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The Role of Institutional Environments on Technical Efficiency: A Comparative Stochastic Frontier Analysis of Cotton Farmers in Benin, Burkina Faso, and Mali

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The Role of Institutional Environments on Technical Efficiency: A Comparative Stochastic Frontier Analysis of Cotton Farmers in Benin, Burkina Faso, and Mali[*]

Abstract

This paper examines the role of institutional environments on cotton farmer technical efficiency scores in Benin, Burkina Faso, and Mali using a stochastic frontier production approach. First, the key institutional changes that have occurred with the recent market-oriented reforms are discussed. Then, farm efficiency per country is measured using cross-sectional data collected by the Cotton Sector Reform Project of the Africa, Power, and Politics Programme in 2009. Results from a one-stage estimation procedure suggest that while no technical inefficiency exists in Benin, an average technical efficiency of 69% and 46% is found in Burkina Faso and Mali, respectively. Agricultural development policies focusing on reducing the inefficiency at the farm level in Mali and Burkina Faso should be adopted; whereas policies designed to shift outward the production frontier seem more appropriate in Benin. Interestingly, institutional environment factors explaining variations in efficiency scores differ across countries. In Mali, farms that are food secure and that cultivate more hectares of cereals are more technically efficient in producing cotton. In contrast, Burkinabe farmers who are dissatisfied with the management of their producer organizations are more technically efficient. To be successful, efforts to promote efficiency would have to work in concert with the local realities in each country.

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1 Introduction

Cotton is a key cash crop commodity with important implications for agricultural development and poverty alleviation in West Africa[1]. The importance of the cotton sectors can be gauged by considering that they provide employment and income to millions of smallholder farmers and cotton exports represent about 20%, 60%, and 80% of total agricultural export values in Benin, Mali, and Burkina Faso, respectively (FAO, 2011) In addition to being a major source of foreign exchange for the government and a main source of revenues for poor rural households, West African cotton sectors have multiplier effects on the rural economy and even on the economy as a whole (See Baden and Alpert, 2007; Nubukpo and Keita, 2005). Therefore, improving efficiency in cotton sectors has the potential to induce economic growth and poverty reduction.

Traditionally, West African cotton sectors have been vertically integrated, with state-owned enterprises acting with near monopsony power in seed cotton markets and near monopoly power in credit market for the distribution of agricultural inputs necessary for cotton production, such as seeds, fertilizers, and pesticides. In addition to purchasing all seed cotton at fixed and guaranteed pan-territorial prices, state-run companies oversaw agricultural advice, input supply, transport, ginning, and marketing services. Under this system, the viability of West African cotton sectors depended on the ability of the state-owned enterprises to produce surplus in times of high world prices and to rely on financial support from national governments in times of low international prices (Badiane et al., 2002). A combination of low world prices, lack of transparency, and general mismanagement in ginning operations led to significant deficits in West African cotton sectors in the 1990s. Given the importance of cotton in West Africa economies, governments and international institutions stepped in to cover their financial losses during this time period.

In response to the financial problems posed by poor performance of West African cotton sectors, reforms within the framework of the structural adjustment programs (SAPs) have been recommended. Major intents of the SAPs have been to resolve the financial crisis faced by governments and to revitalize the production structures by removing structural rigidities and inefficiencies in the economy (Baffes and Gautam, 1996; p.765). For instance these policies have encouraged the progressive withdrawal of state-run enterprises in the agricultural sector. It is assumed that successful reforms would stimulate cotton production by allowing farmers to allocate more efficiently their resources.

Concretely, West African countries started to reorganize their cotton sector by privatizing certain market operations (e.g., transport, ginning, and marketing), liberalizing other segments of the market (e.g., input procurement), and by strengthening their farmer organizations to involve them more actively in critical decisions. The dismantlement of state-owned enterprises also led to the curtailment of technical assistance and extension services. However, the withdrawal of the government in the provision of these services has not been accompanied by the entrance of new actors. There have been discussions on “getting the prices right” by aligning seed cotton prices (a.k.a., farm-gate prices) with world prices, but this liberalization policy has not been implemented[2]. To enhance West African cotton sector competitiveness and ensure its long-run viability, efforts to promote efficiency are crucial, especially at the gin and farm levels.

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[1] In this present work, West Africa refers to Benin, Burkina Faso, and Mali cotton sectors.

[2] The Malian cotton sector has experienced with price liberalization policy during 2005-08 but has since reverted (See Nubukpo and Keita, 2005)

With millions of smallholder farmers depending partially or totally on cotton for their livelihood, it is important to better understand which factors influence farm efficiency to ensure that the implemented reforms would lead to the desired outcomes. The objective of this research is, therefore, to expand the existing literatures on cotton reforms and efficiency by briefly discussing the institutional environments in which farmers have been producing cotton first, and, then, quantitatively estimate the technical efficiency scores of producers in Benin, Burkina Faso, and Mali using a stochastic frontier production model. Specifically, a one-stage estimation procedure is used to examine the effects of institutional environments on the technical efficiency scores at the farm-level in all three countries[3]. Cotton producers' technical efficiency is defined as their ability to produce maximum amount of output from a given set of inputs and technology. Using a unique dataset derived from surveys of cotton producers (conducted under the Cotton Reform Project teams of the Africa, Power and Politics Programme in summer 2009), this work show how farmers' performance and their determinants vary from one country to another, and provides guidance on the fundamental environmental factors that should be taken into account for the cotton sector to be successful and sustainably revitalized in each country.

This paper is organized as follows. The institutional environments, including market structures of the cotton sectors in Benin, Burkina Faso and Mali are briefly described in section 2. The measurement of technical efficiency is addressed in section 3. A description of the data, variables, and model used is provided in section 4. Empirical results are presented and discussed in section 5. Section 6 concludes.

2 Institutional Environments

This section briefly discusses changes that have occurred in the market structures, ginning company ownership and activities, input procurement functions, and producer organizations since the implementation of cotton reforms in Benin, Burkina Faso, and Mali (See Table 1).

2.1 Pre-Reform Institutional Settings

Historically, West African cotton sectors shared a similar institutional setting that was laid out during the colonial period. In all three countries, the French company, CFDT[4], played an important role in the development of their cotton sectors by providing technical advice and inputs to farmers, and by transporting, ginning, and marketing cotton (see Baffes, 2001). Following the country's independence, cotton sectors got nationalized and state-owned enterprises were created; the CMDT in Mali, the SOFITEX in Burkina Faso, and the SONAPRA in Benin[5]. Unlike in Benin, where the SONAPRA was fully owned by the state, the CMDT and the SOFITEX were initially a joint venture between the CFDT[6] and the Malian and Burkinabe government, respectively. Following the vertical structure already established by the CFDT, these state-run companies were responsible for input procurement, technical assistance and extension, transport, ginning and marketing services.

[3] Regressions are at the country level, since statistical evidences are found against pooling the datasets (See section 5.4 for a detailed description of the statistical test.

[4] CFDT is the acronyme for «Compagnie française pour le développement des fibres textiles»

[5] CMDT is the acronyme for "Compagnie Malienne de développement des textiles"
SOFITEX is the acronyme for "Société Burkinabé des fibres et textiles "
SONAPRA is the acronyme for "Société Nationales de Promotion Agricole "

[6] The CFDT became Dagris in 2001 and then Geocoton in 2008.

The first producer organizations (POs) to be established were village-wide and they regrouped both cotton and non-cotton farmers. They were known as village associations (AVs)[7] in Mali and as village groups (GVs)[8] in Benin and Burkina Faso. Through their POs, farmers were able to get inputs on credit provided by the state-owned enterprises at the beginning of the season. After the harvest, state-owned enterprises recouped their costs by deducting what farmers owned them from their cotton payment. Although their establishment contributed positively to empower cotton farmers by transferring them responsibilities in the collection, grading and weighting of seedcotton, the absence of exclusive membership in the AVs and GVs made input distribution and credit management more difficult to manage. Indeed, non-cotton farmers were allowed to get inputs on credit, even though cotton remained the principal means of revenues to pay back loans and some farmers decided to free-ride by selling inputs obtained on credit on the black market, assuming that other farmers would cover their loans (Gray, 2008). As a result of input diversion, bad governance, and mismanagement, there was accrued indebtedness at both individual and PO levels.

Although cotton producer organizations from the three West African cotton sectors under study have suffered from indebtedness, only the Burkina Faso government made the decision of canceling their debts accumulated over the past campaigns. On the other side of the border, the Malian government is examining whether solvable farmers should be rewarded for their good credit rather than eliminating insolvable farmer's debts. The argument is that eliminating debts sends the wrong incentives to farmers and forgiveness of agricultural debt reduces the costs of credit default for farmers, making such outcomes more likely to occur again (Govereh, 1999; Dorward et al. 1998).

2.2 Post-Reform Institutional Settings

Even though the pre-reform institutional setting was similar, the pace and path of the market-oriented reforms have considerably differed across the three countries. Contrary to Mali, where cotton reforms have been mainly undertaken to satisfy international institutions and donors, restructuration of the Benin cotton sector was from the beginning wanted by the State (Yerima and Affo, 2009; p.59). Therefore, Benin has been a first mover by privatizing the input procurement activities and by establishing privately owned ginning companies by the mid-1990. However, it is only in 2008, after several postponements, that the partial privatization of the Beninese state-owned enterprise, SONAPRA became finalized through the creation of SODECO. A private partner holds 33.5% of SODECO`s share whereas the government holds 66.5%, from which 33% will eventually be transferred to producers, local authorities, citizens and gin workers (EU-ACP, 2009) Interestingly, the private shareholder in SODECO also owns other gins in Benin. In fact, with his involvement in SODECO, this private actor has secured its dominant position in the Benin cotton sector by owning 16 gins out of 18 nationwide (Saizonou, 2008). Given that almost all ginning and marketing activities within the Benin cotton sector are managed by the same private operator, the transit toward a more competitive structure seems compromise. Indeed, a monopolistic structure better characterizes the Beninese cotton market, but private rather than public this time.

In 1999, the partial privatization of the Burkinabe state-owned enterprise, SOFITEX, followed an unconventional market reforms path by transferring 30% of the governmental shares to farmers rather than to private investors (Kaminski and Serra, 2011). This initiative aimed at empowering farmers by involving them more actively in critical decisions such as input and producer price

[7] AVs is the acronyme for "Associations villageoises"
[8] GVs is the acronyme for "Groupement villageois"

determination. The government retained 35% of the capital in SOFITEX and private operators owned the remaining 35%. Particularly, the French company, Dagris, held a 34% ownership and the local banks the remaining 1% (Sofitex, 2005).

The cotton reforms also led to the establishment of two new ginning companies, FASO COTON and SOCOMA, in 2004. A particularity of the Burkinabe cotton sector is the presence of zoning, which consists of demarcating the cotton producing area into exclusive zones for specific companies. Farmers producing within a zone have to deal exclusively with the gin company assigned to operate there. The principle of zoning is to limit problems of malpractices in the cotton sector, such as poaching[9] and unsatisfactory technical and extension services (ICAC, 2010).

Even though the reforms undertaken by the Burkina Faso to revitalize their cotton sector has been considered as a success story in the early 2000s (World Bank, 2004; Goreux and Macrae, 2003), they did not lead to better financial performances in the long-run. Indeed, in 2007 SOFITEX was first recapitalized entirely by the government after the major private investor decided to not contribute, and, then, FASO COTON and SOCOMA had to be recapitalized the following years to avoid bankruptcy. It has been suggested that the inflexibility in the price mechanism to pass world price fluctuations to farmers contributed to the financial losses incurred by the gin companies during 2004-06 (Yartey, 2008). With approximately 85% of the national cotton production managed by SOFITEX, which is now largely owned by the government, the Burkinabe cotton sector is again characterized by the presence of a large public monopoly. Since the recapitalization, the government has adopted a multifaceted strategy to reduce SOFITEX costs, which should ultimately lead to the sale of 30% shares to a private investor.

In comparison with Benin and Burkina Faso, Mali has been a latecomer to undertake the privatization reform process recommended by the international institutions and donors. Indeed, the privatization of the state-owned enterprise, CMDT, has not been completed yet. Proposed dates of privatization have been several times postponed. At the latest, national and foreign investors made purchasing offers to the Malian government to acquire one or more of the four regional monopolies that will be created with the dismantlement of the CMDT and the establishment of cotton production zoning. Once the privatization is completed, the four regional gin monopolies- Northeastern, Southern, Central, and Western- will be owned at 61% by private operators, 20% by producers, 17% by the State, and 2% by the workers (ICAC, 2008a).

Refocusing the ginning company activities on the cotton system is one of the key strategies proposed by the reforms to improve the efficiency and performance of the West African cotton sectors. As a result, gins have gradually withdrawn from rural development activities. For instance, the CMDT progressively disengaged from the provision of public services outside the cotton sectors (such as maintaining roads and ensuring access to drinkable water to rural population) and from the active promotion of integrated farming systems based on livestock production and cereals. Furthermore, there has been a decline in the technical and extension services offered to producers, since neither the government nor private investors stepped in to offer services no longer considered to be the gin responsibilities. To deal with the lack of technical support, the Beninese

[9] Poaching occurs when farmers receive input on credit by one ginning company at the beginning of the cotton season on promise of selling them their production but at the moment of the harvest, they sell it to a competitor that offered them higher prices. As a result, the gin that initially offered inputs on credit cannot recoup totally its costs and, thus, will eventually limit its services of inputs on credit to farmers.

"Interprofession[10]" decided to hire more technicians to ensure a better service to its producers (Yerima, 2010, p:31 vol.I). To our knowledge, this initiative has not been followed in Mali and Burkina Faso yet.

With the cotton reforms, the POs have been reorganized with the aims of becoming solvable and better positioned to defend their member interests within the cotton sector. The Malian village associations were transformed in cotton producer cooperative societies (SCPCs[11]), the village groups in Benin and Burkina Faso into village cotton producer groups (GVPCs[12]) and cotton producer groups (GPCs[13]), respectively. Under these new structures, membership is restricted to cotton farmers only. Cotton producers can freely create their own organizations based on other member affinities, such as levels of indebtedness or field proximity. However, the presence of strong kinship makes exclusion of members less likely. A joint liability program, known as "caution solidaire" prevails in the SCPCs, GPCs, and GVPCs. Therefore, members of a same PO are jointly liable for each other's loans. Given that the most performing farmers have to use their own profits to cover the financial losses of the less performing ones, tensions among members exist. In some cases, the best performing farmers even stopped cultivating cotton (Gray, 2008). Indeed, the joint liability program has been the source of conflict among POs in each country, since indebtedness remains highly problematic (See Yerima 2010; Kaminski,et al., 2009, and Fok 2007 for a description of the problems faced in Benin, Burkina Faso, and Mali, respectively).

With the reforms, Beninese cotton farmers became able to order inputs on credit for both their cereal and cotton production. Opening the input access to both types of crops was seen as a solution to reduce input diversion from cotton to cereal fields. Input diversion has always existed and has even been tolerated to some extent. However, difficulties emerge when input diversion becomes greater than a minimum acceptable and when monitoring of repayment is slack. With less inputs used on cotton fields, cotton production declines, and farmers are more likely to default on their credit repayment. Therefore, input diversion was and remains a potential cause of high level of indebtedness faced by the majority of POs. With the privatization process, import and distribution of inputs became two separate activities in Benin and led to the introduction of a new intermediary, the Cotton Inputs Commission (CIC), formerly the Provisioning and Management Agricultural Inputs cooperative (CAGIA) (Saizonou, 2008). Political interests highly interfered in the selection process of private firms to provide essential inputs to farmers. As a result, firms were more likely to be selected based on their social networks rather than on the quality of their services and their expertise (Yerima, 2009; p.55). Therefore, farmers have often complained about the poor quality of inputs purchased.

Interestingly, by refocusing the ginning activities toward cotton only, the CMDT progressively disengaged from rural developmental services, such as access to inputs and advice for cereals crops in cotton areas. Indeed, all activities related to inputs meant for CMDT cereal crops were transferred to the cotton and cereal producer union group, GSCVM[14]. However, due to the lack of experience in handling logistical operations and lacks of collateral to ensure loan repayment to input suppliers, GSCVM has had important difficulties in providing cereal inputs on credit to farmers

[10] An "interprofession" is a formally organized association that groups key stakeholders involved in the cotton sector. Their objectives are to enhance market performance, through more efficient coordination and to defend the sector interests.
[11] SCPCs is the acronyme for "Societes cooperatives des producteurs de coton"
[12] GVPCs is the acronyme for "Groupements villageois des producteurs de cotton"
[13] GPCs is the acronyme for "Groupement des producteurs de coton"
[14] GSCVM is the acronyme for "Goupement des syndicats cotonniers et vivriers du Mali"

(IFDC, 2004). Being used to cultivate in integrated systems, it is not uncommon for Malian producers to divert some of their cotton inputs toward their cereal fields. On one hand, diversion may be a mean to cope with the lack of access to cereal inputs on credit. On the other hand, diversion may be more a sign that cotton prospects are bleak rather than due to lack of access to inputs. With the privatization of the CMDT, activities related to cotton input procurement has been progressively transferred to the national union of the cotton producer cooperatives, UN-SCPC[15].

In Burkina Faso, input supply functions have also been transferred to the national union of Burkinabe cotton producers, UNPCB, following the privatization of SOFITEX. However, unlike in Mali, inputs meant for both cereal and cotton crops are managed by the UNPCB. After the harvest, credit for both cotton and cereal inputs are directly deducted from farmer cotton payment. Linking cereal inputs on credit to cotton payment have contributed to increase their availability.

For the reforms to be successful in sustainably revitalizing West African cotton sectors, it is essential to get a better understanding on how the institutional environments, in which farmers are growing cotton, influence their performance. A wide array of applied work has looked at the sources of inefficiency in agriculture of developing countries, including the cotton sector. However, previous studies on farm-level efficiency of cotton producers have focused on a single-country case and have not specifically assessed the roles of institutional environments (e.g., Audibert et al., 2003; Shafiq and Rehman, 2000; Bravo-Ureta and Evenson, 1993). At present, there is no known cross-country empirical analysis that explicitly examines the roles of institutional environments on African cotton sectors efficiency at the farm-level. This paper contributes to the literature by measuring and comparing the technical efficiency scores of cotton producers in three West African countries and by analyzing the role of institutional environments, such as joint liability credit programs and extension services, on farmer performance. Results should provide useful insight to policy-makers regarding how cotton producer performances are influenced by local market and institutional realities.

3 Measurement of Technical Efficiency

Literature on efficiency of productive units, which has been shaped by the seminal work of Farrell (1957), can be classified according to whether the measurement technique used is non-parametric or parametric. The development envelopment analysis (DEA) and the stochastic frontier analysis (SFA) are the most commonly non-parametric and parametric methods, respectively, used to measure the relative efficiency on farm-level data at one point in time[16]. Both the DEA and the SFA approaches recognize the possibility of inefficiency in production. They do not assume that all farmers are technically efficient. Being both extensively used in measuring production efficiency in agricultural sector of developing countries, the advantages and limits associated with these two competing methods, DEA and SFA, are briefly discussed[17].

Developed in 1978 by Charnes et al., the DEA method consists of mathematical programming formulations, where inefficient producing units are compared with the most efficient (best) units within the sample. The initial assumption of constant returns to scale was relaxed by Banker et al. (1984) to allow for variable returns to scale. The advantage of non-parametric techniques, such as

[15] UN-SCPC is the acronym for “Union nationale des sociétés coopératives des producteurs de coton

[16] In addition to cross-sectional data, both the DEA and SF methods can also be used to measure efficiency on panel data.

[17] See Coelli et al. (2005) for a more comprehensive discussion on both methods.

the DEA, is that they do not rely on assumptions about the functional form or about the distribution of the error terms. The main limitation of the DEA method comes from its deterministic nature, which assumes that any deviation from the production frontier is due to inefficiency. Therefore, any measurement error and/or random stochastic error in the data are confounded with farmer inefficiency. As a result, the DEA estimates are very sensitive to the sample data, and especially to outliers (Greene, 1993).

The SFA approach, which estimates the parametric form of a production function and recognizes the presence of random errors terms in the data, was first introduced by Aigner et al. (1977) and by Meeusen and van den Broeck (1977). This regression-based method incorporates a composed error term. One component of the error term reflects the inefficiency in production while the other component represents the random effects outside producer control, including luck, (un) favorable climate conditions, measurement error and other statistical noise from the data. The production frontier itself is stochastic since it varies randomly across farms due to the presence of the random error component (Coelli et al. 1999). Unlike the DEA method that estimates the best observed practice, the SFA approach econometrically estimates the best theoretical practice. The main criticism of this econometric technique is that strong assumptions have to be made concerning the selection of a particular functional form and the distribution of the inefficiency component in the composed error term. Nevertheless, the SFA model has the advantages of being able to measure the individual inefficiency in the presence of statistical noise in the dataset and to estimate standard errors.

Given that both have virtues and shortcomings, the choice of an approach to measure efficiency becomes almost philosophical. Empirical studies on technical efficiency for cotton farmers have used either the DEA (e.g.,Gul et al., 2009; Helfand and Levine, 2004; Audibert et al. 2003; Shafiq and Rehman, 2000) or the SFA (e.g., Thirtle et al., 2003; Bravo-Ureta and Evenson, 1994) or both (e.g., Chakraborty et al., 2002). In the context of agriculture in developing countries, where imperfections in credit and chemical input markets exist, the assumption that random shocks, such as weather and unpredictable variation in labor performance, do not influence productivity becomes questionable. In addition to being influenced by the main underlying assumptions, the decision to use one approach over the other depends upon the data available and the types of analysis. For instance, the DEA technique has the ability to easily handle multiples outputs and inputs. Alternatively, the stochastic frontier is better suited to analyze the determinants of inefficiency since the inclusion of environmental variables can be done in one-stage rather than two-stages to avoid implicit bias. Given that the objective is to examine how different environmental contexts, market structures and institutional arrangements in the cotton sector influence efficiency at the farm-level, and given that random effects non controllable by farmers are considered to impact productivity, the SFA method is considered more appropriate.

Comparing 32 frontier studies using farm-level data from developing countries, Thiam et al. (2001) did not find TE estimates from SFA to be statistically different from those using the DEA deterministic approach. Obviously, the smallest the component of the error term due to random shocks and statistical noise, the closest the estimates from both methods are. The use of panel data rather than cross-sectional also improves the accuracy of the measured efficiency (Greene, 1993). Using panel data, Ruggiero (2007) also concluded that DEA and SFA methods generated similar results. Therefore, the decision of measuring cotton farmer efficiency through econometric techniques rather than linear programming should not be seen as a limitation, since it has been shown to lead to similar results.

3.1 Stochastic Frontier Analysis

Following the model proposed by Aigner et al. (1977), the general stochastic frontier production function can be expressed as,

$$Y_i = f(x_i;\beta) + \varepsilon_i = \exp(x_i\beta + \varepsilon_i), \qquad i = 1 \dots . N \qquad (1)$$

where, Y_i denotes the output of the i-th farmer, x_i represents a (Kx1) vector of input quantities of the i-th farmer, β is a (Kx1) vector of unknown production elasticity parameters to be estimated, and ε_i is the double component error term. It is postulated that $\varepsilon_i = v_i - u_i$, where v_i represents the classical symmetric disturbance term and u_i is the technical inefficiency component to be estimated. The symmetric error component, v_i, is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. The one-side error component, u_i, is assumed to be distributed independently of v_i, to satisfy $u_i \geq 0$, and is derived from a $N(0, \sigma_u^2)$ half-normal distribution. A higher value of the one-side component, u_i, implies an increase in the farmer technical inefficiency. A value of u_i equals to zero means that there is perfect technical efficiency. Borrowing from Battese and Coelli (1988), the technical efficient of the i-th farm can be represented as,

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{Y_i}{\exp(x'_i\beta + v_i)} = \frac{\exp(x'_i\beta + v_i - u_i)}{\exp(x'_i\beta + v_i)} = \exp(-u_i) \qquad (2)$$

A basic stochastic production frontier is depicted in Figure 1. The vertical axis represents the level of cotton output whereas the horizontal axis represents the inputs used to produce cotton output. In absence of noise effects (v_i), the production frontier is considered to be deterministic rather than stochastic. The deterministic production frontier is represented by the curve. The observed cotton production levels of two farmers, 1 and 2, are represented by squares. The first farmer uses inputs defined by X_1 and obtains a level of cotton production equals to Y_1. In the presence of favorable conditions, the noise effects are positive, and the frontier output (Y_1*) is above the deterministic production frontier. The second farmer uses inputs defined by X_2 and produces Y_2. The frontier output Y_2* is below the deterministic frontier production due to the presence of unfavorable conditions (negative noise effects). Interestingly, the second farmer is judged technically more efficient relative to the unfavorable conditions associated with the production cotton activities than if judged relative to the maximum output possible given the deterministic production frontier. The inefficiency effect (u_i) can be seen as the difference between what farmers are producing (observed cotton output Y) and what they are capable of producing given the conditions (frontier output Y*).

Note that the production frontier above does not take into account the possibility that cotton farmers may be facing different institutional arrangements that may influence their technical efficiency. Later research has extended this basic model in order to take into account the environment in which farmers are producing. Two major alternative extensions have been developed (See Coelli et al., 1999). The first one assumes that the environment directly affects the production function and the shape of the technology available. Consequently, each farmer is assumed to face a different production frontier. The environmental condition variables are added to the original model as follows,

$$Y_i = f(x_i, z_i;\beta, \theta) + \varepsilon_i = \exp(x_i\beta + z_i\theta + \varepsilon_i), \qquad i = 1 \dots . N \qquad (3)$$

where, z_i represents a (Mx1) vector of environmental factors in which the i-th farmer produce and θ is a (Mx1) vector of unknown parameters to be estimated. The technical efficiency becomes net of environmental influences.

In the second approach, the environment directly affects the technical efficiency score rather than the production frontier and technology. This model extension relies on the assumption that all farmers share the same technology and, therefore, face the same production frontier. The distance between farmer's efficiency score and the best practice function varies with the environment conditions. The impact of environment on technical efficiency can be measured using either a two-stage or a one-stage procedure. In the two-stage method, the stochastic production frontier and the technical efficiency (TE) scores, as stated by equations 1 and 2 respectively, are first estimated. Then, the TE scores are regressed upon a set of environmental explanatory variables, including farmer demographic characteristics and institutional arrangements.

The two-stage estimation in the second approach has been criticized for being contradictory (Kumbhakar and Lovell, 2000, p.262-264; Coelli, 1998, p.207-209). In the first stage, both components of the error term are assumed to be identically and independent distributed, however, the regression of different factors on the inefficiency score in the second stage suggests that these latter are not identically distributed (e.g., Coelli et al., 1999; Battese and Coelli, 1995). The omission of environmental variables in the first-stage is also criticized for leading to biased estimated coefficients in both the production frontier and technical efficiency scores (Coelli, 2005; Wang and Schmidt, 2002).

The one-stage estimation of the second approach satisfies the assumptions while estimating the effect of environment directly through the technical efficient score. This approach, which allows the environmental factors to directly affect the stochastic component error term of the production frontier, has been developed for cross-sectional data by Kumbhakar et al. (1991), and extended to panel data by Battese and Coelli (1993). Under this approach, the inefficiency score of the i-th farm has a distribution that varies with the farm-specific characteristics, z_i, and, therefore, the one-sided error terms are no longer identically distributed. The new technical inefficiency term is described as;

$$\mu_i = \delta' z_i + w_i \qquad (4)$$

where, z_i is a (Mx1) vector of environmental factors in which the i-th farmer produce and δ is a (Mx1) vector of unknown parameters to be estimated. The asymmetric error component, u_i, is assumed to be distributed independently and to follow a $N(\delta' z_i, \sigma_u^2)$ distribution truncated at zero. Equation (4) is then added to equation (1) in order to estimate simultaneously all the unknown parameters (β_s, δ_s, σ_u^2, and σ_v^2) of the production frontier and inefficiency using the maximum likelihood method. Following Battese and Coelli (1992), the variances are parameterized as;

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 \ ; \quad \gamma = \sigma_u^2 / \sigma_s^2 \qquad (5)\ ;\ (6)$$

where, γ must lie between 0 and 1 in order to start the iterative maximization process. If γ is statistically different from zero using a one-sided likelihood test, then there is presence of inefficiency in the model. With inefficiency, the production frontier method is more appropriate than ordinary least squares.

Whether to choose the first (environment affects directly production frontier) or the second (environment influences directly technical efficiency) approach is a matter of philosophical perspective as mentioned by Coelli et al. (1999, p.252). Although both approaches have been used, the one-step estimation in the second approach has received further attention in the recent literature (e.g., Bhandari and Maiti, 2007) and seems more appropriate for the analysis of institutional arrangements in the context of West African cotton sector. It is assumed that each farmer faces a similar production frontier, but the environment in which they are producing influences their efficiency.

4 Data and Model

4.1 Data

The data used for this analysis comes from the Africa, Power, and Politics (APP) surveys conducted by the cotton sector reform research teams in Benin, Burkina Faso, and Mali during summer 2009. The survey instrument consisted of an individual 13-page questionnaire, divided into two sections. Although a similar version of the questionnaire was used across the three West African countries under study, some personalized questions were added to account for the local realities of each country. Both qualitative and quantitative information were collected through the survey. The quantitative data is processed with statistical tools in order to compare determinants and contexts for differing technical efficiency across the three countries. The qualitative information collected during the interview process serves as a validation tool for the empirical results and is used to enrich the discussion.

The first section of the survey encompassed all questions related to demographic (e.g., education and experience), household (e.g., number of people and food self-sufficiency), and farm characteristics (e.g., equipment, and crop production) of the respondent. The second section of the survey included all questions related to determinants of cotton supply. For instance, reasons that would incite (discourage) farmers to grow more (less) cotton, types of intervention that would improve the cotton sector overall, issues related with the input provision, technical assistance received, difficulty with the joint liability program, and quality of the relationship with union representatives, among others. The second part provided information regarding the level of coordination achieved among stakeholders and, therefore, revealed the elements of the institutional arrangements that work well and the ones that need to be improved to ensure the viability of West African cotton sectors.

In each country, 5 to 10 cotton producer organizations (GVPCs in Benin, GPCs in Burkina Faso, and SCPCs in Mali) were initially selected from different cotton regions. The main objective of this survey was to gather information at the farm level from a fairly diverse population in order to get deeper insights about their realities as cotton farmers (Serra, 2008). Therefore, producer organizations (POs) presenting different characteristics were picked for interviews across the different cotton regions. In each POs, 10 to 12 cotton growers were randomly selected using the member list. The farmer sample was not stratified per farm size- small, medium, or large- as it has been done in other studies (e.g., Carter, 1984), since the definition of farm size is not consistent across the three countries. For instance, the number of equipment (e.g., ploughs and carts) and plough animals (e.g., oxen) are at the base of the definition in Mali, whereas the number of hectares is the criteria used in Benin.

In Benin, surveys were conducted in 4 GVPCs located in the North and in 1 GVPC from both the Central and South regions of the country. More GVPCs were selected in the North to account for the fact that cotton is mainly produced there. In total, 90 cotton producers, 15 in each GVPC, were interviewed across the three main cotton regions. In Burkina Faso, 12 cotton growers per GPC were interviewed across two main cotton regions. In Houndé, 2 GPCs were chosen whereas interviews were conducted in 3 GPC in the Bobo region. The sample of Burkinabe cotton producers totaled 60. In Mali, surveys were conducted in 12 SCPCs located across 5 cotton regions (3 SCPCs in Koutiala, 2 SCPCs in Sikasso, Fana, Ouéléssébougou, and Kita, and 1 SCPC in Bougouni). The total number of farmer interviews totaled 114[18].

Production economic theory is based on several assumptions concerning both the output and input sets (See Coelli, 2005 for a detailed description). Two assumptions are of particular interest for this study. First, zero production is impossible from a given sets of inputs. Second, zero level of inputs cannot produce positive level of output. Therefore, all interviewed farmers that did not produce cotton and/or did not use a positive quantity of each traditional input (labor, land, chemical inputs on credit, and equipment) during the crop campaign 2008/2009 are excluded from the dataset. Other efficiency studies at the farm level also had to deal with restrained dataset due to the deletion of non-producing farmers and incomplete records (e.g., Bravo-Ureta and Evenson, 1994). At the end, the sample used for estimating the technical efficiency at the farm level includes 81 observation from Benin, 56 from Burkina Faso, and 82 from Mali.

4.2 Model

A Cobb-Douglas functional form for the stochastic frontier is chosen for the analysis of technical efficiency in the three cotton sectors. The Cobb-Douglas has been widely used in efficiency studies on agricultural sector of developed and developing countries, and especially on cotton (e.g., Gebremedhin et al. 2009; Chakraboborty et al., 2002; Shafiq and Rehman, 2000; Bravo-Ureta and Evenson 1994). Despite being less flexible than other functional forms, the Cobb-Douglas provides a nice economic interpretation (coefficients measure elasticity) and allows saving some degrees of freedom (which is important given the relatively small number of observations in each country). Results from previous studies suggest that technical efficiency measures are not significantly affected by the choice of the functional form (Ahmad and Bravo-Ureta, 1996; Koop and Smith, 1980).

The Cobb Douglas stochastic frontier model used for the econometric analysis is written as;

$$lnY_{ic} = \beta_0 + \sum_{j=1}^{m} \beta_j lnx_{jic} + v_{ic} - u_{ic} \qquad (7)$$

where the subscripts i and c represent the i-th farmer growing cotton in the c-th country, respectively. The traditional explanatory variables included in the stochastic frontier production model are similar to those used in previous cotton efficiency studies (Helfand and Levine, 2004;Audibert et al., 2003; Chakraborty et al., 2002; Battese and Broca, 1997; Bravo-Ureta and Evenson, 1994). These variables can be classified into four general categories: labor, inputs, equipment, and land. Given that cotton production is mainly rain-fed in West Africa, there was not

[18] In each CPC, 10 cotton growers were interviewed at the exception of one CPC in the Kita region, where only 6 surveys were conducted due to an external event. A tornado hit the village few days earlier and, therefore, many farmers were too busy repairing the damage to answer the questionnaire (10*12 + 6= 114).

need to make a distinction between irrigated and non-irrigated fields. Following is a description of the traditional variables used in the regression;

Y represents the logarithmic quantity of cotton harvested (in kgs)

x_1 represents the logarithm of total amount of active family labor (in person)[19]

x_2 is a dummy variable having a value of one if the farm hires non-family labor to work on the cotton fields; zero otherwise

x_3 represents the logarithm of total purchased inputs- seeds, fertilizers, pesticides, and insecticides (in CFAs). This includes both direct and credit purchases.

x_4 represents the logarithm of total amount of equipment- owned ploughs, carts, sprayers, and tractors (in CFA)

x_5 represents the logarithm of the ratio of cotton acreage over total cultivated land (%)[20]

x_6^m represents the regional dummy variables to taken into account soil and climatic condition differences.

v_{ic} represents the stochastic component error

u_{ic} represents the technical inefficiency

Table 1 provides a statistic summary of the production factors for each country sample. The mean is reported as a measure of central tendency. The standard deviation as well as the minimum and maximum are included to show the dispersion of the observations within each sample. The average production per farm is higher in Benin (6250 kg) than in Burkina Faso (3055 kg) and in Mali (3571 kg). This can be explained by the fact that interviewed Beninese farmers cultivate more hectares of cotton, purchased more cotton inputs such as pesticides, and have higher cotton yields. Moreover, the majority of the Beninese farms hired non-family labor whereas the work on Malian cotton fields is mainly done by family labor. No interviewed producers reported owing a tractor in Benin and Burkina Faso, compared with 2 farmers in Mali. Note that these tractors can be seen as a gift from the government to encourage cotton production, since their purchases have been highly subsidized. Owning a tractor does not necessarily reflect the purchasing power of the farmer. In our sample, the Burkinabe farmers are the most specialized in cotton production across the three countries. Indeed, half of their cultivated land is planted with cotton. The lower number of active family members working on cotton field in Burkina Faso can be explained by the smaller size of their farm compared to those in Benin and Mali.

Following production theory, it is expected that a greater endowment of labor, inputs, equipment, and land devoted to cotton contribute positively to higher level of cotton production. However, it is still unclear how the institutional context affects farmer's ability to be technically efficient. This cross-country study contributes to the literature by empirically assessing how the use of traditional production factors is impacted by the environment in which farmers are working. Given that the APP dataset used in this study is based on information collected through similar survey questionnaire and methodology across the three West African countries, comparative analysis is possible.

[19] A better measure would have been the total number of man days of work spent on cotton fields, but this information was not collected by the surveys used in this study. Male and female workers are not weighted equally. Given that females also have to take care of the children, and domestic chores, they generally have less time to spend on the cotton fields. Therefore, they receive a lower weight (0.8).

[20] Note that cotton acreage and purchased cotton inputs are strongly correlated in Burkina Faso (corr=94%) and in Mali (corr=88%). The correlation between cotton land and inputs is weaker, but still strong, in Benin (corr=74%). To avoid correlation between these two explanatory variables, land has been included in the regression through the use of a ratio rather than acreage. A very weak correlation exists between cotton land ratio and value of inputs in all three countries.

Environment is a broad term that encompasses four different categories as defined by Audibert et al. (2003). The first category includes structural factors such as food self-sufficiency and cereal acreage. The second category deals with human capital, including education and farm experience. Social factors, such as satisfaction with the management of producer organizations and local culture, compose the third category. The last category consists of institutional factors, such technical assistance and extension services. Unlike the human capital category, social and institutional factors as well as structural (with the exception of farm size), have received less attention in studies of efficiency in agriculture. Therefore, structural, social and institutional variables shaping the cotton sector in West Africa are included in the inefficiency score regression in order to examine their roles on performance.

The model of technical inefficiency effects on the stochastic frontier equation (7), including environmental factors, is determined by

$$u_{ic} = \delta_0 + \sum_{j=1}^{8} \delta_j z_{jic} + w_{ic} \quad (8)$$

where, z_{jic} represents the j-th environmental characteristics of the i-th farmer producing in the c-th country.

z_1 is a dummy variable having a value of one if the farm is food self-sufficient; zero otherwise
z_2 represents the number of hectares cultivated with cereals-sorghum, millet and maize (ha)
z_3 represents farmer experience in growing cotton (in years)
z_4 is a dummy variable having a value of one if the farmer is literate; zero otherwise
z_5 is a dummy variable having a value of one if the farmer consider the norms prevailing in the cooperative to be restrictive to the achievement of high performance; zero otherwise
z_6 is a dummy variable having a value of one if the farmer has experienced difficulty with the joint liability program; zero otherwise
z_7 is a dummy variable having a value of one if the farmer has received technical assistance and extension services over the last five years; zero otherwise
z_8 is a dummy variable having a value of one if the farmer is optimistic about the future of the cotton sector; zero otherwise.

Table 3 reports the summary statistics for the institutional environment variables include in this analysis. In average, 2.82 hectares of land are allocated to cereals per cotton farm in Burkina Faso. This number is larger in Benin and Mali with 5.17 and 7.46 hectares, respectively. However, levels of self-sufficiency among Malian and Burkinabe farmers are comparable. The percentage of literate farmers is very similar in Burkina Faso and Mali, but higher in Benin. A majority of the Burkinabe farmers are dissatisfied with how their GPC is managed, whereas the Malian producers seem overall satisfied. The joint liability program appears to be a more important issue in Benin than in Mali and Burkina Faso, with 87% of farmers who experienced problems with it. Also, more Beninese farmers have received technical assistance over the past years and they are more confident that the cotton situation will improve.

The hypotheses regarding the influence of the non-traditional factors on cotton farmer technical inefficiency are presented below.

Structural Factors[21]

To our knowledge, no study on technical efficiency has examined the role of food self-sufficiency on cash crop outputs. Looking at the interrelation between food self-sufficiency and cotton production in the 18th century in the South of the United States when food markets were not well-developed, Gallman (1970) found that plantations with high levels of maize output also have higher levels of cotton output. Given the presence of imperfect food markets (e.g., inadequate roads and transport systems) in our three countries, it is expected that farmers that are food self-sufficient are more efficient in producing cotton.

The expected sign of the coefficient of cereal hectares is ambiguous. On one hand, cereal and cotton crops are directly competing for certain resources such as land allocation and chemical inputs. In the absence of an efficient cereal input distribution channel, there is a high incentive for Malian farmers to divert some of their cotton inputs toward their cereal fields. Therefore, cereal hectares may negatively impact cotton production. On the other hand, complementary dimensions of cotton and cereal crops may be more important than the competing ones. Given that both crops require use of labor and equipment at different periods, growing cereals should not reduce cotton capacity (Jayne, 1994; Gallman, 1970). In comparison with farms practicing cotton monoculture, farmers who practice crop rotations are more likely to get higher yields due to a better conservation of soil resources (Hulugalle and Scott, 2008; Naudin and Balarabe, 2005). Indeed, sustainable cereal-cotton rotations may maintain or may even improve soil structure and fertility by increasing soil organic matter content and decreasing soil erosion, and minimize disease and pest incidence. Therefore, cotton farmer inefficiency may decline with cereal acreage.

Human Capital Factors

Unlike previous studies that include farmer age, we prefer to use years of farming experience since its effect on efficiency can be more directly measured. Indeed, it is expected that more cotton farming experience leads to higher cotton productivity (Thirtle et al., 2003). The influence of age on efficiency is not as straightforward. On one hand, older farmers may have more years of farming experience, and, therefore, efficiency may be higher. On the other hand, older farmers may be more reluctant to changes in cotton farming practices, and, therefore, productivity may be lower.

Literate farmers are generally assumed to have better farming capacity and access to information, and, therefore, to be more efficient (Gebremedhin et al., 2009). However, the lack of statistically significant relationship between basic level of education and efficiency in previous works has been explained by the potential presence of a stage of development threshold below which the expected positive relation is not found (Bravo-Ureta and Evenson, 1994).

[21] No direct measure of farm size is included in the regression, since there is no consensus over a definition across the three countries. As previously mentioned, farm size is defined in terms of acreage in Benin, whereas owned equipment is the measure used to differentiate small, medium, and large farms in Mali. Nevertheless, this structural factor is indirectly taken into account through the use of inputs, cotton land ratio, and equipment variables in the production model.

Social Factors

Governance problems and internal conflicts inside collective action organizations may restrain production to reach its full potential and may lead to the withdrawal of some producers, as was the case for rice farmers in Benin (Kinkinggninhoun-Medagbe et al., 2010; p59). In our case, it is assumed that farmers, who subjectively believe that the norms prevailing in their cotton producer organizations are restrictive, are technically more efficient. Indeed, producers who are dissatisfied with management of their cooperatives are more likely to be entrepreneurial and, thus, to understand the discrepancy between status-quo and what would be possible under efficient management (Mude, 2006).

Institutional Factors

Although group lending programs are very common among cotton farmer organizations in Africa, their influences on productivity is still debatable. The principle of joint liability in loan programs is not problematic, per se, but its application may lead to undesirable outcomes. If every producer decided to participate actively, they would all be better-off under this cooperative arrangement (Lawrence, 2003). However, cooperation requires a high level of commitment from everyone. Lack of commitment may lead to opportunistic behaviors that are detrimental for the group lending initiative. Local realities, such as conflicts between age, ethnicity, and class groups, have been found to affect cooperative efficiency (Woods, 1999). The expected sign for the joint liability dummy is ambiguous.

A positive relationship between technical inefficiency and farmers that reported having issues with the joint liability would suggest that these latter are struggling to produce enough to cover their loans. Indeed, less performing farmers may have to sell assets or ask for outside help in order to be able to repay their loans. In contrast, a negative sign would suggest that the most performing farmers are the ones experiencing problems with the joint liability program, since a part of their profits go to cover the financial losses of other members.

In the developing world, technical support and extension services offered to producers have been widely recognized as a key factor contributing positively to production by providing advice and information on how to improve technical skills in farming operations (e.g Keil et al., 2007; Haji, 2006). However, expectations regarding the performance of agricultural extension services remain low since their delivery faces many limitations (Poulton et al., 2010). For instance, technical assistance received by farmers may be of poor quality or the method use to transmit the information may be inadequate.

A very limited number of studies have examined how farmer attitude toward market reforms influences their productivity. Among those, Mude (2006) found that pessimistic farmers, those lacking of confidence in policymakers to improve their situation, are more likely to be less technically efficient.

5 Empirical Results

Ordinary least squares (OLS) estimates of average production function as well as the maximum likelihood parameters (MLE) of the stochastic production frontier for different distributional forms are first estimated using the software Stata version 11.1. A one-sided likelihood ratio[22] is used to test whether technical inefficiency is present in the dataset. If technical inefficiency is detected, the stochastic production frontier is more appropriate. Otherwise, the OLS estimator is better-suited for the data. Then, the stochastic production frontier model providing the best goodness of fit is analyzed using the computer program, Frontier 4.1 (see Coelli, 2005 for a description of the program). The advantage of the software Frontier 4.1 is that it allows analyzing the impact of environment on individual technical efficiency score using a one-stage estimation procedure.

5.1 Benin

As seen in Table 4, the average production (OLS) function better fits the Beninese dataset. Indeed, the likelihood ratio test for the presence of inefficiency fails to be rejected. Therefore, the stochastic production frontier model reduces to a simple OLS model with a normal disturbance term, i.e. that the Beninese cotton producers in the sample appear to be fully technically efficient. A first hypothesis would be that unfavorable conditions during the 2008/2009 crop campaign (large noise effects) reduced the gap between the observed and frontier outputs to non-statistically significant levels (See Figure 2). A second hypothesis would be that the market-oriented reforms in the cotton sector led to the withdrawal of underperforming farmers and, therefore, cotton is, now, mainly produced by the most efficient ones. From 1999 to 2003, approximately forty percent of Beninese households, who were once producing cotton, stopped production due principally to debt issues related to policy implemented over the years (Siaens and Wodon, 2003). A third possible hypothesis is that the actual production frontier is so low that farmers can easily produce on its frontier. If this is the case, new technologies, such as BT cotton, should be introduced to move the production frontier outward (See Figure 2). Otherwise, failure to push the production frontier outward could jeopardize the ability of Beninese cotton farmers to be competitive on the international market (Kelly and al., 2011).

As expected, all input factors-labor, inputs, equipment, and land- have a significant positive effect on cotton production. The estimated elasticity coefficients for value of inputs (seeds, pesticides, insecticides, and fertilizers) purchased[23] and for value of equipment are significant at the 99% and 95% confidence intervals, respectively. Farms that are better equipped and that have better access to inputs on credit are more likely to get higher level of cotton production. A negative relationship exists between cotton output and farms located in the southern region of Benin. This result is pertinent since the agro-climatic conditions in the South are less appropriate to cotton crops than those in the Northern part of the country. The central region appears to be the best location to grow cotton in Benin. One possible explanation is that farms located in the central region benefit from both appropriate agro-climatic conditions and good access to services due to their proximity to the port and the largest city, Cotonou.

It is important to keep in mind that, in our sample, Beninese farmers are technically efficient, which does not necessary imply that they are also allocatively efficient. Indeed, they are producing the optimal level of outputs given the productive factors they use and the technology available, but they might not allocate them the most efficiently. Increased production would lead to a decline in farmer income if this increase was associated with additional costs that exceed the additional revenues from the marginal gain in outputs. Therefore, being technically efficient does not imply that

[22] Likelihood ratio (LR)=2(Log-likelihood of the unrestricted model- log-likelihood of the restricted model)~ χ^2_1 (2α)
Ho: Y=0, where Y=σ_u^2/σ^2. This implies that $\sigma_u^2 = 0$, and therefore, there is no technical inefficiency.
[23] Over 95% of the inputs are obtained through credit.

Beninese farmers are less poor. Unfortunately, it is not possible to measure the allocative efficiency, since costs of productive factors were not all collected.

5.3 Burkina Faso

The estimated elasticity coefficients for non-family labor and cotton land ratio are not statistically different from zero in the Burkina Faso dataset (see Table 5). Given that these two input factors are statistically insignificant; they have been disregarded in the model specification[24]. The magnitude and level of significance of the other input variable coefficient estimates remain relatively unchanged across the different OLS models. The high adjusted R^2 value (0.83) suggests that the predictive ability of the model is high.

Results from OLS and MLE are reported in Table 6. With the exception of the regional dummy, all coefficient parameters estimated by maximum likelihood are smaller in magnitude than those obtained through OLS. The likelihood ratio test rejects the null hypothesis of absence of technical inefficiency. Therefore, the stochastic production frontier is better suited for the analysis of the Burkinabe sample. Among the different distributional forms, the half-normal specification is the one chosen to estimate the stochastic production function and the technical efficiency scores[25]. As expected, a greater endowment of family labor, purchased inputs and equipment contribute positively to higher level of production. The purchased input elasticity coefficient is the largest and is significant at the 99% confidence level. The regional dummy is also statistically significant from zero. Farms located in the Bobo region are more likely to have lower level of cotton production than those in Hounde.

In Burkina Faso, over 99% of the cotton inputs are obtained through credit allocated by the ginning companies at the beginning of the crop season. An important aspect of the Burkinabe cotton market is that farmers have access to inputs on credit for both cotton and cereals through their national union, UNPCB. Interestingly, the quantity of cotton inputs purchased by farmers is highly correlated with the number of cotton acreage (corr= 94%). In comparison, 85% of the cereal inputs are obtained through credit and the correlation with acreage is relatively low (corr=52%).

When asked what the main constraint to diversify from cotton was, Burkinabe farmers almost unanimously answered the lack of market access for other crops (51 farmers out of 56). Given that inadequate access to credit and insufficient access to inputs were among the possible answer choices, this suggests that the highest correlation between cotton acreage and inputs is not a manifestation of issues within the input market for cereals. It might imply that farmers are getting a quantity of inputs that is close to the optimal recommendation per hectare made by the ginning companies. No information on the level of indebtedness of farmers and on their previous credit reimbursement rates was collected. Otherwise, it would have been interesting to investigate whether inputs on credit are mainly allocated as a function of the cotton acreage planted or as a function of the farmer past solvency rates. Given that previous debts incurred by Burkinabe cotton producers were forgiven, they might have an incentive to get the maximum amount of inputs per hectare possible, no matter their capability to repay.

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[24] An F-test is used to compare whether model 1 (including hired labor dummy and cotton land ratio) gives a significantly better fit to the data than model 2 (excluding hired labor dummy and cotton land ratio). The null hypothesis that model 1 does not provide a better fit than model 2 fails to be rejected: F(2,49)= 3.187> 1.029.

$$\text{F-test}= \frac{(RSS_2 - RSS_1)/(P_1-P_2)}{RSS_1/(N-P_1)}$$

[25] As seen in Table 5, results obtained from the half-normal and exponential distributional forms are very similar.

Table 10 reports the frequency distribution of TE estimates for the Burkina Faso sample. The mean technical efficiency (TE) is estimated to be 69% among the interviewed Burkinabe cotton producers. Although the TE showed great variability (TE ranging from 26% to 96%), only 16% of producers are below 0.50. Variations in the technical efficiency of cotton farmers have been analyzed through the use of environmental factors.

The coefficient estimates of the inefficiency model in the Burkinabe cotton sector are reported in Table 7. It is important to keep in mind that a negative sign of a coefficient stands for a negative impact on inefficiency- an efficiency enhancing factor-, whereas a positive coefficient sign implies an efficiency reducing effect. Among all environmental variables, the human social capital factors- years of cotton farming experience and literacy- and the number of cereal hectares have the largest standard errors relative to their coefficient estimates[26]. Given the small size of the sample, these three variables have been excluded from the final model specification, based on the results from a generalized likelihood ratio test, in order to save some degrees of freedom.

The institutional factors- whether farmers have received technical assistance and extension services over the past five years and whether they have struggled with the joint liability program- are not statistically different from zero. The social factor- cooperative norms- is negative and statistically significant at the 10% level. Producers, who believe that social norms are restraining their GPC to be better managed, are technically more efficient. How producer organizations, GPCs in Burkina Faso, deal with farmer payment, indebtedness, and their internal funds, are considered by these farmers to be efficiency reducing. Norms prevailing inside the cooperative structure do not effectively encourage timely payment to farmers, good management of indebted farmer cases, and a productive and transparent use of the internal GPC funds. This situation is not unique to cotton growers. Govereh et al. (1999) report that coffee farmers in Kenya started to side-sell in order to avoid working with poorly functioning coffee cooperative societies. Mude (2006)'s results also suggest that the most performing Kenyan coffee producers are dissatisfied with the poor management of their cooperatives. Similarly, Audibert et al. (2003) find a negative relationship between social cohesiveness and efficiency for Ivorian cotton producers. Their results show that cotton farms located in villages where social cohesiveness is lower, are more efficient. A new question arising from this finding is whether farmers that consider social norms prevailing in the cooperatives as being efficiency reducing are more individualistic-driven and/or business-oriented.

5.3 Mali

As seen in Table 8, all elasticity coefficients are statistically significant, with the exception of family labor. Using the likelihood ratio test, the null hypothesis stipulating the absence of inefficiency is rejected. Therefore, it is more appropriate to analyze the Malian dataset with a stochastic production frontier than an OLS model. The largest estimated elasticity parameter is cotton land ratio. Farms with a higher proportion of their cultivated land planted with cotton are more likely to produce more. Interestingly, the Malian farmers are the less specialized in cotton across the three countries, by growing cotton on less than 1/3 of their cultivable land. This percentage is consistent with Fok (2008)'s result that cotton share in the Malian cropping system does not exceed 30% of the cultivated land. The elasticity coefficient for equipment is also relatively large in Mali.

[26] Other studies, such as Mude (2006), found that socio-demographic variables were not statistically related with degree of efficiency.

A statistically significant difference was found across farms located within the Old Cotton Basin. Cotton production in the Northeastern and Central regions is lower than in the Southern region. As expected, level of cotton output from the New Cotton Basin (Western region) is significantly lower than in the Southeast region.

The frequency distribution of TE estimates for the Malian sample is reported in Table 10. The mean technical efficiency (TE) among the Malian cotton producers is 46% and over 60% of the farmers are below a TE score of 0.50. The TE ranges from 15% to 95%. Differences in farmer technical inefficiency are examined through the use of environmental factors.

Table 9 reports the coefficient estimates for the one-stage technical inefficiency model. Given that cooperative norm and technical assistance variables were highly insignificant- their standard errors largely exceeded the estimated parameter values- they have been dropped from the final model. Farmers that are food self-sufficient are more technically efficient in producing cotton as expected. First, farmers that produce enough food to meet their family needs are more likely to spend more time on their fields and less on off-farm activities. Indeed, the availability of off-farm income is found to be efficiency reducing (Keil et al., 2007). Secondly, they might also have better farm managerial and technical skills, which are also beneficial to cotton crop.

Interestingly, the cereal hectare coefficient estimates is negative and highly significant. Cultivating more hectares of cereals- maize, millet, and sorghum- reduces cotton grower technical inefficiency. The Malian cotton sector is characterized by the absence of an efficient distribution channel for cereal inputs. Given that cotton farmers have been used to farm in an integrating system that involves livestock production and cereal-cotton crop rotation, they have coped with the limited access to cereal inputs on credit by deviating some of their cotton inputs, such as fertilizers and pesticides, on their cereal fields. Although, input deviation might reduce cotton production if a sub-optimal dosage is applied, it might bring some benefits too. First, soil fertility is generally better preserved on farms practicing rotation between cotton and cereals compared to those practicing only cotton monoculture (Hulugalle and Scott, 2008). Second, farmers with greater cereal area might be in a better position to feed their animals during the dry season, which also coincides with the plowing season. Indeed, the use of cereal straw improves the feed situation of animal in the dry season (Bakker et al., 1997).

Literacy and farming experience are both statistically insignificant. Previous study shows that illiteracy does not restrain Malian farmers to cope with scouting cotton pest and to properly use the right chemical (Michel, 2000; cited by Fok, 2008; p.200). The coefficient for the joint liability variable is positive but not statistically different from zero. The estimated parameter for whether farmers are confident that the cotton situation will improve in the future is positive and statistically significant. This suggests that optimistic farmers are more technically inefficient. This finding contrasts with Mude (2006)'s result that Kenyan coffee producers lacking of confidence in the future are less efficient. Qualitative information gathered during interviews reveals that optimistic farmers believe that inputs will become cheaper and that better support to purchase equipment will be provided with the reform process. The higher level of inefficiency among optimistic farmers may suggest that they have access to fewer resources and, thus, hope that their farming situation will improve with the reforms.

5.4 Comparisons

Overall, the production factors are all positive and mainly statistically significant in the three countries. The family labor elasticity coefficient is 0.252 in Benin and 0.172 in Burkina Faso. In the stochastic production frontier model including inefficiencies, the family labor is statistically insignificant in the Malian sample. Hiring labor positively influences the level of cotton production in Benin (β_{hired}=0.399) and Mali (β_{hired}=0.226). The value of owned equipment is highly significant in all countries, but the magnitude of the coefficient is larger in Mali. This is explained by the fact that Malian producers are better-equipped than their West African fellows[27]. This finding is consistent with Fok (2008; p.199), who mentioned that “Mali distinguishes itself by the popularization of animal-drawn so that only a small share of the peasants is strictly conducting manual farming”.

In Benin and Burkina Faso, where farmers can more easily access inputs on credit for both cereal and cotton crops, the largest elasticity coefficient is value of inputs (fertilizers, pesticides, insecticides, and seeds). Unlike these two countries, cotton land over total cultivated land has the largest elasticity coefficient in the Malian dataset. Interestingly, access to inputs on credit is mainly available for cotton growers and the quantity on inputs available is proportional to the number of cotton hectares. Therefore, a strong incentive to plant cotton exists for Malian farmers.

Among our three countries, inefficiency fails to be found in the Beninese dataset. Producers obtain the maximal (frontier) level of cotton outputs from a given set of inputs. However, before concluding that all Beninese farmers are fully technically efficient, it would be preferable to collect more data and over more than one year, to ensure that efficient level of outputs are not the result of a aggregate negative shock, such as bad luck or unfavorable climatic conditions. Data collected from developing countries are also more susceptible to be contaminated by statistical noise due to measurement errors and variability in climatic conditions, resulting in underestimated TE scores (Coelli et al., 1998; p.219). In our case, random disturbances or random events might have lead to overestimate the TE of Beninese farmers. However, if Beninese farmers are truly technically efficient, there is an important need to find productive technologies that would shift outward the production frontier in order to improve their ability to compete on the international market.

Technical inefficiency is present in both the Burkinabe and Malian datasets. An examination of the sources of inefficiency reveals that human capital factors have a positive sign but they are not statistically significant. Findings from previous studies on the influence of human capital on farmer technical efficiency in developing countries are mixed. Some studies find literacy to be efficiency reducing (Audibert et al., 2003), others to be efficiency enhancing (Gebremedhin et al. 2009; Keil et al., 2007), and others do not find any statistically significant relationship (Gul et al. (2009); Haji, 2006; Battese and Coelli, 1995). As in previous studies such as Idiong (2007), a lack of association between farming experience and efficiency is obtained. This is in contrast with Gul et al. (2009)’s finding that farmer experience on cotton farming positively influences efficiency. Technical assistance and extension services offered to cotton farmers do not statistically impact their productivity[28]. This finding is consistent with other research focusing on African cotton sectors (Ngassam et al., 2010). The coefficient for the joint liability variable is positive in both countries. However, we cannot conclude that farmers having issue with the joint liability program prevailing

[27] Dropping the two observations with a tractor does not change the finding. Indeed, the minimum and maximum values remain unchanged and the mean value goes from just above one million CFA (1 111 370 CFA) to just below one million CFA (995 770 CFA) .

[28] A dummy variable accounting for technical assistance and extension services received over the previous year was created but it remained statistically insignificant.

inside the cotton cooperatives are less efficient in producing cotton, since the coefficient is not statistically significant at the 10% level.

The estimated coefficients that are statistically significant in the Malian inefficiency model appear insignificant in the Burkinabe model and vice-versa. For instance, being food self-sufficient and having a larger number of cereal hectares do not significantly influence farmer performance in Burkina, whereas they are highly efficiency enhancing factors in Mali. These findings suggest that cereal and cotton crops can be complementary to each others. Even though cereal crops and cotton may compete in terms of land allocation, their relationship with other production factors such as labor, working capital, and crop management has complementary dimensions (Govereh et al., 1999; p.3)

Social norms prevailing in Burkinabe cotton producer organizations, GPCs, are reducing farmer efficiency. These social norms are considered inadequate to manage farmer payment, indebtedness, and cooperative funds. The accrued internal debts from 2006-2009 have raised questions relative to the level of social cohesiveness that exists inside GPCs (Kaminski et al. 2009; p.16).

With the Malian cotton sector facing many challenges, such as widespread indebtedness, farmers were asked whether the situation will improve. Interestingly, producers expressing confidence in the future of the Malian cotton sector are more likely to be less efficient. One possible explanation is that these farmers are optimistic that the reforms will provide them with better support to access equipment and inputs on credit.

In our case study, the Burkinabe farmers are closer to their production efficiency frontier with an average TE score of 0.69, while Malian producers are further away from their own production possibility frontier with an average TE score of 0.46. Although the range of the TE scores is similar across both countries, more farmers are above the 0.50 threshold in Burkina Faso than in Mali. In comparison with other technical efficiency studies on cotton sector in developing countries, the Burkinabe and Malian TE scores appear to be slightly higher and lower, respectively (See Table 11).

The possibility of pooling the Malian and Burkinabe datasets is examined, since it will increase the number of degrees of freedom and will provide a greater space for comparisons. However, before pooling these two cross-sectional datasets together, it important to test for homogeneity to determine whether pooling is appropriate to avoid biased estimates (Brobst and Gates, 1977). An F-test (a.k.a Chow test) based on the comparison of the residual sum of squares from the OLS individual country regressions with the residual sum of squares of the pooled OLS regression is estimated (Gould, 2005)[29]. Given that the null hypothesis of homogeneity is rejected at the 99% confidence interval, pooling of these two datasets is inappropriate. The coefficients in the two OLS country regressions are statistically different, and, therefore they should not be pooled into one single regression.

[29] $F(K, N1+N2-2K) \sim \frac{[RSSp - (RSS1 + RSS2)] / K}{(RSS1+RSS2)/(N1+N2-2K)}$ Fcritical(10, 118) ~2.95 < Fcomputed=6.06

6 Conclusions

This paper has discussed the main institutional changes that have taken place in the West African cotton sectors following the introduction and implementation of market reforms aimed to improve their performance. Traditionally, West African cotton sectors were characterized by the presence of a state-owned enterprise that was in charge of providing inputs, transporting, ginning, marketing, and exporting seed cotton. Interestingly, each country has undertaken the market-oriented reforms at a different pace and following a distinct path. Among our three countries, Benin has been the first one to reform, following by Burkina Faso and further behind by Mali Issues with the joint liability program prevailing inside cotton producer organizations are common to all three countries. Market structures, levels of farmer empowerment in the ownership of the privatized state-run companies and distribution channels for cereal and cotton inputs are the main distinguishing elements across these three West African cotton sectors.

A stochastic frontier production has been used to estimate and compare the technical efficiency score of producers in Benin, Burkina Faso, and Mali. Specifically, a one-stage estimation procedure is used to examine the effects of institutional environment on the technical efficiency scores at the farm-level in all three countries. Data used in this analysis are derived from surveys of cotton producers, conducted by the Cotton Sector Reform Project teams of the Africa, Power and Politics Programme in summer 2009. All production factors- labor, equipment, land, and inputs- have a positive sign and statistically impact the level of cotton output in the three countries. Higher production level could be achieved through a better access to inputs on credit and equipment, such as traction animals.

The empirical results from the stochastic frontier analysis suggest that Beninese farmers are fully technically efficient, whereas the presence of technical inefficiency is found in the Burkinabe and Malian datasets. Agricultural development policies focusing on reducing the inefficiency at the farm level in Mali and Burkina Faso should be adopted, whereas policies designed to shift outward the production frontier are more appropriate for the case of Benin. The estimated average technical efficiency (TE) scores in Burkina Faso (0.69) and Mali (0.46) are consistent with those reported in previous efficiency studies on cotton production in developing countries. The TE scores suggest that Burkinabe cotton farmers are closer to their own best production frontier given the particular country's conditions, while Malian farmers are further away from their production efficiency frontier. Technical assistance and human capital factors- literacy and farming experience-, do not statistically explain differences in inefficiency among producers in both countries. The absence of significant relationship between these variables and efficiency has also been found in previous research. Even though all countries face some issues with the joint liability program prevailing in producer organizations, the dummy variable used to capture this institutional constraint is not statistically significant. Therefore, there is a need to develop a variable that will better capture the influence of group lending program on cotton farmer efficiency.

In addition to the path and pace of the market reforms, the Burkina Faso and Mali cotton sectors can be differentiated in terms of their farmer inefficiency sources. In Burkina Faso, farmers that criticize the poor functioning of their producer organization are more efficient than those who think that they perform well. This new finding raises questions on whether these farmers are more driven by individualistic goals rather than group welfare, and whether the norms governing the functioning of producer organizations are more beneficial to the less performing farmers.

In Mali, farmers that are food-secure and with more hectares of cereals are more efficient in producing cotton. These results support the argument that cotton and cereal crops have some complementary dimensions. Although cereal and cotton crops are directly competing for the allocation of land and inputs, they both benefit from improvement in labor, working capital, managerial and technical skills, and soil fertility from practicing crop rotation. Another interesting finding is that Malian cotton farmers who believe that the sector would improve with the market reforms are more likely to be technically less efficient. One possible explanation is that these farmers have lower endowment, and, therefore, have more to gain than to lose with the reforms.

Overall, the findings show the importance of considering environmental factors in stochastic frontier production and technical efficiency analysis. Although Benin, Burkina Faso, and Mali cotton sectors have some characteristics in common, their level of farmer technical efficiency differs. More importantly, the sources of inefficiency are different from one country to another. For the reforms to be successful in improving the performance of the West African cotton sector, they would have to work in concert with the local realities.

In Mali, a special attention should be given to the fact that cotton growers have been used to farm in integrating systems, where livestock production, cotton and cereal crops are strongly interconnected. Improving access to cereal inputs on credit for cotton farmers would be a first step to revitalize the cotton sector. One way to increase cereal inputs availability would be to provide initial support to the GSCVM in the handling of logistic and financial operations. This would require a certain level of engagement from the government and financial institutions, such as the BNDA. For instance, if GSCVM future payment were secured by the government and the BNDA, input suppliers would be more likely to deliver the quantity needed and to do it on time. Another option that requires a deeper investigation would be to transfer cereal input functions to the producer union, UNSCPC. So far, cotton farmers in Burkina Faso have benefited from a good access to both cereal and cotton inputs on credit through their producer union, UNPCB. This is an avenue that might be interesting for Malian cotton farmers too.

Improving social cohesiveness inside Burkinabe producer organizations, GPCs, would require structural and behavioral changes. One option that deserves more analysis would be the creation of several sub-lending groups (known as “cercle de caution”) inside each GPC to facilitate peer-monitoring. Those sub-groups would be in charge of monitoring each other’s behavior to ensure that the right quantity of inputs is purchased on credit and that they are used adequately and at the appropriate time. An ad-hoc committee should also be established to verify the work done by the GPCs’ representatives in order to promote transparency and good governance. In some cases, this might even lead to prompter and higher farmer payment. This would require the provision of training sessions to farmers to teach them how to prevent, detect, and deal with opportunistic behaviours at both farmer and GPC levels.

A better understanding of local realities relevant to cotton farmers and the implementation of reforms that are consistent with them are important steps to revitalize West African cotton sectors while having the potential to induce economic growth and poverty alleviation.

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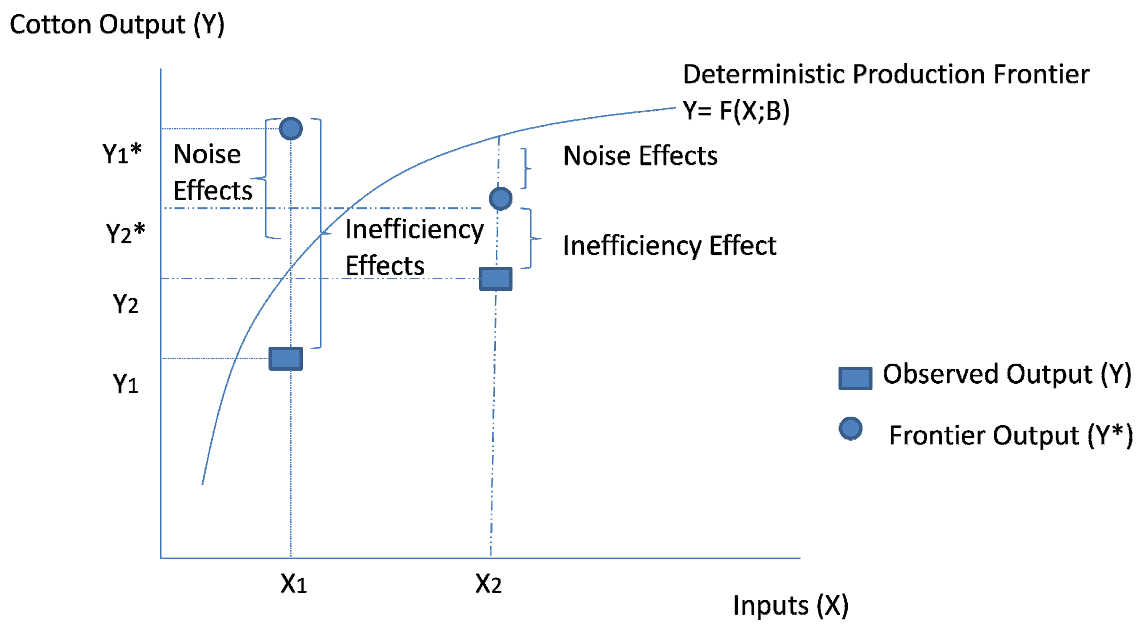

Figure 1, Stochastic Frontier Production

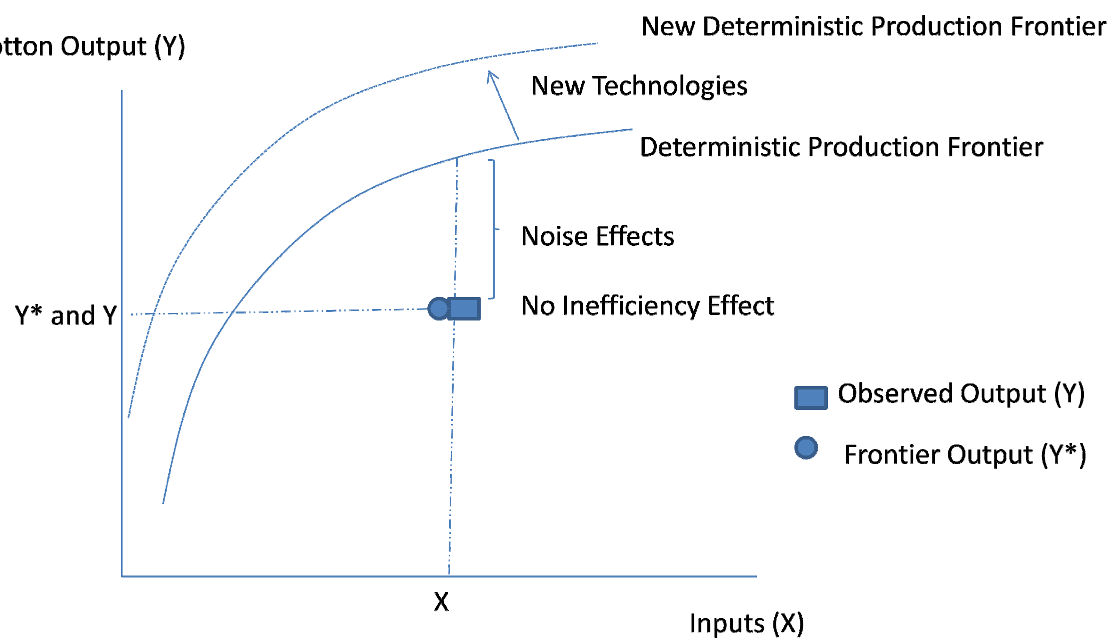

Figure 2, The Beninese Stochastic Production Frontier Case

Table 1, Changes in the Institutional Environments of West African Cotton Sectors

	Market Structure		Ownership		Input Supply		POs	
	Before	After	Before	After	Before	After	Before	After
Benin	SONAPRA	SODECO (10 gins) New gins: SOCOBE, ICB, CCB, IBECO, LCB, SEIBC, MCI, SODICOT	State 100%	State 33.5% Private 33.5% Citizen 17.5% Local authority 8.5% GVPCs 6% Workers 1% Private 100%	SONAPRA	Private 1-Cotton and cereals 2-Import and distribution are separated	GVs	GVPCs
Burkina Faso	SOFITEX	SOFITEX New gins: Faso Coton SONOMA	State 65% CFDT 34% Private 1%	State 35% Private 35% Farmers 30% Private 90% Farmers 10% Private 80% Farmers 20%	SOFITEX	UNPCB 1-Cotton and cereals	GVs	GPCs
Mali	CMDT	Southern (Sikasso+Bougouni) Northeastern (San+Koutiala) Central (OHNV+Fana) Western (Kita)	State 60% CFDT 40%	 State 17% Private 61% Farmer 20% Workers 2%	CMDT	UN-SCPC 1-Cotton only GSCVM 2-Cereal only	AVs	SCPCs

Table 2, Production Factor Summary Statistics

Variables	Benin (N=81)		Burkina Faso (N=56)		Mali (N=82)	
	Mean (S.D)	Min-Max	Mean (S.D)	Min-Max	Mean (S.D)	Min-Max
Cotton Production (kg)	6250 (8849)	135-50000	3055 (2458)	400-14500	3571 (5513)	300-34739
Cotton Land (ha)	4.43 (4.87)	0.5-27	950 (311)	360-1657	961 (400)	110-1878
Family Labor (person)	8.51 (7.43)	2-49	5.35 (2.72)	2-12	10.70 (11.96)	1-100
Hired Labor (dummy)	0.84 (0.37)	0-1	0.57 (0.49)	0-1	0.31 (0.46)	0-1
Equipment (CFA)	219274 (263126)	1000-925000	319006 (178396)	1000-746500	1111370 (1875026)	1000-1430000
Purchased Inputs (CFA)	394629 (523055)	15500-2800000	235619 (149070)	55740-844210	333361 (459156)	15000-3269365
Cotton Land Ratio (%)	33.74 (20.68)	3.44-88.88	50.70 (14.81)	21.59-80	27.33 (11.50)	7.14-63.15
Total Cultivated Land (ha)	14.16 (12.65)	1.9-85	6.13 (3.14)	2-16	12.04 11.68	1.5-69.6

Table 3, Institutional Environment Factor Summary Statistics

Variables	Benin (N=81)		Burkina Faso (N=56)		Mali (N=82)	
	Mean (S.D)	**Min-Max**	**Mean (S.D)**	**Min-Max**	**Mean (S.D)**	**Min-Max**
Cereal Land (ha)	5.17 (4.98)	0-25	2.82 (1.58)	0.5-6	7.46 (6.50)	1-39
Farming Experience (years)	19.16 (9.15)	1-45	10.89 (5.62)	2-31	23.03 (12.50)	2-50
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
Food Self-Sufficiency	0=39 1=42	48.15 51.85	0=22 1=34	39.29 60.71	0=29 1=53	35.37 64.63
Literacy	0=31 1=50	38.27 61.73	0=30 1=26	53.57 46.43	0=43 1=39	52.44 47.56
Norms Cooperative			0=12 1=44	21.43 78.57	0=78 1=4	95.12 4.88
Joint Liability	0=10 1=71	12.35 87.65	0=31 1=25	60.71 39.29	0=61 1=21	74.39 25.61
Technical Assistance	0=19 1=62	23.46 76.54	0=32 1=24	57.14 42.86	0=43 1=39	52.44 47.56
Optimistic	0=24 1=57	29.63 70.37	0=43 1=13	76.79 23.21	0=58 1=24	70.73 29.27

0 = no, 1=yes

Table 4, OLS and MLE Production Function Estimates, Benin (N=81)

Variables	OLS	Half-Normal	Exponential	Truncated-Normal
Constant	-1.349*	-1.338	Does not fit	-1.340
	(0.756)	(0.896)	the data	(0.901)
Family Labor	0.252**	0.252**		0.252**
	(0.105)	(0.100)		(0.100)
Hired Labor	0.399**	0.399**		0.399**
	(0.182)	(0.173)		(0.173)
Equipment	0.087**	0.087**		0.087**
	(0.035)	(0.034)		(0.034)
Inputs on Credit	0.570***	0.570***		0.570***
	(0.081)	(0.077)		(0.077)
Cotton Land Ratio	0.216*	0.216*		0.216*
	(0.120)	(0.114)		(0.114)
Regions:				
Central	0.429*	0.429*		0.429*
	(0.235)	(0.223)		(0.223)
South	-0.373*	-0.373*		-0.373*
	(0.225)	(0.214)		(0.214)
Lambda	--------	0.025		----------
		(0.681)		
Sigma2	--------	0.267		0.268
		(0.043)		(0.002)
Sigma v	--------	0.517		---------
		(0.041)		
Sigma u	--------	0.0133		
		(0.673)		
Prob>F	0.000	0.000	-----------	-----------
R^2_{adj}	82.38	---------	-----------	-----------
Log Likelihood		-61.522		-61.522
Test u=0				
(Prob>chibar2)		1.000		----------
(Prob ≤ z)				0.698

Standard errors are in parentheses. *, **, and *** = statistically significant at the 90, 95 and 99-percent confidence levels, respectively. North is the omitted cotton region.

Table 5, OLS Production Function Estimates, Burkina Faso (N=56)

Variables	Model 1	Model 2
Constant	-2.491**	-2.664**
	(1.098)	(1.065)
Family Labor	0.169*	0.1651*
	(0.100)	(0.106)
Hired Labor	0.096	----------
	(0.091)	
Equipment	0.075***	0.076***
	(0.025)	(0.025)
Inputs on Credit	0.712***	0.775***
	(0.111)	(0.101)
Cotton Land Ratio	0.150	----------
	(0.147)	
Region	-0.374***	-0.328***
	(0.095)	(0.088)
Prob>F	0.000	0.000
R^2_{adj}	83.05	83.02
Likelihood	-8.993	-10.153

Standard errors are in parentheses. *, **, and *** = statistically significant at the 90, 95 and 99-percent confidence levels, respectively. Hounde is the omitted cotton region.

Table 6, OLS and MLE Production Function Estimates, Burkina Faso (N=56)

Variables	OLS	Half-Normal	Exponential	Truncated
Constant	-2.664**	-1.403*	-1.539	Do not converge
	(1.065)	(0.849)	(0.997)	
Family Labor	0.1651*	0.135*	0.150*	
	(0.106)	(0.078)	(0.079)	
Equipment	0.076***	0.067***	0.065***	
	(0.025)	(0.018)	(0.023)	
Inputs on Credit	0.775***	0.721***	0.724***	
	(0.101)	(0.082)	(0.092)	
Region	-0.328***	-0.416***	-0.428***	
	(0.088)	(0.064)	(0.078)	
Lambda	--------	5.698	1.959	
		(0.094)	(0.131)	
Sigma2	--------	0.233	0.100	
		(0.057)	(0.033)	
Sigma v		0.083	0.143	
	--------	(0.042)	(0.060)	
Sigma u		0.476	0.281	
	--------	(0.064)	(0.079)	
Prob>F	0.000			
R^2_{adj}	83.02			
Loglikelihood	-10.153	-6.958	-8.053	
Likelihood ratio test sigma u=0 (Prob> Chibar2)		0.006	0.020	

Standard errors are in parentheses. *, **, and *** = statistically significant at the 90, 95 and 99-percent confidence levels, respectively. Hounde is the omitted cotton region.

Table 7, Production Function and Technical Inefficiency Estimates, Burkina Faso (N=56)

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant	-1.293	-1.011	-1.005	-0.554
	(0.900)	(0.909)	(0.929)	(0.803)
Family Labor	0.151*	0.172**	0.157*	0.087
	(0.084)	(0.078)	(0.089)	(0.083)
Equipment	0.055**	0.069***	0.060***	0.069***
	(0.022)	(0.021)	(0.022)	(0.022)
Inputs on Credit	0.723***	0.685***	0.695***	0.659***
	(0.083)	(0.084)	(0.085)	(0.080)
Region	-0.426***	-0.439***	-0.443***	-0.427***
	(0.077)	(0.077)	(0.074)	(0.063)
Constant	0.496**	0.441*	0.573**	0.765**
	(0.227)	(0.253)	(0.226)	(0.322)
Structural :				
Self-Sufficiency	-0.290	-----------	-0.240	-0.189
	(0.208)		(0.185)	(0.192)
Cereal	-----------	-----------	-----------	-0.029
Acreage				(0.076)
Human Capital :		-----------	-----------	
Cotton Farming	------------			-0.006
Experience				(0.020)
Literacy	------------	------------	-----------	0.006
				(0.201)
Social :				
Cooperative	-0.331*	-0.387*	-0.376*	-0.356*
Norms	(0.200)	(0.223)	(0.211)	(0.207)
Institutional :				
Technical	-0.171	-0.224	-0.199	-0.197
Assistance	(0.173)	(0.201)	(0.193)	(0.209)
Joint Liability	0.189	0.200	0.161	0.112
	(0.181)	(0.193)	(0.177)	(0.183)
Situation	-----------	-0.273	-0.188	-0.166
		(0.227)	(0.216)	(0.273)
Sigma-squared	0.137**	0.139*	0.132**	0.128***
	(0.065)	(0.070)	(0.060)	(0.041)
Gamma	0.953***	0.960***	0.959***	0.999***
	(0.062)	(0.056)	(0.063)	(0.000)
Loglikelihood	-2.095	-2.861	-1.639	0.693
LR Test- one sided error	16.115	14.583	17.027	21.694
# of restrictions	6	6	7	10
Mean Eff.	0.699	0.694	0.695	0.677

Standard errors are in parentheses. *, **, and *** = statistically significant at the 90, 95 and 99-percent confidence levels, respectively. Hounde is the omitted cotton region.

Table 8, OLS and MLE Production Function Estimates, Mali (N=82)

Variables	OLS	Half-Normal	Exponential	Truncated-Normal
Constant	-2.818***	-1.823**	-2.246**	-2.042*
	(0.932)	(0.927)	(0.821)	(0.120)
Family Labor	0.344***	0.343***	0.337***	0.336***
	(0.095)	(0.087)	(0.085)	(0.087)
Hired Labor	0.371***	0.444***	0.441***	0.441***
	(0.126)	(0.124)	(0.120)	(0.120)
Equipment	0.274***	0.254***	0.262***	0.258***
	(0.060)	(0.045)	(0.049)	(0.050)
Inputs on Credit	0.316***	0.282***	0.295***	0.291***
	(0.079)	(0.077)	(0.071)	(0.077)
Cotton Land Ratio	0.718***	0.774***	0.762***	0.766***
	(0.148)	(0.145)	(0.149)	(0.147)
Regions:				
Northeastern	-0.191	-0.175	-0.148	-0.158
	(0.168)	(0.153)	(0.156)	(0.163)
Central	-0.233	-0.237*	-0.231*	-0.235*
	(0.147)	(0.134)	(0.134)	(0.134)
Western	-1.058***	-1.148***	-1.114***	-1.126***
	(0.211)	(0.211)	(0.190)	(0.206)
Lambda	--------	2.144	0.876	----------
		(0.264)	(0.159)	
Sigma2	--------	0.489	0.235	0.720
		(0.165)	(0.045)	(1.994)
Sigma v	--------	0.295	0.364	---------
		(0.103)	(0.066)	
Sigma u	--------	0.634	0.319	---------
		(0.170)	(0.104)	
Prob>F	0.000	---------	-----------	-----------
R^2_{adj}	0.750	---------	-----------	-----------
Log Likelihood	-56.192	-54.980	--55.047	-54.977
Likelihood ratio test u=0 (Prob>chibar2)		0.060	0.065	

Standard errors are in parentheses. *, **, and *** = statistically significant at the 90, 95 and 99-percent confidence levels, respectively. Southern is the omitted cotton region.

Table 9, Production Function and Technical Inefficiency Estimates, Mali (N=82)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	0.947	1.019	0.633	-1.143*	-1.902
	(1.193)	(0.969)	(0.993)	(0.653)	(1.292)
Family Labor	0.084	0.086	0.092	0.176*	0.100
	(0.087)	(0.077)	(0.083)	(0.096)	(0.183)
Hired Labor	0.210*	0.203*	0.226*	0.382***	0.271
	(0.122)	(0.105)	(0.117)	(0.129)	(0.176)
Equipment	0.210***	0.206***	0.212***	0.231***	0.256***
	(0.042)	(0.035)	(0.039)	(0.041)	(0.059)
Inputs on Credit	0.128*	0.130*	0.143**	0.213***	0.262***
	(0.071)	(0.069)	(0.066)	(0.637)	(0.142)
Cotton Land	1.023***	1.015***	1.029***	1.050***	1.062***
Ratio	(0.132)	(0.136)	(0.147)	(0.149)	(0.327)
Regions:					
Northeastern	-0.336**	-0.375***	-0.315**	-0.097	-0.177
	(0.155)	(0.127)	(0.160)	(0.149)	(0.357)
Central	-0.356**	-0.401***	-0.356**	-0.288**	-0.277
	(0.135)	(0.111)	(0.134)	(0.132)	(0.427)
Western	-0.797***	-0.771***	-0.801***	-0.956***	-0.836
	(0.205)	(0.214)	(0.200)	(0.232)	(0.606)
Constant	1.651***	1.707***	1.541***	----------	0.476
	(0.316)	(0.245)	(0.316)		(1.109)
Structural :					
Self-Sufficiency	-0.309**	-0.298**	-0.308**	-0.627**	-0.531
	(0.139)	(0.128)	(0.137)	(0.293)	(0.705)
Cereal	-0.113***	-0.112	-0.112***	-0.144***	-0.147**
Acreage	(0.010)	(0.013)	(0.011)	(0.034)	(0.077)
Human Capital :					
Cotton Farming	0.004	----------	0.004	0.033***	0.028
Experience	(0.006)		(0.006)	(0.008)	(0.024)
Literacy	----------	0.064	0.064	0.358***	0.259
		(0.108)	(0.112)	(0.230)	(0.661)
Social :					
Cooperative	-----------	----------	----------	-0.010	-0.026
Norms				(0.980)	(0.994)
Institutional :					
Technical	-----------	----------	-----------	0.325	0.175
Assistance				(0.255)	(0.811)
Joint Liability	0.205	0.223	0.211	0.472*	0.325
	(0.139)	(0.164)	(0.149)	(0.270)	(0.816)
Situation	0.160***	0.255**	0.281**	0.749***	0.562
	(0.034)	(0.118)	(0.130)	(0.231)	(0.743)

Sigma-squared	0.160***	0.160***	0.162***	0.383**	0.391**
	(0.034)	(0.033)	(0.038)	(0.146)	(0.196)
Gamma	0.812***	0.788***	0.812***	0.866***	0.822***
	(0.081)	(0.089)	(0.106)	(0.136)	(0.256)
Loglikelihood	-30.766	-30.988	-30.590	-39.121	-40.667
LR Test- one sided error	50.852	50.408	51.203	34.141	31.050
# of restrictions	7	7	8	9	10
Mean Eff.	0.442	0.443	0.463	0.617	0.597

Standard errors are in parentheses. *, **, and *** = statistically significant at the 90, 95 and 99-percent confidence levels, respectively. Southern is the omitted cotton region.

Table 10, Technical Efficiency Scores of Burkinabe and Malian Cotton Farmers

	Eff. ≤ 0.25	0.25< Eff. ≤ 0.50	0.50< Eff. ≤ 0.75	Eff. >0.75
Burkina Faso (n=56)	0	9	24	23
Mali (n=82)	14	37	20	11

Table 11, Review of Cotton Technical Efficiency Studies

Authors (year)	Country	# Obs.	TE Scores	TE Range
Ngassam et al. (2010)	Cameroon	202	0.602	0.11-0.91
Gul et al. (2009)	Turkey	79	CRS=0.720	0.23-1.00
			VRS=0.890	0.55-1.00
Audibert et al. (2003)	Ivory Coast	75[1]	0.547	0. 02-1.00
		167[2]	0.466	0.03-1.00
Chakraborty et al. (2002)	USA	54	CRS=0.799	0.33-1.00
			VRS=0.886	0.43-1.00
			SFA=0.800	0.53-1.00
Shafiq and Rehman (2000)	Pakistan	120	…	<0.40- 1.00
Bravo-Ureta and Evenson (1994)	Paraguay	87	0.582	0.19-0.85

1= low malaria density infection, 2= high density malaria infection