farmers to have access to inputs for cereals production, they have to grow conventional or genetically modified cotton. By this mechanism, farmers then preferred to grow conventional or genetically modified cotton farming. The commitments made by cotton farmers to their cotton company and their association bring farmers to be less willing to adopt organic cotton farming. Cotton companies and cotton farmers' organisations therefore play a strong role in the decision to grow organic cotton. Farmers follow the orientation choose by cotton companies or the producers' group in which they are involved. In addition to the factors already mentioned, the authors also identified factors such as extension services, training on cotton production, gender, education and the availability of virgin lands as factors that can influence the adoption of one type of cotton farming system relative to another.

(Burton et al. 1999) in the case of the UK investigated on the sociological factors associated with the adoption of organic, non-certified organic and conventional horticulture practices based on a sample of 237 producers of horticulture crops and a multivariate probit model. He drew the conclusion that female operators are more likely to adopt organic practices. Producers' awareness of environmental issues and membership with environmental organizations are also found to have a positive influence on the decision to adopt organic farming. However farmers' age was found to have a negative influence on organic certified farming adoption. (Ragasa 2012) based on a wide review of agricultural technology adoption argued that in general women have slower rate of adoption of agricultural technologies due to the limited access to inputs and services. (Wollni & Andersson 2014) in the case of Honduras analyse the effects of spatial patterns in organic farming adoption. The spatial patterns considered by the authors are related to a variety of factors such as social conformity concerns, the availability of information in the farmer's neighbourhood, and perceived positive external effects of the adoption decision. Based on survey data and a spatially explicit adoption model, the authors found that the availability of information in the farmer' neighbourhood network and his beliefs that he is acting in accordance with his neighbours' expectations are important factors that positively affect the decision to adopt organic farming. In contrast the perceived positive productivity external effects to neighbouring plots tend to discourage organic farming adoption. (Sarker et al. 2005) applying a logistic regression on a set of data collected from 195 rice and vegetable growers in Bangladesh came to the conclusion that the perception of organic farming, the number of family labourers, household income and household access to extension services are factors that affect farmers decision to adopt organic farming. Regulations and subsidies are also raised by a number of authors to be some key determinants of organic farming adoption.

(Lohr & Salomonsson 2000) in the Sweden case did not explicitly analyse the factors affecting the conversion to organic agriculture but were interested to determine under what conditions subsidies are required to motivate the conversion to organic farming. To do so, the authors distinguish between farmers who needed subsidies payments to convert to organic farming and those who did not. This study was conducted to support organic farming reforms in the US where the development of the organic sector was essentially market driven with less support from the government compared to conventional farming systems. Based on a sample of 550 organic farmers of whom 234 converted after having received subsidies payments, the authors applied a utility maximisation model to compare farmers who converted based on subsidies payments and those who did not need subsidies to convert. The results of the study revealed that factors such as farm size, payment level, farmers' satisfaction with extension services and their exposure to other organic farmers were positively related to subsidy requirements. Whereas the sources of information, the number of marketing outlets, livestock diversity and non-economic reasons where negatively associated to subsidies requirements. As a lesson for organic farming development in the US, the authors drew the conclusion that market opportunities and the assistance for organic extension and education could substitute for direct spending and favour organic farming adoption in an area where government support is unavailable. A study by (Flaten et al. 2010) analyse the reasons of Norwegian farmers ceasing or planning to cease certified organic production. Based on surveyed data collected from 220 farmers ceasing organic production between 2004 and 2007, and a random sample of 407 farmers with certified organic management in 2006, the authors used factor analysis to aggregate indicators and applied linear regression to analyse the motives of farmers who abandoned organic farming. The results of this study suggested that economic factors (poor financial results, organic farming payments too low, unpredictable organic farming policy, high income risk, cost of inputs), and regulations (complicated organic standards, excessive bureaucracy associated with certification and control, changes in organic standards, strict inspections) are the primary factors for dropping out from the organic sector in Norway. (Khaledi et al. 2010) in the case of Canada raise the marketing issue as the main determinant of organic agriculture adoption. By estimating an upper limit Tobit model, the authors found that fewer problems in marketing and the use of internet marketing are critical factors in farmers' decision to engage in organic farming in Canada. By this study, it also appeared that older farmers with large cultivated areas and the distance from the farm to cleaning location are negatively associated to the decision to adopt organic farming. In the same order of ideas, (Kuminoff & Wossink

2010) developed a theoretical model and apply a switching regression model to assess the option value to switch to organic farming and the reasons of the slow growth of organic soybean farming in the case of USA. The sunk costs and the uncertainty related to the profitability of organic farming have been found to be the crucial barriers for US farmers to adopt organic farming practices. Factors such as ideological, philosophical, and religious beliefs, profitability and market demand, environmental protection and health concerns, yields decline, issues of pest management are also considered to impact significantly the decision to adopt organic farming practices.

2.2.1.2 Social networks effects

The econometric analysis also emphasised the importance of individuals' social network in the decision to adopt agricultural technologies in general and organic farming as a form of innovation. As (Young 2002) argued, new ideas and ways of doing do not definitely take place at once but most often spread through social networks. In the first stage of an innovation, few people adopt. After that, people in contact with the first innovators also adopt, and then people in contact with those people adopt and by this way the innovation will spread in the entire community. (Burton et al. 1999) in the case of UK confirmed that farmers who are converting from conventional to organic farming receive advices not from extension services but from farmers already converted and located in the same region. Neighbouring organic farmers is therefore found to be a key information channel for the conversion to organic farming. For (Lakner et al. 2011), the importance of information exchange is more pronounced in organic agriculture than in conventional agriculture. The authors argued that in recent years, they were few specialised extension services in the field of organic farming even in the case of Europe, bringing therefore organic farmers to generate and share organic farming knowledge by themselves and among themselves via social networking. (Ramirez 2013) in the case of Texas used social network analysis to analyse the social factors influencing farmers decision to adopt water conservation technologies. This paper built on the fact that social factors are influencing farmers' decision to adopt irrigation technologies. Farmers do not act unilaterally when adopting a technology. The decision to adopt an innovation is influenced by the flow of knowledge, interactions and ideas embedded in their social interactions with other farmers. Based on a sample of 195 fields farmed over a five-year period in southeast Texas by 37 farmers, this paper applied Girvan Newman algorithm to identify subgroups in the farming social networks and show how the decision to adopt irrigation technology is influenced by the day to day transfer of knowledge through the interactions within farming subgroups. The results of this study showed that the participation in organisation is a key determinant influencing farmers' decision to adopt irrigation technologies. After the introduction of the technology by central farmers, this technology is transferred through tenant or kinship. (Abebaw & Haile 2013) in the case of Ethiopia, used propensity score matching to analyse the impact of cooperatives on agricultural technology adoption such as fertilisers, improve seeds and pesticides. This paper built on the fact that most of the adoption studies in Ethiopia ignore the importance of cooperative membership as an important factor influencing farmers' decision to adopt agricultural technologies or did not control for the endogeniety of the cooperative membership variable. The analysis involved 965 households randomly selected and residing in 7 districts. Based on propensity score matching between cooperatives members and non-members, this study provide evidence that cooperative membership has a positive and significant impact on fertilisers adoption by farmers. The cooperative membership effect is found to be more pronounced among illiterate households and households located far away from an all-weather road. The adoption of improved seeds and pesticides is also found to be significantly sensitive to the cooperative membership variable depending on the estimation methods used. This study also highlighted the importance of social networks in agricultural technology adoption. (Matuschke & Qaim 2009) distinguish between endogenous and exogenous social network effect to analyse the impact of social network on the decision to adopt hybrid pearl millet and hybrid wheat in the Indian state of Maharashtra. The endogenous effect has been defined as the effect of the behaviour of a network member on individuals' decision to adopt a technology (Whether the member himself is an adopter or not). The exogenous effect however refers to the impact of the specific characteristics of a network member (age, education, etc.) on individuals' decision to adopt. This analysis draw on a simple social learning model where the adoption decision is supposed to depend on farm households characteristics as well as on the adoption decision of the farmer social network members and their characteristics. For instance, a farmer can be willing to adopt improved seeds varieties if there are adopters in his social network with whom he can share information regarding cultivation techniques. This effect is said to be endogenous. At the same time, a farmer can be willing to adopt improved seeds varieties if there are in his social network some seeds dealers with whom he can get advices. This effect is said to be exogenous. To obtain information on individuals' specific networks, farmers were asked by the authors to cite a maximum of three people with whom they discuss when it comes to take agricultural decisions. On the one hand the share of adopting network members is considered to capture the endogenous effect of social network. On the other hand network member characteristics such as age of network member, farm size of network member, communication with network member and distance to network member are considered to capture the exogenous effect of social network on technology adoption. The results of this study showed that the behaviour of farmers' individual network members has an important impact on their decision to adopt new technologies. Information constraints are also raised by this study as the main institutional barrier to technology adoption. (Di Falco & Bulte 2013) in the case of Ethiopia investigated the effect of social network on the adoption of farm management practices such as tree planting, soil and water conservation. According to these authors compulsory sharing within a social network can reduce the incentives of the members to adopt self-protection measures. To verify this hypothesis the authors tested whether larger kinship network can reduce member's willingness to invest in self-protection against weather shocks. A statistical relationship have been established between investments in tree planting, soil and water conservation on the one hand and the size of the kinship network on the other. The kin variable in this study have been considered as the number of relatives of the household living in the same village. Kin is defined as family members up to nephews, nieces and cousins. Based on a probit model and survey data of 1000 households located in the nil basin of Ethiopia, the author estimated how the decision to adopt a risk mitigating strategy is affected by the size of individual's social network. They found that the number of kinship links adversely affect the decision to invest in soil conservation strategies. Statistically speaking, an increase of 10% in the kinship size reduce the probability to invest in soil conservation strategies by 0.5%. In addition to the size of the kinship network, other kinship variable have been introduced in the model such as the number of adopters in the village and the availability of other risk mitigating strategies. An increase in 10% in the number of adopters in the village is found to be associated with an increase in the probability of undertaking soil conservation by 2%. However having access to other risk mitigating networks increases this probability by 29%. The results of the estimate for tree planting showed that there is a positive correlation between the size of the kinship network and the adoption of this innovation. Although Bayesian averaging models and duration analysis have been applied in adoption studies related to organic farming, the most widely used methods remain discrete choice models.

2.2.2 Efficiency analysis in organic farming systems

Productivity and efficiency analysis are important tools used in economics to compare the performances of different farming systems (Lakner & Breustedt, 2017). Different studies have been conducted to analyse the efficiency of organic farming practices. Most of the modelling approaches are based on Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA).

2.2.2.1 Analyses centred on organic farming technical efficiency

By summarizing the literature related to efficiency analysis in organic farming, (Lakner & Breustedt, 2017) identify four specific factors influencing organic farming technical efficiency. These factors are essentially related to farmers' management skills and education, farm structure and resources, the location of farm and regional differences. Management kills and education which are under the control of farmers and continuously improved are supposed to influence positively organic farm technical efficiency. The ecological motivation of the farmer however is found to have a negative influence on farm technical efficiency. The farm structure and resources in relation with the type of organisation put in place have been also found to have some implications in farm technical efficiency. Organic farmers achieving high degree of specialisation are more technically efficient than those with low degree of specialisation. Family farms are mostly found to be less technically efficient while capital endowment and the size of the farm contribute to increase farm technical efficiency. The location of the farm plays also a critical role in farm technical efficiency. Farms which are located on good soil are generally predicted to be more efficient than those which are not. A controversial results is that farm with high share of rented land are more technically efficient than those with less restriction on land availability. (Lohr & Park 2006) based on a sample of 774 farmers in the US investigate the influence of organic farmers experience and the role of soil management techniques on farm technical efficiency. These authors drew from the general observation that the productivity of sustainable agricultural systems increase with the experience of the farm manager, the long term economic viability of the farm and the capacity of the manager to put in place productive management and input acquisition strategies. Soil improving inputs acquisition is a critical issue in organic farming where the utilization of synthetic nutrient and pests control is prohibited. In the study, five types of soil improving inputs have been considered. These inputs included green waste for compost, animal manures for compost, mineral soil amendments, finished compost, and biological soil fertilizers. To evaluate the effect of farming experience and soil improving inputs on organic farming technical efficiency, the authors used a stochastic frontier model applied to a Translog production function. Efficiency scores have been estimated by dividing the sample into two groups of organic farmers. A first group of farmers with less than five years' experience in organic and the other one with more than five years' experience in organic farming. The results of the efficiency analysis showed that farmers experience in organic farming is an important factor influencing farm technical efficiency. Farmers who have more experience in farming and a better knowledge of their local soil conditions know more about how to match inputs to farm needs and achieve higher level of technical efficiency. Investments in soil improvement is also identified by the authors to have a significant influence on organic farm technical efficiency. Efficiency improvement in organic farming can be achieved by specific farm management practices. Farms with more than 5 years' experience in organic practices was found to be more efficient. (Francksen et al. 2007) based on data of 461 organic farms investigated the issue of the impact of farm degree of specialisation on productivity gains. For that purpose, the author estimated three specific frontiers (each of them representing a degree of specialisation) and an all-encompassing meta-frontier, by applying Data Envelopment Analysis and window analysis. The results of the analysis indicated that a large proportion of farmers did not chose the optimal degree of specialisation. When estimating the potential productivity gain by switching to the higher specialisation class, it has been found that farmers with moderate degree of specialisation are more and more efficient when reaching higher degree of specialisation. The results of this study confirm the observation made in (Lakner & Breustedt 2017) that the degree of specialisation influence organic farms technical efficiency. (Sauer et al. 2007) in the case of Denmark investigate the change in productivity for Danish organic farming sector by using a panel of 56 organic milk producers over the period 2002-2005. This study took place in a context of declining of the Danish organic sector due to the exit of dairy farms. The study period was also characterised by the change of the political approach in the Danish organic farming sector which switch from an inflexible environmental oriented to a market oriented approach. In contrast to the environmental oriented approach, the market oriented approach of organic farming emphasised the link between subsidy payments and environmental benefits. Based on a Trans log production frontier approach, this study analysed the technical and scale efficiencies of organic milk farms following a time trend and a general index model specification. The significance of subsidies in promoting long term development of organic farming in Denmark is also analysed by estimating a bivariate probit model with respect to the factors influencing organic market exit. The results of this study showed significant differences of technical efficiencies between organic farms and a significant positive effect of subsidies on the improvement of organic farms technical efficiencies. Evidence has also been found through this study that subsidies as well as off farm income contribute to organic farms technological improvement and reduce the probability of organic market exit. The learning effect in organic farm management in relation to the farmer experience is also emphasised by this study as in (Lohr and Park, 2006). (Timo Sipiläinen 2005) also investigated and confirmed the effects of experience on organic farming technical efficiency improvement. According to these authors, organic farming technical efficiency may increase or decrease over time depending on the nature of the technology and the learning process. It may also take time to the soil to reach the optimal nutrient stock under organic farming because of the impossibility to use synthetic fertilisers. Based on a sample of organic and conventional dairy farms in Finland, and applying a stochastic frontier distance function, the authors estimated the technical efficiency of organic farming and its development over time after controlling for regional heterogeneity and possible selection bias. The technical efficiency of organic farming has been found to diminish at the beginning of the conversion period and start increasing only after 6 years from the switch. So the length of the conversion and the learning process in organic dairy farming has been estimated by the authors to be in average 6-7 years in the case of Finland. A number of studies also investigated the effect of location on organic farm technical efficiency. Using data from 396 farms over the period 1994/1995-2005/2006 and applying a stochastic frontier production function, (Lakner et al., 2011) investigated empirically the effects of farm localization and urbanization economies on organic pasture farms technical efficiency in Germany. Localisation and urbanization economies can affect organic farms technical efficiencies via different ways. Localization economies occurred in a situation where many firms operating in the same industry are located in a given area. This proximity between firms offer a number of advantages such the ease of access to skilled labour and intermediate inputs, the ease of access to information which can generate technological spill overs effects. Urbanization economies are linked to the effects of regional economic activity on a firm's economic performance. Organic farmers operating in highly dense areas where people are aware of environmental concerns and willing to pay higher prices for organic products will find better organic market opportunities. In the case of Germany (Lakner et al, 2011) found that regional effects have a significant effect on organic farms technical efficiency. Two kind of variables have been used in this study to capture the effects of urbanization economies on organic farms’ technical efficiency. The first variable is the distance between organic farm and the nearest organic dairy processor. The second variable is the results of local election for the green party in Germany which is used as a proxy of the local acceptation of organic farming. The share of organic farmers in the region have been also introduced in the model to capture regional effects (eastern, northern and western Germany was the regions concerned in this study). Besides farmer’s age and education that are commonly found to have an impact on organic farms technical efficiency, the results of this study also found that organic farms technical efficiency in Germany increase with the regional share of organic farmers; increase with a decreasing distance to organic dairy processors; and increase with an increasing share of the regional votes for the green party.

2.2.2.2 Comparative analyses of the technical efficiency of organic and conventional farming systems

Some analyses focused on the comparison of organic and conventional farming systems. In most of these studies organic farming is found to achieve lower productivity than the conventional farming due to inputs restriction (Kumbhakar et al. 2009); (Mayen et al. 2010). (Kumbhakar et al., 2009) argued that organic farming is less productive than the conventionnal one because the organic production process is based on the use of restricted specific inputs that tend to increase the production costs. For the organic production to be profitable, the price differential should be high enough to compensate the loss of productivity due to the conversion. Based on a sample of 49 organic and 279 conventional dairy farms over the period 1995-2002 (Kumbhakar et al., 2009) found that in average organic farms are 5% less efficient than conventional farms. (Mayen et al. 2010) in the case of the US dairy sector compare the productivity and efficiency of both types of farms. According to these authors, farmers usually self-select into organic farming. The differences in productivity and efficiency between organic and conventional farming practices might be influenced by the self-selection in the choice of the production technology. To control for selectivity bias (Mayen et al. 2010) apply propensity score matching approach to select the groups of organic and conventional dairy farmers to be included in the analysis. Separate technologies have been estimated for both types of dairy farming practices after rejecting the hypothesis of homogeneity of production technologies. Organic and conventional farms has been matched based on farms’ and operators’ characteristics. From the results of this analysis, it appeared than organic farms are 13% less productive than the corresponding matched conventional farms. (Lansink et al.

2002) used a DEA framework to analyse the efficiency and productivity differences in organic and conventional livestock and crop farming in Finland based on an unbalanced panel of crop and livestock farms over the period 1994-1997. The results of this study showed that organic farms are more efficient than conventional farms when distance is measured relatively to their own frontier but are using a less productive technology compare to conventional farms. The productivity of inputs in organic farms is estimated to be 40% less than the productivity of inputs in conventional farming. Inputs such as capital, land and labour are even found to present low productivities on organic farms. (Tiedemann & Latacz-Lohmann 2011) in the case of Germany investigate the development of total factor productivity in organic and conventional farming over the period 1999/2000 to 2006/2007. Based on a balanced panel of 151 organic and conventional farmers, the productivity development of these farming practices has been assessed using malmquist indices and stochastic frontier analysis. To control for selectivity bias, a matching procedure is applied by the authors to identify for each organic farm a conventional farm presenting similar observable characteristics. The results of this study reveal similar development trends of the productivity for both organic and conventional grazing livestock and mixed farms. Organic arable farms have been found to be less productive than their conventional counterparts over the study period. The slowed productivity development in the organic sector is explained by the authors as a result of the lack of technical and scale efficiency. Most of the studies comparing organic and conventional farms have faced many critics due to selectivity bias and the difference of reliability between organic and conventional groups. It is not fair to find homogeneous groups in terms of observable characteristics and the comparison between two groups of farming practices can be affected by this selection bias. In most of the comparative studies the sample of organic farmers is always too small compare to the sample of conventional farmers. To overcome these issues some estimations or sampling technics have been proposed in the literature. These technics include the estimation of metafrontiers instead of considering subgroups frontiers. Matching methods or the estimation of selectivity models are also applied to make the two groups of farmers as homogeneous as possible in terms of observable characteristics. A sampling method also used to control for selectivity bias is to consider a sample of organic and conventional farms that are the more closed in the field.

2.2.2.3 Integration of environmental variables in organic farming efficiency analysis

Another important issue related to efficiency analysis in organic farming is the integration of environmental variables. For (Lansink et al. 2002) the measurement of environmental performance from a productive efficiency perspective follow various methodological frameworks. Methods such as life cycle assessment and environmental impact assessment are considered to be inappropriate for comparison purposes. Frontier based environmental efficiency models are classified into several groups. The first type of models include SFA or DEA efficiency models adjusted for environmental variables where environmental variables are treated as inputs or undesirable outputs. Another type of frontier based environmental efficiency models are frontier eco-efficiency models which relate economic outcomes to ecological outcomes in order to generate eco-efficiency indicators. A third type of models allow the incorporation of the material balance principle into frontier based environmental efficiency models. In the material balance approach the environmental outcome is generated through the production process. The material balance condition implies that agricultural production activities are regulated by the law of mass conservation. So nutrients balance condition hold in this situation and the nutrients which are not contained in desirable outputs are returned into the environment as undesirable outputs. The incorporation of the material balance approach into frontier based environmental efficiency models have been seen as an alternative to the approaches incorporating environmental variables as inputs or as weakly disposable output given that these methods do not satisfy the law of mass conservation. (Hoang & Rao 2010) considered that though the material balance approach is useful for the evaluation of some specific types of pollution, it also has some drawbacks. The material balance approach does not provide a clear way of treatment of immaterial inputs such as labour, capital and farm services and suffer from the lack of universally-accepted weights to incorporate various materials. In order to overcome the limitations of the material balance principle, the authors proposed the incorporation of the energy balance principle into frontier based environmental efficiency models. The energy balance measure the value or usefulness of any form of mass or energy. To their point of view, the energy balance approach goes beyond the material balance approach as the incorporation of the cumulative energy balance over the supply chain allow to capture cumulative pollution and to measure the total effects of agricultural activity on natural resources. The incorporation of the energy balance over the supply chain provide a more comprehensive framework for the evaluation of the sustainability of agro ecosystems (Hoang & Rao 2010). Authors like (Alauddin & Hoang 2012) combined both the material balance and the energy balance into a frontier framework to evaluate the cost efficiency, the environmental efficiency and the ecological efficiency of agricultural systems. Regarding the empirical applications related to the incorporation of environmental variables in farm efficiency analysis, (Dreesman 2007) integrated environmental variables in the measurement of the productivity and the efficiency of agricultural farms. Based on different models setups the author consider three environmental variables that could affect the productivity or the efficiency of organic milk farms. These variables are nitrogen, phosphorus and energy use. Using both DEA and SFA models (Dreesman 2007) established that both phosphorus and energy contribute significantly to productivity while nitrogen was found to not contribute to productivity. (Kantelhardt et al. 2009) analyse the economic and environmental efficiency of farmers engaged in an agro-environmental program named Bavarian KULAP in Germany. Based on survey data covering 102 farmers and through a DEA-model the authors compared the economic and environmental efficiency of various types of agro-environmental schemes (No participation, Reduced extensification of grassland use, Enlarged extensification of grassland use, Diversification of arable land use, Organic farming). The results of efficiency calculations showed that the economic and environmental efficiency scores are different under the agro-environmental schemes considered. The variables "low-intensively used area" and "area covered with landscape elements" are considered as desirable outputs while nitrogen use is introduced in the model as an undesirable output. Among the different agro-environmental schemes considered by this study, organic farming has been found to achieve both high economic and environmental efficiency scores. The authors concluded that organic farming is successful in combining economic and environmental objectives. (Sutherland & Darnhofer 2012) in the case of England compared the performances of 16 organic farmers and 16 conventional farmers using a DEA-based model. In addition to the agricultural output, two biodiversity indices has also been included in the model as desirable outputs. The results of the analysis showed that organic farmers performed higher efficiency levels when they are located in areas dominated by the organic production. Analogically, conventional farmers also performed higher efficiency levels in areas with higher shares of conventional farmers. Though the data of this study is very detailed, the sample size is not large enough for a reliable DEA analysis. In the same line of research, (Sipilainen & Huhtala 2013) analysed how crops diversity can affect organic as well as conventional crops farms efficiency. Here crops diversity is used as an environmental desired output in addition to the crops production output. Taking into account this environmental variable result in a substantial change of the efficiency scores. Organic farms achieve the same level of efficiency as conventional farms in this case. (Aldanondo-Ochoa et al. 2014) investigated the private and environmental efficiency of organic versus conventional farming using a DEA-based model combined with a metafrontier analysis. In a first step the private efficiency of organic and conventional farms are computed by considering only the relationship between inputs and output. The private model does not take into account environmental detrimental variables. In a second step, environmental variables are included in the model to capture the environmental soundness of each production system. The results of this study showed that in terms of private efficiency, organic farmers are more efficient than conventional farmers. Since organic farmers are operating in a highly regulated area, they are much more constrained in terms of inputs use compared to conventional farmers. This situation bring organic farmers to develop their farm management skills and to be more careful in inputs choice. When the environmental detrimental variables (nitrogen excess and an index of pesticide impact) are included in the model as undesirable outputs to compute the social efficiency, organic farmers appeared to be the best alternative in a social point of view. (Beltrán-esteve et al. 2017) also combined Life Cycle Analysis and Data Envelopment Analysis to compare the Eco efficiency of organic and conventional farming systems in the case of citrus farming in Spain. This study involved 200 Spanish citrus farms belonging to organic and conventional systems. Eco-efficiency is defined here as the ratio of the economic outcomes to the potential environmental impact. To account for the technological heterogeneity between groups of farmers the authors included a metafrontier analysis in order to allow for the comparison of the eco-efficiency between groups of farmers and to measure the distance between the production frontier of individual groups and the meta-technology. The economic outcome considered here is farm revenue per acre of land whereas ecological outcomes are related to the global warming potential of farm activity, the ozone layer depletion potential of farm activity, the eutrophication potential, the Eco toxicity and human toxicity (carcinogenic or non – carcinogenic). These ecological outcomes have been generated through life cycle assessment. The results of this study revealed that shifting from organic to conventional farming system would allow a potential reduction of environmental impact of 80% without any reduction of economic output. (Tuomisto et al. 2012) in a meta-analysis compare the environmental impact of organic and conventional farming in European countries. This comparison was done based on selected indicators related to the impact of agriculture on the environment. These indicators are of two categories: Life Cycle Assessment (LCA) indicators and non-LCA indicators. LCA indicators are indicators capturing the environmental impact occurring during the production chain going from inputs manufacturing and transportation to farming processes. LCA indicators aim to evaluate the magnitude of the overall impact that might be due to pollutants. Non-LCA indicators are indicators capturing only the impact occurring through the farming process. The LCA indicators considered in this study were: land use, energy use, greenhouse gases emissions, eutrophication potential, and acidification potential while the non-LCA indicators were: nitrogen leaching, ammonia emissions, phosphorus losses, biodiversity. After analysing 275 papers, the authors draw the conclusion that organic farming practices have generally a positive impact on the environment per unit of area and not necessarily per production unit. Though organic farming practices have been found to achieve higher soil organic matter content and lower nitrogen losses per unit of field area, ammonia emissions, nitrogen leaching and nitrous oxide emissions per product unit are higher. Organic farming systems have lower energy requirement but higher land use and higher eutrophication potential and acidification potential per product unit. In terms of biodiversity losses organic farming practices have been unanimously found to have lower environmental impact. In the same order of ideas (Meier et al. 2015) conducted a meta-analysis of studies using the LCA methodology to compare the environmental performance of organic and conventionnal farming systems. This study aimed essentially to investigate if the higher environment impact per unit of product observed in organic farming is due to the lower yields observed in organic farming or to methodological issues related to the implementation of the LCA analysis. As the authors argued comparative LCA studies on organic and conventional farming systems most often do not appropriately differentiate the specific features of both farming systems in the goal and scope definition and also in the inventory analysis. In addition to that, N-emissions in LCA studies are generally based on model calculations which do not correspond to the actual level of the nitrogen left in the system. N-models are not well adapted to the mode of action of organic fertilizers because they are most often built on assumptions from conventional agriculture. For a better application of the LCA methodology, the authors recommended a more precise differentiation between organic and conventionnal farming systems and the development of N-emissions models that fit well the realities of the ground in terms of N-fluxes. More representative background data on organic farming should be generated for more complete LCA inventories according to these authors.

2.2.3 Impact of organic farming on farm household' livelihoods

There is a growing evidence in the empirical literature that the adoption of organic farming has economic, environmental and social impacts that can contribute to solve agricultural and rural development issues. To date few empirical studies have investigated the impact of organic farming on farm households livelihoods.

(Udin 2014) in the case of Shimoga in the Karnataka state of India, analysed the impact of organic farming practices on farmers' income and family needs for food consumption. Based on a farmer-centred research approach, this study aimed to capture the perceptions and realities of farmers practicing organic agriculture. The study also compare organic farming organised and supported by the government on the one hand and organic farming based on individuals' efforts on the other. The results of the study showed that organic farming present a great potential to fulfil the requirement of households in terms of food consumption and also is a source of income and an opportunity to reduce production costs while enhancing the sustainability of agro eco systems. The government support for organic farming have been found to be essentially in nature while individuals efforts come from innovative perceptions of farmers in terms of agro ecological practices. (Ndungu, et al. 2013) in order to establish the contribution of organic farming to households livelihoods evaluated the impact of organic farming on the profitability of vegetable production system among smallholder producers in Kiambu and Kajiado counties of Kenya. This analysis was done by the means of propensity score matching methods where the estimated treatment effects were compared to a counterfactual of no treatment. PSM was used as an impact estimator to get unbiased estimates of the average treatment effects. Nine variables representing social, economic and farm specific characteristics were introduced into a logit model to establish the matching. These variable included land size, location, gender, age, occupation of household head, years of experience, number of farm parcels owned, availability of irrigation and land ownership. Based on a sample of 208 smallholder farmers composed of 78 organic and 130 conventional farmers, data were collected on costs and returns of vegetables production. The study revealed that organic production system presents the potential to increase the profitability of smallholder vegetable producers by 89.5% in Kiambu and Kajiado counties of Kenya. This positive impact in vegetable organic farmers' profitability can be attributed to higher prices (28%-71%) according to the authors. Despite higher transaction costs (43%) and higher production costs (2-43%) compared to conventional farming system, organic farming system still more profitable than the conventional one. Organic farming system can therefore be promoted as a strategy to improve rural households' livelihoods. (Uematsu & Mishra 2012) in the case of the US farming sector used large farm-level data and a matching estimator to analyse the relationship between organic certification and the various components of farm household income. This study took place in a context of a rapidly expanding organic sector in the US economy. By applying the nearest neighbour matching method, the authors estimated the average treatment effects of being a certified organic farm on farm household income, off-farm income, gross cash income (farm revenue) and on various components of production costs (total production expenses, fertilizers and chemicals expenses, labour expenses, cash wages, insurance expenses and marketing charges). In contrast to the expectations found in (Ndungu, et al. 2013) this study revealed that certified organic farmers do not earn significantly higher household income than conventional farmers. Even though the average gross cash income of organic farmers is higher than the conventional one, organic farmers faced higher production costs such as insurance expenses, labour and marketing charges and large fixed costs of converting to certified organic production. (Eyhorn et al. 2005) analysed the impact of the conversion to organic cotton on the livelihoods of organic farmers in the case of Madhya Pradesh in Central India. The methodology used in this study was essentially based on a comparison between farm profile data, material and financial inputs/outputs and soil organic parameters between organic and conventional farming systems over two cropping periods. The results of the study showed that organic farms achieved almost the same yields than the conventional one. The gross margin of organic farming system however is found to be substantially higher than that of the conventional one because organic farming achieve low production costs and benefit from a 20% organic price premium. Even if the crops produced in rotation with organic cotton are sold without price premium, organic farming still more profitable than the conventional one. In addition to the opportunity of higher profits offered by organic systems, organic farmers perceived that soil fertility improve significantly after the conversion to organic farming. (Altenbuchner et al. 2017) examined how the conversion to organic cotton cultivation influences the livelihoods of smallholder farmers in rural India. This study was essentially based on interviews with farmers, interviews with key experts and observations on the field. It was a qualitative investigation to understand the interactions between organic farming and different factors influencing famers' livelihoods. 30 farmers was selected and interviewed using a purposive sampling approach which is based on the research questions, the quality of the informants and farmers' willingness to share their experiences. The results of this study revealed that organic farming have an impact on farmers' livelihoods in the environmental, economic and social points of view. The main environmental impacts identified here were the reduction of the emissions of toxic materials into the environment, the diversification of cropping patterns, the preservation of biodiversity and the improvement of soil conditions. The economic impacts described by farmers are essentially the reduction of input costs, the easier access to seeds, a higher market power, the less dependency on money lenders and an increased income from more diverse income sources. The social impacts of organic farming according to this study include better living conditions, increased food security, the improvement of health conditions, more investments in children's' education and improved standard of living, the empowerment and capacity building through training and institutions building. However some challenges to organic cotton production expansion have been mentioned such as higher work load, insufficient organic price premium, the difficult access to organic seeds and weather conditions that increase production risks. (Mzoughi 2014) based on two samples of organic and conventional farmers in the PACA region of France investigate the question of psychological concerns in the economic analysis of organic farming. This study referred to behavioural economics where psychological concerns are considered to be more important than what is generally claimed in standards economic models. Individuals can undertake actions only for intrinsic reasons such as pleasure and personal satisfaction (Kahneman 2003); (Camerer et al. 2004). Using an ordered probit model, the author tested the effect of practicing organic farming on farmers' level of life satisfaction. The dependant variable which is an ordered one range from 1 (not satisfied at all) to 10 (fully satisfied). In order to control for farm level heterogeneity a set of farm level characteristics and other factors related to life satisfaction are included in the analysis. The results of this study reveal that there is a strong positive relationship between organic farming adoption and the life satisfaction of farmers. The adoption of environmental friendly practices is not only motivated by monetary gains but also non-monetary gains such as pleasure and personal satisfaction. (Parvathi & Waibel 2015) in the case of India examined the difference of gains of adoption of black pepper production under two certification schemes. The organic certification scheme on the one hand and the organic under fair trade certification scheme on the other. More precisely the authors sought to analyse the causal impact of the adoption of organic or organic and fair trade certification on smallholder livelihoods and welfare. The study took place in a context where poor farm management, the depletion of soil fertility, natural calamity and outbreaks of diseases and pests coupled with increasing input costs led to a decline of the productivity of India's black pepper sector. The decline in productivity levels combined with the instabilities in the international prices make the revenues from black pepper highly volatile. As a response to these instabilities, black pepper producers in India massively shifted to organic production. For the purpose of this analysis a two years set of panel data collected from 300 farmers distributed in three categories equally represented (100 conventional farmers; 100 organic farmers; 100 organic farmers under fair trade) is used. Data collected from the first year covered the whole sample but during the second year of data collection 3 conventional farmers were excluded. To correct for unobserved heterogeneity between farmers in the adoption decision, two adoption models have been compared. The first model is a multinomial logit applied for both survey years separately and the second one is a panel adoption model which is supposed to capture unobserved heterogeneity in adoption decisions. To measure the differential gain in adoption between organic and organic and fair trade schemes, propensity score matching with multiple treatment effect has been applied. The results revealed that farm size and market distance are the major factors that influence organic black pepper adoption. Moreover it was established that certified organic black pepper farmers have a significantly higher income than the conventional one but participation in fair trade regimes does not generate additional monetary benefits. (Kleemann 2016) examined the adoption and impact of organic certification in the pineapple sector in Ghana by using a set of farm level data collected from 386 pineapple farmers from the central and eastern greater Accra regions of Ghana. In contrast to the previous studies which focused on the impact of organic certification on welfare measures such as household income, this study examine the impact of organic certification on the farm return on investment. For the author this indicator takes into account the fact that farmers operating as entrepreneurs do not concentrate only on improving farm income, but also consider the profitability of their investments. The investment mentioned here account for production costs and include direct and indirect certification costs. The study compared two different market-oriented certification schemes: the organic certification and the Global Gap certification which is an export-oriented conventional certification scheme. The main objective was to identify between both certification schemes the one offering better opportunities to Ghana pineapple farmers. To control for selectivity bias based on both observable and unobservable factors and to measure the differential impact of organic certification on both adopters of organic certification and Global Gap certification, endogenous switching regression framework has been employed in this study. The empirical results revealed that both certification schemes result in a positive return on investment. However, when comparing the individual effects of each certification scheme on farm return on investment, it appeared that organic certified farming yields a significantly higher return on investment compared to Global GAP certified farmers, mainly due to the price premium on the organic market.

Chapter III: Research methods

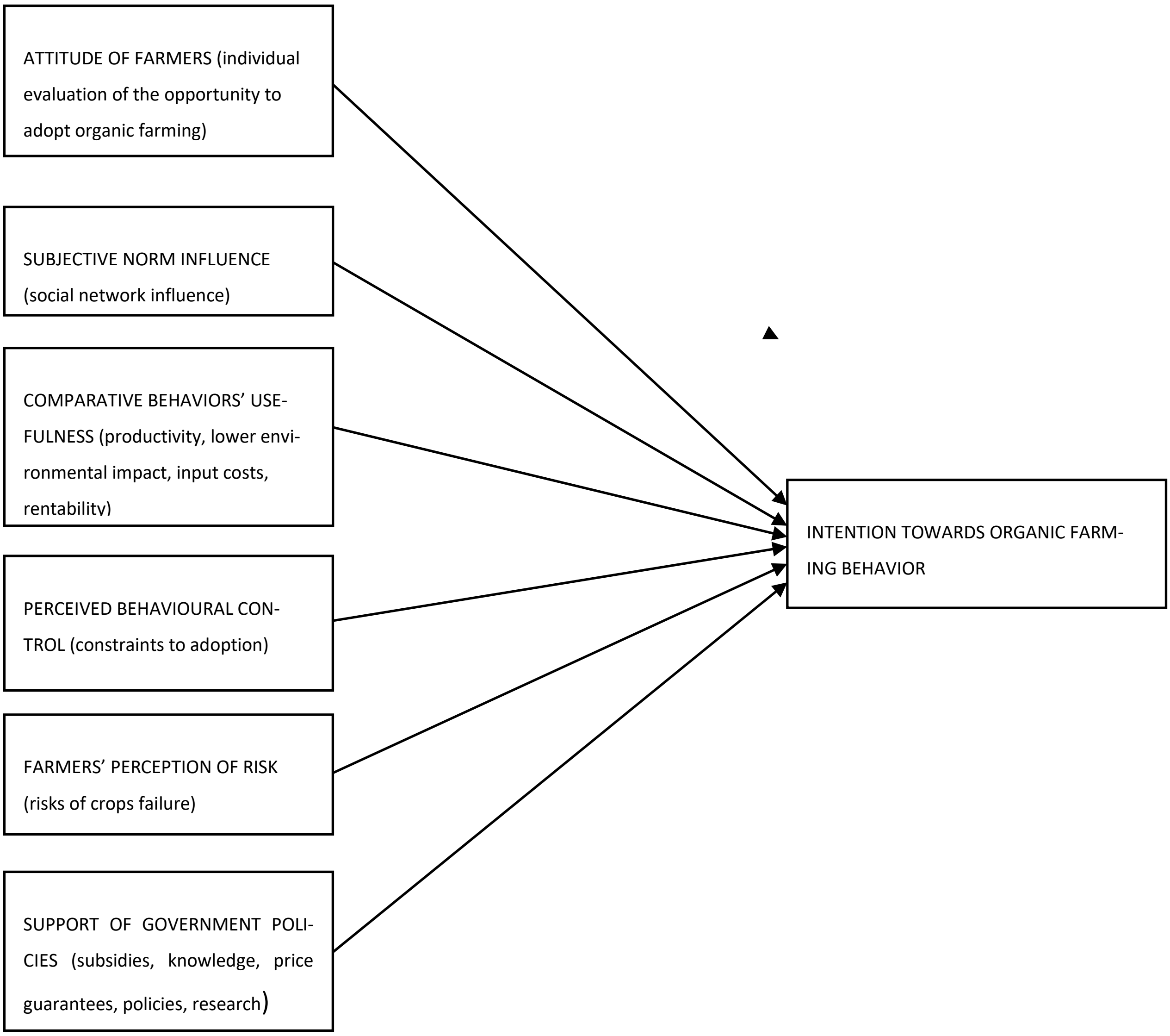
This chapter describe the general theoretical framework, the study area and sampling technics used for data collection and also the different methods applied for data analysis in order to confirm or invalidate hypotheses.

3.1 General theoretical and conceptual framework

The issue of the adoption and diffusion of organic farming practices still an attractive debate in the literature of sustainable agriculture and investigators are continuously looking for an appropriate conceptual framework to understand farmer's behaviour towards organic farming (Yanakittkul & Aungvaravong 2017). (Läpple & Kelley 2013), (Krueger et al. 2000) considered the theory of planned behaviour as the best theoretical framework to describe farmers' attitude towards organic farming. The authors argued that the adoption of organic farming practices require first a good planning. Therefore farmers should be aware of the potential constraints that might occur during the transition process and develop appropriate mitigation strategies to control for these constraints. These authors considered also that technical and social factors are determinant in the decision of farmers to engage in the organic production scheme. (Padel 2001) in contrast to (Läpple & Kelley 2013) and (Krueger et al. 2000) considered organic farming as a social innovation that took place after World War II in order to change the relationship between agriculture and the environment. So the main motives of the conversion to organic farming identified by (Padel 2001) are factors such as the connexion with the nature, the desire to develop another production system and to build an holistic approach of life. (Yanakittkul & Aungvaravong 2017) merged both the theory of planned behaviour and the theory of diffusion of innovations to develop a more complete conceptual framework analysing farmers' behaviour towards organic farming. This theoretical framework is built on six main factors. The three factors borrowed from the theory of planned behaviour are essentially the attitude of farmers towards organic farming, the subjective norm influence and the perceived behavioural control. Those extracted from the theory of diffusion of innovations are the relative usefulness of organic farming, farmer's perception of risk, and the support from government policies. As it is emphasised in the theory of planned behaviour (Ajzen 1991), the attitude of a farmer towards organic farming is related to his individual beliefs or his own evaluation of this farming system. If this attitude is positive then there will be a strong intention to adopt organic farming. The subjective norm influence which is the individual perception of the social pressure to perform or not a behaviour play also a crucial role in the decision to adopt organic farming. The social acceptance of organic farming as it is perceived by the farmer within his own community may have an influence on the farmer attitude towards organic farming. The third and last factor extracted from the theory of planned behaviour is the perceived behavioural control. Farmer's intention toward organic farming is then determined by the easiness or the complexity to implement the organic production technology. The relative usefulness of organic farming which is an element of the theory of diffusion of innovations (Rogers 1995); (Rogers 2003) is also identified by (Yanakittkul & Aungvaravong 2017) to be an important factor affecting farmers decision to adopt organic farming. The relative usefulness is related to the relative advantage of organic farming compared to alternative farming systems. This factor is part of the main attributes of an innovation (relative advantage, compatibility, complexity, triability, observability) described by (Rogers 1983) in the diffusion theory of innovations. Since any agricultural technology adoption include risks, farmer's perception of risk is also a key factor determining farmers' attitude towards organic farming (Yanakittkul & Aungvaravong 2017). Farmers are concerned of the risks of crop failure which might result from this new production technology. The sixth and last factor mentioned in the conceptual framework proposed by (Yanakittkul & Aungvaravong 2017) is the support from government policies. The support from government policies is an external motivation that could bring farmers to engage in organic production (Smit et al. 2009). Government support can take various forms such as providing knowledge on organic farming through research, providing equipment and price guarantees, building an institutional framework for the promotion of organic farming (Dang et al. 2014); (Blackstock et al. 2010).

Schematically the conceptual framework proposed by (Yanakittkul & Aungvaravong 2017) can be presented as in the figure 1 below:

Figure 1: Organic farming adoption conceptual framework



***Source**: Author adapted from (Yanakittkul & Aungvaravong 2017)*

3.2. Analysis of the adoption and impact of organic cotton farming practice

We model the adoption decision under the assumption that farmers choose between organic cotton farming and conventional cotton farming. We assume that farmers are risk neutral and take into account the expected utility derived from the technology in the decision making. The adoption decision is then captured as a binary choice based on the maximisation of a utility function. If we consider D_{1i}^* as the expected utility derived from the adoption of organic farming practices and D_{2i}^* the expected utility derived from the adoption of conventional practices, the choice of an individual farmer $i = (1, \ldots\ldots, N)$ of an observed population of size N will be revealed by the difference of expected utilities between both practices $D_i^* = D_{1i}^* - D_{2i}^*$. Although the actual level of utility derived from the adoption decision is not directly observed, the characteristics of the farmer and the attributes of the technology can be observed through data collection. The utility derived from the adoption decision can therefore be represented by a latent variable which is not directly observed but can be expressed as a function of observed characteristics and attributes in a latent variable model as follows:

$$D_i^* = Z_i^{'}\alpha + \varepsilon_i$$

$$D_i = 1 \; if \; D_i^* > 0$$

$$D_i = 0 \; if \; D_i^* \leq 0$$

The dummy variable $D_i(\{0,1\})$ represent the observed choice and take the value $D_i = 1$ when treatment is assigned (organic farming adopted) and $D_i = 0$ when conventional practice is adopted. Z is a vector of exogenous covariates that affect the level of utility. The error term ε with mean 0 and variance σ^2 captures unobserved factors and measurement errors. The probability of adoption can be expressed as $P(D_i = 1/Z_i) = P(D_{1i}^* > D_{2i}^*) = P(D_i^* > 0) = F(Z_i^{'}\alpha)$. Where F is the cumulative distribution function of ε. Various types of outcome variables have been used in the literature of the assessment of the impact of organic agriculture on farm household livelihoods. These variables include among other farm household income, family needs for food security (Udin 2014), farm profitability (Ndungu, et al. 2013), off-farm income, gross cash income (farm revenue), various components of production costs (Uematsu & Mishra 2012), social variables such as food security, health improvements, investments in children's education, improved standards of living, empowerment and capacity building through training and institution building (Altenbuchner et al. 2017), psychological concerns such as farmers' level of life satisfaction (Mzoughi 2014), farm return on investment (Kleemann 2016), poverty (Ayuya et al. 2015). Here, we are interested in analysing the determinants of the adoption of organic cotton farming and the impact of the adoption of organic cotton farming on farm household's return on cotton production and on farm household's non-cotton crops production value. The relationship between the adoption decision and the outcome variables can be expressed as: $Y_i = f(X_i, D_i)$ where X represents a vector of exogenous covariates affecting the outcome variables and D_i is the dummy variable related to the adoption decision. If Y_{D_i} is the outcome variable of an individual i as a function of the adoption status, Y_i can take two forms, Y_{1i} and Y_{2i}. Where Y_{1i} represents the outcome variable in case of adoption and Y_{2i} the outcome variable in case of non-adoption. As (Abdulai & Huffman 2014); (Musa et al. 2017); (Tesfaye & Tirivayi 2018); (Manda et al. 2016) argued, it is difficult to fully attribute the differences in outcome to the adoption of the technology when evaluating the impact of agricultural technologies. In a situation where experimental data are available through randomized control trials, information on the counterfactual is provided and the problem of causal inference can be solved (Uematsu & Mishra 2012). A major issue in impact assessment is the issue of selection bias. When treatment is non-random, untreated individuals may differ systematically from treated individuals because of individual self-selection into treatment. Estimating the impact of organic cotton farming on farm household's return on cotton production and on farm household's non-cotton crops production value by simply comparing the outcome variables for both groups of adopters and non-adopters presents a number of selection bias that have to be controlled for. Since the adoption of organic farming is not randomly distributed to the two groups of farmers (as adopters and non-adopters), farmers' specific characteristics may influence the assignment to the treatment and the outcome variable. The farmer itself decide to adopt organic farming given the information he received and the expected benefits. As (Uematsu & Mishra 2012) argued, certain farmers are more likely to voluntary choose to obtain organic certification than others. For instance if the education level of the farmer affect both the adoption decision and the outcome variable, the difference in income between both group of farmers (adopter of organic farming and non-adopter) may be due to the treatment status and also to the education level. Failing to control for this selection bias lead to biased estimates. The tools commonly used to control for selection bias in parametric methods are essentially the Heckman two step method and instrumental variables approach. The Heckman two step method is based on one regime of observations

(Dutoit 2007); (Becerril & Abdulai 2010). Instrumental variables approach are complex to implement due to the complexity of finding and identifying instruments in the estimation procedure (Becerril & Abdulai 2010). Moreover, both Heckman and instrumental variables methods are based on the linear specification of a single equation implying that the coefficient in the control variables of the outcome equation are similar for the treatment and the control group (Becerril & Abdulai 2010). This restrictive assumption may not hold since coefficient could differ (Jalan & Ravallion 2003) as it is emphasised in endogenous switching regression models (Lee 1982) where a specific outcome equation is specified for each group. Unlike parametric methods, the propensity score matching approach proposed by (Rosenbaum & Rubin 1983) is a non-parametric estimation technique that do not require the specification of a functional form and distributional assumptions. PSM constructs a statistical comparison group that is based on a model of the probability of participating in the treatment conditional on observed characteristics X, or the propensity score: $P(X) = P(D = 1 / X)$ (Rosenbaum & Rubin 1983). Estimating the treatment effect based on propensity score matching require however two assumptions: the conditional independence assumption and the common support assumption (Becerril & Abdulai 2010). The conditional independence assumption implies that the assignment to the treatment is independent of the potential outcome variables of both adopters and non-adopters if certain observable covariates are held constant (Imbens 2004). This assumption also implies that after the matching is done, any remaining difference of the outcome variable between adopters and non-adopters can be fully attributed to the treatment status (Imbens 2004). In the literature of impact evaluation, the conditional independence assumption is also termed as ignorability (Wooldridge 2001), selection on observables (Fitzgerald et al. 1997) and unconfoundedness (Imbens 2004); (Rosenbaum & Rubin 1983). The common support or overlap assumption aims to ensure that treatment observations have some comparable observations based on the propensity score distribution. The average treatment effect on the treated is only estimated within the region of common support (Heckman et al. 1997). PSM requires a large number of comparable participants and non-participants so that a region of common support can be found. The ATT is given by the following expression: $ATT = E\left[Y_1/D = 1\right] - E\left[Y_2/D = 1\right]$ where $E\left[\bullet\right]$ represents the expected value operator. The method is attractive as it allow to compare the observed outcomes variables of technology adopters with that of non-adopters (Heckman et al. 1998). Considering that the propensity score is computed, the ATT is estimated as follows:

$$ATT = E\{Y_{1i} - Y_{2i} / D = 1\},$$
$$ATT = E[\{Y_{1i} - Y_{2i} / D_i = 1, p(X)\}],$$
$$ATT = E[E\{Y_{1i} / D_i = 1, p(X)\} - E\{Y_{2i} / D_i = 0, p(X)\} / D = 1]$$

A number of matching technics have been proposed in the literature to match adopters to non-adopters. These technics include: the nearest neighbour matching estimator, the caliper matching estimator, the interval matching estimator, the kernel matching, the local log linear matching and the difference in difference matching estimators. But the most commonly used methods are the nearest neighbour matching estimator and the kernel based matching estimator (Becerril & Abdulai 2010). The nearest neighbour matching estimator proposed by (Abadie & Imbens 2002) is flexible in a way that it allow the user to specify the number of matches to use for each treated individual. The basic idea is to match each treated observation with the observation in the control group with the closest distance. But the choice of the appropriate number of matches impose a trade-off. When the chosen number of matches is small, any unmatched observation in the treated group will not be used to estimate the average treatment effect. In contrast when the number of matches is larger, more observations can be utilized in the estimation of the treatment effect but the quality of the matching may be compromised. The nearest neighbour matching estimator is usually applied with replacement in the control group. Once the matching is established, the difference of each pair of match is computed and the overall impact is obtained as the average of these differences. The kernel matching approach use a weighted average of all nonparticipants to construct the counterfactual match for each participant. All treated individuals are matched with a weighted average of all controls using weights that are inversely proportional to the difference of propensity score between participants and non-participants. Though PSM tries to compare the outcome variable of adopters and non-adopters based on observable characteristics, it fails to control for unobservable bias. Selection bias may also occurs if unobservable factors affect both the adoption decision and the outcome variables. Such unobservable factors include for instance innate managerial and technical abilities of the farmers, risk aversion, trust, discrimination by firms or NGOs, or the types of social networks formed by the farmers as it is indicated in (Barrett et al. 2012); (Abdulai & Huffman 2014). (Abdulai & Huffman 2014) argued that one of the limits of the PSM method is the unconfoundedness assumption which implies that once the observable characteristics are controlled for, the technology adoption decision can be considered to be uncorrelated to the outcome variables. For (Smith & Todd 2005) systematic differences between the outcome variables of adopters and non-adopters will be observed even after conditioning on observable characteristics because the selection is also influenced by unobservable characteristics. Since unobservable characteristics may affect both the selection model and the outcomes equations, a possible correlation between the errors terms of both the selection model and the outcome equations has to be considered. Failing to control for these unobservable characteristics may yield biased estimates (Abdulai & Huffman 2014). In addition the selection equation estimated in the case of the PSM approach cannot be considered to analyse the determinants of adoption since the objective of PSM is to balance the observed distribution of covariates across the group of adopters and non-adopters (Abdulai & Huffman 2014). Regarding the interest of this study which focus on the adoption and the impact of the adoption of organic cotton farming practices on both adopters and non-adopters, we are using Endogenous Switching Regression (ESR) technics to estimate the ATT and the ATU in order to correct for selection bias arising from both observable and unobservable characteristics. Developed by (Lee 1982), the ESR framework is a generalisation of the (Heckman 1979) selection correction approach. In contrast to the (Heckman 1979) approach, the outcome variables are observed for the whole sample including adopters and non-adopters. Thus the switching regression approach use two different equations to represent both regimes of adoption (conventional as well as organic farming). The adoption decision is estimated by a probit model and the outcome equations are expressed differently for each regime conditionally to the adoption decision. Number of recent studies (Fuglie & Bosch 1995); (Feleke et al. 2016); (Wossen et al. 2017) ; (Khonje et al. 2015) ; (Coulibaly et al. 2017); (Parvathi & Waibel 2015) ; (Manda et al. 2016) ; (Abdulai & Huffman 2014); (Ma & Abdulai 2016); (Kassie et al. 2015); (Lapple et al. 2013); (Musa et al. 2017); (Tesfaye & Tirivayi 2018); (Meda 2016) have used an endogenous switching regression model to analyse the impact of technology adoption in agriculture. The outcome equations conditionally to organic farming adoption can be expressed as:

Regime 1: $Y_{1i} = x_{1i}\beta_1 + w_{1i} \quad if \;\; D = 1$

Regime 2: $Y_{2i} = x_{2i}\beta_2 + w_{2i} \quad if \;\; D = 0$

Where x_{1i} and x_{2i} represent the vectors of exogenous covariates affecting the outcome variables; β_1 and β_2 are vectors of parameters, w_{1i} and w_{2i} are random disturbance terms associated to each regime of selection. Self-selection into the adopters or non-adopters groups cause the error terms of the selection model and the outcome equations to have a nonzero covariance.

The errors terms in the outcome equations and the selection model are assumed to have a tri-variate normal distribution with mean zero and covariance matrix:

$$\Omega = \mathrm{cov}(\varepsilon, w_1, w_2) = \begin{pmatrix} \sigma^2 & \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} \\ \sigma_{1\varepsilon} & \sigma_1^2 & \sigma_{12} \\ \sigma_{2\varepsilon} & \sigma_{21} & \sigma_2^2 \end{pmatrix}$$

Since Y_{1i} and Y_{2i} are not simultaneously observed, σ_{12} and σ_{21} cannot be defined. So the co-variance of the errors terms in the outcome equations can be rewritten as:

$$\Omega = \mathrm{cov}(\varepsilon, w_1, w_2) = \begin{pmatrix} \sigma^2 & \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} \\ \sigma_{1\varepsilon} & \sigma_1^2 & . \\ \sigma_{2\varepsilon} & . & \sigma_2^2 \end{pmatrix}$$

. Where $\sigma_{12} = \sigma_{21} = \mathrm{cov}(w_1, w_2)$ is replaced by dots because not observed; $\sigma^2 = \mathrm{var}(\varepsilon)$; $\sigma_{\varepsilon 1} = \sigma_{1\varepsilon} = \mathrm{cov}(\varepsilon, w_1)$; $\sigma_{2\varepsilon} = \sigma_{\varepsilon 2} = \mathrm{cov}(\varepsilon, w_2)$.

The error structure implies that the errors terms of the selection equation is correlated with the errors terms of the outcome functions w_j, $j = 1; 2$. As a result of that, the expected values of the errors terms in the outcome equations conditional on sample selection criterion are non-zero. An ordinary least square estimation of the parameters of the outcome equations may suffer from sample selection bias since $E(w_j / \varepsilon_i) \neq 0;\ j = 1; 2$ (Lee 1983), (Lapple et al. 2013). As it is defined in (Abdulai & Huffman 2014), the expected values of the truncated errors terms conditionally on sample selection are:

$$E(w_1/D=1) = E(w_1/\varepsilon > -Z'\alpha) = \sigma_{1\varepsilon}\frac{\phi(Z'\alpha)}{\Phi(Z'\alpha)} = \sigma_{1\varepsilon}\lambda_1$$

$$E(w_2/D=0) = E(w_2/\varepsilon < -Z'\alpha) = \sigma_{2\varepsilon}\frac{-\phi(Z'\alpha)}{1-\Phi(Z'\alpha)} = \sigma_{2\varepsilon}\lambda_2$$

Where ϕ is the standard normal density function, Φ is the standard normal cumulative density function. $\lambda_1 = \frac{\phi(Z'\alpha)}{\Phi(Z'\alpha)}$ and $\lambda_2 = -\frac{\phi(Z'\alpha)}{1-\Phi(Z'\alpha)}$ are the inverse mills ratio derived from the selection equation and to be included in the outcome equations to correct for sample selection bias. The two step estimation procedure consists first to determine the probability of adoption through a probit regression and obtained an estimate of the parameter α. Afterwards these estimates are used to compute the selectivity terms $\lambda_1 = \frac{\phi(Z^{'}\alpha)}{\Phi(Z^{'}\alpha)}$ and $\lambda_2 = -\frac{\phi(Z^{'}\alpha)}{1-\Phi(Z^{'}\alpha)}$.

(Lokshin & Sajaia 2004) however argued that the two step procedure may result in heteroscedastic residuals that cannot be used to obtain consistent standards errors without adjustments. As it is emphasized in (Di Falco et al. 2011), estimating simultaneously the adoption model and the outcome equations by the full information maximum likelihood (FIML) estimation procedure allow to account for the endogeniety of the adoption decision. Since the structure of the model is recursive, a good identification of the model impose that at least one variable in the selection equation does not appear in the outcome equations (Abdulai & Huffman 2014); (Fuglie & Bosch 1995). More specifically the identification of the model requires the inclusion of selection instruments that affect the decision to adopt but not the outcome variable (Lapple et al. 2013); (Di Falco et al. 2011). (Dutoit 2007) explicitly highlights this condition by considering that the endogeneity come from the inclusion of Y_{1i} and Y_{2i} in the regressors of the latent variable equation $D_i^* = Z_i^{'}\alpha + \varepsilon_i$ [8]. In the case of the presence of additional selection instruments, the selection equation is estimated based on all exogenous covariates specified in the outcome equations plus instruments. But if there are not additional selection instruments in the model, the model is only identified through non-linearities and the selection equation

[8] Recall that the baseline model is as follows:

$$Y_{1i} = x_{1i}\beta_1 + w_{1i}$$
$$Y_{2i} = x_{2i}\beta_1 + w_{2i}$$
$$D_i^* = Z_i^{'}\alpha + \varepsilon_i$$
$$Y_i = \begin{cases} Y_{1i} \ if \ D_i^* > 0 \\ Y_{2i} \ if \ D_i^* < 0 \end{cases}$$

$\sigma_{1\varepsilon} = \text{cov}(w_1, \varepsilon) \neq 0; \sigma_{2\varepsilon} = \text{cov}(w_2, \varepsilon) \neq 0$. These additional assumptions on the errors terms implies that the outcome equations cannot be independent from the selection equation since the switch is endogenous. By including Y_{1i} and Y_{2i} in the expression $D_i^* = Z_i^{'}\alpha + \varepsilon_i$, we have $D_i^* = Z_i^{'}\alpha + \gamma_1 Y_{1i} + \gamma_2 Y_{2i} + \eta_i$ where γ_1 and γ_2 are parameters and η_i a compound error term. By this last equation we can clearly observe that the occupational choice depends on the value (outcome) of being in either regime and on other factors Z_i. By substituting the equations of the outcome variables into the occupational choice equation we can rewrite: $D_i^* = Z_i^{'}\alpha + x_{1i}\gamma_1\beta_1 + x_{2i}\gamma_2\beta_2 + \eta_i$. Finally the matrix of covariates in the selection equation is expressed as: $W_i = [X_{1i}; X_{2i}; Z_i]$. So the selection equation contains all the regressors of the outcome equations plus additional selection instruments Z_i.

will contain the same exogenous covariates that enter in the outcome equations (Lokshin & Sajaia 2004). Variables related to information sources are likely to affect the adoption decision as it is emphasised in the diffusion theory of innovations (Rogers 2003) and the theory of planned behaviour (Ajzen 1991) but not the outcome variable. As in (Di Falco et al. 2011), we used as selection instrument a variable related to information sources such as the information on cotton farming got through radio emissions. A simple falsification test will be used to confirm the validity of the instrument. A variable is considered to be a valid instrument if this variable affect the adoption decision but is not affecting the outcome variable of those who did not adopted (Di Falco et al. 2011). The average treatment effects of the adoption of organic cotton farming on the treated and on the untreated are estimated by comparing the expected values of the outcome variables in the actual and counterfactual basis. As in (Shiferaw et al. 2014), the estimates from the ESR model of the expected values of outcome variables in the real and counterfactual scenarios are defined below:

Adopters with adoption (observed in the sample)

$$E(Y_{1i}/D=1,x)=x_{1i}\beta_1+\sigma_{\varepsilon 1}\lambda_{1i} \text{ (a)}$$

Non-adopters without adoption (observed in the sample)

$$E(Y_{2i}/D=0,x)=x_{2i}\beta_2+\sigma_{\varepsilon 2}\lambda_{2i} \text{ (b)}$$

Adopters without adoption (counterfactual basis)

$$E(Y_{2i}/D=1,x)=x_{1i}\beta_2+\sigma_{\varepsilon 2}\lambda_{1i} \text{ (c)}$$

Non-adopters with adoption (counterfactual basis)

$$E(Y_{1i}/D=0,x)=x_{2i}\beta_1+\sigma_{\varepsilon 1}\lambda_{2i} \text{ (d)}$$

The average treatment effect on the treated is computed as the difference between equations (a) and (c):

$$\begin{aligned} ATT &= E(Y_{1i}/D=1,x)-E(Y_{2i}/D=1,x) \\ &= x_{1i}(\beta_1-\beta_2)+\lambda_{1i}(\sigma_{\varepsilon 1}-\sigma_{\varepsilon 2}) \end{aligned}$$

Since λ_1 is included in both equations (a) and (c), unobservable factors are account for. Thus considering the difference in effects $\sigma_{\varepsilon 1} - \sigma_{\varepsilon 2}$ by maintaining λ_1 constant allow to cancel out the effects of unobservable factors (Abdulai & Huffman 2014).

The average treatment on the untreated is given by the difference between equations (d) and (b):

$$\begin{aligned} ATU &= E(Y_{1i}/D=0,x) - E(Y_{2i}/D=0,x) \\ &= x_{2i}(\beta_1 - \beta_2) + \lambda_{2i}(\sigma_{\varepsilon 1} - \sigma_{\varepsilon 2}) \end{aligned}$$

The first term on the right hand side of the ATT equation represents the expected change in adopter's mean outcome if adopters had similar characteristics as non-adopters. The second term represents the selection term that aim to capture all the potential effects of the difference in unobserved variables. Similarly the first term in the ATU equation can be considered as the expected change in the non-adopters mean outcome if non-adopters had similar characteristics as adopters. The second term adjusts the ATU for the effect of unobservable factors (Shiferaw et al. 2014). The signs of the covariance terms $\sigma_{\varepsilon 1}$ and $\sigma_{\varepsilon 2}$ have also an economic interpretation (Fuglie & Bosch 1995); (Lapple et al. 2013). If the covariance terms have alternate signs, there is a positive selection for both groups (Lapple et al. 2013). So individuals decide to adopt or not to adopt organic cotton production based on expected returns from membership (Lapple et al. 2013). Those who adopt have above average return from adoption and those who chose not to adopt have above average returns from non-adoption (Fuglie & Bosch 1995). In contrast if the covariance terms have the same sign, this implies a positive selection into the group of adopters and a negative selection into the group of non-adopters (Lapple et al. 2013). (Fuglie & Bosch 1995) qualified this effect as a hierarchal sorting. Adopters have above average returns whether they adopt or not but they are better off adopting than not adopting. Non-adopters have below average returns in both cases but there are better off not adopting. ATT and ATU parameters give the expected outcome effects of organic cotton production on a randomly chosen household from the groups of adopters or non-adopters respectively. ATT and ATU are policy relevant treatment effects (Carter & Milon 2005). However policy relevant treatment effects should be distinguished from heterogeneity effects (Carter & Milon 2005). In fact due to the possible existence of endogenous determinants of adoption that may be unobservable (skills, motivation), farm household that adopt may gain more revenue than farm household that did not adopt regardless of the fact that they decided to adopt.

According to (Carter & Milon 2005), this base heterogeneity effect (BH) can be defined for two states of nature BH_1 and BH_2.

$$BH_1 = E(Y_{1i}/P=1, x) - E(Y_{1i}/P=0, x) = (x_{1i} - x_{2i})\beta_1 + \sigma_{\varepsilon 1}(\lambda_{1i} - \lambda_{2i})$$
$$BH_2 = E(Y_{2i}/P=1, x) - E(Y_{2i}/P=0, x) = (x_{1i} - x_{2i})\beta_{i2} + \sigma_{\varepsilon 2}(\lambda_{1i} - \lambda_{2i})$$

Where BH_1 and BH_2 are the differences in outcome between the adopters and non-adopters groups respectively. (Carter & Milon 2005); (Di Falco et al. 2011) also investigate the transitional heterogeneity TH that is whether the effect of adopting organic cotton production is larger or smaller for farm households that actually adopted or for farm households that actually did not adopt in the counterfactual case that they did. The transitional heterogeneity is the difference between ATT and ATU (Carter & Milon 2005).

$$TH = ATT - ATU$$

In summary, the conditional expectations, treatment and heterogeneity effects can be recapitulated in the table 2 below as follows:

Table 2 : Conditional expectations, treatment and heterogeneity effects

	Decision Stage		**Treatment effects**
Subsamples	**To adopt**	**Not to adopt**	
Farm household that adopted	$E(Y_{1i}/D=1, x)$	$E(Y_{2i}/D=1, x)$	ATT
Farm household that did not adopted	$E(Y_{1i}/D=0, x)$	$E(Y_{2i}/D=0, x)$	ATU
Heterogeneity effects	BH_1	BH_2	TH

Source: Author

In the empirical literature, a wide range of explanatory variables like household characteristics, socioeconomic and physical factors are considered to influence organic farmers' adoption decisions. These factors include farmers' age (Tiffin & Balcombe 2011), (Kassie et al. 2009); (Genius et al, 2006), (Kassie et al. 2009), (Burton et al. 1999), gender (Tovignan & Nuppenau 2004); (Burton et al. 1999), the level of education (Tovignan & Nuppenau 2004), (Genius et al. 2006), (Kassie et al. 2009), farmer's experience in farming (Tovignan & Nuppenau 2004), (Genius et al. 2006), (Kassie et al. 2009), (Mzoughi 2011), the household size (Wollni & Andersson 2014); (Sarker et al. 2005), the availability of family labour, the access to irrigation, soils characteristics (fertility, erosion), farm assets (machinery, animals), access to credit, membership of producers organization (Burton et al. 1999), off farm work, farm yield, farmers belief about organic farming potential to meet the needs of the society (Tiffin & Balcombe 2011), environmental regulations, subsidies, (Lohr & Salomonsson

2000); (Flaten et al. 2010), organic farming marketing opportunities (Khaledi et al. 2010), the costs of conversion to organic farming etc. The empirical literature also emphasized how farmers' social network influence their decision to adopt organic farming. In addition to the usual variables influencing agricultural technology adoption cited in the literature, we introduced a set of variables capturing individuals' specific networks influencing they decision to adopt organic cotton farming. Since social network effects are essentially informational, variables like **farmer to farmer extension, radio information, neighbourhood information and the number of relatives producing the same type of cotton** are introduced to capture the effects of farm household's social network on his decision to adopt organic cotton production. The variables to be introduced in the ESR model and the expected signs are summarised in the table 3 below:

Table 3: List of variables in adoption and impact analysis

Outcome variables		
cr_ha	*return on cotton production per hectare*	
ncr_ha	*Non-cotton crops production value per ha of cotton farm size*	
Selection equation dependant variable		
cotton_type	*Dummy (1 if organic cotton, 0 if conventional cotton)*	
Selection model control variables		***Expected sign***
age	*Age of household head (measured in years)*	+/-
educ	*Formal education of household head (years)*	+
hhsize	*Household size (number of household members)*	+
offfarm_work	*Off farm work (dummy: 1 if household head have an off farm job, 0 otherwise)*	-
educ_child	*Number of children going to school in the household*	-
gender	*Gender of household head*	+
exp_cotton	*Experience of household head in cotton production in general (years)*	+/-
rotation	*Rotation (dummy: 1 if rotation, 0 otherwise)*	+
dist_house	*Distance from household to cotton farm*	-
safe_equip	*Equipments for safety (dummy: 1 if available, 0 otherwise)*	+
soil_fetility	*Soil fertility status (dummy: 1 if soil is declared to be fertile, 0 otherwise)*	+
relatives_numb	*Number of relatives producing the same type of cotton*	+
Neighbour_inf	*Neighbourhood information on cotton farming (dummy: 1 if farmer got information from the neighbourhood on cotton farming, 0 otherwise)*	+
farmer_ext	*Farmer to farmer extension (dummy: 1 if farmer got practical advises from other farmers, 0 otherwise)*	+
radio_inf	*Radio information on cotton farming (dummy: 1 if farmer got information on cotton farming from the radio, 0 otherwise)*	+

Source: *Author*

The sign of the parameter associated to the variable age of the head of household is not predetermined in the selection equation because the descriptive statistics show that the difference of age between organic cotton farmers and conventional farmers is not statistically significant. The formal education of the head of household is expected to have a positive effect on the adoption decision since organic farming can be considered as a new technology which is supposed to be more easily understood and adopted by educated farmers. The household size is expected to have a positive effect on the organic cotton farming adoption decision since organic farming is presented as a labor intensive technology. So farmers with large household size are more likely to self-select into organic cotton farming. By the same way farmers who have an off farm business may be reluctant to grow organic cotton because of the labor requirement of the organic production technology. The number of children going to school in the household can be perceived in the context of rural areas in Africa as a reduction of the available family labor force and discourage farmers to adopt labor intensive technologies like organic farming. Farmers' experience in cotton farming is also supposed to guide them to appreciate the advantages and disadvantages associated to this farming activity. The knowledge gained by farmers over time may help them to evaluate the informations that are likely to influence their adoption decisions. For instance cotton farmers who have several years of experience in conventional cotton production can be reluctant to adopt organic cotton production due to the kind of networks they have already created in the conventional cotton sector. Farmers with more experience in conventionnal cotton farming can also be more likely to self-select into organic cotton farming because of their perception of the environmental adverse effects of conventional farming methods. Because of this ambiguous situation we cannot predetermined the sign of influence of the variable experience in the adoption decision. Rotation is an exigency of the organic cotton farming technology. Those farmers who are already using rotation as a land management practice are more likely to adopt organic farming methods. The distance from the household to cotton field is not in favor of the adoption of organic cotton farming since the transportation of the organic manure or compost on the cotton field could be costly to the farmer. Having fertile soils favor the adoption of organic farming practices due to the restriction on inputs use which impose organic farms to have fertile soils. Social network variables such as information obtained from the radio or from the neighborhood on cotton farming, farmer to farmer extension and also the number of relatives practicing cotton farming are all supposed to have positive effect on the adoption of organic cotton farming. Aside of the variable radio information which is used here as a selection instrument, the rest of the variables in the selection equation are also supposed to affect the outcome variables which are: the return on cotton production per hectare of cotton crops produced and the value of non-cotton crops produced per hectare of cotton crops produced.

3.3. Analysis of the technical efficiency of organic cotton production

Efficiency refers to the ability of a decision making unit to minimize waste. The minimisation of waste comes through the minimization of the quantity of inputs used to produce a given level of output or the maximisation of the output given the quantity of inputs available (Coelli et al. 2005). Economic efficiency consist of two types of efficiency levels: the technical and the allocative efficiencies. The technical efficiency is the ability of a decision making unit to maximise the output produced given the quantity of inputs used or to produce a given level of output using the minimum feasible amount of inputs (Watkins et al. 2014). (Koopmans 1951) argued that a decision making unit is qualified as efficient if and only if it is impossible to produce more of any output without reducing the quantity produced of other outputs or using more of inputs. (Fraser & Cordina 1999) define technical efficiency as the measure of farm success to produce the maximum level of output from a given set of inputs. The technical inefficiency of a given firm is defined to be the factor by which the level of production for the firm is less than its frontier output. While in technical efficiency, the goal is to maximize the output given the set of inputs used, in allocative efficiency the goal is to allocate resources in order to maximize profit given input prices. Allocative efficiency refers to the producer ability to allocate inputs in an optimal way in light with the prevailing prices of outputs and inputs. Allocative inefficiency is perceived when the inputs mix is not consistent with cost minimization. Combining technical and allocative efficiency lead to economic efficiency (Coelli et al. 2005). (Abdulai & Tietje 2007) argued that a firm that failed to be efficient is wasting inputs and thus loose the possibility to reduce costs. Parametric and non-parametric approaches have been widely applied in the field of efficiency analysis. The choice of the wright approach to use still unclear as some studies on efficiency measurement argued that there is no significant difference between the estimates of efficiency obtained through both parametric and non-parametric approaches (Thiam et al. 2001). The DEA technique initiated by (Charnes et al. 1979) following (Farrell 1957) work on individual firm evaluation is the main non-parametric approach of efficiency analysis. Efficiency is defined here as the difference between the observed input-output combinations and the best practice frontier. DEA does not require the specification of a functional form or assumptions on the efficiency term (Mugera & Langemeier 2011). Given that DEA is deterministic, this method is likely to be sensitive to measurements errors because it fully attributes all the deviations from the frontier to inefficiencies. In contrast to non-parametric approaches, parametric approaches are based on the specification and estimation of a stochastic production function representing the best available technology (Chavas et al. 2005). The most widely used parametric approach is the stochastic frontier approach of efficiency analysis. This approach provide a convenient framework for hypotheses testing. The main weaknesses associated to parametric approaches is the assumption of an explicit functional form for the production technology and the model of the distribution of the inefficiency terms (Hjalmarsson et al. 1996). Both methods have in common the concept of frontier. Efficient production units are considered to be those that operate on the production frontier while inefficient production units are those operating below the production frontier. The level of inefficiency depends on the deviation from the frontier of production. The majority of the applications of frontier methodology in efficiency analysis are generally based on one specific method to estimate the production function and the technical efficiency of production.

In this study we are using a stochastic frontier approach to estimate the technical efficiency of organic cotton producers. Stochastic frontier approach is used for its ability to give a clear distinction of inefficiency from deviations that can be attributed to factors beyond the control of farmers (factors like climatic hazards, luck, plant pathology and insect that may cause variability of production). The potential of farmers to achieve technical efficiency can be influenced by factors that are not under their control (Ogunniyi 2008). Thus the assumption in DEA approach that all the deviations from the frontier is attributed to inefficiencies seems to be difficult to accept (Battese & Coelli 1995); (Kirkley et al. 1995). The stochastic frontier model proposed by (Aigner et al. 1977); (Meeussen & Van Den Broeck 1977) is expressed as $Y_i = f(X_{i,}\beta) + \varepsilon_i$ where Y_i represents the output of the farm i; X_i is a vector of inputs used by the farm i ; β is a vector of parameters to be estimated and ε_i is a composite error term defined as: $\varepsilon_i = v_i - u_i$. The v_i component of the composite error is a zero-mean random error. The v_i s are assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ random variables. The u_i component is assumed to be distributed independently of v_i and to satisfy the condition $u_i \geq 0$. (Aigner et al. 1977) argued that this specification implies that the production process is subject to two different random disturbances. Since the random disturbance u_i is strictly non-negative, the farm output lies on or below its stochastic frontier $Y_i \leq f(X_i, \beta) + v_i$.

Any deviation from the frontier caused by the random disturbance u_i is the result of factors under the farmer control. The technical and management capabilities of the producer are essential to reduce inefficiencies. The frontier itself can vary randomly across firms or within the same firm over time due to the random disturbance v_i which can be positive or negative regarding the sign of the effect of the external factors affecting the farm performance. External factors such as climatic hazards, luck, plant pathology and insect which are not under the farmer control can be favourable or unfavourable to the production process. Errors of observations on the output are also included in the random disturbance v_i. (Battese 1992) considers that inferences about the parameters of the model can be done based on the maximum likelihood estimator. (Aigner et al. 1977) proposed the parameterisation $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u / \sigma_v$. γ is the ratio of the standard deviation of the non-positive random disturbance u to the standard deviation of the symmetric error v. (Aigner et al. 1977) considers this parameterisation to be convenient as it is an indicator of the relative variability of both sources of random disturbances that distinguish farms from one to another. $\gamma^2 \to 0$ implies $\sigma_v^2 \to \infty$ and/or $\sigma_u^2 \to 0$. In this particular case the symmetric random disturbance v dominate in the determination of ε. Similarly $\sigma_v^2 \to 0$ implies that the one side error component u becomes the main source of random disturbance in the model. (Battese & Corra 1977) proposed the parameterisation $\lambda = \sigma_u^2 / \sigma^2$ which is bounded between zero and one. The value of the coefficient λ indicates the presence or not of inefficiencies. If the value of λ is significantly different from zero based on a one-sided likelihood-ratio test, this provide evidence that inefficiency effects are present in the model and frontier estimation of the production function is more appropriate than ordinary least squares (OLS) estimation. (Bravo-Ureta & Rieger 1990) and (Bravo-Ureta & Evenson 1994) proposed a model which allow the measurement of both technical and allocative efficiencies using the decomposition technique introduced by (Kopp & Diewert 1982). Cost minimizing inputs demand functions are derived through the shephard lemma to obtain estimates of allocative efficiencies. This approach requires the stochastic frontier production function to be self-dual in order to have an analytically solution for the dual cost function.

We adopt a Cobb Douglas functional form as in (Sharma et al. 1999); (Chakraborty et al. 2002). (Ahmed et al. 2014) argued that a Cobb–Douglas production function can be preferable compared to a translog specification regarding the collinearity and loss of degrees of freedom that may happened in the translog function due to the multitude of interactions terms. The Cobb Douglas functional form has been widely used in farm efficiency studies for both developed and developing countries (Bravo-Ureta & Evenson 1994); (Kopp & Smith 1980). (Ahmad & Bravo-Ureta 1996) also indicated that efficiency measures are not significantly affected by the choice of the functional form. The Cobb Douglas stochastic frontier production function of the ith farm can be expressed as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{m} \beta_j \ln X_{ji} + v_i - u_i$$

Where Y is the actual level of output; X a vector of exogenous inputs; β a vector of parameters to be estimated.

The log of the maximum possible level of output $\left(Y^*\right)$ using the Cobb-Douglas specification is then: $\ln Y_i^* = \beta_0 + \sum_{j=1}^{m} \beta_j \ln X_{ji} + v_i$. So $\ln Y_i$ the log of the actual level of output $\left(Y\right)$ can be rewritten as: $\ln Y_i = \ln Y_i^* - \mu_i$

$$\ln Y_i = \ln Y_i^* - \mu_i \Rightarrow \mu_i = \ln Y_i^* - \ln Y_i$$

μ_i is the log difference between the maximum level of output and the actual level of output. μ_i represent the technical inefficiency effect of the production process and $\mu_i * 100$ denotes the percentage by which the actual level of output can be increased using the same inputs if production is fully efficient. In other words $\mu_i * 100$ gives the percentage of output lost as the consequence of technical inefficiency.

By rearranging the expression $\mu_i = \ln Y_i^* - \ln Y_i$ we obtain $\exp(-\mu_i) = \frac{Y_i}{Y_i^*}$ which is the ratio of the observed actual level of output to the maximum level of output obtained when production is fully efficient. $\exp(-\mu_i)$ vary between 0 and 1 and represent the measure of the output oriented technical efficiency. The value $\exp(-\mu_i) * 100$ is the percentage of the maximum level of output produced by the decision making unit.

The inputs are categorized into four groups: land, labour, seeds and batik. These inputs are considered to be the major inputs used in organic cotton production. Land is measured in hectares while labour is evaluated in man-day. Cotton seeds are measured in terms of the number of bags of seeds of 30 kg used on the farm and batik is related to the use of the batik which is an organic insecticide. The use of the batik is measured in terms of the number of sachets of

12 g applied on the farm. The variables assumed to influence organic cotton farms efficiencies are: the formal education of the producer in years, the experience in cotton production evaluated in years, the distance between the producer house and his farm, his household size (number of members), the organic cotton farm size, the soil fertility status and the off farm work status of the farmer. The list of the variables and the expected signs are given in the table 4 below:

Table 4: List of variables in technical efficiency analysis

variable	Description	Expected sign
Cotton output	Kg	
Input variables for Coob Douglas frontier production function		
Land	ha	+
Labour	Man-day	+
Seed	Bags of 30 kg	+
batik	Sachet of 12 g	+
Exogenous determinants of technical inefficiency		
farm_size	Total area of farm measured in hectares	+
educ	Formal education of the head of household measured in years	-
exp_cotton	Experience in cotton production in general (years)	-
dist_house	Distance between household and farm (km)	+
hhsize	Household size (number of household members)	-
soil_fetility	Dummy variable capturing soil fertility status (1=fertile, 0=not fertile)	-
offfarm_work	Off farm work (1 = yes, 0 = no)	+

Source: *Author*

As in standard production theory, a higher endowments in inputs is supposed to increase the quantity of cotton production. Then a higher endowment in land, labour, seed and batik is expected to have a positive impact on the level of production. Efficiency enhancing factors are factors that have a negative impact on the inefficiency term. So factors like the formal education of the farmers, the experience in cotton production, the household size and soil fertility are considered to be efficiency enhancing factors in organic cotton production. Educated farmers are generally assumed to be more skilled and to be more likely to adopt new technologies compared to non-educated farmers. Education can improve farmer management skills and limit inefficiencies in the process of production. As organic farming is hardly grown in an extensive way due to the restrictions in inputs use and the requirements of the organic technology in terms of farm management practices, we expect large farm to be less efficient than those with small size. A small farm can be easily managed in a way to use available inputs efficiently and fulfil the requirements of the technology. The farm size is then expected to be positively associated with the level of inefficiency. Household size is considered to be an efficiency enhancing factor given that labour in the study area is essentially characterised by family labour and mutual aid labour. Farmers with large household size are better endowed in labour force and are more likely to be efficient than those with small household size. The experience in organic cotton production as in any other agricultural production technology play a significant role in the capacity of farmers to improve labour productivity. More experienced farmers are supposed to be more efficient than new entrants. We also expect the distance between household and farm to have a negative impact on technical efficiency. Organic cotton production relies essentially on organic manure and compost for fertilisation. These inputs are generally made home and carry on the farm. A long distance separating household and farm can bring a farmer to loose motivation for organic cotton production and to fail to fulfil the requirements of the organic cotton production technology. Soil fertility is an efficiency enhancing factor since fertile farms are supposed to be more productive. Since organic farming is considered to be a labour intensive technology, farmers conducting off farm activities may not be able to allocate sufficient time to organic cotton production activities. So we expect the off farm work status of the farmer to be an efficiency reducing factor.

The estimation of parametric models of efficiency implies estimating first the parameters of the frontier production function afterwards estimating the inefficiency term. Various technics have been proposed in the empirical literature for the estimation of frontier production functions. (Kumbhakar & Wang 2014) made a review of the estimation technics in stochastic frontier analysis going from distributional free approaches to models with distributional assumptions on the inefficiency term. According to the authors distributional free approaches have the advantage to not impose a specific distributional assumption on the inefficiency term μ_i but are limited when it comes to draw the statistical properties of this error term. The authors added that the issue of the separability of the inefficiency term μ_i and the stochastic term v_i arises in cross sectional data when distributional free approaches are applied. The Corrected Ordinary Least Square (COLS) estimator proposed by (Winsten, 1957) is an illustration of distributional free approach used in efficiency analysis. This model is a deterministic frontier model since it excludes the stochastic disturbance v_i of the frontier function. The estimation procedure consist first to obtain consistent estimates of the slope coefficients of the model through OLS regression. Afterwards the OLS intercept of the estimated production function is adjusted by the amount of the maximum of the OLS residue to the extent that the frontier function obtained bounds all the observations. The estimated frontier function using COLS method and assuming a Coob Douglas production function can be written as: $\ln y_i = \hat{\beta}_0 + \max\left\{\hat{e}_i\right\} + x_i' \hat{\beta}$ where $\hat{\beta}$ is a consistent estimate of the slope coefficients of the production function, $\hat{\beta}_0$ an estimate of the intercept and $\hat{e}_i$ the estimate of the residue. The intercept of the production function is then adjusted by $\max\{e_i\}$ to obtain the deterministic frontier function. The inefficiency term which is theoretically the difference between the actual output $\ln y_i^* = \hat{\beta}_0 + x_i' \hat{\beta} + \hat{e}_i$ and the frontier output $\ln y_i = \hat{\beta}_0 + \max\left\{\hat{e}_i\right\} + x_i' \hat{\beta}$ is: $u_i \equiv -(\ln y_i^* - \ln y_i) \equiv -\left[(\hat{\beta}_0 + x_i' \hat{\beta} + \hat{e}_i) - \left(\hat{\beta}_0 + \max\left\{\hat{e}_i\right\} + x_i' \hat{\beta}\right)\right] \equiv -(\hat{e}_i - \max\left\{\hat{e}_i\right\})$. The Corrected Mean Absolute Deviation (CMAD) is also a distributional free approach following the same procedure as the COLS. While COLS is based on an OLS regression, the CMAD technic passes through median regression. CMAD is generally used as a robustness check for COLS. The thick frontier approach proposed by (Berger and Humphrey, 1991) is also known as a distributional free approach. The thick frontier approach is different from the COLS and the CMAD approach since decision making units are grouped into quartiles given the observed value of a chosen efficiency indicator. This indicator can be the observed output or the production costs. Decision making units located in the first quartile are supposed to be less efficient or to have a lower-than-average production efficiency. Those located in the last quartile are supposed to be the most efficient. Production functions are then estimated within each strata and the difference between both production functions evaluated at their mean values is interpreted as a result of market factors or inefficiency. A measure of the production inefficiency between the most and the least efficient groups is obtained after purging market factors influence. Unlike distributional free approaches, parametric assumptions on the composite error term $\varepsilon_i = v_i - u_i$ allow to distinguish clearly the stochastic component of the error term v_i from its deterministic component μ_i. The stochastic component of the error term is widely assumed to follow a zero-mean normal distribution in efficiency studies (Bravo-Ureta & Pinheiro 1997). For the deterministic component, numerous distributional assumptions have been proposed in the literature. (Aigner et al. 1977), (Meeussen & Van Den Broeck 1977) all assumed that the v_i component of the error term is distributed standard normal with mean 0 and variance σ_v^2. (Aigner et al. 1977) assumed that the u_i component of the error term is generated from a half-normal distribution (nonnegative truncation of a zero-mean normal distribution) while (Meeussen & Van Den Broeck 1977) assumed an exponential distribution with parameter σ_u as the distribution of the u_i component. Since models with distributional assumptions are estimated through the maximum likelihood procedure, the joint distribution of the two components of the composite error term $\varepsilon_i = v_i - u_i$ should have a closed form (Parmeter & Kumbhakar 2014). Not all the distributions provide a closed form for the joint distribution $f(\varepsilon)$ (Parmeter & Kumbhakar 2014). The normal-half normal (nonnegative truncation of a zero-mean normal distribution) or the normal-exponential distribution ensure the joint distribution $f(\varepsilon)$ to have a closed form and allow a direct application of the maximum likelihood estimator. Once the distributions of u_i and v_i are determined, the joint distribution is specified as $f(\varepsilon) = f(u) * f(v) = f(u) * f(\varepsilon + u)$ given the assumption of the independence of u_i and v_i. Aside of the half normal (nonnegative truncation of a zero-mean normal) distribution and the exponential distribution, other alternative specifications exist in the literature of stochastic frontier analysis. These alternatives include: the normal distribution $N(\mu, \sigma^2)$ truncated from above at a point α [9], the Gamma density, the Pearson density, the uniform distribution, the Beta distribution, and the doubly truncated normal distribution. In the specific case of this study, we are expecting to test several models based on the original model proposed by (Aigner et al. 1977). The normal-half normal (nonnegative truncation of a zero-mean normal distribution) distributional assumption of the composite error term $\varepsilon_i = v_i - u_i$ ensure a closed form of the joint distribution of u_i and v_i (Parmeter & Kumbhakar 2014). This distributional assumption has been widely used in efficiency studies (Chakraborty et al. 2002), (Lohr & Park 2017), (Madau 2007), (Salhofer & Sinabell 2006). Since we are expecting some exogenous variables (**formal education of the producer in years, experience in cotton production in years, distance between the producer house and his farm, household size, farm size, soil fertility status and off farm work**) to affect the expected

[9] Called the truncated normal distribution, this specification is a generalisation of the half normal distribution. A half normal distribution is derived from the truncated normal distribution if $\mu = 0$ and $\alpha = 0$

values of inefficiency, the original normal-half normal (nonnegative truncation of a zero-mean normal distribution) model of (Aigner et al. 1977) with homoscedasticity in u_i and v_i may not be appropriate. The assumption of the homoscedasticity in u_i and v_i implies that σ_v^2 and σ_u^2 are constant. (Kumbhakar & Lovell 2000); (Wang and Schmidt, 2002) argued that ignoring the heteroscedasticity of the errors terms in stochastic frontier models may lead to biased estimates[10]. In order to investigate the relationship between the level of inefficiency and the exogenous determinants that are likely to affect this inefficiency, the early literature propose the two step procedure (Reifschneider & Stevenson 1991), (Huang & Liu 1994), (Battese & Coelli 1995). The two step procedure consists to estimate the observation-specific inefficiency in a first step and then regress the inefficiency scores on a set of exogenous co-variates in a second step. The following relationship expresses a model of inefficiency scores in a two-step procedure:

$$\eta_i = \delta_0 + \sum_m \delta_m Z_m + \rho_i$$

Where η_i is a variable representing the observation-specific inefficiency measure of the farm i; δ a vector of unknown parameters; Z a vector of exogenous determinants of inefficiency; ρ_i an error term that is independently and normally distributed with mean zero and variance σ^2. The variables z_i that will have a negative coefficient in the regression will be declared as efficiency enhancing factors. The two step procedure however have faced a number of critics in the literature because considered to be mis-specified and biased (Battese & Coelli 1995). (Wang & Schmidt 2002) argued that measuring technical efficiency independently of exogenous influence will lead to biased estimates of the inefficiency term in a first step (model mis-specified) and consequently biased estimates of the model of inefficiency scores in a second step. The single-step procedure has been proposed as an alternative to avoid the statistical undesirable properties of the two step procedure. Unlike the two step procedure where inefficiency is measured independently of exogenous influence, the single-step procedure accounts for exogenous influence by directly parameterizing the distribution of the inefficiency term u_i as a function of exogenous factors that are likely to affect inefficiency scores. By

[10] Ignoring the heteroscedasticity of v_i still gives consistent estimates of the frontier function parameters (***β***) except for the intercept, which is downward-biased. Estimates of the technical efficiency are biased. Ignoring the heteroscedasticity of u_i causes biased estimates of the frontier function's parameters as well as the estimates of technical efficiency.

assuming a normal-half normal distribution of the composite error term $\varepsilon_i = v_i - u_i$ (nonnegative truncation of a zero-mean normal distribution) as we did, the parameterization will be only on the variance term σ^2 since the variance constitute the unique parameter of the zero-mean normal distribution. (Caudill & Ford 1993), (Caudill et al. 2014), and (Hadry 1999) proposed the following parameterization to account for the heteroscedascity of u_i and v_i.

$\sigma_{u_i}^2 = \exp(z'_{u_i} w_u)$
$\sigma_{v_i}^2 = \exp(z'_{v_i} w_v)$
Where z'_{u_i} and z'_{v_i} are the vectors of exogenous covariates expected to affect the variance of u_i and v_i. w_u and w_v are the corresponding parameter vectors. The exponential function is used for parameterization in order to ensure positive values for the variance. The heteroscedastic-consistent parameterization enable that the exogenous determinants of inefficiency enter into the model. The marginal effect of exogenous variables z_k on the measure of inefficiency is given as $\frac{\partial E(u_i)}{\partial z_k}$ where $E(u_i)$ is the unconditional mean of u_i. In a normal-half normal distributional assumption of the composite error term $\varepsilon_i = v_i - u_i$, the unconditional mean of inefficiency under consistent heteroscedastic parameterization is derived as: $E(u_i) = \sigma \frac{\varphi(0)}{\phi(0)} \sqrt{2/\pi} \exp(z'_i w)$ where $\varphi(0)$ and $\phi(0)$ are respectively the density function and the cumulative density function of the non-negative zero-mean half normal distribution.

The marginal effect $\frac{\partial E(u_i)}{\partial z_k}$ of the kith variable of z_i on the unconditional mean $E(u_i)$ is $\frac{\partial E(u_i)}{\partial z_k} = w[k] \frac{\sigma_{u_i}}{2} \left[\frac{\varphi(0)}{\phi(0)} \right] = w[k] \sigma_{u_i} \varphi(0)$. As we observe it on the formula of $E(u_i)$, the value of the unconditional mean of inefficiency depends also on exogenous covariates z_i. The sign of the influence of the kith variable z_k on the inefficiency is guided by the sign of the associated parameter $w[k]$ since $\sigma_{u_i} \varphi(0)$ is a positive value. There are four different possible parameterizations that can be tested in this study based on the assumption of a normal-half normal distribution of the composite error term $\varepsilon_i = v_i - u_i$ that we consider. The specifications can be summarised on the table 5 below:

Table 5: Distributional assumptions on u_i and v_i

Distributional assumption	**Type of parameterization of u_i and v_i**
Normal-half normal assumption of the composite error term $\varepsilon_i = v_i - u_i$	**Model 1**: homoscedasticity of u_i and v_i
	Model 2: heteroscedasticity of u_i and v_i
	Model 3: heteroscedasticity of u_i and homoscedasticity of v_i
	Model 4: homoscedasticity of u_i and heteroscedasticity of v_i

Source: *Author*

3.4 Study area and sampling procedure

Cotton production in Burkina Faso is organised around three production zones: the Western production zone, the Central production zone and the Eastern production zone. These production zones are respectively under the control of three cotton companies respectively named SOFITEX, FASOCOTON, and SOCOMA. SOCOMA and FASOCOTON put together contribute to 15% of cotton production in Burkina Faso while SOFITEX controls the remaining 85% of the production (Meda 2016). Cotton producers in their side are grouped together under the national union of cotton producers in Burkina Faso (UNPCB) which is composed of groups of cotton producers at the village level and cotton producers unions at the department and province levels. This union of cotton producers aims to facilitate the collaboration between cotton farmers and cotton companies and also between cotton farmers and the government. The sub-sector of organic cotton is entirely under the control of the UNPCB for production activities as well as for the commercialization. The UNPCB and the three cotton companies (grouped under the Cotton professionals association in Burkina Faso (APROCOB)) have put in place the Inter-professional Cotton Association of Burkina (AICB) which received government supports in terms of cotton research, credit guarantees for cotton companies and input guarantees for conventional and GM cotton farmers. The present study focus on the Central-Eastern region of Burkina Faso which is the biggest organic cotton production zone in terms of the number of producers engaged. The Central-Eastern region of Burkina Faso counts 3 provinces including the province of Boulgou (Tenkodogo), the province of Kouritenga (Koupéla) and the province of Koulpélogo (Ouargaye). For a total area of 81811 km2 the Central-eastern region of Burkina Faso according to projections from the National Institute of Statistics and Demography (INSD) was expected to reach a population of 1 607 993 in 2018. Located between latitudes 11º30 'north and 0º15'west, the Central-Eastern region of Burkina Faso is located in the Sudano-Sahelian zone where precipitations lie between 600 and 900 mm of rain per year. Agricultural production is the main economic activity and is characterized by subsidence farming. The major crops produced in this region are: sorghum, millet, rice, maize and cotton. The organic cotton production in the Central-Eastern region covers more than 40 villages distributed in various organic cotton producers groups. Organic cotton production activities in the Central-Eastern region cover only the province of Boulgou which is composed by 4 departments including the department of Tenkodogo, the department of Bagré, the department of Bané and the department of Bittou. The sample size of organic cotton producers to be considered in the study is defined according to the formula proposed by (Newbold et al 1995) with a margin error of 10% and a 95% confidence interval. (Newbold et al 1995) proposed a method for determining the sample size in the case of a random sampling with a known population size. This formula has been applied by (Adanacioglu & Olgun 2012) to study the efficiency of organic cotton production systems in Turkey. (Newbold et al 1995) considers the problem of estimating the proportion P of individuals in a population of size N who possess a certain attribute. The sample size needed to achieve any specified value of the variance of the proportion σ_p^2 is defined as: $n = \frac{NP(1-P)}{(N-1)\sigma_P^2 + P(1-P)}$. As (Newbold et al 1995) argued, a 95% confidence interval for the population proportion will extend approximately $1.96\sigma_P$ on each side of the sample proportion. So a 95% confidence interval implies $1.96\sigma_P$ margin error. In our specific case where we consider 95% confidence interval and 10% margin error, we then have $1.96\sigma_p = 10\% \Rightarrow \sigma_p = \frac{0.1}{1.96} = 0{,}05102041$. To reach a reasonable number of sample size, P is accepted as 0.3. P here represents the proportion of organic cotton farmers over all cotton farmers in the Central-Eastern region. From the latest list of organic cotton farmers in the Central-Eastern region, the total number of organic cotton farmers in this zone is estimated to be 2119. The sample size of organic cotton farmers to be considered in the study is determined as: $n = \frac{2119 * 0.3(1-0.3)}{(2119-1) * 0.05102041 * 0.05102041 + 0.03(1-0.03)} \cong 80$. The calculations indicate a total number of 80 organic cotton producers to be investigated. For the sampling, we decided to consider 7 organic cotton producing villages located in 3 of the four departments of the Central-Eastern region in which organic cotton is grown (the department of Tenkodogo, the department of Bagré, the department of Bané and the department of Bittou). The department of Tenkodogo, the department of Bittou and the department of Bané were randomly chosen. The department of Tenkodogo counts 6 villages producing organic cotton for a total number of 105 producers. The department of Bittou counts 21 villages producing organic cotton for a total number of 1075 producers and the department of Bané counts 731 producers for a total number of 15 villages. Based on the total number of organic cotton producers in the Central-Eastern region which is about 2119, the Bittou department represents 51% of the total number of organic cotton producers in this region. The departments of Bané and the department of Tenkodogo represent respectively 34% and 5% of the total number of organic cotton producers in the region. The rest of organic cotton producers in the central-eastern region are located in the department of Bagré (11%). Based on these data, we decided to randomly select 2 villages in the department of Bittou, two villages in the department of Bané and 1 village in the department of Tenkodogo. The two villages randomly selected in the department of Bittou include the village of Larguer which counts 27 producers and the village of Zampa which counts 63 producers. The two selected villages in the department of Bané include the village of Nai which counts 24 producers and the village of Kô which counts 35 producers. The only village randomly selected in the department of Tenkodogo is the village of Cella which count 19 producers. The Newman's (1995) sample size calculation method proposed a sample size of 80 organic cotton producers to be considered. Based on the distribution of organic cotton producers within the four producing departments in the central-eastern region, we decided to surveyed 43 producers in the department of Bittou, 30 producers in the department of Bané and 7 producers in the department of Tenkodogo. The 7 producers to be investigated in the department of Tenkodogo cover the village of Cella that was randomly selected from the 6 producing villages in the department of Tenkodogo. The 43 producers to be surveyed in the department of Bittou are distributed as follows among the two villages randomly selected in this department: 15 producers in the village of Larguer and 28 producers in the village of Zampa. In the department of Bané, the 30 producers to be surveyed have been equally distributed among the two villages randomly selected in this department: 15 producers in the village of Nai and 15 producers in the village of Kô. The distribution of producers per village has been made in proportion to the weight of each selected village in terms of its total number of organic cotton producers within the department in which that village is located.

For comparison purposes, a sample of 180 conventional cotton producers in the Central eastern region is also considered. Conventional cotton farmers have been purposively selected in three villages. The village of Cella that belong to the Department of Tenkodogo and the villages of Kampoaga and Ouada that belong to the Department of Bané.

Chapter IV: Empirical results and discussions

4.1 Characteristics of the sampled cotton farmers

4.1.1 Variables measurement

The data for this study have been essentially gathered through a field survey conducted from May to June 2018 in the central eastern region of Burkina Faso. Survey were conducted by trained extension agents recruited from the cotton company FASOCOTON and also from the organic and fair-trade cotton program in Burkina Faso. The survey method consisted of individual interviews based on an individual farmer questionnaire. The questions were related to farm household socioeconomic characteristics (demographic, education, revenue), farm technical characteristics (farm size, level of production, inputs used, methods of pests' control, extension contact, and inputs credit) and farmers' perception of organic cotton farming. The individual farmer's questionnaire has been pretested during two days' work where cotton farmers have been randomly approached to get their perception of the survey questionnaire. Twenty farmers participated to this exercise which allowed us to clearly redefined and set the methods of measurement of some variables like labour, farm household non-cotton crops production value and off farm income. The factor labour which was initially supposed to be evaluated in days of work has been redefined and considered in man-day. A man-day is considered to be the work done by an adult man in 08 hours during a day. Labour in the study area is essentially composed by family and mutual aid labour. Labour is first evaluated for each cultural operation and then sum up to get the total quantity of labour used on the farm. For each cultural operation the survey questionnaire allowed to have the number of workers used on the farm and the total duration of work (estimated in hours) corresponding to this cultural operation. This was done based on farmers' capacity to recall data. The total number of workers corresponding to a given cultural operation is converted in man-equivalent by taking a weighted sum of the number of male, female and children that have participated to the work and supposing that female and children work represent respectively 75% and 50% of man work. The total manpower obtained in man equivalent is then converted into man-day by multiplying its calculated value by the total duration of work corresponding to the cultural operation in consideration and divided by eight. The man-day concept have been applied in many agricultural research studies (Coulibalyl & Quenum 2002); (Paraiso et al. 2012). Cotton net returns is evaluated by subtracting the value of inputs credit from the value of the cotton production evaluated at the prevailing cotton price. Given that labour in the region is particularly composed by family labour and mutual aid labour, labour costs have not been included in the calculation of cotton net returns. The quantities of cotton production harvested during the 2016-2017 cropping season and the values of inputs have been easily recalled by most of the farmers. These data have been confronted with those held by the cotton company FASOCOTON and the organic and fair-trade cotton program to insure their reliability. The inputs of the same nature for organic as well as for conventional cotton farming are land and labour. While organic cotton farmers for certification requirements are asked to use for fertilisation, organic manure, crop rotation, crop association and other adapted cultural methods, conventional cotton farmers in their side focus on the use of synthetic fertilisers like NPK and urea. For pests and weed control the methods used are also different from organic to conventional cotton farming. In conventional cotton farming, agricultural chemicals like insecticides, “herbicides pré-levé”, “herbicides post-levé”, “and herbicides total” are essentially used by farmers. In organic cotton farming, pests and weed control is essentially based on the use of adapted cultural practices, the use of local insecticides made by farmers themselves through the seeds of some plants (neem seeds), the use of trap plants and an industrially made organic pesticide called “batik”. Some other organic industrially made pesticides called “bio protect HN” or “bio protect PIOL” are also proposed to organic cotton farmers. The industrially made organic pesticide which is widely adopted by organic cotton farmers in the central eastern region is the one called “batik”. In order to evaluate non-cotton crops production value during the 2016/2017 cropping season, farmers have been asked to evaluate the quantities of crops other than cotton that they have cultivated and harvested during the same cropping season. These crops was essentially cereal crops composed by maize, sorghum, millet and leguminous crops like peanut, soya, sesame and cowpea. The quantity harvested for each crop have been evaluated at its prevailing price at this moment. The total monetary value of the crops produced have been considered as a proxy of non-cotton crops production value. Data have been also gathered on farm household self-employment off farm income. These variables captured incomes generated from activities other than crop production initiated and conducted by farm household members for their own account. It was essentially small businesses activities including cattle trade, milling trade, stonework, small shops, etc. Farmers have first been asked to determine the period of time within which they have conducted these activities during the 2016/2017 cropping season. Afterwards they recalled the monthly mean gain generated from each activity. Base on the period of time the activity has been conducted and the monthly mean gain estimated by the famer, we got an idea of the total income generated by the activity during the 2016/2017 cropping season. The overall income resulting from the different activities is considered here as a proxy of farm household self-employment off farm income. The monthly mean consumption expenditures has also been evaluated with framers' assistance. Data on education level have been evaluated in years considering the last class attended by the farmers. Some variables have binary outcome taking the values 0 or 1. These variables are essentially soil fertility status (fertile or not fertile), plant rotation (applied or not), gender (male or female), the type of cotton produced (organic or conventional), farmer to farmer extension (use or not), radio information on cotton production (received or not), neighbourhood information on cotton production (received or not), off farm work (yes or no), equipment for safety (yes or no), extension contact (yes or no). Having initially targeted 80 organic cotton producers and 180 conventional cotton producers, we finally gathered data on 79 organic cotton farmers and 179 conventional cotton farmers. Two questionnaires were not usable due to the lack of some data. The summary statistics of the collected data are presented in the table 5 below:

4.1.2 Descriptive statistics

The table 6 below present the descriptive statistics of the variables

Table 6 : Descriptive statistics of the variables

Variable	*Observed mean values*									*Mean differences*
	Full sample (n=258)			*organic cotton farmers (n=79)*			*conventionnal cotton farmers (n=179)*			*Organic vs conventional (two sample t-test)*
	Mean (sd)	*Min*	*Max*	*Mean (sd)*	*Min*	*Max*	*Mean (sd)*	*Min*	*Max*	
age	*43.53101 (12.34243)*	*15*	*77*	*42.77215 (13.48213)*	*20*	*77*	*43.86592 (11.82902)*	*15*	*73*	*-1.09377*
gender	*0.8488 (0.35)*	*0*	*1*	*0.5443038 (0.5012157)*	*0*	*1*	*0.9832402 (0.128730)*	*0*	*1*	
Education of the head of household	*0.6666667 (1.952085)*	*0*	*10*	*0.2911392 (1.210551)*	*0*	*6*	*0.8324022 (2.18392)*	*0*	*10*	*-0.54***
Number of children going to school	*3.2558 (2.7736)*	*0*	*22*	*2.240506 (1.784658)*	*0*	*8*	*3.703911 (3.008702)*	*0*	*22*	*-1.463404****
Experience in cotton production in general	*10.5814 (8.48)*	*1*	*44*	*5.544304 (1.906786)*	*3*	*10*	*12.80447 (9.285169)*	*1*	*44*	*-7.260165****
Farm size	*1.71907 (1.193944)*	*0.1*	*6.87*	*0.9613924 (0.650604)*	*0.1*	*2.9*	*2.053464 (1.226969)*	*0.5*	*6.87*	*-1.092071****
Household size	*11.18217 (6.792201)*	*3*	*42*	*7.78481 (5.011962)*	*3*	*35*	*12.68156 (6.943936)*	*3*	*42*	*4.896754****
Quantity of cotton production	*1371.391 (1282.542)*	*9*	*7020*	*385.9114 (429.8185)*	*9*	*2719*	*1806.324 (1293.349)*	*269*	*7020*	*-1420.413****

Cotton net returns	*218825 (226971.7)*	*-170690*	*1537990*	*126605.1 (154375)*	*-18460*	*963206*	*259525.4 (241860.8)*	*-170690*	*1537990*	*-132290****
extension contact	*0.9263566 (.2616974)*	*0*	*1*	*1 (0)*	*1*	*1*	*.8938547 (.3088875)*	*0*	*1*	
Number of extension contacts	*2.837209 (1.947924)*	*0*	*12*	*4.670886 (1.93299)*	*1*	*12*	*2.027933 (1.300087)*	*0*	*6*	*2.642953****
Cotton inputs credit value	*130636.9 (125790.3)*	*525*	*74400*	*11937.08 (14249.88)*	*525*	*59250*	*183024 (117233.9)*	*8700*	*724000*	*-171086.9****
Distance from household to cotton field	*3.459089 (2.967797)*	*0.02*	*20*	*2.596835 (2.876188)*	*0.2*	*20*	*3.839637 (2.935352)*	*0.02*	*17*	*-1.242801****
Distance from house to the nearest mar-ket	*2.748508 (2.116873)*	*0.02*	*10*	*4.589873 (1.782795)*	*0.2*	*10*	*1.935838 (1.705357)*	*0.02*	*10*	*2.654035****
Number of relatives producing cotton	*20.57752 (28.58729)*	*0*	*300*	*20.62025 (43.71654)*	*0*	*300*	*20.55866 (18.50602)*	*0*	*100*	*0.0615939*
Non-cotton crops production value	*265486.3 (192297.2)*	*6550*	*987991*	*164411.7 (124732.4)*	*6550*	*662175*	*310094.7 (200092.6)*	*17800*	*987991*	*-145683****
Self-employment off farm work	*0.4379845 (0.4971035)*	*0*	*1*	*0.4683544 (0.5021861)*	*0*	*1*	*0.424581 (0.4956657)*	*0*	*1*	
Self-employment Off farm income	*110329.7 (184868.3)*	*0*	*955000*	*84357.97 (135072.4)*	*0*	*720000*	*121792 (202282.2)*	*0*	*955000*	*-37434.04**

Monthly consumption expenditure	*40779.38*	*(30375.82)*	*3000*	*219000*	*36890.51* (34280.93)	*9000*	*200000*	*42495.7* (28417.56)	*3000*	*219000*	*-5605.192**
Labour force	*163.3721*	*(138.4794)*	*12*	*861*	*80.44304* (70.86982)	*12*	*387*	*199.9721* (145.2146)	*35*	*861*	*-119.529****
Quantity of seeds used	*1.659225*	*(1.090626)*	*0.33*	*6*	*0.9250633* (0.634176)	*0.33*	*4.5*	*1.98324* (1.093776)	*0.5*	*6*	*-1.058177****
rotation	*0.9069767*	*(0.2910296)*	*0*	*1*	*0.9367089* (0.2450417)	*0*	*1*	*0.8938547* (0.3088875)	*0*	*1*	
Radio information	*0.7868217*	*(0.4103486)*	*0*	*1*	*0.443038* (0.4999189)	*0*	*1*	*0.9385475* (0.2408322)	*0*	*1*	
Neighbourhood information	*0.9612403*	*(0.1933969)*	*0*	*1*	*0.9620253* (0.1923564)	*0*	*1*	*0.9608939* (0.1943913)	*0*	*1*	
Farmer to farmer extension	*(0.9027237*	*(0.2969118)*	*0*	*1*	*0.8333333* (0.3750902)	*0*	*1*	*0.9329609* (0.2507912)	*0*	*1*	
Equipments for safety	*0.0348837*	*(0.1838419)*	*0*	*1*	*0.0379747* (0.1923564)	*0*	*1*	*0.0335196* (0.1804937)	*0*	*1*	
Soil fertility	*0.1937984*	*(0.3960411)*	*0*	*1*	*0.2531646* (0.4376029)	*0*	*1*	*0.1675978* (0.3745564)	*0*	*1*	

Source: *Author by survey data* ******p<0.01,**p<0.05,*p<0.1***

The analysis of the table 6 above shows some disparities between organic and conventional cotton farmers. In average organic cotton farmers have the smallest farm size with a mean farm size value less than 1 hectare. In contrast, conventional cotton farmers have a mean farm size value of 2 hectares. This result is not surprising given the restrictions on inputs use imposed to organic cotton farmers. Certification requirements of the organic production technology made it difficult to grow organic cotton in an extensive way. Both groups of farmers present almost the same mean value of age (42.77215 for organic farmers and 43.86592 for conventional cotton farmers) which is close to the mean value of age in the full sample (43.53201). The t-test of mean differences did not revealed any statistical difference of age between organic and conventional cotton farmers. The statistical insignificance of the differences in age mean values between organic and conventional cotton farmers have been also encountered with data collected by (Meda, 2018) in 2015. The observation of the full sample shows that globally 16% of women participated in cotton production activities but this global view hide disparities between organic and conventional cotton farmers' groups. While in organic cotton production 46% of the surveyed producers were women, in conventional cotton farming only 2% of the surveyed farmers were women. Women marginalized in conventional cotton production mostly dominated by men have widely adopted the organic cotton production technology. In terms of the experience in cotton production, organic cotton farmers are far behind conventional cotton farmers. The organic and fair-trade cotton program which is supporting the organic cotton production sector in Burkina Faso took place in the central eastern region in 2008. That is the reason why the more experienced organic cotton farmers have less than 10 years' of experience while in conventional cotton farming, some farmers present more than 40 years of experience of cotton production. The quantity of cotton grain harvested during the 2016/2017 cropping season also emphasized the limitations of the organic production technology in terms of productivity. While conventional cotton farms had an average yield per hectare of 722 Kg of cotton grain, organic cotton farmers present an average yield per hectare of 401Kg. The price premium paid to organic cotton farmers aims to compensate these yields losses. In organic cotton production, the prevailing price for 1 Kg of grain cotton is about 359 FCFA including the price premium. In contrast, conventional cotton production is bought at 245 FCFA per Kg of grain cotton. Organic cotton farmers argued that yields are significantly improved when the production technology is rigorously followed and when organic manure is sufficiently bring on farm. The small sizes of organic cotton farms leads to small returns for organic cotton farmers compare to conventional farmers. In average, organic cotton farmers have a net return on cotton production of 126605 FCFA while conventional cotton farmers have a mean net return on cotton production of 259525 FCFA. The differences in inputs credits for cotton production contracted by organic cotton farmers from the organic and fair-trade cotton program or conventional cotton farmers from the cotton company FASOCOTON is highly perceptible. The mean inputs credit value for organic cotton production is found to be 11937 FCFA while this mean is about 183024 FCFA for conventional cotton farmers. These differences in inputs credits values highlight the differences between both technologies. While conventional cotton farmers rely essentially on agricultural chemicals provided on credit by cotton companies for fertilisation, pests and weed control, organic cotton farmers rely on locally available inputs and agricultural practices which limit their dependence to credits provided by cotton companies. Cotton production is also supposed to have an impact on the quantities of the other crops simultaneously produced by the farmer. As (Meda, 2018) and (Coulty, 2011) argued, the institutional organisation of the cotton sector in Burkina Faso is determinant for the choice made by the farmer of which technology to use. The inputs provided by cotton companies for conventional cotton production are also used to produce other crops mainly cereal crops. In this context, one should expect conventional cotton farmers to produce more other crops than organic cotton farmers. This result is emphasized by the statistics in the table above. While the mean non-cotton crops production value is about 310000 FCFA for conventional cotton farmers, this mean value is about 160000 FCFA for organic cotton producers. Organic cotton farmers were more engaged (46%) in self-employment off farm work than conventional cotton farmers (42%) but they generated less income from these activities compare to conventional cotton farmers. In average, organic cotton farmers had a self-employment off farm income of 84357 FCFA per year while conventional cotton farmers had a mean self-employment off farm income of 121792 FCFA per year. In terms of extension contacts, organic cotton farmers received two times more extension contacts than conventional cotton farmers during the 2016/2017 cropping season. The challenges posed by the organic production technology in terms of certification require extension agents to be close to farmers to insure that the restrictions imposed by the organic production technology are not violated. Organic cotton farmers have been found to be more close to their fields compared to conventional cotton farmers. While for organic cotton farmers, the average distance from the house to the field is about 2.59 Km, conventional cotton farmers are far from their fields for about 3.86 km. Organic cotton farmers declared to spent less than conventional cotton farmers in terms of monthly consumption expenditure. The mean monthly consumption expenditure is 36890 FCFA for organic cotton farmers and 42495 FCFA for conventional cotton farmers. One can argue that conventional cotton farmers spend more in health care due to the exposition to agricultural chemicals since only 3.35% of them declared to have a complete equipment for protection when spraying. Plants rotation is practiced by both types of cotton farmers but this technic is more accentuated in organic cotton farming (93.67%) where plant rotation is even a requirement of the technology. The labour force used for organic cotton production in average (80 man-days) was less than what is used in conventional cotton production (199 man-days in average). This result is mainly due to the smallness of organic cotton farms. By considering the labour force per hectare of land, it appeared that one hectare of organic cotton farm needed 83 man-days of labour while one hectare of conventional cotton farm needed 79 man-days of labour. This result support the thesis that organic farming is a labour intensive technology compare to conventional farming.

4.2 Analysis of the adoption and impact of organic cotton farming practice

4.2.1 Determinants of farmers participation in organic-certified cotton production schemes

We begin this analysis by going through the descriptive statistics of the outcome variables and the variables to be included in the selection equations and the outcomes equations. The table below gives the results of these statistics.

Table 7 : descriptive statistics of the selection and the outcomes equations variables

Variable	*organic cotton farmers (n=79)*			*conventionnal cotton farmers (n=179)*			*Organic vs conven-tional (two sample t-test)*
	Mean (sd)	*Min*	*Max*	*Mean (sd)*	*Min*	*Max*	
Outcome variables							
Return on cotton production per ha of cotton farm size	*133558.9 (11627.63)*	*471541.7*	*-36920*	*128865 (5918.111)*	*-71636*	*384497.5*	*-4693.895*
Non-cotton crop production value per ha of cotton area cultivated	*218932.3 (23332.14)*	*6550*	*1469350*	*185395.2 (10186.31)*	*8216.363*	*830700*	*-33537.09**
Selection equation and outcomes equations variables							
Household size	*7.78481 (5.011962)*	*3*	*35*	*12.68156 (6.943936)*	*3*	*42*	*4.896754****
age	*42.77215 (13.48213)*	*20*	*77*	*43.86592 (11.82902)*	*15*	*73*	*-1.09377*
gender	*0.5443038 (0.5012157)*	*0*	*1*	*0.9832402 (0.128730)*	*0*	*1*	
Education of the head of household	*0.2911392 (1.210551)*	*0*	*6*	*0.8324022 (2.18392)*	*0*	*10*	*-0.54***
Number of children going to school	*2.240506 (1.784658)*	*0*	*8*	*3.703911 (3.008702)*	*0*	*22*	*-1.463404****
Experience in cotton production in general	*5.544304 (1.906786)*	*3*	*10*	*12.80447 (9.285169)*	*1*	*44*	*-7.260165****
Distance from household to cotton field	*2.596835*	*0.2*	*20*	*3.839637 (2.935352)*	*0.02*	*17*	*-1.242801*

							***
	(2.876188)						
Number of relatives producing cotton	*20.62025*	*0*	*300*	*20.55866 (18.50602)*	*0*	*100*	*0.0615939*
	(43.71654)						
Self-employment off farm work	*0.4683544*	*0*	*1*	*0.424581 (0.4956657)*	*0*	*1*	
	(0.5021861)						
rotation	*0.9367089*	*0*	*1*	*0.8938547 (0.3088875)*	*0*	*1*	
	(0.2450417)						
Radio information	*0.443038*	*0*	*1*	*0.9385475 (0.2408322)*	*0*	*1*	
	(0.4999189)						
Neighbourhood information	*0.9620253*	*0*	*1*	*0.9608939 (0.1943913)*	*0*	*1*	
	(0.1923564)						
Farmer to farmer extension	*0.8333333*	*0*	*1*	*0.9329609 (0.2507912)*	*0*	*1*	
	(0.3750902)						
Equipments for safety	*0.0379747*	*0*	*1*	*0.0335196 (0.1804937)*	*0*	*1*	
	(0.1923564)						
Soil fertility	*0.2531646*	*0*	*1*	*0.1675978 (0.3745564)*	*0*	*1*	
	(0.4376029)						

Source: Author by survey data

By looking at these statistics we observe significant differences between the outcome variables of both groups of farmers. Farmers that engaged in organic cotton farming seem to be better off than conventional cotton farmers in terms of the returns on cotton production and the quantity of non-cotton crops produced per ha of cotton area cultivated. In average organic cotton farmers have a return of cotton production per ha of about 133558.9 FCFA while conventional cotton farmers present a mean value of return on cotton production per ha of 128865 FCFA. The difference of 4693.895 FCFA observed between the two mean values using a mean-comparison t-test has not been found to be significant. So statistically speaking there is no difference between the return on cotton production per ha basis between organic and conventional farmers. This result was not expected since organic cotton farms have lower yields compare to their conventional counterfactual and more surprisingly present very small size. While conventionnal cotton farmers present an average yield value of 902.2795 Kg per hectare, organic cotton farmers present an average yield value of 412.972 Kg per hectare of farm size. Conventional cotton farmers are therefore two times more productive than organic cotton farmers. The higher selling price that benefit organic cotton farmers due to the organic price premium compensate the loss of yield. While the price of 1 Kg of conventional grain cotton is about 245 FCFA, 1 Kg of organic grain cotton cost about 359 FCFA to organic cotton buyers. The lowest yields observed in organic cotton farming is 6.67 Kg/ha while the lowest yields observed in conventional cotton farming is 234.6Kg/ha. The most productive farm in organic cotton farming system reach a maximum yield of 1333.33 Kg/ha while the most productive farm in conventional cotton farming system reach a maximum yield of 2108.333 Kg/ha. The average farm size is about 0.96 ha for organic cotton farms and 2.05 ha for conventional cotton farms. The gap between the minimum and the maximum yields achieved in organic cotton farming show a great potential to improve the productivity of organic cotton farming and the livelihoods of organic cotton farmers. Despite the low yields observed in organic cotton farming which are two times less than the yields observed in conventionnal cotton production, organic cotton farms tend to achieve the same or even more than the economic performances achieved in conventional cotton production. Improving organic cotton production yields by enhancing its productive efficient may significantly contribute to improve the economic performances of organic cotton farmers. Another outcome variable analysed here is the value of non-cotton crops produced per ha of cotton area cultivated. We observe a significant difference between the mean values of non-cotton crops produced per ha of cotton area cultivated for organic and conventional cotton farmers. A mean-difference t_test shows that in terms of non_cotton crops production organic cotton farmers in average produced 33537.09 FCFA more than conventional cotton farmers. While organic cotton farmers present a mean value of 218932.3 FCFA for the total value of non_cotton crops produced, conventional cotton farmers have a mean value of non_cotton crops produced of 185395.2 FCFA. This result tend to reject the hypothesis that we had. Indeed the institutional organisation of the cotton sector make more easier to conventional cotton farmers the access to fertilisers for the production of non_cotton crops mostly cereals. Thus we are expecting conventional cotton farmers to perform more than organic cotton farmers in terms of the value of non-cotton crops produced per hectare of cotton area cultivated. Regarding the variables to be included in the selection equation and the outcomes equations, only one variable appears in the selection equation and does not appear in the outcomes equation. This variable is related to the radio information on cotton farming which has been successfully tested to be a valid instrument for the endogenous switching regression model. Aside of the variable radio information on cotton farming, the other variables to be included are the household size, the age of the head of household, his gender, the level of the formal education of the head of household, the number of children going to school in the household, the experience of the head of household in cotton production, the distance from household to cotton field, the number of the relatives of the head of household producing cotton, the off farm work status of the head of household, the information on cotton production received from the neighbourhood, farmer to farmer extension, the availability of equipment for safety, the soil fertility status. Variables like the household size, the education of the head of household, the number of children going to school, the experience in cotton production, and the distance from household to cotton field present significant differences between organic and conventional cotton farmers. As in (Di Falco et al. 2011); (Shiferaw et al. 2014); (Tesfaye & Tirivayi 2018) we use a simple falsification test to test the validity of the variable radio information as an instrument. A variable is considered to be a valid instrument if this variable affect the adoption decision but is not affecting the outcome variable of those who did not adopted (Di Falco et al. 2011); (Shiferaw et al. 2014); (Tesfaye & Tirivayi 2018). The results of the falsification tests are summarised in the table below:

Table 8 : Results of the falsification tests

	Model 1	***Model 2***	***Model 3***
	Adoption decision 1/0	***Return on cotton production per ha of cotton farm size***	***Non-cotton crop production value per ha of cotton area cultivated***
exp_cotton	*-0.1443342*** (0.0353281)*	*1898.157** (760.8073)*	*186.8931 (1271.386)*
educ	*-0.1351489* (0.0811716)*	*-994.4291 (2594.289)*	*-1927.981 (4335.321)*
age	*0.0295763*** (0.0105179)*	*-1216.598** (546.4004)*	*1559.677* (913.0907)*
hhsize	*-0.0542287* (0.0280128)*	*551.0109 (1152.264)*	*2717.476 (1925.55)*
offfarm_work	*0.4408549 (0.2773328)*	*19553.07*** (12850.55)*	*84583.39 (21474.58)*
educ_child	*0.074751 (0.0711604)*	*3833.028 (2644.844)*	*-7072.492 (4419.804)*
gender	*-2.191995*** (0 .4607043)*	*-34047.61 (45613.93)*	*-38348.79 (76225.52)*
rotation	*0.6538865 (0.413783)*	*-979.8588 (19074.83)*	*42590.59 (31875.99)*
dist_house	*-0.055874 (0.0436294)*	*636.5918 (1999.662)*	*-3415.884 (3341.639)*
relatives_numb	*-0.0030546 (0.004131)*	*-31.97906 (323.4843)*	*-1329.819** (540.5752)*
safe_equip	*0.1880956 (0.645579)*	*21613.55 (31457.21)*	*-82473.54 (52568.2)*
Soil_fetility	*0.351683 (0.3148231)*	*32856.99** (16595.42)*	*60313.47** (27732.63)*
Neighbour_inf	*0.4794462 (0.5431651)*	*35825.45 (33923.46)*	*36783.93 (56689.56)*
radio_inf	*-1.379204*** (0.2912656)*	*-35642.21 (24269.61)*	*38392.67 (40556.99)*
farmer_ext	*-0.5779689 (0.3772089)*	*5053.808 (27271.37)*	*-9014.937 (45573.23)*
constant	*2.05616** (0.906578)*	*149915.5** (64140.27)*	*41791.06 (107184.9)*
number of obs	*257*	*179*	*179*
LR chi2(15)	*181.04****		
Prob > chi2	*0.0000*		
Pseudo R^2	*0.5738*		
R^2		*0.20*	*0.24*
F(15, 163)		*2.79****	*3.62****
Prob > F		*0.0007*	*0.0000*

Source: Author by survey data
Note: * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level. The numbers into brackets are the standards deviations

The falsification test confirm the validity of the variable radio information as an instrument to be used in the estimation procedure of the ESR model. As we observe it on the table, the variable radio information is significant at 1% in the probit model (Model 1) then susceptible to affect the adoption decision but it is not significant in the outcome equations of non-adopters (Models 2&3). So the variable radio information fit well the characteristics of a valid instrument as it is defined in (Di Falco et al. 2011); (Shiferaw et al. 2014); (Tesfaye & Tirivayi 2018). The estimates of the selection equation and the outcomes equations in the ESR models[11] using the full information maximum likelihood approach can be summarised in the table 9.

Table 9 : Parameters estimates of the ESR model

Variable	***Adoption decision 1/0***			*Outcome equations*					
	Probit	*Select_ESR_1*	*Select_ESR_2*	***Return on cotton production per ha of cotton farm size***			***Non-cotton crop production value per ha of cotton area cultivated***		
				OLS	*ESR_outcome_1*		*OLS*	*ESR_outcome_2*	
					Adopters	*Non-adopters*		*Adopters*	*Non-Adopters*
exp_cotton	*-0.1443342*** (0.0353281)*	*-0.146495*** (0.0362141)*	*-0.1624695*** (0.0342326)*	*1782.841** (775.3868)*	*-6273.01 (6035.208)*	*2143.584*** (818.0208)*	*1657.343 (1393.636)*	*22966.3* (12187.96)*	*-1128.54 (1326.619)*
educ	*-0.1351489* (0.0811716)*	*-0.1174203 (0.0809016)*	*-0.1901143** (0.0852458)*	*152.6979 (2765.577)*	*1816.957 (9142.766)*	*-334.6711** (2508.883)*	*1207.813 (4970.688)*	*25835.37 (18582.84)*	*-3471.687 (4207.707)*
age	*0.0295763*** (0.0105179)*	*0.0296658*** (0.0107648)*	*0.0259986** (0.0100259)*	*-450.2809 (475.2965)*	*818.4947 (936.1511)*	*-1308.757 (540.7214)*	*909.2342 (854.2706)*	*-1089.666 (1912.448)*	*2080.043** (901.4472)*
hhsize	*-0.0542287* (0.0280128)*	*-0.054631* (0.0282096)*	*-0.0689056** (0.0289655)*	*1318.55 (1156.055)*	*5697.012* (2913.722)*	*725.1619 (1108.332)*	*2887.022 (2077.827)*	*9626.473 (6173.939)*	*2572.696 (1857.313)*
offfarm_work	*0.4408549 (0.2773328)*	*0.4439861 (0.2794491)*	*0.4156596 (0.2779097)*	*4787.626 (11712.68)*	*-40818.03* (22372.74)*	*17169.31 (12541)*	*50163.97** (21051.7)*	*-32232.96 (47573.02)*	*92291.46*** (20867.29)*
educ_child	*0.074751 (0.0711604)*	*0.0809047 (0.0712146)*	*0.0912637 (0.0773256)*	*-48.18483 (2774.2)*	*-20792.41*** (7691.165)*	*3525.286 (2539.845)*	*-9200.277* (4986.186)*	*-26859.69* (16303.47)*	*-7081.015* (4277.704)*
gender	*-2.191995*** (0.4607043)*	*-2.19249*** (0.4666506)*	*-2.70638*** (0.6429218)*	*10557.43 (17187.39)*	*20271.64 (32014.68)*	*-15997.69 (45704.04)*	*-104554.1*** (30891.63)*	*-35482.72 (56466.1)*	*-92742.72 (73662.06)*
rotation	*0.6538865 (0.413783)*	*0.6654835 (0.4117665)*	*0.6129015 (0.4151618)*	*24299.98 (19005.44)*	*41474.88 (44415.26)*	*-1212.386 (18456.58)*	*33153.18 (34159.28)*	*-23373.4 (91532.44)*	*50633.93 (30923.44)*
dist_house	*-0.055874 (0.043629*	*-0.0490862 (0.044765)*	*-0.0503319 (0.0430346)*	*-574.5229 (1877.119*	*-4165.579 (3767.034*	*734.3171 (1931.423*	*352.7689 (3373.826*	*14041.54**	*-3632.386 (3226.012*

[11] ESR model with the outcome variable Return on cotton production per ha of cotton farm size and ESR model with the outcome variable Non-cotton crop production value per ha of cotton area cultivated

	4)			)	)	)	)	(8141.857)	)
relatives_numb	*-0.0030546 (0.004131)*	*-0.0032911 (0.0041971)*	*-0.003178 (0.0039488)*	*3.595495 (189.9883)*	*-40.48023 (248.8928)*	*-14.70515 (311.7432)*	*-623.0008* (341.474)*	*-340.9082 (553.7985)*	*-1442.861*** (523.6475)*
safe_equip	*0.1880956 (0.645579)*	*0.326545 (0.6243169)*	*0.2045243 (0.6496817)*	*32266.14 (29562.54)*	*67564.32 (61147.32)*	*21658.12 (30307.72)*	*-47919.71 (53134)*	*15182.15 (128111.2)*	*-85282.67* (50640.26)*
Soil_fetility	*0.351683 (0.3148231)*	*0.2797177 (0.3230224)*	*0.3521569 (0.3144134)*	*38362.92*** (14057.54)*	*23539.05 (25964.11)*	*34225.68** (15925.65)*	*56551.24** 25266.21*	*64033.71 (56129.83)*	*61520.65** (26519.69)*
Neighbour_inf	*0.4794462 (0.5431651)*	*0.4654015 (0.5312144)*	*0.4734734 (0.5435538)*	*-18783.74 (29659.22)*	*-135510** (55826.25)*	*34410.74 (32781.16)*	*15930.86 (53307.77)*	*-25542.75 (116883.6)*	*53969.27 (54574.54)*
radio_inf	*-1.379204*** (0.2912656)*	*-1.327273*** (0.2777175)*	*-1.452536*** (0.293283)*	*-32860.38** (14824.97)*	-	-	*-15805.75 (26645.55)*	-	-
farmer_ext	*-0.5779689 (0.3772089)*	*-0.5121593 (0.3639419)*	*-0.5747628 (0.3783075)*	*12949.88 (19791.86)*	*-2755.669 (30336.82)*	*3366.677 (26353.88)*	*16137.16 (35572.75)*	*30397.57 (66420.34)*	*-25220.8 (43251.19)*
constant	*2.05616** (0.906578)*	*2.914623*** (0.9958651)*	*2.07646*** (0.9232084)*	*108791.8*** (40079.54)*	*246581.2*** (88611.75)*	*97591.82 (59413.89)*	*157899.4** (72036.65)*	*190025.5 (187277.2)*	*132260.7 (95433.33)*
number of obs	*257*	*257*	*257*	*257*	*257*		*257*	*257*	
Lns0					*11.17439*** (0.0078735)*			*11.69967 (0.0047828)*	
Lns1					*11.40252*** (0.0137427)*			*12.21855 (0.0213207)*	
r0					*-0.2483514 (0.2399841)*			*.5591627 (0.2333267)*	
r1					*-0.1753987 (0.3721115)*			*-.7883714 (0.2991622)*	
Sigma0					*71281.02 (561.2338)*			*120532.2*** (576.4775)*	
Sigma1					*89546.96 (1230.615)*			*202512.1*** (4317.695)*	
rh0					*-0.2433683 (0.2257703)*			*0.5073559** (0.1732661)*	
rho1					*-0.1736218 (0.3608944)*			*-0.6574855*** (0.1698382)*	
LR chi2(15)	*181.04****								
Prob > chi2	*0.0000*								
Pseudo R^2	*0.5738*								
F(15, 241)				*1.90*			*3.05*		
Prob > F				*0.0236*			*0.0002*		
R-squared				*0.1059*			*0.1596*		
Wald test of joint significance of the error correlation coefficients in the selection and outcome equations				*Wald chi2(14) = 43.78; Prob > chi2 = 0.0001*			*Wald chi2(14) = 61.63; Prob > chi2 = 0.0000*		
LR test of independence of the selection and the outcome equations				*Wald chi2(14) = 43.78 Prob > chi2 = 0.0001*			*Wald chi2(14) = 61.63 Prob > chi2 = 0.0000*		

***Source**: Author by survey data*

Note: ∗ Significant at the 10% level; ∗∗ Significant at the 5% level; ∗∗∗ Significant at the 1% level. The numbers into brackets are the standards deviations

The full information maximum likelihood approach in contrast to the two-step approach estimate jointly the selection equations and the outcomes equations. The selection equations representing the determinants of adoption are of two specifications here due to the presence of two outcome variables: these are the selection equation related to the outcome variable “**return on cotton production per ha of cotton farm size”** represented by Select_ESR_1 on the table 9 and the selection equation related to the outcome variable “**non-cotton crop production value per ha of cotton area cultivated”** represented on the table 9 by Select_ESR_2. All the variables introduced in both selection equations **Select_ESR_1** and **Select_ESR_1** except the variable “education of the head of household” present statistically similar effects. The Wald test confirmed the joint significance of the errors correlation coefficients in the selection equations and the outcome equations and so the ESR model specification. Significant correlation coefficients between the errors terms of the selection equations and the errors terms of the outcomes equations indicate the presence of self-selection in the adoption of organic cotton farming. Variables like the experience in cotton farming, the education of the head of household, the age of the head of household, the household size, the gender of the head of household and the radio information have been found to affect significantly the decision to grow organic cotton. The experience in cotton production is affecting negatively the decision to adopt organic cotton production. Farmers with large experience in cotton production are less likely to adopt organic cotton production. The same results have been found in (Sodjonou et al. 2015) in the case of the adoption of organic cotton production in Benin. The negative impact of the variable experience on the adoption of organic cotton production is related to the multiple difficulties faced by the organic and fair trade cotton program. Organic cotton farmers are usually paid late and this situation contribute to delay the start of the next growing season. Farmers with large experience in cotton farming are more aware of these issues and are reluctant to engage in the organic production scheme. The formal education of the head of the household is also affecting negatively the decision to grow organic cotton. This result were not expected since organic production is a knowledge intensive technology and farmers with higher level of formal education are expected to have more skills and capacities to understand and adopt a newly introduced production technology. The negative impact of the formal education of the head of household on the adoption decision also indicate a situation which seems to not be attracting to farmers. The age of the head of household is found to affect positively the decision to grow organic production. Even though in the descriptive statistics there were not a significant difference in the mean-age of organic and conventional cotton farmers, the variable age appears to play a significant role in the decision to grow organic cotton. Old farmers are more likely to engage in organic cotton production than young farmers. Practicing organic farming is more a matter of beliefs or a philosophy of life for old farmers who care more about environmental issues. Moreover small organic cotton farms are easier to be managed by old farmers who do not benefit from an additional support in terms of labour force. The household size push farmers to self-select into conventional cotton production. As we described it in the descriptive statistics, the mean-value of the labour force used is significantly higher in conventionnal than in organic cotton production. Farmers with large household size are likely to engage in conventional cotton production. A large household offers a potential for family labour force. The gender of the head of household measured by a dummy variable (1 when the head of household is male and 0 otherwise) affect negatively the decision to grow organic cotton. This result implies that female farmers are more likely to grow organic cotton. Female farmers are generally excluded from the conventional cotton production system which required more land and capital that they might not be able to afford. The variable radio information on cotton farming which is also a dummy variable (1 received 0 otherwise) does not play in favour of the adoption of organic cotton farming. Since the coefficient associated to this variable is significantly negative, information provided from radio emissions to cotton farmers bring them to self-select into conventional cotton farming. Radio emissions on cotton cultivation are probably more focused on conventional cotton system than organic cotton farming system.

4.2.2 Determinants of the returns on cotton production

The determinants of the returns on cotton production are analysed for organic as well as for conventional cotton farmers. The ESR model specification allow to estimate jointly the outcomes equations models for both groups of farmers. For organic cotton farmers the main determinants of the returns on cotton production are the household size, the off work status, the number of children going to school in the household and the knowledge on cotton production received from the neighbourhood. The household size has a significant positive effect on the return on cotton production for organic cotton farmers while the off work status, the number of children going to school in the household and the knowledge on cotton production received from the neighbourhood have respectively significant negative effect on the return on cotton production for organic cotton farmers. Within the sub-group of organic cotton farmers, a large farm' household is associated to higher returns on cotton production. Farmers with large household benefit more from a support at almost zero cost in terms of family labour and are able to produce more of output. Conducting off farm activities have a negative effect on the return on cotton production for organic cotton farmers although off farm activities constitute a source of diversification of farmer's livelihoods. Since organic farming relies essentially on natural management of farm for pests and weed control, it's a labour demanding technology. Conducting an off-arm activity which is also labour demanding could create a deficit of labour to fulfil properly the requirement of the organic cotton cultivation technology. This situation lead to a loss of cotton output. The number of children going to school in the household is also found to affect negatively the return on cotton production for the sub-group of organic cotton farmers. This result might also be explained by the deficit of labour force created by the partial participation of school children to farming activities. Finally the information on cotton production received from the neighbourhood which constitute a channel for the dissemination of the organic production technology has a significant negative impact on the return of cotton production for organic cotton producers. For conventional cotton farmers, the determinants of the return on cotton production are different from those observed in organic cotton farming. The determinants of the returns on cotton production in conventional cotton farming are the experience in cotton farming, the education level of the head of household and the soil fertility status. While the experience in cotton farming and the soil fertility status have a significant positive impact on the return on cotton production for conventionnal cotton farmers, the education level of the head of household is associated to a negative impact. Farmers with large experience in conventionnal cotton farming are more skilled and more efficient in terms of farm management than farmers with little experience. Combining fertile soils with the use of synthetic fertilisers ensure better productivity and net returns for conventionnal cotton farmers. The negative impact of the level of education of the head of household on the returns on cotton production is an unexpected result.

4.2.3 Determinants of non-cotton crops production value

The determinants of the value of non-cotton crops production are also analysed for organic as well as for conventional cotton farmers. For organic cotton farmers variables like the experience in cotton production, the number of school children in the household and the distance from household to cotton farm are found to affect significantly the value of non-cotton crops production. While for the variables "experience in cotton production" and "distance from household to cotton farm" the effects are positive, the number of school children in the household show a significant negative effect on the quantity of non-cotton crops production for organic cotton farmers. Within the subgroup of organic cotton farmers, the experience in cotton production impact positively the level of the production of non-cotton crops. Organic cotton farmers with large experience in organic cotton farming acquire skills and management practices that could be used to improve the productivity of non-cotton crops. The more the organic cotton farm is far from the household, the less the organic cotton farmer is likely to focus on the management of the cotton farm. Having the organic cotton farm too much distant from the household make its management difficult in terms of fertilisation since the compost and the manure mainly used for fertilisation in organic cotton production are generally produced at the surroundings of the household and carry on the cotton farm. This situation could bring an organic cotton farmer to be more focused on non-cotton crops farms than cotton crops farms. Regarding the case of conventional cotton farmers, the major determinants of the value of non-cotton crops production are: the age of the head of household, the number of school children in the household, the off farm work status of the head of household, the number of the relatives of the head of household growing cotton, the availability of safety equipment for cotton production and the soil fertility status. Variables like the age of the head of household, the off-farm work status and the soil fertility status show a significant positive impact on the value of non-cotton crops production for conventional cotton farmers while the number of school children, the number of relatives growing cotton and the availability of safety equipment for conventional cotton production show a significant negative impact on the value of non-cotton crops production. Farmers that have a complete safety equipment for conventionnal cotton production are more focused on cotton production rather than non-cotton crops production. A cotton farmer who has a large number of its relatives involved in cotton production might be more likely to prioritize cotton crops production rather than non-cotton crops production activities. The negative impact of the number of school children in the household on the value of non-cotton crops production in the case of conventionnal cotton farming is also due to the deficit of household labour force created by the children going to school during farming activities. The positive impact of the age of the head of household on the value of non-cotton crops production indicate that conventional cotton farmers are more and more involved in non-cotton crops production over time. Fertile soils guarantee higher productivity for cotton as well as for non-cotton crops production.

4.2.4 The average treatments and heterogeneity effects

The tables 10 and 11 present respectively the expected values of the returns on cotton production and the expected values of the quantity of non-cotton crops production in the actual and counterfactual conditions.

Table 10 : Expected values of the returns on cotton production

	Number of obs	Decision stage		Treatment effects
		To adopt	Not to adopt	
Farm households that adopt organic cotton farming	*79*	*A=133889.3 (5984.09)*	*B=98421.92 (7184.604)*	*ATT= 35467.38*** (11586.41)*
Farm households that adopt conventional cotton farming	*179*	*C=103613.3 (3427.395)*	*D=128878.7 (2617.56)*	*ATU= -25265.33*** (4566.312)*
Heterogeneity effects		*BH1= 30275.94*** (6896.112)*	*BH2= -30456.75*** (7646.578)*	*BH= 60732.7*

Source: Author by survey data

Table 11 : Expected values of the quantity of non-cotton crops production

	Number of obs	Decision stage		Treatment effects
		To adopt	Not to adopt	
Farm households that adopt organic cotton farming	*79*	*E=222285.8 (10802.09)*	*F=501007.1 (15611.33)*	*ATT= -278721.2*** (24720.78)*
Farm households that adopt conventional cotton farming	*179*	*G=289575.5 (9557.999)*	*H=185076.1 (5220.834)*	*ATU= 104499.4*** (10114.16)*
Heterogeneity effects		*-67289.68*** (14423.61)*	*315931*** (16461.19)*	*-383220.6*

Source: Author by survey data

The values (A) and (D) are the expected values of the returns on cotton production observed in the sample and (B) and (C) are the counterfactuals. The values (E) and (H) represent the expected values of the quantity of non-cotton crops produced observed in the sample and (F) and (G) are the counterfactuals. Organic cotton farmers have an expected value of returns on cotton production of 133889.3 FCFA while conventional cotton farmers have an expected value of returns on cotton production of 128878.7 FCFA. Regarding the treatments effects, farm household that are growing organic cotton would have gained 35467.37 FCFA less or relatively 36.03% less in terms of return on cotton production per ha if they were growing conventional cotton. Conventional cotton farmers would have gained 25265.33 FCFA less or relatively 19.6% less returns on cotton production per ha if they were growing organic cotton. The negative values of the covariance terms observed for both organic (-0.1736218) and conventional (-0.2433683*)* subgroups of farmers in the ESR model of the returns on cotton production indicate a positive selection into the group of organic cotton farmers and a negative selection into the group of conventional cotton farmers. From this perspective and regarding the results of the treatments effects described above, we conclude that organic cotton farmers have above (compare to a random experiment) average returns on cotton production whether they grow organic or conventional cotton but they are better off growing organic cotton. In contrast, conventional cotton farmers have below (compare to a random experiment) average returns on cotton production whether they grow organic or conventional cotton but they are better off growing conventional cotton. So, growing organic cotton has a significant positive impact on the returns on cotton production of organic cotton farmers. The base heterogeneity effect BH1= 30275.94 FCFA which is the difference between the expected value of the returns on cotton production for organic (A=133889.3 FCFA) and conventional (C=103613.3FCFA) cotton farmers in case they all decided to grow organic cotton indicate that organic cotton farmers farm would have gained 30275.94 FCFA more returns on cotton production than conventional cotton farmers if both groups of farmers were all growing organic cotton. These results also confirmed the presence of unobservable (skills, motivation) determinants of the adoption of organic cotton farming that have significant impact on the returns of cotton production. So in terms of the returns on cotton production, organic cotton farmers can be better off than conventional cotton farmers irrespective of the adoption of organic cotton farming. The base heterogeneity effect BH2= -30456.75 FCFA in contrast indicate that organic cotton farmers would have gained 30456.75 FCFA less returns on cotton production if both groups of farmers were all growing conventional cotton. Finally the transitional heterogeneity effects BH= 60732.7 FCFA indicate that the impact of the adoption of organic cotton on farm household returns on cotton production per ha is 60732.7 FCFA more for organic cotton farmers than conventional cotton farmers. Regarding the impact of the adoption of organic cotton faming on the quantity of non-cotton crops produced per hectare of cotton area, farm household that are growing organic cotton would have produced 278721.2 FCFA more or 1.25 times more of non-cotton crops per hectare of cotton crop area if they were growing conventional cotton. Growing organic cotton has a negative impact on the quantity of non-cotton crops produced. These results confirmed those found in (Coulter et al. 2011); (Meda et al; 2018) who emphasized the negative effect of the institutional organization of the cotton sector on the adoption of organic cotton farming which is however described by (Meda, 2018) to be the most sustainable cotton farming system. The base heterogeneity effects BH1= - 67289.68 FCFA indicate that organic cotton farmers would have produced 67289.68 FCFA less of non-cotton crops regardless of the fact that they are growing organic cotton. The transitional heterogeneity effect TH= -383220.6 FCFA which is the difference between the average treatments effects on the treated and the average treatment effects on the untreated confirmed that the adoption of organic cotton farming is more profitable to conventional cotton farmers than organic cotton farmers in terms of the quantity of non-cotton crops produced. In summary, we could say that the adoption of organic cotton farming has a significant positive impact on the returns on cotton production of organic cotton farmers but affect negatively their capacity to grow non-cotton crops. This state of facts does not incite to the adoption of organic cotton farming practices.

4.3 Analysis of the technical efficiency of organic cotton production

Before estimating a stochastic frontier model a pre-test is needed to check for the validity of the stochastic frontier specification. (Schmidt & Lin 1984) for this purpose proposed the OLS residual test. The OLS residual test is a simple test based on the distribution of the residuals of the OLS estimation of the production function. The logic behind the test is that for a production-type stochastic frontier model with a composite error term $\varepsilon_i = v_i - u_i; u_i \geq 0$ such that v_i follow a $N(0,\sigma_v^2)$ normal distribution (symmetrically distributed around 0), the distribution of the residuals of the OLS estimation of the production function should skewed to the left (negative skewness). Analogically for a cost-type stochastic production frontier model where the composite error term is $\varepsilon_i = v_i + u_i; u_i \geq 0$ and v_i follow a $N(0,\sigma_v^2)$ normal distribution, the residuals of the OLS estimation of the production function should skewed to the right (positive skewness). The test of the null hypothesis of no skewness of the distribution of the OLS estimation is opposed to the alternative hypothesis of presence of skewness. The OLS regression of the production function $Y_i = f(X_{i,}\beta)$ [12] in our case gives the following results:

Table 12: OLS regression of the production function

Number of observations : 74
F(4,69) = 14.96
Prob>F = 0.0000
R_squared = 0.4644
Adj R_squared = 0.4333
Root MSE = 0.83354

Ly	*coefficient*	*Standard*	*t_statistic*	*Prob>|t|*	*95% confidence interval*

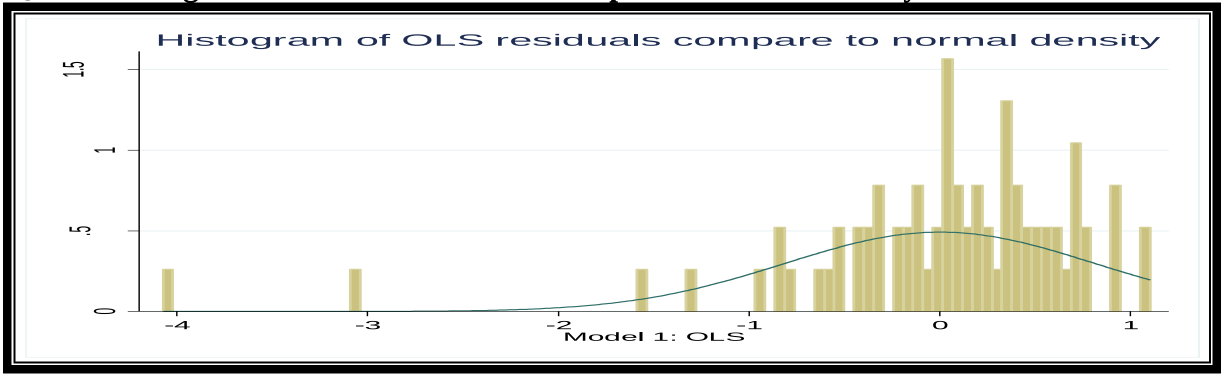
[12] Y_i is the quantity of cotton output (measured in Kg). The inputs X_i are categorized into four groups: land (hectare), labour (man-day), seeds (number of bags of 30 Kg used on the farm and batik (number of sachets of 12 g used on the farm). Batik is an organic insecticide.

		error				
Lseed	*0.7508108******	*0.2291818*	*3.28*	*0.002*	*0.2936056*	*1.208016*
Lland	*0.4242149**	*0.2185608*	*1.94*	*0.056*	*-0.0118019*	*0.8602318*
Lbatik	*0.936738*	*0.2322357*	*0.40*	*0.688*	*-0.3696237*	*0.5569713*
Llabour	*0.1921391*	*0.1916772*	*1.00*	*0.320*	*-0.1902464*	*0.5745247*
constant	*4.780623*	*0.923554*	*5.18*	*0.000******	*2.938183*	*6.623063*

Source: *author by survey data* *****p<0.01; **p<0.05; *p<0.1**

Following the OLS regression of the production function, the following graph represents the histogram of the residuals of the OLS estimation compared to the normal density function. The objective of plotting this graph is to get an overview of the skewness of the residuals of the OLS estimate before a more formal skewness test is conducted.

Figure 2: Histogram of the OLS residuals compare to normal density



Source: *Author by survey data*

As we observe it on the figure above, the OLS residuals graph seems to be skewed to the left. The shape of the histogram is announcing a possible presence of negative skewness in the OLS residuals. To confirm the negative skewness of the OLS residuals, we compute the skewness statistic. The results are summarised in the table 8 below:

Table 13: Skewness statistic of the OLS residuals

Variable	*Skewness statistic*	*Kurtosis statistic*	*Prob(Skewness)*	*Prob(Kurtosis)*	*-----joint----*	
					chi2(2)	*Prob>chi2*
OLS residuals (e)	*-2.517483*	*12.38538*	*0.0000*	*0.0000*	*61.95*	*0.0000*

Source: Author by survey data

As we can observe it from the table 8, the skewness of the OLS residuals (**-2.517493**) is negative and statistically significant at 1%[13]. The skewness statistic confirm that the distribution of the residuals of the OLS estimation of the production function is skewed to the left. The OLS residuals test predicts the validity of the stochastic frontier specification. Except the Model 3

[13]The p value of the skewness/kurtosis test of normality is less than 1%. The null hypothesis of no skewness is rejected

(heteroscedasticity of u_i and homoscedasticity of v_i) where the maximisation procedure failed to converge to a solution, the results of the estimation of the different models are presented in the table 9 below

Table 14: Results of stochastic frontier models estimation

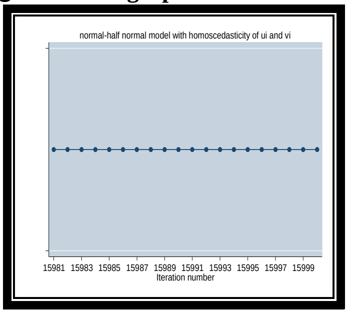
Distributional assumption	***Normal-Half normal assumption on the composite error term*** $\varepsilon_i = u_i - v_i$			
	Model 1 : homoscedasticity of u_i ***and*** v_i	***Model 2 : heteroscedasticity of*** u_i ***and*** v_i	***Model 3: heteroscedasticity of*** u_i ***and homoscedasticity of*** v_i	***Model 4 : homoscedasticity of*** u_i ***and heteroscedasticity of*** v_i
Determinants of production frontier				
Constant	*4.140393*	*4.448422********		*4.254417********
Lseed	*0.4615719********	*0.8535479********		*0.8620489********
Lland	*0.2359115********	*0.2102782********		*0.2428072*
Lbatik	*0 .6012989********	*0 .22978*		*0.0665505*
Llabour	*0 .3250849********	*0.3574573********		*0.4660274********
Exogenous determinants in σ_u^2				
constant		*-4.029024********		
exp_cotton		*0.501163********		
Hhsize		*0.0842287*		
dist_house		*0.1579213*********		
Educ		*-2.597335*		
farm_size		*-0.8834865********		
soil_fetility		*0.0725515********		
offfarm_work		*0.0114285*		
Exogenous determinants in σ_v^2				
constant		*4.605728**		*-3.816427*********
exp_cotton		*-0.4993842*		*0.0648769*
Hhsize		*-0.6870113********		*-0.1158407*
dist_house		*-1.400609********		*0.2711086********
Educ		*0.2910805*		*0.5044242*********
farm_size		*1.086245*		*0.0335912*
soil_fetility		*2.000601*********		*2.996871********
offfarm_work		*0.5475774*		*1.33972********
Number of iterations	*16000*	*21*		*12*
Log likelihood value	*-71.756431*	*-51.464486*		*-66.011147*
Wald chi2(4)	*6.27e+14*	*2434.43*		*219.73*

$prob > \chi^2$	*0.0000*	*0.0000*	*0.0000*

Source: *Author by survey data*

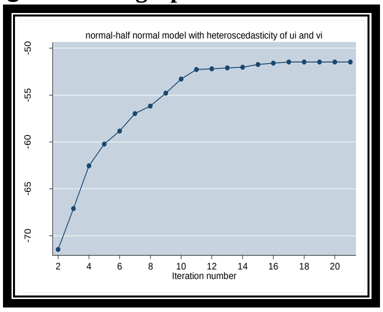
The associated maximum likelihood graphs are presented in the figures 3, 4, 5 below:

Figure 3: ML graph model 1



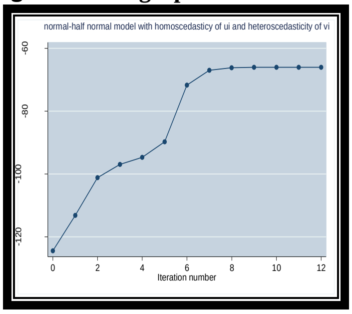
Source: *Author by survey data*

Figure 4: ML graph model 2



Source: *Author by survey data*

Figure 5: ML graph model 4



Source*: Author by survey data*

Source: *Author by survey data*

(Steenbergen 2003) suggested to check for convergence after the maximum likelihood estimation. For this author declaring convergence ensure more trustworthy estimators. He proposed three essential tools that can reveal a lot about the convergence of the estimator based on the iteration log likelihood value. First the author argued that when the algorithm requires a large number of iterations (in the hundreds), convergence problems are likely to occur. The estimation results in Model 1 clearly highlight this situation. This model required 16000 iterations[14] before the stochastic frontier model is computed. The warning message *convergence not achieved* appeared at the end of the iteration process meaning that the software Stata failed to establish a direction vector to guide parameters estimate. Secondly the warning message *not concave* which follow the iteration log likelihood value during the iteration process is also telling much about the convergence of the model according to (Steenbergen 2003). An early appearance of the warning message *not concave* in the iteration process should not worry us about convergence. But when the warning message *not concave* appears on the last iteration this could indicate serious problems about convergence. We encountered this issue with model 1. Lastly the author recommended to always plot the ml graph after running maximum likelihood estimation and to check for the concavity of this graph. He considered the ml graph as a powerful tool to monitor convergence. The ml graph is a plot between the iterations on the

[14] Default number of iterations used by the software Stata

horizontal axis and the corresponding log likelihood values on the vertical axis. This plot should ideally produce a marginally declining or concave graph to ensure convergence. A concave ml graph indicate that the changes in the log likelihood function are initially large between iterations and become relatively tiny nearing the end of the iterations. Small perturbations on the pattern of a concave ml graph can be safely ignored according to the author. However a straight line or convex ml graph indicate an ill-behaved log likelihood function. Based on the convergence criteria of the maximum likelihood estimator proposed by (Steenbergen 2003), we exclude model 1 and model 4 in addition to model 3 which failed to converge to a solution. Model 1 and model 4 present a non-concave ml graph and are expected to not achieve convergence. The ml graph in model 2 follow a concave pattern with small perturbations that can be safely ignored according to (Steenbergen 2003). Therefore we retained the model 2 for the rest of the analysis. Model 2 assumed a normal-half normal distributional assumption of the composite error term $\varepsilon_i = u_i - v_i$ with heteroscedasticity of u_i and v_i. The OLS residuals test performed at the beginning of the analysis to check for the existence of a one side error term in the model (inefficiency) is limited according to (Kumbhakar & Wang 2014). Although the OLS residuals test is useful as a preliminary analysis it should be supported by a more complete likelihood ratio test to confirm for the existence of inefficiency effects in the model. The OLS residuals test in fact does not take into account the information from the distribution functions of the error term. In our specific case for instance we consider four different sub models based on the assumptions of homoscedasticity or heteroscedasticity of the components of the composite error term. Unlike the OLS residuals test which is performed before the maximum likelihood estimation, the likelihood ratio test is a post estimation test that can be performed only after the maximum likelihood estimation. The likelihood ratio test is based on the null hypothesis that no one-side error can be constructed. For a half-normal model as in the case of this study the likelihood ratio test amounts to testing the null hypothesis $\sigma_u^2 = 0$. The likelihood ratio statistic is expressed as: $LR = [L(H_0) - L(H_1)]$ where $L(H_0)$ and $L(H_1)$ are the log likelihood values of the restricted model (OLS) and the unrestricted model (stochastic frontier model). The computed likelihood ratio statistic for the model 2 is $LR = 74.950874$. The critical values of the mix chi square distribution of degree of freedom 1 (only one restriction $\sigma_u^2 = 0$) are summarised on the table 10 below:

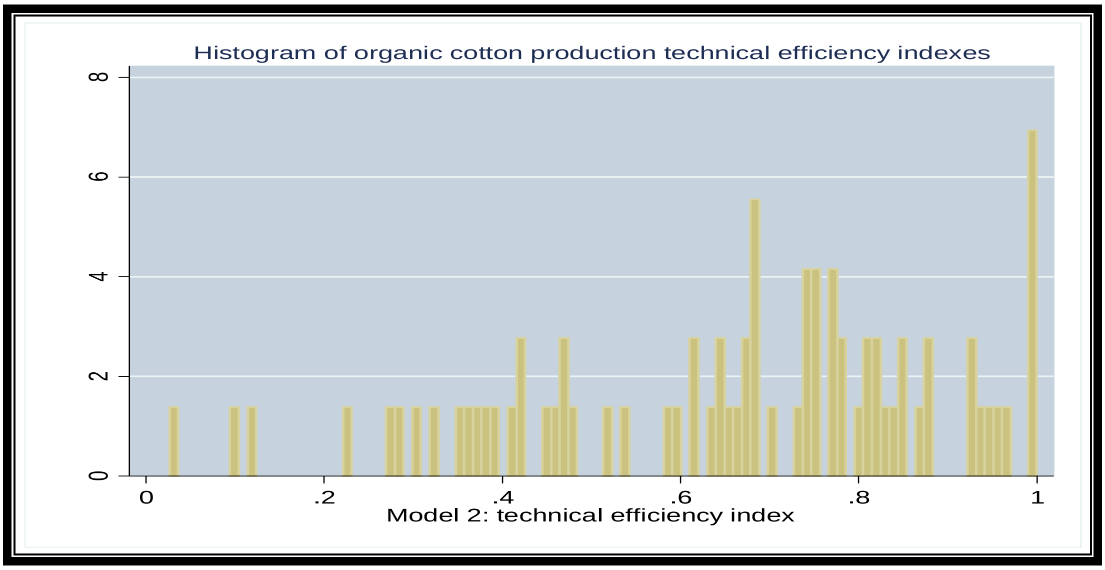
Table 15: Critical values of the mixed chi-square distribution

```
critical values of the mixed chi-square distribution

                              significance level
 dof  |  0.25     0.1       0.05      0.025     0.01      0.005     0.001
-------------------------------------------------------------------------
  1      0.455    1.642     2.705     3.841     5.412     6.635     9.500

source: Table 1, Kodde and Palm (1986, Econometrica).
```

Source: *Extracted from Stata*

Given that the likelihood ratio statistic of the model is **74.950874**, this result indicates and confirm a rejection of the null hypothesis of the absence of a one side error component or of the absence of technical inefficiency in the model 2. The coefficients of the model can now be interpreted. As this can be read on the table 9, seeds, land and labour are the major determinants of the frontier production function. These variables are respectively significant at 1%, 1% and 10% including the constant term which is significant at 1%. All the coefficients of the variables in the production function are positively significant except the coefficient associated to the variable batik which is positive but not significant. These results suggest that the production of organic cotton increases with a higher endowment in inputs like seeds, land and labour. A result that is consistent with standard production theory. The factor batik which is an industrially made organic insecticide is found to not be determinant in increasing organic cotton production. The largest estimated elasticity parameter is for seeds followed by labour and land. An increase of 1% in the quantity of seeds used is supposed to increase the level of organic cotton production by 0.8535479%. An increase of 1% of farm size or 1% of the quantity of labour force are supposed to increase organic cotton production respectively by 0.2102782% and 0.3574573%.The mean technical efficiency index equals **0.6538323** with a confidence interval of **[0.026201;   0.9998788]** at 95% . These findings imply that organic cotton farmers produce 65.38323% of the maximum output and 34.61677% of the potential output is lost due to technical inefficiency. So there is a great potential to increase organic cotton production by reducing technical inefficiencies. The histogram of technical efficiency indexes is reported on the figure 6 below:

Figure 6 : Histogram of technical efficiency indexes



Source: *Author by survey data*

The histogram gives a more complete view of the distribution of technical efficiency among organic cotton farmers. As we can read it on the histogram almost seven farmers tend to achieve full efficiency or to have an efficiency index close to one. Going through the dataset, we identified them as being those in the following table 10.

Table 16: most efficient farmers

Household_id	*23411*	*23401*	*11406*	*35525*	*35518*	*34513*	*34509*
Efficiency index	*0.9941*	*0.9998*	*0.9430*	*0.9525*	*0.9998*	*0.9916*	*0.9617*

Source: *Author by survey data*

A common feature to these farmers is that almost all are not conducting off farm activities in addition to having a mean education level of 2.14 compared to the full sample of organic cotton farmers where the mean education level is 0.29. We therefore expect the education level of the farmer and his off farm work status to play a significant role in reducing inefficiencies.

4.4 Exogenous determinants of inefficiencies in organic cotton production

Variables like the experience in cotton production, the distance from household to house, farm size and soil fertility status are found to significantly affect the variance σ_u^2 of the inefficiency term u_i and the unconditional mean of inefficiency $E(u)$. The sign of the influence and the marginal effects of the exogenous determinants on σ_u^2 and $E(u)$ are summarised on the table 11 below:

Table 17 : Marginal effects of exogenous determinants on σ_u^2 and $E(u)$

Variable	σ_u^2		$E(u)$	
	Sign of influence	***Marginal effect***	***Sign of influence***	***Marginal effect***
exp_cotton	+	*0.11081571****	+	*0.13221044****

hhsize	+	*0.0186244*	+	*0.02222014*
dist_house	+	*0.0349191***	+	*0.04166078***
educ	-	*-0.57431515*	-	*-0.68519578*
farm_size	-	*-0.19535398**	-	*-0.23307015**
soil_fetility	+	*0.01604238**	+	*0.01913961**
offfarm_work	+	*0.00252704*	+	*0.00301493*

Source: *Author by survey data*

As expected, the marginal effects of the exogenous determinants on the unconditional mean of inefficiency is positive for some variables (efficiency reducing factors) and negative for other (efficiency enhancing factors). Among the variables which are found to affect significantly the unconditional mean of inefficiency, farm size is revealed to be an efficiency enhancing factor while the experience in cotton production, the distance from household to cotton farm and the soil fertility status are revealed to be efficiency reducing factors. These results seem to be contradictory since we were expecting the experience in cotton production and soil fertility to contribute to enhance organic cotton farmers' technical efficiency and farm size to be an efficiency reducing factor. The findings of the present study however are inherent to the study area and reflect the general context of organic cotton production in Burkina Faso. Supported by the organic and fair trade cotton program under the coordination of the national union of cotton producers, organic cotton production in Burkina Faso face a number of issues such as the late payment of producers and the late beginning of cotton production activities. Though new entrants in the cotton sector are more likely to adopt the organic and fair trade cotton production scheme, farmers with more experience in cotton production are aware of the issues encountered by the organic and fair trade cotton program and are more reluctant to adopt organic cotton production. Many farmers exit the program after a certain period of time and those staying are less and less motivated. That's essentially the reason why the experience in organic cotton production has a positive effect on the unconditional mean of inefficiency. The positive effect of the distance from household to cotton farm on the unconditional mean of inefficiency is in fact an expected result. The more the producer is close to his cotton farm the more he is supposed to be technically efficient. Organic cotton production relies essentially on organic manure and compost for fertilisation. These inputs are generally produced around the household and carry on the farm. A long distance separating the household from the cotton farm can lead farmers to fail to fulfil the requirements of the organic cotton production technology in terms of fertilization. Being close to the cotton farm reduce the hardness of certain activities on the farm. Unlike the experience in cotton production and the distance from household to cotton farm, farm size is found to be an efficiency enhancing factor. Farmers with large farm size are more efficient than those with small farm size. This result was not expected in the context of organic farming since organic farming is hardly managed at a large scale due to the restrictions in inputs use and the requirements of the technology. As farm size is found here to be an efficiency enhancing factor, organic cotton farmers can therefore be recommended to increase the size of their farms. Soil fertility is also found to be an efficiency reducing factor. So farmers that have declared to have fertile soils are less likely to manage their farms in an efficient way.

Chapter V: Summary, conclusion, policy recommendations, suggestions for future research

5.1 Summary

Organic farming and agro-ecological practices are increasingly presented as the best alternative to food security in the long term since the green revolution technologies over the years has shown their limits in terms of land conservation, human and animals' exposure to toxic materials, biodiversity losses, ect. But still organic farming practices are weakly promoted all over the world and few countries so far have put in place a legislative framework to promote the development of this farming system. Sceptics worry about the ability of organic practices to feed the world since these farming practices are limited in terms of inputs utilization and may not be able to reach high level of productivity. Organic farming is perceived as an extensive farming system which represents a threat to the world's forests, wetlands and grasslands. For some authors organic farming is comparable to agriculture as it was practiced around the 1900s during which agricultural chemicals were not yet used in agriculture and where the world's population was around 3 billion inhabitants. So nowadays since organic farming is still achieving low productivity levels, this farming practice is considered to be unable to feed a world's population which is tending to 9 billion inhabitants. The question of the productivity of organic farming and its ability to impact rural populations' livelihoods is an essential barrier of its acceptance.

Based on organic cotton farming which is one of the earliest and well-structured organic sector in Burkina Faso, this study aims to examine the technical efficiency, the adoption and the impact of organic farming in the specific case of Burkina Faso. Given that the adoption and diffusion of innovations is essentially an informational process, a merged framework of the diffusion of innovation theory and the theory of planned behaviour serves as conceptual framework for this study. The adoption and impact of organic cotton production are investigated through an endogenous switching regression model to control for the endogeniety of the adoption decision while stochastic frontier analysis are applied to determine the technical efficiency of organic cotton farming and its exogenous determinants.

The results of the study revealed that factors such as the experience in cotton farming, the education of the head of household, the household size, the gender of the head of household and the knowledge provided to cotton farmers through radio emissions affect negatively the decision to grow organic cotton. While the age of the head of household has a positive impact on the decision to grow organic cotton.

Moreover the adoption of organic cotton farming has a significant positive impact on the returns on cotton production of organic cotton farmers but affect negatively their capacity to grow non-cotton crops. Organic cotton production contrary to popular beliefs can contribute to improve significantly organic cotton farm households' revenues.

The analysis of the technical efficiency of organic cotton farmers revealed that the mean technical efficiency of organic cotton farmers is about 0.6538323 with a confidence interval of [0.026201; 0.9998788] at 95%. These findings imply that organic cotton farmers produce 65.38323% of the maximum output and 34.61677% of the potential output is lost due to technical inefficiencies. Therefore there is a great potential to increase organic cotton production by reducing technical inefficiencies.

The analysis of the factors responsible of technical inefficiencies revealed that farm size is an efficiency enhancing factor while the experience in cotton production, the distance from household to cotton farm and the soil fertility status are efficiency reducing factors.

5.2 Conclusion

Globally we concluded that although organic cotton farming has a great potential to impact significantly cotton farmers livelihoods and to preserve ecosystems around farmlands, its rate of adoption still very low due to the weak productive efficiency of the organic cotton farming system. The weak technical efficiency achieved in organic cotton farming implies that the organic production technology is not yet well understood by farmers and policy measures should be oriented in the way to reduce technical inefficiencies. The low adoption of organic cotton farming due to the smallness of yields indicate that the adoption of organic cotton farming is more a profit oriented process as predicted by the treadmill of production theory than a simple social innovation aiming to change the relationship between agriculture and the environment as predicted by the ecological modernization theory. Policy measures should then seek to make organic cotton production more and more attractive in terms of profit seeking for farmers.

5.3 Policy recommendations

Policy measures should be put in place to reinforce the organic and fair trade cotton program in Burkina Faso. This passes through more support to organic cotton farmers in terms of equipment, the end of the late payment of cotton revenues to organic cotton farmers and the end of the late starting of the organic cotton growing season. In addition efforts should be made to extend organic cotton farms size and to ensure that organic cotton production is not practiced on marginal lands situated far from households. Institutional arrangements need also to be made to make organic cotton farming as attractive as conventional cotton farming in terms of the access to some facilities.

5.4 Suggestions for future research

The present study focused on one production zone among seven organic and fair trade cotton production zones. Extending the adoption and impact analysis to other production zones could allow to extend the sample size and could also allow to make comparison between production zones. Future studies could also include more outcome variables to analyse the social impacts (living conditions, food security, health conditions, children's' education, capacity building) of the adoption of organic cotton farming or to analyse the impact of the adoption of organic cotton farming on the structure of cotton production costs. A deep understanding of the socio-logical factors impacting farmers' decisions to adopt organic cotton farming constitute also an interesting subject for future researches. Regarding the efficiency analysis of organic cotton farming, future researches could focused on a comparative analysis of the environmental efficiency of organic and conventional cotton farming systems using DEA technics combined to Life Cycle Analysis.

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APPENDIX

ESR MODEL ESTIMATION

```
ESR model estimation for the outcome variable returns on cotton production
*outcome variable generation
.gen cr_ha =(cotton_outpout*cotton_price- credit_value)/farm_size
*falsification test
.probit cotton_type exp_cotton educ age hhsize offfarm_work educ_child gender rota-
tion dist_house relatives_numb safe_equip soil_fetili
> ty Neighbour_inf radio_inf farmer_ext

Iteration 0:   log likelihood = -157.74721
Iteration 1:   log likelihood = -70.949179
Iteration 2:   log likelihood = -67.433894
Iteration 3:   log likelihood = -67.226404
Iteration 4:   log likelihood = -67.225946
Iteration 5:   log likelihood = -67.225946

Probit regression                                 Number of obs   =        257
                                                  LR chi2(15)     =     181.04
                                                  Prob > chi2     =     0.0000
Log likelihood = -67.225946                       Pseudo R2       =     0.5738

------------------------------------------------------------------------------
   cotton_type |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+--------------------------------------------------------------
    exp_cotton |  -.1443342   .0353281    -4.09   0.000    -.2135761   -.0750923
          educ |  -.1351489   .0811716    -1.66   0.096    -.2942424    .0239446
           age |   .0295763   .0105179     2.81   0.005     .0089616    .0501911
        hhsize |  -.0542287   .0280128    -1.94   0.053    -.1091328    .0006754
  offfarm_work |   .4408549   .2773328     1.59   0.112    -.1027075    .9844173
    educ_child |    .074751   .0711604     1.05   0.294    -.0647208    .2142228
        gender |  -2.191995   .4607043    -4.76   0.000    -3.094959   -1.289031
      rotation |   .6538865    .413783     1.58   0.114    -.1571132    1.464886
    dist_house |   -.055874   .0436294    -1.28   0.200     -.141386    .0296379
relatives_numb |  -.0030546    .004131    -0.74   0.460    -.0111511     .005042
    safe_equip |   .1880956    .645579     0.29   0.771    -1.077216    1.453407
 soil_fetility |    .351683   .3148231     1.12   0.264    -.2653589    .9687249
 Neighbour_inf |   .4794462   .5431651     0.88   0.377    -.5851378     1.54403
     radio_inf |  -1.379204   .2912656    -4.74   0.000    -1.950074   -.8083334
    farmer_ext |  -.5779689   .3772089    -1.53   0.125    -1.317285     .161347
         _cons |    2.05616    .906578     2.27   0.023     .2792996     3.83302
------------------------------------------------------------------------------

.regress cr_ha exp_cotton educ age hhsize offfarm_work educ_child gender rotation
dist_house relatives_numb safe_equip soil_fetility Ne
> ighbour_inf radio_inf farmer_ext in 1/179

      Source |       SS       df       MS              Number of obs =     179
-------------+------------------------------           F( 15,   163) =    2.79
       Model |  2.2787e+11    15  1.5192e+10           Prob > F      =  0.0007
    Residual |  8.8806e+11   163  5.4482e+09           R-squared     =  0.2042
-------------+------------------------------           Adj R-squared =  0.1310
       Total |  1.1159e+12   178  6.2693e+09           Root MSE      =   73812

------------------------------------------------------------------------------
         cr_ha |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+--------------------------------------------------------------
    exp_cotton |   1898.157   760.8073     2.49   0.014     395.8478    3400.465
          educ |  -994.4291   2594.289    -0.38   0.702    -6117.176    4128.318
           age |  -1216.598   546.4004    -2.23   0.027    -2295.534   -137.6624
        hhsize |   551.0109   1152.264     0.48   0.633    -1724.277    2826.299
  offfarm_work |   19553.07   12850.55     1.52   0.130    -5821.948    44928.08
```

```
    educ_child |   3833.028   2644.844     1.45   0.149    -1389.546    9055.602
        gender |  -34047.61   45613.93    -0.75   0.456      -124118    56022.78
      rotation |  -979.8588   19074.83    -0.05   0.959    -38645.49    36685.78
    dist_house |   636.5918   1999.662     0.32   0.751    -3311.991    4585.174
relatives_numb |  -31.97906   323.4843    -0.10   0.921    -670.7391     606.781
    safe_equip |   21613.55   31457.21     0.69   0.493    -40502.63    83729.74
 soil_fetility |   32856.99   16595.42     1.98   0.049     87.27189    65626.71
 Neighbour_inf |   35825.45   33923.46     1.06   0.293    -31160.66    102811.6
     radio_inf |  -35642.21   24269.61    -1.47   0.144    -83565.58    12281.15
    farmer_ext |   5053.808   27271.37     0.19   0.853     -48796.9    58904.52
         _cons |   149915.5   64140.27     2.34   0.021     23262.59    276568.5
------------------------------------------------------------------------------

*ESR model
.movestay cr_ha exp_cotton educ age hhsize offfarm_work educ_child gender rotation
dist_house relatives_numb safe_equip soil_fetility N
> eighbour_inf farmer_ext, select(cotton_type = exp_cotton educ age hhsize
offfarm_work educ_child gender rotation dist_house relatives_
> numb safe_equip soil_fetility Neighbour_inf radio_inf farmer_ext)

Fitting initial values .....
initial:       log likelihood = -3341.5971
rescale:       log likelihood = -3341.5971
rescale eq:    log likelihood = -3320.1878
Iteration 0:   log likelihood = -3320.1878  (not concave)
Iteration 1:   log likelihood = -3319.8641  (not concave)
Iteration 2:   log likelihood = -3319.8627  (not concave)
Iteration 3:   log likelihood = -3319.8611
Iteration 4:   log likelihood = -3319.5004  (not concave)
Iteration 5:   log likelihood = -3319.4976  (not concave)
Iteration 6:   log likelihood = -3319.4965
Iteration 7:   log likelihood = -3319.4959
Iteration 8:   log likelihood = -3319.4935  (not concave)
Iteration 9:   log likelihood =  -3319.493
Iteration 10:  log likelihood = -3319.4929

Endogenous switching regression model             Number of obs   =        257
                                                  Wald chi2(14)   =      43.78
Log likelihood = -3319.4929                       Prob > chi2     =     0.0001

------------------------------------------------------------------------------
               |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+--------------------------------------------------------------
cr_ha0         |
    exp_cotton |   2143.584   818.0208     2.62   0.009     540.2927    3746.875
          educ |  -334.6711   2508.883    -0.13   0.894    -5251.991    4582.649
           age |  -1308.757   540.7214    -2.42   0.016    -2368.552   -248.9628
        hhsize |   725.1619   1108.332     0.65   0.513     -1447.13    2897.453
  offfarm_work |   17169.31      12541     1.37   0.171    -7410.595    41749.22
    educ_child |   3525.286   2539.845     1.39   0.165    -1452.718    8503.291
        gender |  -15997.69   45704.04    -0.35   0.726      -105576    73580.58
      rotation |  -1212.386   18456.58    -0.07   0.948    -37386.61    34961.84
    dist_house |   734.3171   1931.423     0.38   0.704    -3051.202    4519.837
relatives_numb |  -14.70515   311.7432    -0.05   0.962    -625.7107    596.3004
    safe_equip |   21658.12   30307.72     0.71   0.475    -37743.93    81060.17
 soil_fetility |   34225.68   15925.65     2.15   0.032     3011.987    65439.38
 Neighbour_inf |   34410.74   32781.16     1.05   0.294    -29839.15    98660.64
    farmer_ext |   3366.677   26353.88     0.13   0.898    -48285.97    55019.32
         _cons |   97591.82   59413.89     1.64   0.100    -18857.26    214040.9
---------------+--------------------------------------------------------------
cr_ha1         |
    exp_cotton |   -6273.01   6035.208    -1.04   0.299     -18101.8    5555.782
          educ |   1816.957   9142.766     0.20   0.842    -16102.53    19736.45
           age |   818.4947   936.1511     0.87   0.382    -1016.328    2653.317
        hhsize |   5697.012   2913.722     1.96   0.051    -13.77908     11407.8
  offfarm_work |  -40818.03   22372.74    -1.82   0.068    -84667.81     3031.74
    educ_child |  -20792.41   7691.165    -2.70   0.007    -35866.82   -5718.003
```

```
        gender |  20271.64   32014.68     0.63   0.527    -42475.97    83019.25
      rotation |  41474.88   44415.26     0.93   0.350    -45577.44    128527.2
    dist_house | -4165.579   3767.034    -1.11   0.269    -11548.83    3217.672
relatives_numb | -40.48023   248.8928    -0.16   0.871    -528.3012    447.3407
    safe_equip |  67564.32   61147.32     1.10   0.269    -52282.23    187410.9
 soil_fetility |  23539.05   25964.11     0.91   0.365    -27349.66    74427.77
 Neighbour_inf |   -135510   55826.25    -2.43   0.015    -244927.4   -26092.54
    farmer_ext | -2755.669   30336.82    -0.09   0.928    -62214.74     56703.4
         _cons |  246581.2   88611.75     2.78   0.005     72905.33      420257
---------------+----------------------------------------------------------------
select         |
    exp_cotton |  -.146495   .0362141    -4.05   0.000    -.2174733   -.0755166
          educ | -.1174203   .0809016    -1.45   0.147    -.2759846     .041144
           age |  .0296658   .0107648     2.76   0.006     .0085672    .0507644
        hhsize |  -.054631   .0282096    -1.94   0.053    -.1099208    .0006588
  offfarm_work |  .4439861   .2794491     1.59   0.112    -.1037241    .9916962
    educ_child |  .0809047   .0712146     1.14   0.256    -.0586733    .2204827
        gender |  -2.19249   .4666506    -4.70   0.000    -3.107108   -1.277871
      rotation |  .6654835   .4117665     1.62   0.106     -.141564    1.472531
    dist_house | -.0490862    .044765    -1.10   0.273     -.136824    .0386517
relatives_numb | -.0032911   .0041971    -0.78   0.433    -.0115173     .004935
    safe_equip |  .2045243   .6496817     0.31   0.753    -1.068828    1.477877
 soil_fetility |  .3521569   .3144134     1.12   0.263     -.264082    .9683958
 Neighbour_inf |  .4734734   .5435538     0.87   0.384    -.5918724    1.538819
     radio_inf | -1.452536    .293283    -4.95   0.000     -2.02736   -.8777119
    farmer_ext | -.5747628   .3783075    -1.52   0.129    -1.316232    .1667062
         _cons |   2.07646   .9232084     2.25   0.025      .267005    3.885915
---------------+----------------------------------------------------------------
         /lns0 |  11.17439   .0078735  1419.23   0.000     11.15895    11.18982
         /lns1 |  11.40252   .0137427   829.72   0.000     11.37558    11.42945
           /r0 | -.2483514   .2399841    -1.03   0.301    -.7187117    .2220089
           /r1 | -.1753987   .3721115    -0.47   0.637    -.9047238    .5539265
-------------+----------------------------------------------------------------
        sigma0 |  71281.02   561.2338                      70189.47    72389.55
        sigma1 |  89546.96   1230.615                      87167.19     91991.7
          rho0 | -.2433683   .2257703                     -.6161107    .2184319
          rho1 | -.1736218   .3608944                     -.7185902    .5034573
------------------------------------------------------------------------------
LR test of indep. eqns. :            chi2(2) =     1.38   Prob > chi2 = 0.5005
------------------------------------------------------------------------------
*Conditional expectations
. predict yc1_1, yc1_1

. predict yc1_2, yc1_2

. predict yc2_2, yc2_2

. predict yc2_1, yc2_1

. sum yc1_1 yc2_2 yc1_2 yc2_1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
       yc1_1 |        78    133889.3    52850.05   19532.58   291565.8
       yc2_2 |       179    128878.7    35020.56   45261.38   234933.8
       yc1_2 |       179    98421.92    96123.46  -195003.1   303513.2
       yc2_1 |        78    103613.3    30269.93   33818.71   180677.2

*ATT, ATU
*ATT
. ttest yc1_1 == yc1_2, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc1_1 |      78    133889.3     5984.09    52850.05    121973.4    145805.1
```

```
   yc1_2 |     179    98421.92    7184.604    96123.46    84243.96    112599.9
---------+--------------------------------------------------------------------
combined |     257    109186.3    5413.474    86784.58    98525.72    119846.9
---------+--------------------------------------------------------------------
    diff |            35467.37    11586.41                12650.13     58284.6
------------------------------------------------------------------------------
    diff = mean(yc1_1) - mean(yc1_2)                              t =   3.0611
Ho: diff = 0                                     degrees of freedom =      255

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9988         Pr(|T| > |t|) = 0.0024          Pr(T > t) = 0.0012

*ATU
. ttest yc2_1 == yc2_2, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc2_1 |      78    103613.3    3427.395    30269.93    96788.53    110438.2
   yc2_2 |     179    128878.7     2617.56    35020.56    123713.2    134044.1
---------+--------------------------------------------------------------------
combined |     257    121210.6    2217.563    35550.24    116843.6    125577.6
---------+--------------------------------------------------------------------
    diff |           -25265.33    4566.312               -34257.81   -16272.84
------------------------------------------------------------------------------
    diff = mean(yc2_1) - mean(yc2_2)                              t =  -5.5330
Ho: diff = 0                                     degrees of freedom =      255

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

*Base Heterogeniety (BH) effects:differences in outcome between adopters and non-
adopters groups
*BH1
. ttest  yc1_1 == yc2_1, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc1_1 |      78    133889.3     5984.09    52850.05    121973.4    145805.1
   yc2_1 |      78    103613.3    3427.395    30269.93    96788.53    110438.2
---------+--------------------------------------------------------------------
combined |     156    118751.3    3645.659    45534.26    111549.7    125952.9
---------+--------------------------------------------------------------------
    diff |            30275.94    6896.112                16652.75    43899.13
------------------------------------------------------------------------------
    diff = mean(yc1_1) - mean(yc2_1)                              t =   4.3903
Ho: diff = 0                                     degrees of freedom =      154

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

*BH2
. ttest yc1_2 == yc2_2, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc1_2 |     179    98421.92    7184.604    96123.46    84243.96    112599.9
   yc2_2 |     179    128878.7     2617.56    35020.56    123713.2    134044.1
---------+--------------------------------------------------------------------
combined |     358    113650.3    3902.074    73830.71    105976.4    121324.2
---------+--------------------------------------------------------------------
    diff |           -30456.75    7646.578                -45494.9   -15418.61
```

```
------------------------------------------------------------------------------
    diff = mean(yc1_2) - mean(yc2_2)                              t =  -3.9831
Ho: diff = 0                                     degrees of freedom =      356

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0001          Pr(T > t) = 1.0000

. *Transitional Heterogeniety (TH) is the difference between ATT and ATU
.end of do-file

ESR model estimation for the outcome variable non cotton crops production value
*outcome variable generation
gen ncr_ha= noncottonagri_value/farm_size
*falsification test
probit cotton_type exp_cotton educ age hhsize offfarm_work educ_child gender rota-
tion dist_house relatives_numb safe_equip soil_fetili
> ty Neighbour_inf radio_inf farmer_ext

Iteration 0:   log likelihood = -157.74721
Iteration 1:   log likelihood = -70.949179
Iteration 2:   log likelihood = -67.433894
Iteration 3:   log likelihood = -67.226404
Iteration 4:   log likelihood = -67.225946
Iteration 5:   log likelihood = -67.225946

Probit regression                                 Number of obs   =        257
                                                  LR chi2(15)     =     181.04
                                                  Prob > chi2     =     0.0000
Log likelihood = -67.225946                       Pseudo R2       =     0.5738

--------------------------------------------------------------------------------
   cotton_type |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
    exp_cotton |  -.1443342   .0353281    -4.09   0.000    -.2135761   -.0750923
          educ |  -.1351489   .0811716    -1.66   0.096    -.2942424    .0239446
           age |   .0295763   .0105179     2.81   0.005     .0089616    .0501911
        hhsize |  -.0542287   .0280128    -1.94   0.053    -.1091328    .0006754
  offfarm_work |   .4408549   .2773328     1.59   0.112    -.1027075    .9844173
    educ_child |    .074751   .0711604     1.05   0.294    -.0647208    .2142228
        gender |  -2.191995   .4607043    -4.76   0.000    -3.094959   -1.289031
      rotation |   .6538865    .413783     1.58   0.114    -.1571132    1.464886
    dist_house |   -.055874   .0436294    -1.28   0.200     -.141386    .0296379
relatives_numb |  -.0030546    .004131    -0.74   0.460    -.0111511     .005042
    safe_equip |   .1880956    .645579     0.29   0.771    -1.077216    1.453407
 soil_fetility |    .351683   .3148231     1.12   0.264    -.2653589    .9687249
 Neighbour_inf |   .4794462   .5431651     0.88   0.377    -.5851378     1.54403
     radio_inf |  -1.379204   .2912656    -4.74   0.000    -1.950074   -.8083334
    farmer_ext |  -.5779689   .3772089    -1.53   0.125    -1.317285     .161347
         _cons |    2.05616    .906578     2.27   0.023     .2792996     3.83302
--------------------------------------------------------------------------------

regress ncr_ha exp_cotton educ age hhsize offfarm_work educ_child gender rotation
dist_house relatives_numb safe_equip soil_fetility N
> eighbour_inf radio_inf farmer_ext in 1/179

      Source |       SS       df       MS              Number of obs =     179
-------------+------------------------------           F( 15,   163) =    3.62
       Model |  8.2605e+11    15  5.5070e+10           Prob > F      =  0.0000
    Residual |  2.4800e+12   163  1.5215e+10           R-squared     =  0.2499
-------------+------------------------------           Adj R-squared =  0.1808
       Total |  3.3060e+12   178  1.8573e+10           Root MSE      =  1.2e+05

--------------------------------------------------------------------------------
        ncr_ha |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
    exp_cotton |   186.8931   1271.386     0.15   0.883    -2323.618    2697.404
          educ |  -1927.981   4335.321    -0.44   0.657    -10488.61    6632.651
```

```
             age |   1559.677   913.0907     1.71   0.090    -243.3342    3362.688
          hhsize |   2717.476    1925.55     1.41   0.160    -1084.762    6519.714
    offfarm_work |   84583.39   21474.58     3.94   0.000     42179.16    126987.6
      educ_child |  -7072.492   4419.804    -1.60   0.111    -15799.95    1654.961
          gender |  -38348.79   76225.52    -0.50   0.616    -188865.6      112168
        rotation |   42590.59   31875.99     1.34   0.183    -20352.52    105533.7
      dist_house |  -3415.884   3341.639    -1.02   0.308    -10014.37    3182.599
  relatives_numb |  -1329.819   540.5752    -2.46   0.015    -2397.252   -262.3861
      safe_equip |  -82473.54    52568.2    -1.57   0.119      -186276    21328.93
   soil_fetility |   60313.47   27732.63     2.17   0.031     5551.928      115075
   Neighbour_inf |   36783.93   56689.56     0.65   0.517    -75156.68    148724.5
       radio_inf |   38392.67   40556.99     0.95   0.345    -41692.15    118477.5
      farmer_ext |  -9014.937   45573.23    -0.20   0.843    -99004.96    80975.08
           _cons |   41791.06   107184.9     0.39   0.697    -169858.9      253441
--------------------------------------------------------------------------------

*ESR model
movestay ncr_ha exp_cotton educ age hhsize offfarm_work educ_child gender rotation
dist_house relatives_numb safe_equip soil_fetility
> Neighbour_inf farmer_ext, select(cotton_type = exp_cotton educ age hhsize
offfarm_work educ_child gender rotation dist_house relatives
> _numb safe_equip soil_fetility Neighbour_inf radio_inf farmer_ext)



Fitting initial values .....
initial:       log likelihood = -3502.9722
rescale:       log likelihood = -3502.9722
rescale eq:    log likelihood = -3467.5137
Iteration 0:   log likelihood = -3467.5137  (not concave)
Iteration 1:   log likelihood = -3466.0259  (not concave)
Iteration 2:   log likelihood = -3465.9975  (not concave)
Iteration 3:   log likelihood = -3465.9975  (not concave)
Iteration 4:   log likelihood = -3465.9974
Iteration 5:   log likelihood = -3465.6999  (not concave)
Iteration 6:   log likelihood = -3465.6791
Iteration 7:   log likelihood = -3465.6663  (not concave)
Iteration 8:   log likelihood =  -3465.665
Iteration 9:   log likelihood = -3465.6641  (not concave)
Iteration 10:  log likelihood = -3465.6639  (not concave)
Iteration 11:  log likelihood = -3465.6637
Iteration 12:  log likelihood = -3465.6636  (not concave)
Iteration 13:  log likelihood = -3465.6613
Iteration 14:  log likelihood = -3465.6582  (not concave)
Iteration 15:  log likelihood = -3465.6572
Iteration 16:  log likelihood = -3465.6556  (not concave)
Iteration 17:  log likelihood = -3465.6533
Iteration 18:  log likelihood = -3465.6507  (not concave)
Iteration 19:  log likelihood = -3465.6499
Iteration 20:  log likelihood = -3465.6495  (not concave)
Iteration 21:  log likelihood =  -3465.638
Iteration 22:  log likelihood = -3465.6337  (not concave)
Iteration 23:  log likelihood = -3465.6335
Iteration 24:  log likelihood = -3465.6332  (not concave)
Iteration 25:  log likelihood = -3465.6249
Iteration 26:  log likelihood =  -3465.623  (not concave)
Iteration 27:  log likelihood = -3465.6226
Iteration 28:  log likelihood = -3465.6225  (not concave)
Iteration 29:  log likelihood = -3465.6192
Iteration 30:  log likelihood =  -3465.618
Iteration 31:  log likelihood = -3465.6179
Iteration 32:  log likelihood = -3465.6179

Endogenous switching regression model              Number of obs    =        257
                                                   Wald chi2(14)    =      61.63
Log likelihood = -3465.6179                        Prob > chi2      =     0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ncr_ha0						
exp_cotton	-1128.54	1326.619	-0.85	0.395	-3728.667	1471.586
educ	-3471.687	4207.707	-0.83	0.409	-11718.64	4775.268
age	2080.043	901.4472	2.31	0.021	313.2389	3846.847
hhsize	2572.696	1857.313	1.39	0.166	-1067.571	6212.963
offfarm_work	92291.46	20867.29	4.42	0.000	51392.32	133190.6
educ_child	-7081.015	4277.704	-1.66	0.098	-15465.16	1303.13
gender	-92742.72	73662.06	-1.26	0.208	-237117.7	51632.26
rotation	50633.93	30923.44	1.64	0.102	-9974.898	111242.8
dist_house	-3632.386	3226.012	-1.13	0.260	-9955.253	2690.481
relatives_numb	-1442.861	523.6475	-2.76	0.006	-2469.191	-416.5308
safe_equip	-85282.67	50640.26	-1.68	0.092	-184535.8	13970.41
soil_fetility	61520.65	26519.69	2.32	0.020	9543.015	113498.3
Neighbour_inf	53969.27	54574.54	0.99	0.323	-52994.85	160933.4
farmer_ext	-25220.8	43251.19	-0.58	0.560	-109991.6	59549.97
_cons	132260.7	95433.33	1.39	0.166	-54785.17	319306.6
ncr_ha1						
exp_cotton	22966.3	12187.96	1.88	0.060	-921.6645	46854.27
educ	25835.37	18582.84	1.39	0.164	-10586.32	62257.05
age	-1089.666	1912.448	-0.57	0.569	-4837.995	2658.662
hhsize	9626.473	6173.939	1.56	0.119	-2474.224	21727.17
offfarm_work	-32232.96	47573.02	-0.68	0.498	-125474.4	61008.44
educ_child	-26859.69	16303.47	-1.65	0.099	-58813.91	5094.538
gender	-35482.72	56466.1	-0.63	0.530	-146154.2	75188.81
rotation	-23373.4	91532.44	-0.26	0.798	-202773.7	156026.9
dist_house	14041.54	8141.857	1.72	0.085	-1916.204	29999.29
relatives_numb	-340.9082	553.7985	-0.62	0.538	-1426.333	744.517
safe_equip	15182.15	128111.2	0.12	0.906	-235911.2	266275.5
soil_fetility	64033.71	56129.83	1.14	0.254	-45978.73	174046.2
Neighbour_inf	-25542.75	116883.6	-0.22	0.827	-254630.4	203544.9
farmer_ext	30397.57	66420.34	0.46	0.647	-99783.89	160579
_cons	190025.5	187277.2	1.01	0.310	-177031.1	557082.2
select						
exp_cotton	-.1624695	.0342326	-4.75	0.000	-.2295642	-.0953748
educ	-.1901143	.0852458	-2.23	0.026	-.3571929	-.0230357
age	.0259986	.0100259	2.59	0.010	.0063483	.045649
hhsize	-.0689056	.0289655	-2.38	0.017	-.125677	-.0121342
offfarm_work	.4156596	.2779097	1.50	0.135	-.1290333	.9603526
educ_child	.0912637	.0773256	1.18	0.238	-.0602918	.2428191
gender	-2.70638	.6429218	-4.21	0.000	-3.966483	-1.446276
rotation	.6129015	.4151618	1.48	0.140	-.2008008	1.426604
dist_house	-.0503319	.0430346	-1.17	0.242	-.1346782	.0340143
relatives_numb	-.003178	.0039488	-0.80	0.421	-.0109175	.0045615
safe_equip	.326545	.6243169	0.52	0.601	-.8970937	1.550184
soil_fetility	.2797177	.3230224	0.87	0.387	-.3533945	.9128299
Neighbour_inf	.4654015	.5312144	0.88	0.381	-.5757597	1.506563
radio_inf	-1.327273	.2777175	-4.78	0.000	-1.871589	-.7829563
farmer_ext	-.5121593	.3639419	-1.41	0.159	-1.225472	.2011538
_cons	2.914623	.9958651	2.93	0.003	.9627628	4.866482
/lns0	11.69967	.0047828	2446.21	0.000	11.6903	11.70905
/lns1	12.21855	.0213207	573.08	0.000	12.17677	12.26034
/r0	.5591627	.2333267	2.40	0.017	.1018507	1.016475
/r1	-.7883714	.2991622	-2.64	0.008	-1.374719	-.2020243
sigma0	120532.2	576.4775			119407.6	121667.4
sigma1	202512.1	4317.695			194223.9	211153.9
rho0	.5073559	.1732661			.1015	.7684268
rho1	-.6574855	.1698382			-.8797631	-.19932

LR test of indep. eqns. : chi2(2) = 8.76 Prob > chi2 = 0.0125

```
*Conditional expectations
. predict yc1_1, yc1_1

. predict yc1_2, yc1_2

. predict yc2_2, yc2_2

. predict yc2_1, yc2_1

. sum yc1_1 yc2_2 yc1_2 yc2_1

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
       yc1_1 |        78    222285.8     95401.5  -15840.54   472041.3
       yc2_2 |       179    185076.1    69849.99   33359.61   363235.2
       yc1_2 |       179    501007.1    208865.3   137760.7    1096958
       yc2_1 |        78    289575.5    84413.96  -74457.41   449449.3

*ATT, ATU
* ATT
.ttest yc1_1 == yc1_2, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc1_1 |      78    222285.8    10802.09     95401.5    200776.1    243795.5
   yc1_2 |     179    501007.1    15611.33    208865.3      470200    531814.1
---------+--------------------------------------------------------------------
combined |     257    416414.6    13886.19    222612.5    389068.9    443760.3
---------+--------------------------------------------------------------------
    diff |           -278721.2    24720.78               -327404.1   -230038.3
------------------------------------------------------------------------------
    diff = mean(yc1_1) - mean(yc1_2)                              t = -11.2748
Ho: diff = 0                                     degrees of freedom =      255

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

*ATU
.ttest yc2_1 == yc2_2, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc2_1 |      78    289575.5    9557.999    84413.96    270543.1    308607.9
   yc2_2 |     179    185076.1    5220.834    69849.99    174773.4    195378.8
---------+--------------------------------------------------------------------
combined |     257    216791.8    5527.834    88617.91      205906    227677.7
---------+--------------------------------------------------------------------
    diff |            104499.4    10114.16                84581.52    124417.4
------------------------------------------------------------------------------
    diff = mean(yc2_1) - mean(yc2_2)                              t =  10.3320
Ho: diff = 0                                     degrees of freedom =      255

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
*Base Heterogeniety (BH) effects:differences in outcome between adopters and non-
adopters groups
* BH1
.ttest  yc1_1 == yc2_1, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
```

```
   yc1_1 |      78    222285.8    10802.09     95401.5    200776.1    243795.5
   yc2_1 |      78    289575.5    9557.999    84413.96    270543.1    308607.9
---------+--------------------------------------------------------------------
combined |     156    255930.7    7679.691    95919.31    240760.3      271101
---------+--------------------------------------------------------------------
    diff |           -67289.68    14423.61               -95783.36   -38796.01
------------------------------------------------------------------------------
    diff = mean(yc1_1) - mean(yc2_1)                              t =  -4.6652
Ho: diff = 0                                     degrees of freedom =      154

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

*BH2
.ttest yc1_2 == yc2_2, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   yc1_2 |     179    501007.1    15611.33    208865.3      470200    531814.1
   yc2_2 |     179    185076.1    5220.834    69849.99    174773.4    195378.8
---------+--------------------------------------------------------------------
combined |     358    343041.6    11723.89    221826.4      319985    366098.1
---------+--------------------------------------------------------------------
    diff |              315931    16461.19                283557.6    348304.4
------------------------------------------------------------------------------
    diff = mean(yc1_2) - mean(yc2_2)                              t =  19.1925
Ho: diff = 0                                     degrees of freedom =      356

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

*Transitional Heterogeniety (TH) is the difference between ATT and ATU
.end of do-file

STOCHASTIC FRONTIER MODEL
Pré-estimations tests
*generation of log variables and OLS estimation
. gen ly= log(cotton_outpout)

. gen lland= log(farm_size)

. gen lseed= log(seeds)

. gen lbatik= log(batik)
(184 missing values generated)

. gen llabour= log(labour)

. drop if _n<=179
(179 observations deleted)

. global xvar lseed lland lbatik llabour

. regress ly $xvar

      Source |       SS       df       MS              Number of obs =      74
-------------+------------------------------           F(  4,    69) =   14.96
       Model |  41.5632465     4  10.3908116           Prob > F      =  0.0000
    Residual |  47.9409345    69  .694796153           R-squared     =  0.4644
-------------+------------------------------           Adj R-squared =  0.4333
       Total |   89.504181    73  1.22608467           Root MSE      =  .83354

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

```
       lseed |   .7508108   .2291818     3.28   0.002     .2936056    1.208016
       lland |   .4242149   .2185608     1.94   0.056    -.0118019    .8602318
      lbatik |   .0936738   .2322357     0.40   0.688    -.3696237    .5569713
     llabour |   .1921391   .1916772     1.00   0.320    -.1902464    .5745247
       _cons |   4.780623    .923554     5.18   0.000     2.938183    6.623063
------------------------------------------------------------------------------

*histogram of OLS residuals and normal density
. predict e, residual
(5 missing values generated)
. label variable e "Model 1: OLS"
. histogram e, bin(100) normal
(bin=100, start=-4.0720677, width=.05173223)
. summarize e, detail

                        Model 1: OLS
-------------------------------------------------------------
      Percentiles      Smallest
 1%    -4.072068      -4.072068
 5%    -1.308918      -3.086671
10%    -.7857184      -1.538581       Obs                  74
25%    -.3164644      -1.308918       Sum of Wgt.          74

50%     .0893702                      Mean           2.45e-09
                        Largest       Std. Dev.      .8103858
75%     .4656928       .9296485
90%     .7248529       .9423074       Variance       .6567251
95%     .9296485       1.052076       Skewness      -2.517483
99%     1.101155       1.101155       Kurtosis       12.38538

. sktest e, noadj

                    Skewness/Kurtosis tests for Normality
                                                      ------- joint ------
    Variable |    Obs   Pr(Skewness)   Pr(Kurtosis)     chi2(2)    Prob>chi2
-------------+---------------------------------------------------------------
           e |     74     0.0000         0.0000        61.95         0.0000

end of do-file

*Models estimations
*A. normal-half normal distributional assumption of the composite error term

*model 1: homoscedasticity of ui an vi
sfmodel ly, prod dist(h) frontier($xvar) usigmas() vsigmas()

sf_srch, frontier($xvar) usigmas() n(1) nograph fast

ml max, difficult gtol(1e-5) nrtol(1e-5)
Iteration 15993: log likelihood = -71.756431  (not concave)
Iteration 15994: log likelihood = -71.756431  (not concave)
Iteration 15995: log likelihood = -71.756431  (not concave)
Iteration 15996: log likelihood = -71.756431  (not concave)
Iteration 15997: log likelihood = -71.756431  (not concave)
Iteration 15998: log likelihood = -71.756431  (not concave)
Iteration 15999: log likelihood = -71.756431  (not concave)
Iteration 16000: log likelihood = -71.756431  (not concave)
convergence not achieved

                                                  Number of obs   =         74
                                                  Wald chi2(4)    =   6.27e+14
Log likelihood = -71.756431                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
```

```
       lseed |   .4615719   1.80e-07  2.6e+06   0.000     .4615716    .4615723
       lland |   .2359115   2.63e-07  9.0e+05   0.000      .235911     .235912
      lbatik |   .6012989   2.30e-07  2.6e+06   0.000     .6012985    .6012994
     llabour |   .3250849   1.03e-07  3.2e+06   0.000     .3250847    .3250851
       _cons |   4.140393          .        .       .            .           .
-------------+----------------------------------------------------------------
usigmas      |
       _cons |   .4877839   .1643993     2.97   0.003     .1655672    .8100005
-------------+----------------------------------------------------------------
vsigmas      |
       _cons |  -57.98141   226381.2    -0.00   1.000    -443756.9      443641
------------------------------------------------------------------------------
convergence not achieved
r(430);
end of do-file
r(430);
ml graph
graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph model 1.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph model 1.gph saved)
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*model 2: heteroscedasticity of ui and vi
sfmodel ly, prod dist(h) frontier($xvar) usigmas(exp_cotton hhsize dist_house educ
farm_size soil_fetility offfarm_work) vsigmas(exp_cotton hhsize dist_house educ
farm_size soil_fetility
> offfarm_work)
sf_srch, frontier($xvar) usigmas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) n(1) nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -126.27562
rescale:       log likelihood = -126.27562
rescale eq:    log likelihood = -117.49584
Iteration 0:   log likelihood = -117.49584  (not concave)
Iteration 1:   log likelihood = -90.512849  (not concave)
Iteration 2:   log likelihood = -71.456362  (not concave)
Iteration 3:   log likelihood = -67.105062  (not concave)
Iteration 4:   log likelihood = -62.553192  (not concave)
Iteration 5:   log likelihood = -60.206426  (not concave)
Iteration 6:   log likelihood = -58.835442  (not concave)
Iteration 7:   log likelihood = -56.974215  (not concave)
Iteration 8:   log likelihood = -56.159617  (not concave)
Iteration 9:   log likelihood = -54.799095
Iteration 10:  log likelihood = -53.280631
Iteration 11:  log likelihood = -52.258773
Iteration 12:  log likelihood = -52.192379
Iteration 13:  log likelihood = -52.100295
Iteration 14:  log likelihood = -52.025916  (not concave)
Iteration 15:  log likelihood = -51.730667
Iteration 16:  log likelihood = -51.581738
Iteration 17:  log likelihood = -51.474453
Iteration 18:  log likelihood =  -51.46482
Iteration 19:  log likelihood = -51.464486
Iteration 20:  log likelihood = -51.464486
Iteration 21:  log likelihood = -51.464486

                                                  Number of obs   =         74
                                                  Wald chi2(4)    =    2434.43
Log likelihood = -51.464486                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
           ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier      |
        lseed |   .8535479   .0485664    17.57   0.000     .7583595    .9487362
        lland |   .2102782   .1083099     1.94   0.052    -.0020053    .4225618
       lbatik |     .22978   .1594536     1.44   0.150    -.0827433    .5423033
```

```
      llabour |   .3574573   .0558239     6.40   0.000     .2480445      .46687
        _cons |   4.448422   .3109578    14.31   0.000     3.838956    5.057888
--------------+----------------------------------------------------------------
usigmas       |
   exp_cotton |    .501163    .153133     3.27   0.001     .2010278    .8012982
       hhsize |   .0842287    .057226     1.47   0.141    -.0279322    .1963895
   dist_house |   .1579213   .0649469     2.43   0.015     .0306277    .2852148
         educ |  -2.597335   2.828124    -0.92   0.358    -8.140355    2.945686
    farm_size |  -.8834865   .4661722    -1.90   0.058    -1.797167    .0301943
soil_fetility |   .0725515   .5986512     0.12   0.904    -1.100783    1.245886
 offfarm_work |   .0114285   .4791703     0.02   0.981     -.927728     .950585
        _cons |  -4.029024   1.049832    -3.84   0.000    -6.086657   -1.971392
--------------+----------------------------------------------------------------
vsigmas       |
   exp_cotton |  -.4993842   .3278173    -1.52   0.128    -1.141894    .1431259
       hhsize |  -.6870113   .2306027    -2.98   0.003    -1.138984   -.2350383
   dist_house |  -1.400609   .4482478    -3.12   0.002    -2.279159   -.5220596
         educ |   .2910805   .2163311     1.35   0.178    -.1329206    .7150816
    farm_size |   1.086245   .8690834     1.25   0.211    -.6171275    2.789617
soil_fetility |   2.000601   .9743415     2.05   0.040     .0909267    3.910275
 offfarm_work |   .5475774   .8892604     0.62   0.538    -1.195341    2.290496
        _cons |   4.605728   2.655654     1.73   0.083    -.5992588    9.810714
-------------------------------------------------------------------------------
end of do-file
ml graph
graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph model 2.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph model 2.gph saved)
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*model 3: heteroscedasticity of ui and homoscedasticty of vi
sfmodel ly, prod dist(h) frontier($xvar) usigmas(exp_cotton hhsize dist_house educ
farm_size soil_fetility offfarm_work) vsigmas()
sf_srch, frontier($xvar) usigmas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) n(1) nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -126.27562
rescale:       log likelihood = -126.27562
rescale eq:    log likelihood = -117.49584
Iteration 0:   log likelihood = -117.49584  (not concave)
Iteration 1:   log likelihood = -109.66626  (not concave)
Iteration 2:   log likelihood = -102.81099  (not concave)
Iteration 3:   log likelihood = -76.167776
Iteration 4:   log likelihood = -64.827167
Iteration 5:   log likelihood = -60.742242
Iteration 6:   log likelihood = -59.729315
Iteration 7:   log likelihood = -59.636825
Iteration 8:   log likelihood =  -59.29241
Iteration 9:   log likelihood =  -59.23084
Iteration 10:  log likelihood = -59.218099
cannot compute an improvement -- discontinuous region encountered
r(430);
end of do-file
r(430);
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*model 4: homoscedasticity of ui and heteroscedasticity of vi
sfmodel ly, prod dist(h) frontier($xvar) usigmas() vsigmas(exp_cotton hhsize
dist_house educ farm_size soil_fetility offfarm_work)
sf_srch, frontier($xvar) usigmas() n(1) nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -129.42363
rescale:       log likelihood = -129.42363
rescale eq:    log likelihood = -124.44878
Iteration 0:   log likelihood = -124.44878  (not concave)
Iteration 1:   log likelihood = -113.16136  (not concave)
```

```
Iteration 2:   log likelihood = -101.15094  (not concave)
Iteration 3:   log likelihood = -96.909736  (not concave)
Iteration 4:   log likelihood = -94.661897  (not concave)
Iteration 5:   log likelihood = -89.706112  (not concave)
Iteration 6:   log likelihood = -71.656748
Iteration 7:   log likelihood = -66.980499
Iteration 8:   log likelihood = -66.175113
Iteration 9:   log likelihood = -66.013785
Iteration 10:  log likelihood = -66.011148
Iteration 11:  log likelihood = -66.011147
Iteration 12:  log likelihood = -66.011147

                                                Number of obs   =         74
                                                Wald chi2(4)    =     219.73
Log likelihood = -66.011147                     Prob > chi2     =     0.0000

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
       lseed |   .8620489   .1794549     4.80   0.000     .5103237    1.213774
       lland |   .2428072   .1673589     1.45   0.147    -.0852102    .5708245
      lbatik |   .0665505   .1241331     0.54   0.592    -.1767459     .309847
     llabour |   .4660274   .1225746     3.80   0.000     .2257856    .7062692
       _cons |   4.254417   .6212912     6.85   0.000     3.036709    5.472125
-------------+----------------------------------------------------------------
usigmas      |
       _cons |  -.9283352   .4203465    -2.21   0.027    -1.752199   -.1044711
-------------+----------------------------------------------------------------
vsigmas      |
  exp_cotton |   .0648769   .1911312     0.34   0.734    -.3097334    .4394872
      hhsize |  -.1158407   .1195298    -0.97   0.332    -.3501148    .1184333
  dist_house |   .2711086   .0855612     3.17   0.002     .1034118    .4388055
        educ |   .5044242   .2213943     2.28   0.023     .0704994    .9383491
   farm_size |   .0335912   .6873746     0.05   0.961    -1.313638    1.380821
soil_fetility |   2.996871   .7922992     3.78   0.000     1.443993    4.549749
 offfarm_work |    1.33972   .8132693     1.65   0.099    -.2542584    2.933698
       _cons |  -3.816427   1.827382    -2.09   0.037     -7.39803    -.234824
------------------------------------------------------------------------------
end of do-file
ml graph
graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph 4.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph 4.gph saved)
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*B. normal-exponential distributional assumption of the composite error term

*model 5: homoscedasticity of ui an vi
sfmodel ly, prod dist(e) frontier($xvar) etas() vsigmas()
sf_srch, n(1) frontier($xvar) etas() nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -129.98489
rescale:       log likelihood = -129.98489
rescale eq:    log likelihood = -123.74669
Iteration 0:   log likelihood = -123.74669  (not concave)
Iteration 1:   log likelihood =   -102.904  (not concave)
Iteration 2:   log likelihood = -86.854943  (not concave)
Iteration 3:   log likelihood = -76.729726
Iteration 4:   log likelihood = -70.999276
Iteration 5:   log likelihood = -70.477446
Iteration 6:   log likelihood = -69.112897
Iteration 7:   log likelihood = -69.083065
Iteration 8:   log likelihood = -69.083052
Iteration 9:   log likelihood = -69.083052

                                                Number of obs   =         74
```

```
                                                  Wald chi2(4)    =     173.52
Log likelihood = -69.083052                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
       lseed |   .6866208   .1418195     4.84   0.000     .4086596    .9645819
       lland |   .3513592   .1420391     2.47   0.013     .0729677    .6297507
      lbatik |   .1934433   .1493976     1.29   0.195    -.0993707    .4862573
     llabour |    .314825   .1133572     2.78   0.005      .092649     .537001
       _cons |   4.693605   .5532923     8.48   0.000     3.609172    5.778038
-------------+----------------------------------------------------------------
etas         |
       _cons |  -.8997338   .3361697    -2.68   0.007    -1.558614   -.2408532
-------------+----------------------------------------------------------------
vsigmas      |
       _cons |  -2.411893   .4080341    -5.91   0.000    -3.211625   -1.612161
------------------------------------------------------------------------------
end of do-file
ml graph
graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph model 5.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph model 5.gph saved)
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*model 6: heteroscedasticity of ui and vi
sfmodel ly, prod dist(e) frontier($xvar) etas(exp_cotton hhsize dist_house educ
farm_size soil_fetility offfarm_work) vsigmas(exp_cotton hhsize dist_house educ
farm_size soil_fetility off
> farm_work)
sf_srch, n(1) frontier($xvar) etas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)
Iteration 15995: log likelihood = -53.076061  (not concave)
Iteration 15996: log likelihood = -53.076061  (not concave)
Iteration 15997: log likelihood = -53.076061  (not concave)
Iteration 15998: log likelihood = -53.076061  (not concave)
Iteration 15999: log likelihood = -53.076061  (not concave)
Iteration 16000: log likelihood = -53.076061  (not concave)
convergence not achieved

                                                  Number of obs   =         74
                                                  Wald chi2(4)    =    1753.78
Log likelihood = -53.076061                       Prob > chi2     =     0.0000

-------------------------------------------------------------------------------
           ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
frontier      |
        lseed |   1.043399   .0572286    18.23   0.000     .9312333    1.155565
        lland |   .1350191   .0982569     1.37   0.169    -.0575609    .3275991
       lbatik |   .1919893   .0753893     2.55   0.011      .044229    .3397497
      llabour |   .4289432    .056337     7.61   0.000     .3185248    .5393616
        _cons |   4.073543   .2673691    15.24   0.000     3.549509    4.597577
--------------+----------------------------------------------------------------
etas          |
   exp_cotton |   .4074856   .1772746     2.30   0.022     .0600339    .7549374
       hhsize |   .0273148          .        .       .            .           .
   dist_house |   .1845886   .0998962     1.85   0.065    -.0112043    .3803815
         educ |  -3.231564   .0978087   -33.04   0.000    -3.423266   -3.039863
    farm_size |   -.186346          .        .       .            .           .
soil_fetility |    1.32543    .665987     1.99   0.047     .0201191     2.63074
 offfarm_work |   .2801932   .1049299     2.67   0.008     .0745345     .485852
        _cons |  -4.912234   1.235081    -3.98   0.000    -7.332948   -2.491521
--------------+----------------------------------------------------------------
vsigmas       |
   exp_cotton |  -.7099255    .231273    -3.07   0.002    -1.163212   -.2566388
```

```
         hhsize |  -.4000648     .08651    -4.62   0.000    -.5696212   -.2305083
     dist_house |  -.0679554   .1690455    -0.40   0.688    -.3992785    .2633677
           educ |   .4082436   .0753464     5.42   0.000     .2605674    .5559199
      farm_size |  -.1077495   .6620734    -0.16   0.871     -1.40539    1.189891
 soil_fetility |   .6905462   .8094053     0.85   0.394    -.8958591    2.276951
   offfarm_work |   .7257875   .2925759     2.48   0.013     .1523492    1.299226
          _cons |   2.986059   1.267553     2.36   0.018     .5017008    5.470417
------------------------------------------------------------------------------
convergence not achieved
r(430);
end of do-file
r(430);
ml graph
graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph model 6.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph model 6.gph saved)
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*model 7: heteroscedasticity of ui and homoscedasticty of vi
sfmodel ly, prod dist(e) frontier($xvar) etas(exp_cotton hhsize dist_house educ
farm_size soil_fetility offfarm_work) vsigmas()
sf_srch, n(1) frontier($xvar) etas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -127.18803
rescale:       log likelihood = -127.18803
rescale eq:    log likelihood = -117.95828
Iteration 0:   log likelihood = -117.95828  (not concave)
Iteration 1:   log likelihood = -96.226319  (not concave)
Iteration 2:   log likelihood = -68.437822  (not concave)
Iteration 3:   log likelihood = -65.854898  (not concave)
Iteration 4:   log likelihood = -63.457305  (not concave)
Iteration 5:   log likelihood = -62.454344  (not concave)
Iteration 6:   log likelihood =  -61.70536  (not concave)
Iteration 7:   log likelihood = -61.506925  (not concave)
Iteration 8:   log likelihood = -61.481353  (not concave)
Iteration 9:   log likelihood =   -61.4667
Iteration 10:  log likelihood = -61.464212
Iteration 11:  log likelihood = -61.462802  (not concave)
Iteration 12:  log likelihood = -61.462685  (not concave)
Iteration 13:  log likelihood = -61.462492
Iteration 14:  log likelihood = -61.462406
Iteration 15:  log likelihood = -61.462385  (not concave)
Iteration 16:  log likelihood =  -61.46238

                                                  Number of obs   =         74
                                                  Wald chi2(4)    =     145.57
Log likelihood =  -61.46238                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
            ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+---------------------------------------------------------------
frontier      |
         lseed |   .6857181    .146869     4.67   0.000     .3978601     .973576
         lland |   .3182541    .148942     2.14   0.033     .0263331    .6101751
        lbatik |   .2124648   .1444266     1.47   0.141    -.0706061    .4955358
       llabour |   .4186757   .1154808     3.63   0.000     .1923374     .645014
         _cons |   4.062831   .5705764     7.12   0.000     2.944522     5.18114
--------------+---------------------------------------------------------------
etas          |
    exp_cotton |   .3495776   .1728923     2.02   0.043     .0107149    .6884404
        hhsize |   .0015587   .0679338     0.02   0.982    -.1315891    .1347066
    dist_house |   .1636901   .0860516     1.90   0.057    -.0049679    .3323481
          educ |  -2.406308   4.223195    -0.57   0.569    -10.68362    5.871002
     farm_size |   .2056274   .6829327     0.30   0.763    -1.132896    1.544151
soil_fetility |   .7504247    .782569     0.96   0.338    -.7833824    2.284232
  offfarm_work |   1.030894   .6871135     1.50   0.134     -.315824    2.377611
```

```
        _cons |  -4.988467   1.581334    -3.15   0.002    -8.087825   -1.889108
-------------+----------------------------------------------------------------
vsigmas      |
        _cons |  -2.005142   .3048676    -6.58   0.000    -2.602671   -1.407612
end of do-file
. ml graph

. graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph model 7.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph model 7.gph saved)
do "C:\Users\HP\AppData\Local\Temp\STD03000000.tmp"

*model 8: homoscedasticity of ui and heteroscedasticity of vi
sfmodel ly, prod dist(e) frontier($xvar) etas() vsigmas(exp_cotton hhsize
dist_house educ farm_size soil_fetility offfarm_work)
sf_srch, n(1) frontier($xvar) etas() nograph fast
ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -129.98489
rescale:       log likelihood = -129.98489
rescale eq:    log likelihood = -123.74669
Iteration 0:   log likelihood = -123.74669  (not concave)
Iteration 1:   log likelihood = -96.712489  (not concave)
Iteration 2:   log likelihood = -84.130647  (not concave)
Iteration 3:   log likelihood = -77.945418  (not concave)
Iteration 4:   log likelihood = -70.125549  (not concave)
Iteration 5:   log likelihood = -69.749968  (not concave)
Iteration 6:   log likelihood = -66.690701  (not concave)
Iteration 7:   log likelihood = -63.431412  (not concave)
Iteration 8:   log likelihood = -62.263812  (not concave)
Iteration 9:   log likelihood = -62.131446  (not concave)
Iteration 10:  log likelihood = -61.844033
Iteration 11:  log likelihood =  -61.69516
Iteration 12:  log likelihood = -61.683016
Iteration 13:  log likelihood = -61.682994
Iteration 14:  log likelihood = -61.682994

                                                  Number of obs   =         74
                                                  Wald chi2(4)    =    1645.67
Log likelihood = -61.682994                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
           ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
        lseed |   .9276421   .0320684    28.93   0.000     .8647892     .990495
        lland |   .3857134   .0659602     5.85   0.000     .2564337    .5149931
       lbatik |   -.037942   .1275966    -0.30   0.766    -.2880268    .2121428
      llabour |   .3792224   .0799065     4.75   0.000     .2226085    .5358363
        _cons |   4.887354   .1477918    33.07   0.000     4.597688    5.177021
-------------+----------------------------------------------------------------
etas         |
        _cons |  -1.036963   .3011309    -3.44   0.001    -1.627168   -.4467571
-------------+----------------------------------------------------------------
vsigmas      |
   exp_cotton |   .3787826   .2213014     1.71   0.087    -.0549602    .8125255
       hhsize |  -.4673435   .3055053    -1.53   0.126    -1.066123    .1314359
   dist_house |   -.399197   .4325067    -0.92   0.356    -1.246895    .4485005
         educ |   .8703268    .380239     2.29   0.022     .1250721    1.615581
    farm_size |  -1.061939   1.242905    -0.85   0.393    -3.497989     1.37411
soil_fetility |   3.568368   1.876705     1.90   0.057    -.1099067    7.246643
 offfarm_work |  -.1097834   1.207965    -0.09   0.928    -2.477351    2.257784
        _cons |   -2.02187   2.084921    -0.97   0.332    -6.108241      2.0645
------------------------------------------------------------------------------
end of do-file
ml graph
graph save Graph "C:\Users\HP\Desktop\ml graphs\ml graph model 8.gph"
(file C:\Users\HP\Desktop\ml graphs\ml graph model 8.gph saved)
```

```
save "C:\Users\HP\Desktop\stata output2.dta"
file C:\Users\HP\Desktop\stata output2.dta saved

Post-estimation tests for selected model 2

. *Model 2 likeloihood ratio test
. *generation of log variables and OLS estimation
. gen ly= log(cotton_outpout)
. gen lland= log(farm_size)
. gen lseed= log(seeds)
. gen lbatik= log(batik)
(184 missing values generated)
. gen llabour= log(labour)
. drop if _n<=179
(179 observations deleted)
. global xvar lseed lland lbatik llabour
. sfmodel ly, prod dist(h) frontier($xvar) usigmas(exp_cotton hhsize dist_house
educ farm_size soil_fetility offfarm_work) vsigmas(exp_cotton hhsize dist_house
educ farm_size soil_fetility
> offfarm_work)
. sf_srch, frontier($xvar) usigmas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) n(1) nograph fast
. ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -126.27562
rescale:       log likelihood = -126.27562
rescale eq:    log likelihood = -117.49584
Iteration 0:   log likelihood = -117.49584  (not concave)
Iteration 1:   log likelihood = -90.512849  (not concave)
Iteration 2:   log likelihood = -71.456362  (not concave)
Iteration 3:   log likelihood = -67.105062  (not concave)
Iteration 4:   log likelihood = -62.553192  (not concave)
Iteration 5:   log likelihood = -60.206426  (not concave)
Iteration 6:   log likelihood = -58.835442  (not concave)
Iteration 7:   log likelihood = -56.974215  (not concave)
Iteration 8:   log likelihood = -56.159617  (not concave)
Iteration 9:   log likelihood = -54.799095
Iteration 10:  log likelihood = -53.280631
Iteration 11:  log likelihood = -52.258773
Iteration 12:  log likelihood = -52.192379
Iteration 13:  log likelihood = -52.100295
Iteration 14:  log likelihood = -52.025916  (not concave)
Iteration 15:  log likelihood = -51.730667
Iteration 16:  log likelihood = -51.581738
Iteration 17:  log likelihood = -51.474453
Iteration 18:  log likelihood =  -51.46482
Iteration 19:  log likelihood = -51.464486
Iteration 20:  log likelihood = -51.464486
Iteration 21:  log likelihood = -51.464486

                                                Number of obs   =         74
                                                Wald chi2(4)    =    2434.43
Log likelihood = -51.464486                     Prob > chi2     =     0.0000

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
       lseed |   .8535479   .0485664    17.57   0.000     .7583595    .9487362
       lland |   .2102782   .1083099     1.94   0.052    -.0020053    .4225618
      lbatik |     .22978   .1594536     1.44   0.150    -.0827433    .5423033
     llabour |   .3574573   .0558239     6.40   0.000     .2480445      .46687
       _cons |   4.448422   .3109578    14.31   0.000     3.838956    5.057888
-------------+----------------------------------------------------------------
usigmas      |
  exp_cotton |    .501163    .153133     3.27   0.001     .2010278    .8012982
      hhsize |   .0842287    .057226     1.47   0.141    -.0279322    .1963895
```

```
   dist_house |   .1579213   .0649469     2.43   0.015     .0306277    .2852148
         educ |  -2.597335   2.828124    -0.92   0.358    -8.140355    2.945686
    farm_size |  -.8834865   .4661722    -1.90   0.058    -1.797167    .0301943
soil_fetility |   .0725515   .5986512     0.12   0.904    -1.100783    1.245886
 offfarm_work |   .0114285   .4791703     0.02   0.981     -.927728     .950585
        _cons |  -4.029024   1.049832    -3.84   0.000    -6.086657   -1.971392
--------------+----------------------------------------------------------------
vsigmas       |
   exp_cotton |  -.4993842   .3278173    -1.52   0.128    -1.141894    .1431259
       hhsize |  -.6870113   .2306027    -2.98   0.003    -1.138984   -.2350383
   dist_house |  -1.400609   .4482478    -3.12   0.002    -2.279159   -.5220596
         educ |   .2910805   .2163311     1.35   0.178    -.1329206    .7150816
    farm_size |   1.086245   .8690834     1.25   0.211    -.6171275    2.789617
soil_fetility |   2.000601   .9743415     2.05   0.040     .0909267    3.910275
 offfarm_work |   .5475774   .8892604     0.62   0.538    -1.195341    2.290496
        _cons |   4.605728   2.655654     1.73   0.083    -.5992588    9.810714
-------------------------------------------------------------------------------

. scalar ll_h=e(ll)

. regress ly $xvar

      Source |       SS       df       MS              Number of obs =      74
-------------+------------------------------           F(  4,    69) =   14.96
       Model |  41.5632465     4  10.3908116           Prob > F      =  0.0000
    Residual |  47.9409345    69  .694796153           R-squared     =  0.4644
-------------+------------------------------           Adj R-squared =  0.4333
       Total |   89.504181    73  1.22608467           Root MSE      =  .83354

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lseed |   .7508108   .2291818     3.28   0.002     .2936056    1.208016
       lland |   .4242149   .2185608     1.94   0.056    -.0118019    .8602318
      lbatik |   .0936738   .2322357     0.40   0.688    -.3696237    .5569713
     llabour |   .1921391   .1916772     1.00   0.320    -.1902464    .5745247
       _cons |   4.780623    .923554     5.18   0.000     2.938183    6.623063
------------------------------------------------------------------------------

. scalar ll_ols=e(ll)

. display -2*(ll_ols - ll_h)
74.950874

. sf_mixtable, dof(1)

critical values of the mixed chi-square distribution

                              significance level
 dof  |  0.25     0.1       0.05      0.025     0.01      0.005     0.001
-----------------------------------------------------------------------
  1      0.455    1.642     2.705     3.841     5.412     6.635     9.500

source: Table 1, Kodde and Palm (1986, Econometrica).


. *estimation of efficiency index
. sfmodel ly, prod dist(h) frontier($xvar) usigmas(exp_cotton hhsize dist_house
educ farm_size soil_fetility offfarm_work) vsigmas(exp_cotton hhsize dist_house
educ farm_size soil_fetility
> offfarm_work)

. sf_srch, frontier($xvar) usigmas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) n(1) nograph fast

. ml max, difficult gtol(1e-5) nrtol(1e-5)
```

```
initial:       log likelihood = -126.27562
rescale:       log likelihood = -126.27562
rescale eq:    log likelihood = -117.49584
Iteration 0:   log likelihood = -117.49584  (not concave)
Iteration 1:   log likelihood = -90.512849  (not concave)
Iteration 2:   log likelihood = -71.456362  (not concave)
Iteration 3:   log likelihood = -67.105062  (not concave)
Iteration 4:   log likelihood = -62.553192  (not concave)
Iteration 5:   log likelihood = -60.206426  (not concave)
Iteration 6:   log likelihood = -58.835442  (not concave)
Iteration 7:   log likelihood = -56.974215  (not concave)
Iteration 8:   log likelihood = -56.159617  (not concave)
Iteration 9:   log likelihood = -54.799095
Iteration 10:  log likelihood = -53.280631
Iteration 11:  log likelihood = -52.258773
Iteration 12:  log likelihood = -52.192379
Iteration 13:  log likelihood = -52.100295
Iteration 14:  log likelihood = -52.025916  (not concave)
Iteration 15:  log likelihood = -51.730667
Iteration 16:  log likelihood = -51.581738
Iteration 17:  log likelihood = -51.474453
Iteration 18:  log likelihood =  -51.46482
Iteration 19:  log likelihood = -51.464486
Iteration 20:  log likelihood = -51.464486
Iteration 21:  log likelihood = -51.464486

                                                  Number of obs   =         74
                                                  Wald chi2(4)    =    2434.43
Log likelihood = -51.464486                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
       lseed |   .8535479   .0485664    17.57   0.000     .7583595    .9487362
       lland |   .2102782   .1083099     1.94   0.052    -.0020053    .4225618
      lbatik |     .22978   .1594536     1.44   0.150    -.0827433    .5423033
     llabour |   .3574573   .0558239     6.40   0.000     .2480445      .46687
       _cons |   4.448422   .3109578    14.31   0.000     3.838956    5.057888
-------------+----------------------------------------------------------------
usigmas      |
  exp_cotton |    .501163    .153133     3.27   0.001     .2010278    .8012982
      hhsize |   .0842287    .057226     1.47   0.141    -.0279322    .1963895
  dist_house |   .1579213   .0649469     2.43   0.015     .0306277    .2852148
        educ |  -2.597335   2.828124    -0.92   0.358    -8.140355    2.945686
   farm_size |  -.8834865   .4661722    -1.90   0.058    -1.797167    .0301943
soil_fetility |  .0725515   .5986512     0.12   0.904    -1.100783    1.245886
 offfarm_work |  .0114285   .4791703     0.02   0.981     -.927728     .950585
       _cons |  -4.029024   1.049832    -3.84   0.000    -6.086657   -1.971392
-------------+----------------------------------------------------------------
vsigmas      |
  exp_cotton |  -.4993842   .3278173    -1.52   0.128    -1.141894    .1431259
      hhsize |  -.6870113   .2306027    -2.98   0.003    -1.138984   -.2350383
  dist_house |  -1.400609   .4482478    -3.12   0.002    -2.279159   -.5220596
        educ |   .2910805   .2163311     1.35   0.178    -.1329206    .7150816
   farm_size |   1.086245   .8690834     1.25   0.211    -.6171275    2.789617
soil_fetility |  2.000601   .9743415     2.05   0.040     .0909267    3.910275
 offfarm_work |  .5475774   .8892604     0.62   0.538    -1.195341    2.290496
       _cons |   4.605728   2.655654     1.73   0.083    -.5992588    9.810714
------------------------------------------------------------------------------

. sf_predict, bc(bc_h) ci(95)
(5 missing values generated)

. summarize bc_h

    Variable |       Obs        Mean    Std. Dev.       Min        Max
```

```
-------------+---------------------------------------------------------
        bc_h |         74    .6538323    .2378466    .026201   .9998788
```

```
. list bc_h bc_h_95U bc_h_95L in 1/79
```

	bc_h	bc_h_95U	bc_h_95L
1.	.52188987	.75386915	.34722867
2.	.65097649	.97657379	.29374941
3.	.31985232	.32806846	.31178939
4.	.27298347	.5721836	.10868859
5.	.99416459	.99976907	.98368881
6.	.35939299	.38422438	.33576907
7.	.64500029	.69155523	.60080515
8.	.83644451	.99163771	.60819368
9.	.78304674	.78876685	.77735738
10.	.74611414	.78596888	.70777436
11.	.2888861	.30075153	.27737053
12.	.63482771	.66462628	.60602909
13.	.538408	.91149013	.26535456
14.	.37024512	.37453894	.36598782
15.	.99987702	.99999517	.99965456
16.	.93046482	.996142	.83221463
17.	.	.	.
18.	.85339038	.98556847	.70265051
19.	.84832934	.99259795	.62890056
20.	.42310842	.61933071	.2771419
21.	.92909373	.95072045	.90783308
22.	.35698585	.48296956	.25712897
23.	.6741083	.97845722	.32958911
24.	.47852779	.69190937	.31817731
25.	.64491521	.96596072	.3368989
26.	.42064846	.48504694	.36280358
27.	.76817382	.98497614	.49820094
28.	.29892744	.35862791	.24691658
29.	.94106841	.99709917	.85142912
30.	.02620102	.0323743	.0209448
31.	.72763339	.80344199	.65725008
32.	.94303359	.99827853	.81777676
33.	.61942194	.92644021	.37241855
34.	.7798587	.80766688	.75276514
35.	.68155527	.98008521	.33260953
36.	.88201924	.98151063	.77896078
37.	.6833613	.92583623	.47981356
38.	.82209862	.99182308	.55937676
39.	.59863686	.84160279	.41015435
40.	.45891814	.53146684	.39396825
41.	.95255527	.99562987	.89911245
42.	.68616769	.97753218	.36307782
43.	.68797756	.92633175	.48719676
44.	.75525794	.9844899	.47006324
45.	.74839665	.98808539	.40360366
46.	.38398378	.40168439	.36686685
47.	.70398678	.96904365	.44084777
48.	.99986964	.99999488	.9996338
49.	.47227442	.61200135	.35766986
50.	.58754579	.64067442	.53774848

```
     |----------------------------------|
 51. |   .7727101   .79641177   .74953426 |
 52. | .74221984   .74509323   .73935465 |
 53. | .46581899   .52235543   .41394134 |
 54. | .82323664    .9912668   .57368143 |
 55. | .80808456   .99208393   .50534065 |
     |----------------------------------|
 56. | .87296997   .99405987   .68126691 |
 57. |         .           .           . |
 58. | .74197509    .9849631   .43122197 |
 59. | .74720427    .9865631   .42502782 |
 60. | .67806776   .96708643   .39643597 |
     |----------------------------------|
 61. | .82968009   .99244994    .5707038 |
 62. |  .9998788   .99999524   .99965951 |
 63. | .87646566   .99491863   .67286878 |
 64. | .77393305   .98927184   .45818102 |
 65. |         .           .           . |
     |----------------------------------|
 66. | .44551423    .4455165   .44551196 |
 67. | .99163163   .99844368   .98432925 |
 68. | .39319764   .39398365   .39241279 |
 69. | .22149294   .22285107   .22014094 |
 70. |         .           .           . |
     |----------------------------------|
 71. |  .9617305   .99734583   .91256141 |
 72. | .11693423   .11746654   .11640371 |
 73. | .81395575   .99140891   .54157196 |
 74. |  .6107484   .62237264   .59928554 |
 75. | .09636436   .09636437   .09636436 |
     |----------------------------------|
 76. | .66225152   .66278431   .66171905 |
 77. | .41053545   .41486606   .40623838 |
 78. | .79638464   .88642933   .71328561 |
 79. |         .           .           . |
     +----------------------------------+

. *marginal effects of exogenous determinants of inefficiency
. sfmodel ly, prod dist(h) frontier($xvar) usigmas(exp_cotton hhsize dist_house
educ farm_size soil_fetility offfarm_work) vsigmas(exp_cotton hhsize dist_house
educ farm_size soil_fetility
> offfarm_work)

. sf_srch, frontier($xvar) usigmas(exp_cotton hhsize dist_house educ farm_size
soil_fetility offfarm_work) n(1) nograph fast

. ml max, difficult gtol(1e-5) nrtol(1e-5)

initial:       log likelihood = -126.27562
rescale:       log likelihood = -126.27562
rescale eq:    log likelihood = -117.49584
Iteration 0:   log likelihood = -117.49584  (not concave)
Iteration 1:   log likelihood = -90.512849  (not concave)
Iteration 2:   log likelihood = -71.456362  (not concave)
Iteration 3:   log likelihood = -67.105062  (not concave)
Iteration 4:   log likelihood = -62.553192  (not concave)
Iteration 5:   log likelihood = -60.206426  (not concave)
Iteration 6:   log likelihood = -58.835442  (not concave)
Iteration 7:   log likelihood = -56.974215  (not concave)
Iteration 8:   log likelihood = -56.159617  (not concave)
Iteration 9:   log likelihood = -54.799095
Iteration 10:  log likelihood = -53.280631
Iteration 11:  log likelihood = -52.258773
Iteration 12:  log likelihood = -52.192379
Iteration 13:  log likelihood = -52.100295
Iteration 14:  log likelihood = -52.025916  (not concave)
Iteration 15:  log likelihood = -51.730667
```

```
Iteration 16:  log likelihood = -51.581738
Iteration 17:  log likelihood = -51.474453
Iteration 18:  log likelihood =  -51.46482
Iteration 19:  log likelihood = -51.464486
Iteration 20:  log likelihood = -51.464486
Iteration 21:  log likelihood = -51.464486

                                                Number of obs   =         74
                                                Wald chi2(4)    =    2434.43
Log likelihood = -51.464486                     Prob > chi2     =     0.0000

------------------------------------------------------------------------------
          ly |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
frontier     |
       lseed |   .8535479   .0485664    17.57   0.000     .7583595    .9487362
       lland |   .2102782   .1083099     1.94   0.052    -.0020053    .4225618
      lbatik |     .22978   .1594536     1.44   0.150    -.0827433    .5423033
     llabour |   .3574573   .0558239     6.40   0.000     .2480445      .46687
       _cons |   4.448422   .3109578    14.31   0.000     3.838956    5.057888
-------------+----------------------------------------------------------------
usigmas      |
  exp_cotton |    .501163    .153133     3.27   0.001     .2010278    .8012982
      hhsize |   .0842287    .057226     1.47   0.141    -.0279322    .1963895
  dist_house |   .1579213   .0649469     2.43   0.015     .0306277    .2852148
        educ |  -2.597335   2.828124    -0.92   0.358    -8.140355    2.945686
   farm_size |  -.8834865   .4661722    -1.90   0.058    -1.797167    .0301943
soil_fetility |   .0725515   .5986512     0.12   0.904    -1.100783    1.245886
 offfarm_work |   .0114285   .4791703     0.02   0.981     -.927728     .950585
       _cons |  -4.029024   1.049832    -3.84   0.000    -6.086657   -1.971392
-------------+----------------------------------------------------------------
vsigmas      |
  exp_cotton |  -.4993842   .3278173    -1.52   0.128    -1.141894    .1431259
      hhsize |  -.6870113   .2306027    -2.98   0.003    -1.138984   -.2350383
  dist_house |  -1.400609   .4482478    -3.12   0.002    -2.279159   -.5220596
        educ |   .2910805   .2163311     1.35   0.178    -.1329206    .7150816
   farm_size |   1.086245   .8690834     1.25   0.211    -.6171275    2.789617
soil_fetility |   2.000601   .9743415     2.05   0.040     .0909267    3.910275
 offfarm_work |   .5475774   .8892604     0.62   0.538    -1.195341    2.290496
       _cons |   4.605728   2.655654     1.73   0.083    -.5992588    9.810714
------------------------------------------------------------------------------

. sf_predict, bc(bc_e) marginal
(5 missing values generated)

The following is the marginal effect on unconditional E(u).

The average marginal effect of exp_cotton on uncond E(u) is .13221044 (see
exp_cotton_M).
The average marginal effect of hhsize on uncond E(u) is .02222014 (see hhsize_M).
The average marginal effect of dist_house on uncond E(u) is .04166078 (see
dist_house_M).
The average marginal effect of educ on uncond E(u) is -.68519578 (see educ_M).
The average marginal effect of farm_size on uncond E(u) is -.23307015 (see
farm_size_M).
The average marginal effect of soil_fetility on uncond E(u) is .01913961 (see
soil_fetility_M).
The average marginal effect of offfarm_work on uncond E(u) is .00301493 (see
offfarm_work_M).

The following is the marginal effect on uncond V(u).

The average marginal effect of exp_cotton on uncond V(u) is .11081571 (see
exp_cotton_V).
The average marginal effect of hhsize on uncond V(u) is .0186244 (see hhsize_V).
The average marginal effect of dist_house on uncond V(u) is .0349191 (see
dist_house_V).
```

```
The average marginal effect of educ on uncond V(u) is -.57431515 (see educ_V).
The average marginal effect of farm_size on uncond V(u) is -.19535398 (see
farm_size_V).
The average marginal effect of soil_fetility on uncond V(u) is .01604238 (see
soil_fetility_V).
The average marginal effect of offfarm_work on uncond V(u) is .00252704 (see
offfarm_work_V).

. label variable bc_e "Model 2"

. *histogram of efficency scores
. histogram bc_e, bin(100) `kden´
(bin=100, start=.02620102, width=.00973678)
```

RESEARCH TIMELINE

	2017				2018				2019			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Research proposal writting												
Literature review												
Data collection												
Data analysis and interpretation												
Submission of articles to peer reviwed journals												
First draft of dissertation												
Review and revise first draft												
Dissertation due												
Thesis defence												