An analysis of the Impact of Land Tenure Security on Agricultural Productivity in Burkina Faso

Doubahan Adeline Coulibaly

Research Paper 466

AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

Bringing Rigour and Evidence to Economic Policy Making in Africa

An Analysis of the Impact of Land Tenure Security on Agricultural Productivity in Burkina Faso

By

Doubahan Adeline Coulibaly

Institute of Training and Research in Management Science and Economics (UFR/SEG) Université Ouaga 2, Ouagadougou, Burkina Faso

AERC Research Paper 466
African Economic Research Consortium, Nairobi
September 2021

This research study was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

ISBN 978-9966-61-164-2

© 2021, African Economic Research Consortium.

Contents

List of tables

Acknowledgments

This research received grant support from African Economic Research Consortium (AERC). The authors acknowledge the members of the AERC research network who acted as resources for their valuable comments and colleagues who provided expertise that greatly assisted this research.

Abstract

This article examines the impact of land tenure security on agricultural productivity in Burkina Faso through a two-stage approach, using data from the Permanent Agricultural Survey (EPA) of the agricultural campaign (2011/2012) of the Ministry of Agriculture. First, productivity scores are calculated using the scholastic frontier method, then an interval regression model is used which combines the endogenous variable with an endogenous treatment variable to estimate the impact of land tenure on agricultural productivity. This method allows us to specifically cater for the double censorship of the levels of productivity and the endogeneity of land tenure security . The analyses show that, on average, farmers in Burkina Faso are not efficient (0.408). The results demonstrate that land tenure security has a positive and significant impact on agricultural production of farms in Burkina Faso to the order of 0.661. This impact could be explained through the adoption of water and soil conservation techniques. The direct impact of land tenure security on productivity is to the order of 0.308.

Key words: Land tenure security, agricultural productivity, Burkina Faso

1.0 Introduction

Background

Agriculture is a source of growth and a tool for poverty reduction in so far as there are direct upstream and downstream links that exist within the rural sector and with other sectors of the economy that produce a growth stimulus effect and income generation (Hirschman, 1958; Adelman, 1984). However, agriculture in Africa is characterized by low productivity growth and is not very well exploited in regard to its potential. The productivity of agriculture in Burkina Faso remains low as its corollary food insecurity and poverty. According to the 2013 World Development Indicators (World Bank, 2013), yields from cereals in 2012 were only 1,417 kg/ha and 1,230 kg/ha respectively in sub-Saharan Africa and in Burkina Faso, against 5,922 kg/ha, 5,837 kg/ha and 7,524 kg/ha in United States of America, China and France respectively.

In Burkina Faso, family agriculture is the most common type, practised by more than 70% of the active population and representing close to 34% of the gross domestic product (GDP) (World Bank, 2013). During the period 2000 to 2006, the Burkina Faso economy recorded an average growth rate of 6%, which was largely based on the agriculture sector. In 2005, the year during which growth was highest (7.4%), the agriculture sector contributed to close to four percentage points (or 54%). Considering the significance of the sector in the development of the country and the improvement of the household food situation, the government committed to higher investments in agriculture. Thus, over the period 2004 to 2013, public expenditure estimated for the agriculture sector surpassed the set target of 10% of the national budget that had been established by the Maputo Declaration of 2004. Indeed, expenditure in agriculture tripled over the period, increasing from FCFA65 billion in 2004 to FCFA197 billion in 2013 (MASA, 2014).

Statement of the problem

Land tenure security is one of the factors that contributes to growth of agricultural productivity because it leads to investment, provides access to finance and allows for land transfer. According to Deville (2010), “we talk of land tenure security when the rights that we legitimately own (whether acquired formally or through customary

means) are not contested without reason and that, in case of unfounded contestation, the legitimate rights are confirmed". In other words, land tenure security is the process through which rights are recognized and guaranteed. When property rights are poorly defined, it leads to conflicts among farmers or between farmers and pastoralists, and to expropriations. We note the foundations of a land crisis that is progressively taking place in the rural areas of Burkina Faso. The actors are always fighting for the control, use and development of land and natural resources. Development by rural entrepreneurs or agrobusiness and the low efficiency of judicial and institutional mechanisms of land and conflict management in rural areas are the elements that contribute to land insecurity in these areas. To bring about lasting and effective responses to the problem of land security for rural actors, the Government of Burkina Faso has undertaken a series of actions since the 1980s. In addition to updating the Agrarian and Land Reforms (RAF) of the 1980s to the 1990s, Burkina Faso formulated and adopted a National Policy for Land Tenure Security in Rural Areas (PNSFMR) in 2007 whose implementing instrument is Act N° 034-2009/AN on rural land reform.

Theoretically, when the rights are well defined and the duration of rights of ownership cover a period necessary to allow for a return of investment, producers are more likely to invest (Feder and Onchan, 1987; Besley, 1995). According to Dorner and Saliba (1981), when property rights are well established, budgetary constraints of farmers come undone in so far as the land acquires market value that could be used as a guarantee for access to finance. This aspect is particularly significant in relation to sources of finance in the formal sector. Finally, well defined land rights could contribute to an improvement in efficiency because they allow for land transfer from a less effective land owner to a more efficient farmer (Feder and Feeny, 1991). The question of the empirical relationship between land tenure security and agricultural productivity has been the subject of discussion in several research studies. Whereas several researchers find that land tenure security has a positive impact on productivity (Bangwayo-Skeete et al, 2010; Newman et al, 2015), others do not find for a relationship between land tenure security and productivity (Place and Hazell, 1993; Place and Otsuka, 2002).

In a context where the aim of agricultural policy is to improve productivity, the objective of this study is to examine the effect of land tenure security on the productivity of farms. More specifically, the study measures the levels of technical efficiency of farms, examines the determinants of land tenure security and, finally, evaluates the impact of land security tenure on technical efficiency of farms in Burkina Faso.

In this paper, technical efficiency was calculated using a stochastic frontier method and the Cobb-Douglas Production Function. To control the endogenous character of land tenure security to take into account the double censor of technical efficiency of farms (measurement is between zero and one), we use an interval regression model (Bettin and Lucchetti, 2012) that combines an endogenous variable and an endogenous treatment variable. This model is referred to as the extended regression

model (STATA, 2017). The empirical analysis used data from the Permanent Empirical Survey of 2011/2012.

The rest of the paper is organized as follows: Section 2 covers the literature review on the relationship between land tenure security and agricultural productivity, while giving a background on the situation in Burkina Faso in terms of land tenure security. Sections 3 and 4 present the theoretical framework and the methodology respectively. Section 5 presents the data and descriptive statistics of the variables used. The empirical results are discussed in Section 6 and the last section presents that conclusion and some recommendations.

2.0 Literature review

Land tenure security and agricultural productivity

Most theoretical literature suggests that improved land tenure security improves the productivity of farms. The main ways by which property rights affect the efficiency of resource allocation can be placed in two categories: investment and more flexibility in terms of financial transactions.

According to Feder and Noronha (1987), the absence of land tenure security has the effect of increasing uncertainty and reducing expectations of gains enjoyed by the producers. There follows a reduction in investment incentives, which leads to low productivity levels. Furthermore, the existing ambiguities in terms of land rights lower the impetus of farmers to undertake improvements and to adopt new technologies that would as a result be likely to increase their productivity (Ely and Wehrwein, 1940; Harrison, 1987). Various researchers have suggested that partial or incompatible property rights encourage farmers to adapt measures that lead to soil degradation and to deforestation. Hardin (1968) argues that when property rights are non-existent, natural resources are subjected to over-exploitation because the costs are borne by the community, but all the potential advantages will benefit an individual. Coase (1960) also asserted that the absence of clearly defined property rights inevitably leads to the degradation of soils and other natural resources. Property rights, however, provide security in regard to expropriation and this contributes to improving incentives from farmers to invest in production factors and to maintain their farms (Demsetz, 1967; Alchian and Demsetz, 1973). Feder and Feeny (1991) also argue that secure land rights allow for land to be a formal guarantee in financing agricultural investments. A reduction in the number of land disputes also frees resources that could be directed towards the production system (Feder and Noronha, 1987).

Despite these theoretical developments that justify a positive relationship between land tenure security and productivity, empirical results vary substantially. The difference in results could be explained by taking into account the endogenous character of land tenure security in estimations (Besley, 1995). Indeed, working in Ghana, Migot-Adholla et al (1994) found that land tenure security clearly improved agricultural investments. By using the same data and controlling for endogeneity, Besley (1995) arrived at entirely different conclusions. Brasselle et al (2002) observe that in Burkina Faso land tenure security is influenced by agricultural investment and

when the endogeneity bias is well-controlled, an improvement in land rights does not stimulate investments. Place and Otsuka (2002) demonstrate that farmers plant coffee bushes to improve their property rights, indicating that producers do not consider the implications in terms of land rights when they make investment decisions. Whereas Midot-Adholla et al (1994) and Pinkney and Kimuyu (1994) observe that the impact of land rights on investments in land development and in tree planting remain low, Jacoby et al (2002) in China and Carter and Olinto (2003) in Paraguay argue that land tenure security has a positive and significant effect on investments.

In regards to the relationship between land tenure security and productivity, Banerjee et al (2002) found a positive impact of land reforms on agricultural productivity in India, partly due to the increase in investments caused by land tenure security. Bangwayo-Skeete et al (2010) examined the impact of the land law programme in Zimbabwe on the technical efficiency of beneficiaries. Their results reveal that the beneficiaries of the programme are technically more efficient than the non-beneficiaries. According to Newman et al (2015), land rights have a positive effect on agricultural yields in Vietnam. However, studies undertaken in Indonesia (Suyanto et al, 2001), Madagascar (Jacoby and Minten, 2007) and Malawi (Matchaya, 2010) demonstrated that land tenure security is not a key determinant in agricultural productivity .

Beyond the problem of endogeneity, the prevailing judicial system also has an influence on the results. Harrison (1987) shows that the traditional system of property rights does not give enough security to lead farmers to undertake investments in improvement of agricultural productivity. In the case of Malawi, Place and Otsuka (2001) note the differences in investments between farmers as a function of the type of law, the farmers who have well-established rights engage in more sustainable development than those who do not. Gebremedhin and Swinton (2003) and Deininger and Chamorro (2004) find that farmers who have well-defined formal rights are more likely to undertake long-term investments on their land. Lovo (2016) notes that customary rights have a negative effect on investments in soil conservation in Malawi. By studying the effect of formal and informal property rights on agricultural productivity in Madagascar, Bellemare (2013) found that formal land rights do not have a significant impact on agricultural productivity.

From the foregoing, we note that the debate on the impact of land tenure security on productivity of agricultural land is inconclusive. Indeed, Brasselle et al (2002) examined land tenure security in Burkina Faso, but the study only focused on the western part of the country (Bobo Dioulasso Zone). Furthermore, their analyses focused on the impact of land tenure security on investment. This study, however, examines the impact of land tenure security on the productivity of Burkina Faso's agricultural land, using data that covers the entire country. Furthermore, land tenure security is defined in accordance with national policy (PNSFMR). According to this policy, a farmer is said to have tenure when they possess either a lease, an operating licence or a title deed.

Land tenure security in Burkina Faso

Before and after colonization, Burkina Faso adopted several bills and passed laws on land regulation. However, although colonization introduced modern laws, customary laws have always been predominant in the management of rural land. Rural areas have several types of land access: inheritance, land lending, renting and the sale of land.

- Inheritance: This is the main way of accessing land, notably within local communities. It is done through a transfer of heritage from father to son. The rights of women have not improved since colonization in the local practices. They remain excluded from inheriting a share of family land, despite the favourable measure laid out in current texts (agricultural and land reforms, family and private law).

- Land lending: Generally, this is a means to land access that is used by immigrants who have come to settle in a certain area. These immigrants are supposed to respect the traditions and the local customs of the region. In the past, land lending was not compensated financially; it was viewed as a means of regulating the local social relationships and the organization of family and inter-village alliances. Gradually, social obligations gave way to the imposition of conditions by land owners for such assistance, conditions which were sometimes harsh, and those who did not follow them found themselves threatened with eviction from the land.

- Renting and selling of land: These are the emerging modes of land transactions currently taking place in several regions of Burkina Faso. Renting is a disguised form of short-term lending especially practised by agricultural immigrants. Land sales are related to various factors among which are the promotion of certain cash crops (cotton) and the development of modern agricultural firms. Land is gradually becoming a precious commodity that one can sell and that people accumulate, both in urban and rural areas.

Since Burkina Faso's independence in 1960, the definition of pertinent modalities of land management has been an important preoccupation of the successive governments. One of the first steps taken by the government after independence was the "formalization" of various pieces of land for better control of the management of resources. This formalization led to the coexistence of two systems (modern law and customary law) of land management. The opposition between legal (modern law) and legitimate (customary law) was thus born, creating a contrast between theory (modern law) and practice (customary law). Customary law was, however, made acceptable by the local administration.

The 1960s were notably marked by the establishment of two laws, namely:

- Act n° 77/60/AN of 12 July 1960 focusing on land regulation and making the State the potential owner of all unregistered land; and
- Act n° 29/63/AN of 24 July 1963 allowing the State to reserve the pieces of land that had experienced special development as well as properties in areas that were not densely populated.

These measures enabled the State to establish a private domain comprising developed and undeveloped land.

With the dawn of the revolution, a law focusing on Land and Agricultural Reform (RAF) was adopted in 1984 and focused on, among other things, the curtailing of customary laws, the annulment of title deeds, the creation of a National Land Agency and the principal of non-discrimination. However, in actual fact, customary laws continue to apply in rural areas.

To correct the deficiencies of RAF, the regime that took power in 1987 revised the law. From 1991, with the adoption of a new Constitution, and the liberalization of various sectors such as that of agriculture, RAF was revised twice (1991 and 1996). These revisions were notable for a return to customary practices. In undeveloped rural areas, multiple judicial systems (customary law, modern law) apply, with an emphasis on customs which are unfavourable to groups such as women, youth, pastoralists and immigrants.

There is increasing recognition that legal dualism, which keeps local actors in an "extra-legal" situation, is one of the major sources of conflicts and land insecurity. Indeed, various actors could claim rights to the same piece of land while referring to different regulations. Actors could also obtain formal rights, which are legally beyond dispute on land that is legally acquired by other parties. In cases of conflict, the arbitration bodies do not know on which laws to base their judgements, and a decision arrived at by one court could be questioned by a different court. Due to the contradictions in the laws, formal public actors should validate the laws and put in place local, extra-legal procedures for establishment of laws or for arbitration.

Abandoning legal dualism allows all citizens to have their rights recognized and protected. Putting in place reliable and accessible mechanisms of land management is also a major factor, which has increasingly enjoyed consensus . There is growing consensus that one cannot address the land question in defiance of these realities and that there is a need for positive law to first of all adapt itself into being capable of taking local land rights into account as is set out in agreements at the local level. The stabilization of land rights is first and foremost a historical process of the consolidation of certain rights, which written law comes in to guide and nurture.

Aware of the importance of alternative thinking on the land question so as to secure land and consequently to improve agricultural productivity, reduce poverty and increase growth, the Government of Burkina Faso has since 2005 committed to a new process of land tenure security. Thus, a national policy, PNSFMR, was adopted in 2007.

The PNSFMR is marked by the notion that land tenure security which is a fusion of modern and customary laws (land legality and legitimacy). With this policy, local realities and the question of land tenure security of women are taken into account. The orientation of this new policy served as a basis for the elaboration of a new rural land law which was promulgated in 2009. It is a major reform in favour of land tenure security for less wealthy small-scale farmers. The law questions the general principle of the monopoly ownership of land by the State, side by side with State rights, those of local communities, and those of individuals.

According to PNSFMR, land tenure security is the set of processes, actions and measures that would allow for the user and the owner of rural lands to effectively carry out their production activities, by protecting them from all contestation and troubles from enjoyment of their rights. This general conception highlights the equilibrium needed in terms of land tenure security between land laws and land legitimacy. Land laws allow a person to successfully defend their land rights before competent jurisdictions. However, land legitimacy leads to spontaneous recognition of the rights of the user by the community and other parties. It fosters a peaceful environment for the user and thus permits them to avoid various land conflicts.

The objective of PNSFMR is to ensure equal land access to all rural actors, guarantee their investment and ensure the effective handling of land conflicts so as to contribute to poverty reduction, to the consolidation of social peace and to the attainment of sustainable development. It thus allows us to rethink the land question, by connecting the land question with major development policies, notably the fight against poverty, the attainment of food security and decentralization.

Within this framework of the formalization of land transactions, rural communities have access to a Rural Land Service (SFR), which works together with village and inter-village institutions in charge of land management for the effective management of the Land Agency for Regional Governments. Village and inter-village land management institutions comprise a village development council, customary and local authorities, devolved technical agencies and local representatives of the regional chambers of agriculture. The aim of SFR is to map and register communal resources, operationalize the procedure for issuing land ownership certificates relative to individual or collective rights of rural farmers, and supervise the entire process of local regulations and procedures for the collection and transfer of rural land rates. At the intermediary level (provincial and regional), rural land management is assured by the devolved land agencies of the State. In addition to their traditional mission, the devolved land agencies of the State should provide support and assistance to the rural land agencies (SFR). Finally, at the national level, the National Agency for Rural Lands (ANTR) was created to promote the valorization of rural land heritage of the State, mainly comprising of rural land that is developed for use as agricultural and pastoralism.

The systematic delivery of land certificates and titles assumes the existence of a land information system capable of ensuring management in a sustainable, reliable and transparent manner. Several experiments of the cadastral type all over the world

have failed due to lack of updates: transfers (inheritance, sell, gifting etc.) are not recorded, and after some years, a new gap is created between the land situation on the ground and the records, making the records redundant and leading to conflicts. The viability of the land information system is a condition for its usefulness.

Since land is a sensitive question, operationalizing land tenure security is done in a progressive manner so as to take into consideration the different contexts, local issues and the diversity of concerned parties (public and private; individual and collective). In particular, the provision of public services in land tenure security should be adapted to the real needs of actors on the ground. Equally, access to land takes into account the necessity for an equilibrium between the various legitimate interests of rural parties. The operationalization also takes into account the time factor, which is important in order to ensure ownership of the process by the rural population, guarantee their effective involvement and ensure the legitimacy of the local rural land management agencies.

In the context of PNSFMR, a Rural Land Ownership Certificate (APFR) is the main document for land security tenure. An application of this certificate could be undertaken either by an individual acting on their own behalf or by a family. When an application for a land ownership certificate meets the conditions, the village land commission informs the local population by all available means of the existence of an application for a rural land ownership certificate. A notice of 45 days from the date of publication of the announcement is given to allow time to listen to any eventual oppositions or claims.

In the absence of any opposition or reservations, the rural land agency or the local federal office prepares a certificate of rural land ownership in the name of the applicant, that will be signed by the mayor. The rural land ownership document is a permanent deed given to natural or legal persons for the occupation of rural lands. It provides the holder with the possibility of obtaining a title deed in conformity with the laws on agrarian and land reform.

In case of opposition or reservations given within the stipulated period, notice of 45 days (which can be renewed only once) is issued to the benefit of the parties that includes the date the opposition was lodged, to allow the parties to reach an amicable solution. If the parties reach an amicable solution, the local authority in charge of conflict resolution draws up a written conciliation statement which is probated by the presiding judge of a territorially competent court of first instance. In default of an amicable agreement, the local court in charge of settlement of land disputes draws up a written non-conciliation statement. The village land commission then notes the failure in conciliation and stops the process of certification of rural land ownership. The commission informs the parties that they should seek the services of a territorially competent court.

For allocation of APFR, indigenous residents are normally prioritized. For immigrants to obtain APFR, they are required to have used the land over a certain number of years without any action being undertaken to recover the land. An immigrant could also obtain AFPR through the purchase of land and if all purchase

documents are in order. All types of land ownership titles are subject to fee payment by the title applicant. According to articles 22, 39, 40 and 48 of law 034-2009/AN of 16 June 2009 on Rural Land Regime, the payment is set up for the benefit of the community budget for income received from services rendered by the rural land agencies or local federal offices. This means that only the farmers who meet these conditions will have access to land tenure security. Land tenure security is therefore endogenous. Taking account of this endogeneity is important to determine the relationship between land tenure security and productivity.

3.0 Theoretical framework

There are two types of measurement of productivity: partial productivity and total factor productivity (TFP). This study focuses on TFP and uses a technical efficiency approach to calculate the TFP of farmers. According to Fuglie, Wang and Ball (2012), TFP is the global growth driver for agricultural productivity. Technical efficiency reflects the capacity of an enterprise to produce a maximum output level as a function of a given set of inputs or to produce a given level of outputs using a minimal quantity of inputs. This indicates the variation of total production in regard to a more complete measurement of all the inputs such as land, labour, capital, chemical fertilizer, and pesticides.

The concept of technical efficiency finds its origin in seminal theoretical papers by Debreu (1951), Koopmans (1951) and Farrell (1957). Farrell was the first to propose an estimation approach using the efficiency frontier. Two decades later, two large families of methods were competing in the manner of constructing the frontier and thus in calculating technical efficiency: the parametric methods or stochastic frontier Analysis (SFA) developed by Aigner and Chu (1968) and Aigner et al (1977) and the non-parametric methods or Data Envelopment Analysis (DEA) developed by Charnes et al (1978) and Banker et al (1984). Whereas the stochastic frontier method derives from economic theory to establish the efficiency frontier, the DEA method does not need any particular hypothesis.

DEA models (Charnes et al, 1994) assume that inputs and the quantities produced are measured by their exact values based on well-defined factors (Despotis and Smirlis, 2002). However, the process of evaluation of efficiency sometimes implies stochastic estimation due to inherent uncertainties inherent in the numerous problems faced in real life. So as to take into account the errors, the Stochastic DEA approach (SDEA) (Land et al, 1993) was developed by considering the value of inputs and outputs as random variables. This article will use the SFA approach to estimate technical efficiency.

Based on studies by Coelli et al (1998) and Kumbhakar and Lovell (2000), let us assume that a farmer produces a product Y with a set of inputs x on land parcel i. By using a Cobb-Douglas production function, the frontier is estimated using the following equation:

$$Y_i = f(x_i, \beta) e^{v_i - u_i} \quad (1)$$

WhereY_i represents production of the inth farm in a given period;

x_i is a vector of inputs given in the format (1xk) used on parcel i;

β is a vector of unknown parameters to estimate (kxand);

$f(x_i,\beta)$ is the determinant and $e^{v_i-u_i}$ is the random part.

$v_i(v\sim N(0,\sigma_v^2))$. represents the error of measurement of variables.

u_i is the set of non-negative random disturbances assumed to represent technical inefficiency in production and assumed to be always independent and identically distributed.,u_i, u_i following a half-normal distribution such as $u_i(u\sim N(|0,\sigma_u^2)|)$ and $u_i \geq 0$ we assume that u_i *et* v_i are independent.

In presenting the logarithm of the production frontier model of Equation 1 we have:

$$\ln Y_i = ln\, f(x_i,\beta) + v_i - u_i \quad (2)$$

Assume that z = z (z_1, $z_{2.....}z_n$) represents a vector of exogenous factors affecting technical inefficiency:

$$u_i = h(z_i,\delta)$$

The stochastic production frontier becomes:

$$lnY_i = ln\, f(x_i,\beta) + v_i - h(z_i,\delta) \quad (3)$$

With$h(z_i,\delta) \geq 0$

$v_i\sim N(0,\sigma_v^2)$ is independent of x_i,z_i and u_i

The variance of the stochastic element$v_i - u_i$ is σ^2broken down in$\sigma^2 = \sigma_u^2 + \sigma_v^2$.

The termλdefined by$\lambda = \frac{\sigma_u}{\sigma}$represents the proportion of total variance due to inefficiency.

The estimation of Equation 1 using the maximum likelihood method or the ordinary least squares method gives the estimators β and λ. The parameter λ is an indicator of the relative variablility of two sources of variations. If λ is close to zero, the symmetrical error term dominates the variation between the frontiers and the level of output observed. In other words, a value of λ close to zero implies that the gap between the observed level and the maximum level of output possible is dominated by random factors. Otherwise, the higher$\lambda$is to the unit, the more production is dominated by the variability derived from technical inefficiency.

The level of technical efficiency (ET) is between 0 and 1, and is given as:

$$ET_i = \frac{y_i}{\exp(x_i\beta+v_i)} \frac{\exp(x_i\beta+v_i-u_i)}{\exp(x_i\beta+v_i)} = \exp(-u_i)$$

4. Method of analysis

The major problem of the estimation of the relationship between land tenure security and agricultural productivity is that of taking endogeneity into account. In our case, the endogenous character is due to a problem of double causality or of joint determination. Indeed, the most productive land is likely to be tenured (Brasselle et al, 2002). Furthermore, although investment incentives are sensitive to ownership rights (Besley, 1995), the act of investment itself could strengthen land tenure security (Sjaastad and Bromley, 1997). Beyond the endogenous nature of land tenure security, it is important to take into account the double censor of technical efficiency of farms (measurement is between zero and one). To take into account all aspects, we use an interval regression model (Bettin and Lucchetti, 2012) that combines an endogenous variable and an endogenous treatment variable. This model is referred to as the extended regression model (STATA, 2017) and it allows not only for a simultaneous estimation of the technical efficiency, adoption of techniques of water and soil conservation and land tenure security but also allows for the consideration of technical efficiency as an interval (somewhere between 0 and 1).

Assuming that estimated technical efficiency (y_i) depends on a hidden variable, y_i^*, which has a linear relationship with a series of independent variables that impact upon real technical efficiency (y_i^*):

$$y_i = \begin{cases} y_{li} & if\ y_i^* \leq 0 \\ y_i^* & if\ y_{li} < y_i^* < y_{ui} \\ y_{ui} & if\ y_i^* \geq 1 \end{cases}$$

$$y_i = \alpha + X_i\beta + W_{ci}\beta_{ci} + \varepsilon_i$$

y_i represents the score of tehnical efficiency of the farm i somewhere between $y_{li}\ et y_{ui}$ $y_{li}\ et y_{ui}$ ($y_{li} < y_i^* < y_{ui}$).

β and β_{ci} are the vectors of the parameters.

X_i Is the set of explanatory variables of technical efficiency (level of education of the manager of the parcel of land, access to finance, the type of seeds used, and the type of association of crops).

ε_i is the error term.

W_{ci} is a probit that represents the probability of investment in techniques of water

and soil conservation on a farm i. The investment is endogenous because according to theoretical literature, investment is explained by land tenure security. We have:

$$\begin{cases} W_{ci} = 1 \text{ si } Z_{ci}\lambda_c + \mathcal{E}_{ci} > 0 \\ W_{ci} = 0 \text{ si } Z_{ci}\lambda_c + \mathcal{E}_{ci} \leq 0 \end{cases}$$

Z_{ci} represents the explanatory variables of adoption of CES (land relief, the level of education of the manager of the parcel of land, the number of individuals in the household, the size of the farm and land tenure security).

In line with Rubin (1974), the treatment effect of land tenure security on the technical efficiency of farmers (y_{ji}-y_{1i}) is determined. It is the difference of the result if individual i receives treatment $t_i t_i$=v_j v_j and what would be the result if individual i did not receive treatmentt_i =v_1 (witness).

For the treatment group j, the conditioned treatment on the x_i

$$TE_j(q_i) = E(y_{ji} - y_{1i} | xq_i)$$

For treatment group j, the treatment effect on the treated (TET) of treatment group h is:

$$TET_j(q_i, t_i = v_h) = E(y_{ji} - y_{1i} | q_i, t_i = v_h)$$

q_i represents the explanatory variables of land tenure security (the duration of use of the land, sex, age of head land user, agroclimatic zone, mode of acquisition of the land parcel (purchase, gift, inheritance, borrowing)).

5. Data and descriptive statistics

A data household survey was carried out by the Ministry of Agriculture and Food Security. To estimate food grain production so as to establish the national cereal balance, the Department of Planning and Research each year carries out a survey on agricultural statistics referred to as the Permanent Agricultural Survey (EPA). In this study, we focused on the data from the agricultural campaign carried out in 2011/2012 for an estimation of the impact of land tenure security on agricultural productivity. The information was collected from 45 provinces in Burkina Faso. The parcels of irrigated land and the lowlands were excluded from the survey. Furthermore, the survey only covers rainfed crops. The village sample was established for each province and was proportional to village size. This was done in a systematic manner after the classification of the villages in respect of increase in size. The number of sampled villages was 706 in total. In each of the sampled villages we drew eight agricultural households of equal probability, regardless of the number of agricultural households in the village. The sampled households were thus 5,648 all over the country. The information collected includes data on demographic characteristics of the households, agricultural investments undertaken on the pieces of land, the rights of land ownership and the characteristics of the piece of land. Questions relating to the rights of ownership were addressed at the farm level. The different levels of rights of ownership were regrouped into secured rights and unsecured rights. After clearance, we had a total of 11,372 pieces of land of which 96.47% (or 10,970 pieces) are not secured and 3.53% (or 402 pieces) are secured.

Technical efficiency was calculated from production frontier. The estimation of this frontier was done using production factors (manpower, size of the land) and factors of intermediary consumption (pesticide, herbicide, urea, NPK and organic manure). The factors that could influence technical efficiency are the relief of the piece of land (RELP), the type of crop association (Typeasso), the type of seeds used (Tsem), and the agroclimatic zone (Zone) among others. Indeed, for the type of seeds, we distinguish between pedigree seeds and local seeds. Considering the differences in the genetic potential of the two varieties, the farmers using pedigreed seeds should produce higher yields than those using local seeds (Chibwana et al, 2012). Land relief is also a production effect in the sense that a piece of land situated on a plateau is less prone to surface runoff than a piece of land situated on a slope. Finally, a binary variable that characterizes the production zone is taken into account.

The variables that could influence food security include the socio-demographic characteristics of the land owner, the mode of acquisition of the piece of land and the period during which the land has been used. According to Sjaastad and Bromley (1997), investing in techniques to improve and conserve soil quality could reinforce land tenure security. However, it was extremely difficult for us to obtain reliable information on expenditure of investments undertaken by farmers for the adoption of soil and water conservation techniques. The investment variable is thus measured by a dummy variable which takes the value of 1 when the farmer has adopted at least one of the soil and water conservation techniques for their piece of land and 0 if not (Brasselle et al, 2002). The descriptive statistics of the variables analysed are summarized in Table 1.

Table 1 Descriptive statistics of the variables

		Total	Secured	Unsecured
Variables	Description	N = 11,372	N = 402	N = 10,970
PROD	Production in kg	432.470	311.793	436.893
Characteristics of the piece of land				
SUP	Size in hectares	1.393	1.339	1.395
CES	Use of a water and soil conservation technique 0= No, 1= Yes	0.138	0.278	0.133
RELP	Relief of the piece of land 0 = "Plain/Plateau" 1 = "Lowlands" 2 = "Slope"	0.191	0.231	0.189
Characteristics of the owner of the piece of land				
AGE	Age of the land owner	33.243	31.67	33.300
NINS	Level of education of the owner of the piece of land (0= Illiterate 1= Literate)	0.439	0.390	0.441
SEXE	Sex of the landowner (0 = Female; 1 = Male)	0.489	0.530	0.488
Inputs				
MO	Manpower in person-days	65.464	54.213	65.876
NPK	Quantity of NPK used for farming in kg	7.588	6.149	7.641
UREA	Quantity of urea used for farming in kg	4.200	3.288	4.233
PEST	Pesticide used in cl	4.649	1.186	4.776
FUM	Quantity of organic fertilizer used for production in kg	195.051	97.196	198.637
HERB	Quantity of organic fertilizer used for production in cl	23.771	17.427	24.004
Tsem	Type of seeds (0 = local; 1 = pedigree)	0.040	0.037	0.0440
Typeasso	Type of crop association (0 = pure; 1 = association)	0.370	0.329	0.371
Mode of acquisition of the piece of land				
PURCHASE	Acquisition by purchase (0 = No; 1 = Yes)	0.002	0.004	0.002
BORROWING	Acquisition by borrowing (0 = No; 1 = Yes)	0.222	0.283	0.220
INHERITANCE	Acquisition by inheritance (0 = No; 1 = Yes)	0.475	0.074	0.490
Other variables				
AREA	0 = Sahelian; 2 = Sudanian	0.811	0.907	0.807
DUREX	Period of use of land in years	14.9068	11.898	15.017

Source: Author using data from 2011/2012 EPA survey

The distribution of farms that adopt water and soil conservation techniques according to the agroclimatic zone (Table 2), shows that the producers in the humid zone (Sudanese) adopt more CES than those in the dry zone (Sahelian). This seems to reveal the fact that resources are wasted in the humid zones in the sense that land in these zones is more fertile than Sahelian zone. Furthermore, land tenure security is more adopted to humid zones.

Table 2: Distribution of farms that adopt to CES and to land tenure security according to agroclimatic zones

	CES		SECF	
	Workforce	Frequency	Workforce	Frequency
Sahelian Area	225	16.33	38	9.48
Sudanian Area	1.316	83.77	363	90.52

Source: 2011/2012 EPA survey

By taking into account the variables, the production function is written as follows:

$$lny_i = lnpk\alpha_1 + lureea_2 + lsupa_3 + lmoa_4 + lpesta_5 + lfuma_6 + lherba_7 + v_i - h(z_i, \delta)$$

The regression equation of y_i is written as follows:

$$y_i = ninsb_1 + acredb_2 + tsemb_3 + assob_4 + cesb_{ci} + \mathcal{E}_i$$

With: $\begin{cases} \text{ces} = 1 \text{ si } relf\lambda_1 + secf\lambda_2 + ninsl_3 + mf\lambda_4 + sup\lambda_5 + \mathcal{E}_{ci} > 0 \\ \text{ces} = 0 \text{ si } relf\lambda_1 + secf\lambda_2 + ninsl_3 + mf\lambda_4 + sup\lambda_5 + \mathcal{E}_{ci} \leq 0 \end{cases}$

6. Discussion

In this section we evaluate the impact of land tenure security on productivity. To do so, the production function is first estimated so as to predict the scores of technical efficiency. Thereafter, the impact of land tenure security on productivity is estimated.

The estimation of technical efficiency of farms

Results of the estimation of the stochastic production function is presented in Table 2. The likelihood-ratio test shows that the model is generally significant and valid. Indeed, the test indicates that one cannot accept the hypothesis of the absence of stochastic errors.

The results (Table 3) show that NPK, herbicide, surface area and manpower improve production. The area cultivated seems to be a contributing factor to agricultural production with an elasticity of 3.960. In other words, when surface area increases by 1%, production increases by close to 4%. This could be explained by the fact that farming in Burkina Faso is of the extensive type. The surface area of cultivated land increases by an average of 2.8% per year (DGPER, 2009). Manpower, herbicide and NPK contribute in increasing production by 0.143%, 0.093% and 0.076% respectively following their respective increase by 1%. This increase remains relatively low. Otherwise, the results reveal that, pesticides and urea do not improve production. Organic manure does not seem to stimulate production either. Generally, the impact of intermediate consumption factors (urea, NPK, pesticide, herbicide and organic fertilizer) on production could be explained by the poor use of these factors (see Annex 1 for the average amount used per hectare).

Table 3: Estimation of the Cobb-Douglas stochastic production function

Variables	Coef	Std error
lNPK	0.076***	0.017
lUREA	-0.045*	0.024
lSUP	3.960***	0.044
lMO	0.143***	0.009
LPEST	-0.085***	0.017
lFUM	0.002	0.004
lHERB	0.093***	0.008
Cons	4.233***	0.044
$l\sigma_u^2 l\sigma_u^2$	-1.076***	0.035
$l\sigma_v^2 l\sigma_v^2$	0.879***	0.023
☒	2.659	0.024
Likelihood-ratio test of sigma_u = 0: chibar2(01) 1.2e+03Prob>=chibar2 = 0.000		

The figures in parentheses are the t-students; *** significant at 1%; ** significant at 5%; * significant to 10%.
Source: Author from 2011/2012 EPA survey

The estimation of the production frontier allows us to predict the scores of technical efficiency. Table 3 presents the descriptive statistics of technical efficiency as a function of land tenure security. The results of the test of the difference of means (Annex 2) show that the producers who had their pieces of land secured are more productive than those who use unsecured pieces of land. In other words, farmers with land tenure security are more efficient in their use of inputs than farmers with unsecured farms. The difference in technical efficiency between two groups, seems low (0.029) but significant to a threshold of 1% (test of difference of means). The estimation allows us to verify the result and to give the real value of the impact of land tenure security on productivity.

Table 4: Descriptive statistics of technical efficiency

	Number of observations	Average	Std dev
Non-secured (SECF=0)	10,970	0.401	0.212
Secured (SECF=1)	402	0.437	0.408
Difference of means (t-student)		-0.0288*** (-2.7209)	

*** significant at 1%; ** significant at 5%; * significant to 10%.
Source: Author from 2011/2012 EPA survey

Estimation of the impact of land tenure security on agricultural productivity

Given the endogenous character of land tenure security and of investment (CES), the endogenous treatment regression model combining an endogenous explanatory variable is used to evaluate the impact of land tenure security on productivity. First, we estimate the impact of land tenure security on productivity through investment (Equation 1) and second, we estimate the direct impact on land tenure security on productivity (Equation 2). The equations for land tenure security (secf) and for investment in techniques of water and soil conservation (CES) give the coefficients of the treatment model and of the endogenous variable (CES). The estimations of the correlation guide us on the endogeneity of our model. The correlation between the errors of the investment and the error of the land tenure security equation Corr(e.ces,e.secf) is significant. We, therefore, cannot reject the hypothesis of the correlationbetween the investment (CES) and land tenure security. We conclude that the simultaneous estimation of investment and land tenure security is justified. The other correlations (Corr(e.secf, e.y1) for those two equations and Corr(e.ces, e.y1)) for only the first equation are also significant at a threshold of 1% and 5% respectively. This demonstrates what we suspected as the choice of endogenous treatment and the endogeneity of the investment in the techniques of soil and water conservation are also confirmed. The equations are thus appropriate for an analysis of the impact of land tenure security on productivity. Furthermore, Equation 1 allows us to verify the theory which stipulates that land tenure security has an impact on productivity through investment.

According to the results, contributing factors of productivity are, among others, access to finance, the type of crop association, the type of seeds used, land tenure security (for both equations) and CES (for Equation 1).

Access to finance has a positive effect on productivity. This result conforms with those arrived at in Peru (Guirkinger and Boucher, 2008), Rwanda (Ali et al, 2014) and China (Zhao and Barry, 2014). It also conforms with those arrived at by Traoré (2012) in Burkina Faso. Traoré (2012) demonstrated that access to microfinance had a positive impact on agricultural productivity in Burkina Faso.

Monoculture of cereals improves productivity as compared to crop association. This is contrary to our expectations because crop association is a strategy that is used by farmers to improve their productivity. The result could be explained by the fact that a poor choice of crops for association does not allow for increase in productivity.

Local seeds have a negative impact on farm productivity. This could be explained by the fact that such seeds are not adapted to the current climate conditions and do not have the genetic potential that could lead to increased production.

In regard to the cross-effect between investment and land security, secure farms or those that are not beneficiaries of CES do not have better productivity. This seems paradoxical because CES are techniques which are used to preserve mineral elements,

water and soil, so as to improve productivity. For the CES to have a positive impact on production, the operational mode must be respected. Furthermore, technical efficiency being production at a maximum output level, with a given amount of inputs, these results could signify, in agreement with the descriptive statistics (Table 2), that the adoption of water and soil conservation techniques does not allow for having a maximum output level. In other words, there is wastage of resources.

In conclusion, land tenure security has a positive effect on productivity. This result does not represent the impact of land tenure security on productivity. It simply gives a sense of the relationship between land tenure security and agricultural productivity. The impact is estimated through an endogenous treatment regression model.

The estimation also allows for the determination of factors that influence land security. The agricultural zone, duration of usage of the piece of land, the acquisition of the piece of land through purchase (for the two Equations) and as a gift (for Equation 1 only) influence the probability to secure a piece of land.

Indeed, the duration of usage of the piece of land increases the probability of securing the land in conformity with the conditions of the PNSFMR. Furthermore, farmers in the Sudanian area have a higher probability of securing their land than the farmers in the Sahelian zone. This could be explained by the fact that the Sudanian area is better watered and the land is more fertile than that of the Sahelian zone and thus more favourable for agriculture. These results agree with those of Besley (1995) and Brasselle et al (2002) which show that the most productive land is more likely to be secured.

The acquisition of a piece of land as a gift also has a positive impact on the probability of securing land. This could be explained by the fact that the owners of land acquired by gift are exposed to expropriation. However, the acquisition of a piece of land by purchase has a negative effect on the probability of land tenure security because purchase gives rise to the need for documents that prove that the applicant is the owner of the piece of land. Indeed, the applicant is not secure, but at least he or she has the proof, allowing him or her to defend ownership of the piece of land in case of conflict.

The results finally give the factors contributing to soil and water conservation techniques (Equation 1). Indeed, relief, land tenure security, the number of individuals in the households and size have an effect on the adoption of CES. CES is a set of techniques that allows for regenerating or conserving the nutritional elements of the soil or also to reduce surface runoff which improves production. Hence, they are more likely to be adopted for hillsides, but not for pieces of land located on plateaus.

In conformity with the theory, the results reveal that land tenure security has a positive effect on investment. Indeed, land tenure security guarantees farmers that the fruit of their investments will not be arbitrarily grabbed either by others or by public authorities. This, therefore, gives them incentives to invest. This result agrees with Besley (1995) in Ghana, Carter and Olinto (2003) in Paraguay and Ghebru and Holden (2013) for Ethiopia. However, it does not allow for a verification of the result by Brasselle et al (2002) who notes that in Burkina Faso, land tenure security is influenced

by agricultural investment and when the endogeneity bias is well controlled, an improvement of land rights does not stimulate investments.

Use of family labour also improves the probability of adoption of CES given that implementing and maintaining these techniques requires abundant manpower. In conclusion, surface area contributes to the adoption of CES. Farmers who do not have the means to procure chemical inputs for large farms are obliged to adopt CES to preserve soil nutrients.

Table 5: Determinants of technical efficiency, adoption of CES and land tenure security

Effect of land tenure security on productivity through investment (Equation 1)		Direct effect of land tenure security on productivity
Technical efficiency		
Level of education		
0	-0.001	-0.004
	(0.005)	(0.004)
1	0.010	0.008
	(0.026)	(0.026)
Access to credit		
0	0.021	0.009
	(0.013)	(0.014)
1	0.117*	0.126*
	(0.063)	(0.054)
Type of seeds		
0	-0.051***	0.061***
	(0.010)	(0.011)
1	0.023	0.009
	(0.053)	(0.049)
Type of crop association		
0	0.070***	0.077***
	(0.004)	(0.004)
1	0.014	0.019
	(0.023)	(0.023)
CES- Land tenure security		
1 0	-0.404***	-
	(0.012)	
1 1	-0.057**	-
	(0.024)	
Land tenure security		
0	0.431***	0.382***
	(0.004)	(0.005)
1	0.976***	0,701***
	(0.032)	(0.133)
Land tenure security		
Duration of usage of the piece of land	0.005***	0.005***
	(0.001)	(0.001)
Sex	0.035	0.012
	(0.034)	(0.053)
Age	0.001	0.001
	(0.001)	(0.001)
Agroclimatic zone	0.233***	0.386***
	(0.056)	(0 .086)
Acquisition of piece of land by purchase	-2.260***	3.326***

	(0.306)	(0.787)
Acquisition of piece of land by borrowing	0.193	0.091
	(0.127)	(0.244)
Acquisition of piece of land as a gift	0.244**	0.303
	(0.125)	(0.237)
Acquisition of piece of land by inheritance	0.078	-0.0007
	0.124	(0.250)
Constant	-2.320***	2.487***
	(0.134)	(0.236)
Adoption of water and soil conservation techniques.		
Relief of the piece of land_(Lowland)	-0.068	
	(0.047)	
Relief of the piece of land_(slope)	0.317***	
	(0.051)	
Land tenure security	2,984***	
	(0.769)	
Level of education of the farmer	0.022	
	(0.0312)	
Total number of individuals in the household	0.003	
	(0.001)	
Surface area of the piece of land	0.253***	
	(0.026)	
Constant	-1.511***	
	(0.048)	
Var (e. y1)	0.065	0.042
	(0.001)	(0.002)
Corr(e.secf, e.y1)	-0.914***	-0.595**
	(0.020)	(0.258)
Corr(e.ces, e.y1)	0.836***	
	(0.013)	
Corr(e.ces, e.secf)	-0.939***	
	0(.021)	

Source: Author using data derived from 2011/2012 EPA survey

Note: The values in parentheses are standard errors; *** significant at 1%; ** significant to 5%; * significant to 10%.

After presenting the determinants of productivity, the probability of securing a piece of land, and of the investment, the value of the impact of land tenure security on agricultural productivity is determined. The results (Table 6) show that land tenure security has a positive impact on the agricultural productivity of farmers in Burkina Faso to the order of 0.661 units. This result is in agreement with results from Banerjee et al (2002) in India Bangwayo-Skeete et al (2010) n Zimbabwe and Newman et al (2015) in Vietnam. It, however, does not agree with Place and Hazell (1993) and Place and Otsuka (2001), who did not find for a significant relationship between rights of ownership and agricultural productivity in their studies. Results from Bellemare (2013) suggest that formal land rights (title deeds) do not have an impact on productivity,

but also that informal land rights have an impact on productivity. In our study land tenure security is a combination of formal and informal rights.

Table 6: Estimation of the impact of land tenure security on productivity through investment

	Coef	Std error	t-statistic
ATET			
Land tenure security	0.661***	0.308	22.45

*** significant to 1%; ** significant to 5%; * significant to 10%.
Source: Author using data from 2011/2012 EPA survey

The impact of 0.661 is partly attributed to investment. Indeed, land tenure security has a direct impact on productivity in the order of 0.308 (Table 7). In this case, the positive impact of land tenure security on productivity could be explained through the channel of transmission and also through psychological factors. These factors make it such that a farmer who now owns land that they farm would invest in it more. Land tenure security acts as a sort of salary that drives the farmer towards more efficiency, as was established by Stiglitz (1976). Indeed, the hypothesis on salary efficiency stipulates that the services that a worker provides are a function of the salary that they receive. A well-paid worker could do the work that two poorly paid workers undertake (Stiglitz, 1976).

Table 7: Estimation of the direct impact of land tenure security on productivity

	Coef	Std err	t-statistic
ATET			
Land tenure security	0.308**	0.135	2.28

*** significant to 1%; ** significant to 5%; * significant to 10%.
Source: Author using data from 2011/2012 EPA survey

7. Conclusion and policy implication

Land tenure security is a major challenge to the development of the agricultural sector in Burkina Faso. This study examined the impact of land tenure security on technical efficiency of farms in the country. The stochastic frontier approach was used on data taken from EPA 2011/2012 to estimate the production frontier. The results demonstrate that farms in Burkina Faso are not efficient (0.408). By using an endogenous treatment model, the results show that access to finance and monoculture contributes to improving productivity. However, the use of local seeds has a negative effect on productivity. Furthermore, land tenure security improves technical efficiency in the order of 0.661 units, partly due to investment. The direct impact of land tenure security on technical efficiency on its part is in the order of 0.308 units.

Establishing an agricultural bank or putting aside agricultural credit funds would provide farmers with access to agricultural credit at a preferential rate and at an opportune time. It is important to correct the imperfections in the capital markets. Farmers who hold title could use the deeds as a collateral to access to finance. The farmers without a guarantee could take advantage of membership in a farmer association which can serve as a form of guarantee (joint surety) for access to finance in rural areas.

Furthermore, the ministry should continue to make improved seeds available to farmers so as to improve agricultural productivity. According to Chibwana et al (2012), taking into account the differences in genetic potential of improved seeds, farms that use improved seeds should produce higher yields than those that use local seeds. Despite efforts by the Ministry of Agriculture in the distribution of improved seeds at subsidized prices, the quality of the seeds made available to farmers is low. Several instances of poor quality seeds being issued have been reported. One notes, for example, seeds with a poor rate of germination, unidentified seed varieties being delivered to farmers, varietal impurities and/or seeds that are not adapted to the agroclimatic conditions of the zone where they have been delivered (MASA, 2014). The poor germination rate could be explained by poor application of the protocols for use of the seeds. To obtain better results, the ministry must correct the weaknesses in regard to seed quality by rigorous monitoring of the quality of enhanced seeds provided and supporting these farmers.

In conclusion, land tenure security improves productivity. Therefore, the Millennium Challenge Account and the Ministry of Agriculture should continue in their efforts of providing land tenure security to provide farmers' access to a Certificate of Possession of Rural Land which is the basic document that gives access to land tenure security according to the PNSFMR. To do so, the conditions and the procedure of access to the certificate should be relaxed.

References

Adelman, I. 1984. “Beyond export-led growth”. World Development, 12(9): 937–49.

Aigner, D. and S.F. Chu. 1968. “Estimating the industry production function”. American Economic Review, 58: 826–39.

Aigner, D., C.A. Lovell and P. Schimidt. 1977. “Formulation and estimation of Stochastic Frontier Production Function. Journal of Econometrics, 6: 21–37.

Alchian, A.A. and H. Demsetz. 1973. “The Property Right Paradigm”. The Journal of Economic History, 33(1): 16–27.

Ali, D.A., K. Deininger and M. Duponchel. 2014. “Credit constraints and agricultural productivity: Evidence from rural Rwanda”. Journal of Development Studies, 50(5): 649–65.

Banerjee, A., P. Gertler and M. Ghatak. 2002. “Empowerment and efficiency: tenancy reform in West Bengal”. Journal of Political Economy, 113: 151–83.

Bangwayo-Skeete, F.P., M. Bezabih and P. Zikhali. 2010. “Are Zimbabwe’s fast track land reform farms more technically efficient than communal farms?” Quarterly Journal of International Agriculture, 49(4): 319–39.

Banker, R., A. Charnes and W.W. Cooper. 1984. “Some models for estimating technical and scale inefficiencies in data envelopment analysis”. Management Science, 30(9): 1078–92.

Bellemare, M.F. 2013. “The productivity impacts of formal and informal land rights: Evidence from Madagascar”. Land Economics, 89(2): 272–90.

Besley, T. 1995. “Property rights and investment incentives: theory and evidence from Ghana”. Journal of Political Economy, 103(5): 903–37.

Bettin, G. and R. Lucchetti. 2012. "Interval regression models with endogenous explanatory variables." Empirical Economics, 43(2): 475–98

Brasselle A.S., F. Gaspart and J.-P. Platteau. 2002. “Land tenure security and investment incentives: Puzzling evidence from Burkina Faso”. Journal of Development Economics, 67(2): 373–418.

Carter, M.R. and P. Olinto. 2003. “Getting institutions 'right' for whom? Credit constraints and the impact of property rights on the quantity and composition of investment”. American Journal of Agricultural Economics, 85(1): 173–86.

Charnes, A., W.W. Cooper and E. Rhodes. 1978. "Measuring the efficiency of decision making units." European Journal of Operational Research, 2(6): 429–44.

Charnes, A., W.W. Cooper, A.Y. Lewin and L.M. Seiford, L.M. 1994. Data Envelopment Analysis: Theory, Methodology and Applications. Boston/Dordrecht/London: Kluwer Academic Publishers.

Chibwana, C., M. Fisher and G. Shively. 2012. "Cropland allocation effects of agricultural input subsidies in Malawi". World Development, 40(1): 124–33.

Coase, R.H. 1960. "The problem of social cost". Journal of Law and Economics, 3: 1–44.

Coelli, T.J., P.D.S. Rao and G. Battese. 1998. An Introduction to Efficiency and Productivity Analysis. Boston: Kluwer Academic Publishers.

Debreu, D.G. 1951. "The coefficient of resource utilisation". Econometrica, 19: 273–92.

Deininger, K. and J.S. Chamorro. 2004. "Investment and equity effects of land regularization: The case of Nicaragua". Agricultural Economics, 30: 101–16.

Deininger, K. and D.A. Ali. 2008. "Do overlapping land rights reduce agricultural investment? Evidence from Uganda". American Journal of Agricultural Economics, 90(4): 869–82.

Deville, L.P. 2010. "Sécurisation foncière, formalisation des droits, institutions de régulation foncière et investissements pour un cadre conceptuel élargi". Revue des questions foncières, 1.10.

Demsetz, H. 1967. "Towards a theory of property rights". The American Economic Review, 57(2): 347–59.

Despotis, D.K. and Y.G. Smirlis. 2002. "Data envelopment analysis with imprecise data". European Journal of Operational Research, 140(1): 24–36.

DGPER. 2009. "Rapport evolution du secteur Agricole". Direction Générale de la Promotion de l'Economie Rurale. Ouagadougou, Burkina Faso

Dorner, P. and B. Saliba. 1981. Interventions in land markets to benefit the rural poor. Madison: Land Tenure Center, University of Wisconsin–Madison.

Ely, R.T. and G.S. Wehrwein. 1940. "Land economics". The Journal of Land and Public Utility Economics, 16(4): 493–96.

Farrell, M.J. 1957. "The measurement of productive efficiency". Journal of the Royal Statistical Society Series A (General), 120(3): 253–90.

Feder, G. and R. Noronha. 1987. "Land rights systems and agricultural development in sub-Saharan Africa". World Bank Observer, 2:143–69.

Feder, G. and T. Onchan. 1987. "Land ownership security and farm investment in Thailand." American Journal of Agricultural Economics, 69: 311-20.

Feder, G. and D. Feeny. 1991. "Land tenure and property rights: Theory and implications for development policy." The World Bank Economic Review, 5(1): 135–53.

Fuglie, K., S. Wang and V.E. Ball. 2012. "Productivity Growth in Agriculture: An International Perspective." Oxfordshire, UK: CAB International.

Gebremedhin, B. and S.M. Swinton. 2003. "Investment in soil conservation in northern Ethiopia: The role of land tenure security and public programmes". Agricultural Economics, 29: 69–84.

Ghebru, H.H. and S.T. Holden. 2013. "Efficiency and productivity differential effects of land certification programme in Ethiopia: Quasi-experimental evidence from Tigray". IFPRI Discussion Paper No. 01295. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127841

Guirkinger, C. and S.R. Boucher. 2008. "Credit constraints and productivity in Peruvian agriculture". Agricultural Economics, 39: 295–308.

Hardin, G. 1968. "The tragedy of the commons". Science New series, 162(3859): 1243–48.

Harrison, P. 1987. The Greening of Africa. London, UK: International Institute for Environment and Development, Earthscan- Palladin.

Hirschman, A. 1958. The Strategy of Economic Development. Yale University. Press, New Haven.

Jacoby, H.G. and B. Minten. 2007. "Is land titling in sub-Saharan Africa cost-effective? Evidence from Madagascar". World Bank Economic Review, 21(3): 461–85.

Jacoby, H.G., G. Li and S. Rozelle. 2002. "Hazards of expropriation: tenure insecurity and investment in rural China". American Economic Review, 92(5): 1420–7.

Koopmans, T. 1951. "An analysis of production as an efficient combination of activities". In T.C. Koopmans, ed., Activity Analysis of Production and Allocation. Proceeding of a Conference. London: John Wiley and Sons Inc..

Kumbhakar, S.A. and C.A.K. Lovell. 2000. Stochastic Frontier Analysis. Cambridge University Press.

Land, K.C., C.A.K. Lovell and S. Thore. 1993. "Chance constrained data envelopment analysis". Managerial and Decision Economics, 14(6): 541–54.

Lovo, S. 2016. "Tenure insecurity and investment in soil conservation. Evidence from Malawi". World Development, 78: 219–29.

Maddala, G.S. 1983. "Limited-dependent and qualitative variables in econometrics". The Economic Journal, 95.

MASA. 2014. "Rapport d'évaluation des opérations de distribution d'intrants et d'équipements agricoles, rapport provisoire". Direction Générale des Etudes et des Statistiques Sectorielles (DGESS), Ministère de L'agriculture et de la Sécurité Alimentaire. Ouagadoudou, Burkina Faso

Matchaya, G. 2010. "Land ownership and productivity in Malawi: A conditional recursive mixed process analysis". Working Paper Series No. 1(3). Leeds University Business School.

Migot-Adholla, S.E., G. Benneth, F. Place and S. Atsu. 1994. "Land, security of tenure, and productivity in Ghana". Searching for land tenure security in Africa, 97-118.

Newman, C., F. Tarp and K. Broeck. 2015. "Property rights and productivity: The case of joint land titling in Vietnam". Land Economics, 91(1): 91–105

Pinkney, T. and P. Kimuyu. 1994. "Land tenure reforms in East Africa: Good, bad or unimportant?" Journal of African Economies, 3(1), 1-28

Place, F. and P. Hazell. 1993. "Productivity effects of indigenous land tenure systems in sub-Saharan Africa". American Journal of Agricultural Economics, 75(1): 10–9.

Place, F. and K. Otsuka. 2001. “Population, tenure and natural resource management: the case of Customary Land Area in Malawi”. Journal of Environmental Economics and Management, 41: 13–32.

Place, F. and K. Otsuka. 2002. “Land tenure systems and their impacts on agricultural investments and productivity in Uganda”. The Journal of Development Studies, 38(6): 105–28.

Rubin, D.B. 1974. “Estimating causal effects of treatments in randomized and non randomized studies”. Journal of Educational Psychology, 66: 688–701.

STATA. 2017. Extended Regression Models Reference Manual. College Station, Texas: Stata Press.

Sjaastad, E. and D.W. Bromley. 1997. “Indigenous land rights in sub-Saharan Africa: Appropriation, security and investment demand”. World Development, 25(4): 549–62.

Stiglitz, J.E. 1976. “The efficiency wage hypothesis, surplus labour, and the distribution of income in L.D.C.s. Oxford Economic Papers, New Series, 28(2): 185–207

Suyanto, S., T.P. Tomich and K. Otsuka. 2001. “Land tenure and farm management efficiency: The case of smallholder rubber production in customary land areas of Sumatra." Agroforestry Systems, 52: 145–60.

Traoré, S. 2012. “Micro-crédit et productivité agricole au Burkina Faso: Une analyse causale a partir des scores de propension”. PhD dissertation,Université Ouaga II, Burkina Faso.

World Bank. 2013. World Development Indicators 2013. Washington, D.C.: The World Bank.

Zhao, J. and P. J. Barry . 2014. “Effects of credit constraints on rural household technical efficiency”. China Agricultural Economic Review, 6(4): 654–68.

Annex 1: Statistical description of the use of inputs per hectare

Variables	Urea/ ha	NPK/ha	Organic manure/ha	Labour/ha	Pesticide/ ha	Herbicide/ ha
Average	2.533	4.128	132.812	44.455	2.413	13.192
Std dev	4.830	10.732	2847.076	61.911	21.821	60.140

Source: Author using data derived from 2011/2012 EPA survey.

Annex 2 Test of the difference of means

sum t if Sécurisationfoncière==1

```
 Variable |   Obs    Mean  Std Dev    Min    Max
-------------+--------------------------------------------------------
    t |   402  .4370045  .2046096  .0038968  .8602496
```

. sum t if Sécurisationfoncière==0 and idprovince==1 and sup_1 <=5

```
 Variable |   Obs    Mean  Std. Dev.    Min    Max
-------------+--------------------------------------------------------
    t |  10970  .4081758  .2087915  .0010894  .9100712
```

. ttest t if idprovince ==1 and sup_1 <=5, by (Sécurisationfoncière)

Two-sample t test with equal variances

```
------------------------------------------------------------------------------
 Group |   Obs    Mean  Std. Err.  Std. Dev.  [95% Conf. Interval]
---------+--------------------------------------------------------------------
   0 | 10970  .4081758  .0019935  .2087915  .4042682  .4120833
   1 |   402  .4370045   .010205  .2046096  .4169425  .4570664
---------+--------------------------------------------------------------------
combined |  11372  .4091949  .0019571  .2087042  .4053586  .4130311
---------+--------------------------------------------------------------------
 diff |    -.0288287  .0105952      -.0495972  -.0080602
------------------------------------------------------------------------------
 diff = mean(0) - mean(1)                t = -2.7209
Ho: diff = 0                     degrees of freedom =  11370
 Ha: diff < 0        Ha: diff != 0        Ha: diff > 0
 Pr(T < t) = 0.0033    Pr(|T| > |t|) = 0.0065    Pr(T > t) = 0.9967
```

Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

www.aercafrica.org

Learn More

www.facebook.com/aercafrica

www.instagram.com/aercafrica_official/

twitter.com/aercafrica

www.linkedin.com/school/aercafrica/

Contact Us
African Economic Research Consortium
Consortium pour la Recherche Economique en Afrique
Middle East Bank Towers,
3rd Floor, Jakaya Kikwete Road
Nairobi 00200, Kenya
Tel: +254 (0) 20 273 4150
communications@aercafrica.org