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Institutional Environment and Technical Efficiency: A Stochastic Frontier Analysis of Cotton Producers in West Africa

Veronique Theriault and Renata Serra[1]

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Abstract

This paper examines the effects of the institutional environment on West African cotton farmers' technical efficiency (TE). First, key aspects of the cotton sector institutional environment are discussed, including input and credit access, and producers' organisations. Then, a stochastic frontier production function, which incorporates technical inefficiency effects, is applied to farm level data collected in Benin, Burkina Faso and Mali. The survey includes farmers' evaluations of the cotton sector institutional environment. Results suggest that institutional level features influence producers' TE, besides farm-level characteristics. Cotton growers who report a negative experience with the joint liability programme, who identify the cotton price mechanism or access to credit as the main constraints to performance, and who cultivate more hectares of cereals are technically more inefficient in producing cotton. Findings suggest that cotton farmers in Mali are less technically efficient in producing cotton than in Burkina Faso and Benin. Agricultural development policies focusing on reducing farmers' financial stress, particularly through the establishment of adequate price mechanisms (i.e. higher farm-gate prices and timely payments to farmers) and improvement in the input–credit markets should be encouraged to improve TE in West Africa.

[1]Veronique Theriault is in the Department of Agricultural, Food and Resource Economics, Michigan State University, 446 W. Circle Dr., Rm. 213-B, East Lansing, MI 48824, USA. E-mail: theria13@msu.edu for correspondence. Renata Serra is in the Center for African Studies, 421 Grinter Hall, PO Box 115560, University of Florida, Gainesville, FL 32611, USA. The authors are grateful to Bourema Kone (IER, Mali), Borgui Yerima (LARES, Benin), Yiribin Bambio (University of Ouagadougou, Burkina Faso), and Jonathan Kaminski for having coordinated fieldwork in the three countries. We also wish to thank the Editor and two anonymous referees for their helpful suggestions on earlier versions of this article. The data were collected as part of the Cotton Sector Reform Project within the wider Africa, Power and Politics Programme. Funding from DfID, Irish Aid, and FQRSC is gratefully acknowledged.

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JEL classifications: *O13, O17, Q12, Q13*.

1. Introduction

Cotton is a key cash crop with important implications for agricultural development and poverty alleviation in West Africa, especially in Benin, Burkina Faso and Mali, which are the focus in this study. For these countries, cotton represents, respectively, 30%, 80% and 85% of total agricultural export values (FAOSTAT, 2013) and provides employment and income to millions of smallholder farmers. In addition to being a major source of foreign exchange for the government and a main source of revenue for farmers, West African cotton sectors have multiplier effects that support rural communities as well as national economies (Nubukpo and Keita, 2005; Baden and Alpert, 2007). Cotton-related activities, such as transport and ginning, generate rural paid employment and contribute to consumer spending by rural households. Efficiency in the cotton sector, especially at the production level, can influence its ability to induce economic growth and help reduce poverty. Therefore, improving technical efficiency (TE) of cotton farmers is a key step if rural incomes are to rise, and the African cotton sector is to remain competitive in the international market (Kelly *et al.*, 2011).

Although initially successful, by the late 1990s and 2000s, state-owned ginning companies in these West African countries had accumulated large deficits, which required continuous state budgetary interventions from governments already in dire financial states. This compromised the viability of their cotton sectors and with them, the promise of economic development. In response to these financial problems, international financial institutions recommended reforms within the framework of the structural adjustment programmes. The main aims of these programmes were to resolve the financial crisis faced by governments and revitalise production structures by liberalising markets and, hence, removing structural rigidities and inefficiencies in the economy (Baffes and Gautam, 1996, p. 765). These policies involved the progressive withdrawal of state-run enterprises in the cotton sector, although to quite different degrees across the three countries (Serra, 2012a). Governments started to reorganise the cotton sector by privatising certain market operations (transport, marketing and in some cases also ginning), liberalising other segments of the market (input procurement), and strengthening farmers' organisations to involve them more actively in critical decision making. The overall consensus is that the implementation of these reforms, or the way they had been conducted, has not been the breakthrough that was expected in order to overcome the financial and structural weaknesses affecting West African cotton sectors (Baffes, 2009a; Delpeuch and Leblois, 2011; Serra, 2012a). This paper starts from the premise that one reason for this failure has been the inability to fully understand how the institutional environment, in which farmers are growing cotton, influences their performance, particularly their TE.

The literature relevant to this study can be classified into two major streams. The first stream includes work on institutions and performance in African cotton sectors. The second stream encompasses research studies on agricultural efficiency, particularly those measuring TE of African cotton farmers. There is an increasing body of qualitative literature on the institutional environment of the African cotton sectors, notably single-country case studies, e.g. Benin (Gergely, 2009), Burkina Faso (Gray, 2008), Ivory Coast (Ajayi *et al*., 2009), Mali (Theriault and Sterns, 2012) and Uganda (Baffes, 2009b). So far, the comparative studies on the effect of institutions on cotton sector performance mainly focus on market structures (Poulton *et al*., 2004; Tschirley *et al*., 2009, 2010; Delpeuch and Vandeplas, 2013). Although these studies differ in terms of scope and tone, they all show that institutions do matter.

In the second stream of literature, a wide array of applied work has examined TE in the agricultural sectors of developing countries, including cotton (Ali and Chaudhry, 1990; Bravo-Ureta and Evenson, 1994; Shafiq and Rehman, 2000; Mal *et al*., 2011). However, fewer studies on cotton sectors look at African contexts. Those previous studies on farm-level efficiency of cotton producers in Africa focused on the adoption of new technologies, such as Bt cotton (Thirtle *et al*., 2003), on farming systems (Stessens, 2002; Demont *et al*., 2007) and on health determinants (Audibert *et al*., 2003). Note that these studies were based on a single country and that the effect of institutions on efficiency was not explicitly discussed. Given the complexity of measuring institutions, empirical studies with a focus on institutions have remained limited.

Our review of the relevant literature shows that previous studies either focused on one stream or the other. This paper aims to fill this gap by building upon both streams of literature to empirically investigate the effect of institutional environment on efficiency. In particular, this paper estimates the TE of cotton producers in West Africa, taking into account the role of the institutional environment, such as farmers' experience with the joint liability credit programme and provision of extension services. As such, this paper makes an important contribution to the literature, by adding new variables of interest and thus broadening our knowledge of the empirical effects of institutions on performance, here measured through TE. The joint liability credit programme and the provision of extension services along with other institutional details of the West African cotton sectors are further discussed in the next section. Results from this analysis are expected to provide useful insights for policy-makers on how cotton producer performance is influenced by institutional conditions and contexts.

This paper is organised as follows. Section 2 describes key features of the institutional environment of the West African cotton sectors, while emphasising similarities and differences across the three countries examined. Section 3 addresses the issue of how to define and measure TE. Sections 4 and 5 describe, respectively, the data used and the empirical model. Empirical results are presented and discussed in section 6, while section 7 concludes.

2. Institutional Environment

Historically, West African cotton producing countries shared a similar institutional setting that was laid out during the colonial period. The French cotton company, CFDT, played an important role in the development of the West African cotton sectors by providing technical advice and inputs to farmers and by transporting, ginning and marketing cotton (Baffes, 2001; Fok, 2008). Following independence, many cotton sectors were nationalised and state-owned enterprises were created, including CMDT in Mali, SOFITEX in Burkina Faso and SONAPRA[2] in Benin. The vertically integrated market structure already established by the CFDT was reinforced during

[2]SONAPRA became SODECO after its partial privatisation in 2008.

the post-colonial period, with the state-run companies acting with near monopsony power in seed cotton markets and near monopoly power in credit and input markets for the distribution of agricultural inputs necessary for cotton production, such as seeds, fertilisers and pesticides. In addition to purchasing all seed cotton at fixed and guaranteed pan-territorial prices, state-run companies provided agricultural extension, credit, inputs, transport, ginning and marketing services.

In response to the poor financial performance of many West African state cotton companies in the 1990s, due to a combination of low world prices, lack of transparency and mismanagement in ginning operations, governments implemented, under pressure from donors, some structural and market-oriented reforms, which were intended to reduce the degree of monopoly in these industries. However, these reforms were implemented unevenly across the region; to a greater degree in the case of Benin and, to some extent in Burkina Faso, but more hesitantly in the case of Mali (Baffes, 2009a; Serra, 2012b). The three countries still have in common a regulatory framework, which does not allow free competition for the purchase of seed cotton, but now differs in terms of the number of buyers of seed cotton (Tschirley *et al.*, 2009). Whereas the CMDT continues to be the single buyer in Mali, state-owned enterprises have been partially privatised in the other two countries and new cotton gins have been established; two in Burkina Faso and eight in Benin[3] Nevertheless, the former national monopolies, SOFITEX and SONAPRA, still remain the dominant actors in Burkina Faso and Benin, respectively. In all three countries, cotton is still produced under contract farming conditions, with guaranteed pre-planting pan-territorial prices, guaranteed seed cotton purchase and input credit provision (Tschirley and Theriault, 2013).

An important change induced by the recent reform process concerns cotton farmers' associations. In the past, producers' organisations were established at the village level and included both cotton and non-cotton farmers. Through their village associations, farmers were able to participate in contract farming schemes to access credit inputs. Although their establishment contributed positively to the empowerment of cotton farmers through the transfer of responsibilities in the collection, grading and weighing of seed cotton, the absence of exclusive membership in these village groups made input distribution and credit management more difficult (Theriault and Sterns, 2012). Indeed, non-cotton farmers were allowed to get inputs on credit, even though cotton remained the principal means of revenue to pay back loans. 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 opportunistic behaviour, bad governance and mismanagement, there was accrued indebtedness at both individual and village mgroup levels across the three countries.

Recent reforms thus aimed to change both the legal status and the incentives within producers' organisations, so that they could become more solvent and better positioned to defend their member interests within the cotton sector. These institutional reforms, albeit taking place in different periods (mid-1990s in Burkina Faso, early 2000s in Mali and mid-2000s in Benin) invariably involved the transformation of village-wide, multi-purpose associations into cotton producer formal cooperatives,

[3]The new gins are Faso Coton and Sonoma in Burkina Faso and SOCOBE, ICB, CCB, IBECO, LCB, SEIBC, MCI and SODICOT in Benin. Note that one private stakeholder manages 16 gins out 19 nationwide in Benin (Saizonou, 2008).

established within a new legal framework (Serra, 2012a). Under these new structures, membership tends to be restricted to cotton farmers only. Moreover, cotton producers can freely create their own organisations based on affinities among members, such as levels of indebtedness or field proximity. Although this was expected to decrease free-riding and increase incentives for more efficient farmers, the presence of strong kinship has made exclusion of least productive members more difficult to enforce in practice, especially in Mali.

In many West African farms, cotton is cultivated in rotation with cereal crops, such as maize, millet and sorghum. Due to imperfect input and credit markets, input diversion from cotton to cereal fields has always existed and has been tolerated to some extent. For instance, farm-level data from the late 1990s in Ivory Coast indicated that about one-fifth of total inputs obtained through cotton production was diverted to food crops (Demont *et al.*, 2007). With sub-optimal use of input, cotton productivity declines and farmers become more at risk of defaulting on their individual loans. New cooperative laws have tried to reinforce the joint liability clause, known as '*caution solidaire'* in French, whereby members of a same group are jointly liable for each other's individual loans. Under this clause, the best performing farmers may have to use their own profits to cover the financial losses of the poorer performers in their group. This situation increases tensions among members, and in some instances, has induced the best performing farmers to stop cultivating cotton altogether (Gray, 2008). The joint liability programme has been highly criticised by cotton producer groups, and indebtedness remains highly problematic (for Benin, see Yerima *et al.*, 2010; for Burkina Faso, Kaminski *et al.*, 2009; for Mali, Fok, 2007). As a way to reduce input diversion, improve loan repayment and increase productivity, the interlinked schemes have been recently extended to cover cereal and cotton crops in Burkina Faso and Benin. After harvest, input loans for both crops, are directly deducted from farmer cotton payments.

Refocusing ginning company activities on the cotton system was one of the key strategies proposed by reform advocates to improve the efficiency and performance of the West African cotton sectors. To some extent, gins have withdrawn from broader rural development activities, including in Mali, where the CMDT progressively disengaged from the active promotion of integrated farming systems based on livestock production and cereals (Theriault *et al.*, 2013). This has also implied an overall decline in the technical and extension services offered to Malian producers, since neither the government nor private investors have been able to step in to offer services no longer considered to be the cotton company's responsibilities. In Burkina Faso, following the decision to disengage the government from production and marketing activities in many sectors, including cotton, technical and extension services have mainly fallen on cotton gin companies (AICB, 2008). In contrast to Mali where the quality of extension services has been declining over time, there is no clear quality trend in Burkina Faso (Tschirley *et al.*, 2009). In Benin, the government has remained the provider of research and development activities as well as technical support and advice to farmers. However, the Benin Cotton Interprofession became more involved in the mid-2000s by recruiting additional extension agents in the cotton production areas (Saizonou, 2008; Yerima and Affo, 2009). In Benin as in Mali, access to quality extension services for cotton farmers remains a challenge.

Table 1 summarises the key features of the institutional environment of the West African cotton sectors, including market structure, contract farming, producers' organisations and technical and extension services. The three sectors differ in terms of

Table 1

Key features of the institutional environment of West African cotton sectors

	Mali	Burkina Faso	Benin
Market structure*	Regulated State has majority control Monopoly (CMDT)	Regulated State has majority control SOFITEX (dominant) Faso Coton SONOMA	Regulated Private control SODECO (dominant) Several gins
Contract farming	Guaranteed purchase, pan-territorial prices Credit input provision for cotton only	Guaranteed purchase, pan-territorial prices Credit input provision for cotton and cereals	Guaranteed purchase, pan-territorial prices Credit input provision for cotton and cereals
Producer's organisation	Restricted to cotton farmers only Joint liability programme	Restricted to cotton farmers only Joint liability programme	Restricted to cotton farmers only Joint liability programme
Technical and extension advice	Government and private sector	Cotton companies	Government and Cotton Interprofession

Note: *The regulated market terminology is as in Tschirley *et al*. (2009).

number of gin companies, extension service providers and access to credit input for cereals. Nonetheless, several institutional features are shared by all of them. Cotton producers in all three countries participate in contract farming and are members of cotton producers' organisations, in which a joint liability programme prevails. They also face similar challenges regarding adequate access to quality technical and extension services, sufficient provision of credit inputs and reduced financial stress.

3. Stochastic Frontier Model

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. Among the parametric methods, the stochastic frontier analysis (SFA) is the most commonly used to measure the relative efficiency on farm-level data. The SFA approach, which estimates the parametric form of a production function and recognises the presence of random error 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 composite error term. One component of the error term reflects the inefficiency in production while the other component represents the random effects outside producer control. 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).

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

$$Y_i = f(x_i; \beta) + \varepsilon_i = \exp(x_i\beta + \varepsilon_i), i = 1, \ldots, N \quad (1)$$

where Y_i denotes the output of the *i*-th farmer, x_i represents a $(1 \times k)$ vector of productive factors of the *i*-th farmer, β is a $(k \times 1)$ 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 a greater farmer technical inefficiency, with u_i equal to zero for perfect TE. Borrowing from Battese and Coelli (1988), the TE score of the *i*-th farm can be represented as:

$$\mathrm{TE}_i = \frac{Y_i}{Y_i^*} = \frac{Y_i}{\exp(x_i\beta + v_i)} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp(-u_i) \tag{2}$$

Following previous work, it is assumed that the institutional environment directly affects the TE score (Kumbhakar *et al.*, 1991; Battese and Coelli, 1993; Bhandari and Maiti, 2007; Lio and Hu, 2009). The technical inefficiency term is described as:

$$u_i = z_i\delta + w_i \tag{3}$$

where z_i is a $(1 \times m)$ vector of institutional environment factors in which the *i*-th farmer produces and δ is a $(m \times 1)$ 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 (3) 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 parameterised as:

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 \tag{4}$$

$$\gamma = \sigma_u^2 / \sigma_s^2 \tag{5}$$

where γ must lie between 0 and 1 in order to start the iterative maximisation 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.

4. Data

The data used for this analysis come from surveys conducted under the Cotton Sector Reform Project within the wider Africa, Power and Politics Programme (APPP). Surveys were conducted by trained APPP research investigators in Benin, Burkina Faso and Mali during the summer of 2009 according to a common methodology. The main survey instrument consisted of an individual farmer questionnaire, encompassing questions related to demographic, household and farm characteristics as well as other questions related to the cotton producing institutional environment during the crop season 2008/09. In each country, cotton farmers were selected based on a multi-stage sampling technique.

The major cotton producing regions in each country were first selected, namely, Koutiala, Sikasso, Fana, Ouelessebougou, Bougouni and Kita in Mali; Hounde and Bobo Dioulasso in Burkina Faso; and the South, Central and North regions in Benin. On average, two villages in each region were selected based on geographical and socio-economic factors such as proximity to roads and levels of the cooperative indebtedness. If there was more than one cotton producers' organisation per village, a random draw was conducted to pick the organisation to be interviewed. As a final stage, 12–15 cotton growers per organisation were randomly selected using the member list. The main objective of these surveys was to gather information at the farm level from a fairly diverse population to gain deeper insights into the realities of cotton farming.

Overall, 263 farmers were interviewed: 90 in Benin, 60 in Burkina Faso and 113 in Mali. After eliminating farmers that did not produce any cotton during that year and other incomplete records, the total number of observations in the sample is 222; 81 observations in Benin, 56 in Burkina Faso and 85 in Mali. A larger number of farmers in the Malian sample decided not to grow cotton during the year 2008/09, largely because of the very late payment during the previous crop year, 2007/08, which reduced farmers' ability to pay back their loans and to access input on credit (Theriault *et al.*, 2013). The elimination of these incomplete observations should not distort our results, as long as the decision to cease cotton production was randomly distributed amongst the farmers.

The variables used in the stochastic frontier production function are derived from the information collected through surveys in each country. The output is represented by the quantity of harvested cotton (kg) in 2008/09. Factors of production refer to land, labour, equipment and inputs used to produce cotton. Land represents the number of hectares (ha) under cotton cultivation. Equipment is defined as the value of farming equipment of hand tools, ploughs, carts, sprayers and tractors used to farm cotton (measured in local currency, the CFA Franc)[4]. Inputs represent the value (in CFA Francs) of cotton seeds, fertilisers, pesticides and insecticides purchased with cash and/or credit. Two variables for labour are included. A dummy variable is created, where a value of one indicates that non-family labour is hired to work on the cotton fields; zero otherwise. The second labour variable represents the total number of active family members working on cotton fields[5]

Table 2 provides summary statistics for the key production variables. The average farm in West Africa produces 4,000 kg of cotton on 3.8 ha of land, with average yields slightly above 1,000 kg/ha. In Burkina Faso, the average yields are 950 kg/ha, which are comparable to the national average (940 kg/ha) reported by cotton companies in 2008/09 (Farats *et al.*, 2010). Likewise, the average yields in Mali (955 kg/ha) are not too far from the national average (1,003 kg/ha) in 2008/09 (CMDT, 2009). In Benin, the average yields (1,073 kg/ha) are a bit higher than in the other two countries, and consistent with national average yields ranging from 1,050 to 1,250 kg/ha (Saizonou, 2008). Over half of the interviewed West African farmers hire non-family labour to work on their cotton fields. Compared to Benin and Burkina Faso, Malian cotton farms, on average, use more family labour and less hired labour. On average, West African cotton farmers use approximately 90,000 CFA Franc (about US$ 180) of inputs per hectare of cotton. Among the three countries, Burkina Faso has the

[4]Following previous studies (Audibert *et al.*, 2003; Binam *et al.*, 2004; Berkhout *et al.*, 2010; Brambilla and Porto, 2011), the equipment variable is added to the production function as farm capital (total expenditures on farming equipment measured in CFA Franc).

[5]As done in previous TE studies in Africa (Kinkingninhoun-Medagbe *et al.*, 2010), the total number of family members is adjusted, by attributing to women farmers a lower weight (0.8) than to men (1) to account for the fact that women take care of children and domestic chores and, as such, have less time to spend on cotton fields. The results remain virtually unchanged if equal weights are used.

Table 2

Production factor summary statistics

Variables	West Africa (N = 222) Mean (SD)	Mali (N = 85) Mean (SD)	Burkina Faso (N = 56) Mean (SD)	Benin (N = 81) Mean (SD)
Cotton	4079	3486	3055	5409
Production (kg)	(5702)	(5432)	(2458)	(7197)
Cotton	3.76	3.57	3.08	4.44
Hectares (ha)	(4.20)	(4.56)	(1.88)	(4.87)
Yields (kg/ha)	997.03	955.10	950.59	1073.12
	(442.80)	(401.20)	(311.55)	(544.66)
Family Labour	7.67	9.57	4.80	7.65
(person)	(7.83)	(10.41)	(2.41)	(6.48)
Hired Labour	0.57	0.31	0.57	0.83
(dummy)	(0.50)	(0.46)	(0.49)	(0.36)
Equipment	584,254	1,106,810	319,006	219,274
(CFA)	(1,223,840)	(184,492)	(178,396)	(263,126)
Cotton Inputs	332,681	337,593	235,619	394,629
(CFA)	(432,505)	(455,010)	(149,070)	(523,055)

lowest cost of cotton inputs per hectare. The value of equipment varies greatly from one farm to another. On some farms, all the activities related to cotton production are done manually whereas on other farms, ox-ploughs, sprayers and even tractors can be used. The average farm owns about 600,000 CFA Franc (about US$ 1,200) in farming equipment, which roughly accounts for two sets of ox-ploughs and one sprayer. The average value of equipment in Mali is higher than in Benin and Burkina Faso, suggesting that farming activities are more mechanised.

Summary statistics for the institutional environment factors are reported in Table 3. Approximately one-third of farmers in our sample have received at least some primary education, but there are important differences across countries. While over half of farmers in Benin have been to primary school, this is true only for 14% of farmers in Mali, whereas Burkina Faso is close to the West African average. The average farmer has about 20 years of experience in growing cotton, but Malian farmers have more experience with cotton (23 years) than farmers in Burkina Faso (11 years), since some areas have been brought to cotton cultivation only recently. On average, cotton producers devote over 5 ha of land to cereals and apply inputs whose approximate value is 18,000 CFA Franc (about US$ 36) per hectare. In Benin and Burkina Faso, where the interlinked schemes have been extended to cover cereal crops, the average value of cereal inputs per hectare of cereals is greater than in Mali, where no such coverage exists. About half of the West African farmers received extension services last year. This percentage is greater in Benin, where additional agents have been recruited to facilitate access to cotton extension services. Moreover, one West African farmer out of two has a negative attitude toward the functioning of the joint liability programme prevailing in their cotton producers' organisation. The negative experience with the joint liability is more acute in Benin than in Burkina Faso and Mali.

Farmers were also asked about the priority area of intervention for increasing performance in the cotton sector. About 30% of West African farmers identified, as first choice, that of improving the price mechanism, through on-time payment and higher

Table 3
Institutional environment factor summary statistics

Variables	West Africa (N = 222) Mean (SD)	Mali (N = 85) Mean (SD)	Burkina Faso (N = 56) Mean (SD)	Benin (N = 81) Mean (SD)
Primary Education (dummy)	0.33	0.14	0.32	0.54
	(0.47)	(0.35)	(0.47)	(0.50)
Cotton Farming Experience (years)	18.66	23.31	10.89	19.16
	(10.97)	(12.39)	(5.62)	(9.15)
Cereal Hectares (ha)	5.48	7.52	2.82	5.17
	(5.37)	(6.45)	(1.58)	(4.98)
Cereal Inputs (CFA)	89,536	20,115	83,178	166,781
	(254,300)	(95,708)	(67,567)	(393,319)
Extension Services Last Year (dummy)	0.48	0.34	0.35	0.728
	(0.50)	(0.47)	(0.48)	(0.44)
Negative Experience with the Joint Liability (dummy)	0.52	0.25	0.42	0.87
	(0.50)	(0.44)	(0.49)	(0.33)
Constraint to Performance				
Pricing mechanism (dummy)	0.27	0.25	0.55	0.11
	(0.44)	(0.44)	(0.50)	(0.31)
Input Supply (dummy)	0.18	0.36	0.10	0.03
	(0.38)	(0.48)	(0.31)	(0.19)
Access to Credit (dummy)	0.08	0.18	0	0.02
	(0.27)	(0.39)	(0)	(0.15)
Joint Liability (dummy)	0.11	0.04	0.05	0.22
	(0.31)	(0.21)	(0.22)	(0.41)
Quality of Extension Services (dummy)	0.06	0.03	0.03	0.12
	(0.25)	(0.18)	(0.18)	(0.33)

farm-gate prices; 20% of farmers mentioned the need to enhance farm input supply, through on-time delivery, high quality inputs and lower input costs; 10% of farmers cited suppressing the joint liability programme; another 10% of farmers pointed to the need for facilitating access to credit for productive resources, notably farming equipment; and 5% of farmers stated increasing access and quality of extension services. The remaining 25% included a variety of different priorities, such as providing better access to public infrastructure, ensuring food security, improving relations between farmers, union and gin companies, dismantling gin monopoly and none of the above. Improving the price mechanism, facilitating access to input supply, and removing the joint liability are the most important areas of intervention in Burkina Faso, Mali and Benin, respectively.

5. Empirical Model

A Cobb-Douglas functional form for the stochastic frontier is chosen for the analysis of TE in the West Africa cotton sector. The Cobb-Douglas has been widely used in efficiency studies on the agricultural sector of developed and developing countries, and especially on cotton (Ali and Chaudhry, 1990; Chakraborty *et al.*, 2002; Gebremedhin *et al.*, 2009; Mal *et al.*, 2011). Despite its limitations, the Cobb-Douglas is preferred over more flexible functional forms since it provides a meaningful economic interpretation with the estimated coefficients capturing the elasticity response between variables. The Cobb-Douglas stochastic frontier model is written as;

$$\ln Y_i = \beta_0 + \sum\nolimits_{j=1}^{m} \beta_j \ln x_{ji} + v_i - u_i \tag{6}$$

where Y_i is quantity of harvested cotton by the *i*-th farmer (kg); X_i represents a set of traditional variables, including land devoted to cotton (ha), family labour (person), hired labour (dummy), input expenses (CFA Franc), and value of equipment (CFA Franc) used by the *i*-th farmer to grow cotton. The explanatory variables included in the above stochastic frontier production model are similar to those used in previous cotton efficiency studies (Audibert *et al.*, 2003; Binam *et al.*, 2004; Helfand and Levine, 2004). Following production theory, it is expected that a greater endowment of labour, inputs, equipment and land devoted to cotton contributes positively to higher level of cotton production. Given that cotton production is mainly rain-fed in West Africa, there is no need to make a distinction between irrigated and non-irrigated fields.

The model of technical inefficiency effects on the stochastic frontier equation (6), including institutional environmental factors, is given by:

$$u_i = \delta_0 + \sum\nolimits_{j=1}^{n} \delta_j z_{ji} + w_i \tag{7}$$

where z_{ji} represents the *j*-th institutional environment characteristics of the *i*-th farmer. Following previous studies, primary education (dummy), cotton farming experience (years), and access to extension services the previous year (dummy) are included in the TE effect estimation (Bozoglu and Ceyhan, 2007; Berkhout *et al.*, 2010).

In addition, we introduce new variables of interest in order to better explain the effects of the cotton sector's wider institutional environment on farmers' efficiency. The number of hectares cultivated in cereals and the expenses in cereal inputs are included in the model as a way to take into account the integrated cotton–cereal system prevailing in these rural areas. Variables based on a subjective evaluation of cotton farmers' attitudes about different institutional characteristics are also included in the model. Those variables capture farmers' attitudes toward the functioning of the joint liability programme and what they consider to be the major constraints to performance. The hypotheses regarding the effects of those variables on cotton farmer technical inefficiency are discussed below.

Educated farmers are generally assumed to have better farming capacity and access to information and, therefore, to be more efficient (Gebremedhin *et al.*, 2009). It is also expected that more cotton farming experience leads to higher cotton productivity (Thirtle *et al.*, 2003). In the developing world, technical support and extension services offered to producers have been widely recognised as a key factor contributing positively to production by providing advice and information on how to improve technical skills in farming operations (Haji, 2006; Keil *et al.*, 2007). Therefore, the extension service dummy is expected to have a negative sign (i.e. to reduce farmer's technical inefficiency).

The expected sign of the coefficient of cereal hectares is ambiguous. On one hand, farmers who practice crop rotations rather than practicing cotton monoculture are more likely to get higher yields due to better conservation of soil resources and residual effects of fertilisers on cereal crops, which are hardly fertilised otherwise (Hulugalle and Scott, 2008). Therefore, cotton farmers' inefficiency may decline with cereal hectares. On the other hand, cereal and cotton crops directly compete for land and other inputs. As discussed in section 2, in the absence of efficient input–credit markets, there are incentives for farmers to divert some of their cotton inputs toward their cereal fields. Therefore, cereal hectares may negatively impact cotton efficiency. Likewise, lower purchases of cereal inputs are expected to reduce cotton efficiency, due to increased input diversion from cotton to cereal fields.

Although group lending programmes are very common among cotton farmers' organisations in Africa, their influence on productivity is still debatable. The principle of joint liability in loan programmes 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 behaviours that are detrimental for the group lending initiative. Local realities, such as conflicts between age, ethnicity and class groups, have been found to affect cooperatives' efficiency (Woods, 1999).

The expected sign for the dummy variable capturing whether farmers deem that the joint liability programme works well is ambiguous. On one hand, we would expect a positive relationship between technical inefficiency and farmers who reported issues with the joint liability, if these farmers are expected to struggle to produce enough to cover their loans. Worse performing farmers are more likely to report problems with joint liability, being at risk of having to sell their assets and/or seeking help in order to pay their loans. On the other hand, the best performing farmers might also be more likely to report problems with the joint liability programme, resenting that a part of their profits go to cover the financial losses of other members. In this case, the expected sign between our dummy for joint liability problems and technical inefficiency would be negative. There is no expectation related to the sign of the country dummy coefficients.

6. Results and Discussion

Our model estimates the effects of several determinants on farmers' TE, including production-related factors and features of the institutional environment. The maximum likelihood parameters (MLE) of the stochastic production frontier with inefficiency effects are estimated using the software Stata version 11.1 (Stata Corp, College Station, TX, USA). A one-sided likelihood ratio is used to test whether technical inefficiency is present in the dataset. The null hypothesis of no inefficiency is rejected and, thus, it is appropriate to analyse the dataset with a stochastic production frontier. For the inefficiency effects, a negative sign of a coefficient implies a negative impact on inefficiency – an efficiency enhancing factor – whereas a positive coefficient sign implies an efficiency reducing effect. As seen in Table 4, all elasticity coefficients associated with land, labour, input and equipment are statistically significant and positive, suggesting that production increases with higher endowments of such factors. Those results are consistent with standard production theory. As found in previous studies (Fuwa *et al.*, 2007; Kinkingninhoun-Medagbe *et al.*, 2010), the largest estimated elasticity parameter is for land. A 1% increase in land devoted to cotton would augment production by

Table 4

Production function and technical inefficiency estimates in West Africa

Determinants of Production Frontier	West Africa			
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Constant	3.95***	4.55***	4.42***	3.95***
	(0.57)	(0.64)	(0.53)	(0.50)
Cotton Hectares	0.76***	0.84***	0.79***	0.81***
	(0.06)	(0.05)	(0.05)	(0.06)
Family Labour	0.08*	0.10**	0.05	0.12***
	(0.05)	(0.49)	(0.05)	(0.04)
Hired Labour	0.13**	0.17***	0.14**	0.14***
	(0.06)	(0.05)	(0.06)	(0.05)
Equipment	0.06***	0.05***	0.05***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)
Cotton Inputs	0.19***	0.15***	0.17***	0.18***
	(0.05)	(0.05)	(0.04)	(0.04)
Determinants of Inefficiency				
Constant	−0.87*	0.99	−2.16***	−4.02***
	(0.32)	(2.42)	(0.68)	(1.2)
Primary Education		−0.62*		−0.42
		(0.34)		(0.52)
Cotton Farming Experience		0.01		0.00
		(0.014)		(0.02)
Cereal Hectares		0.52**		0.76*
		(0.22)		(0.39)
Cereal Inputs		−0.26		0.03
		(0.19)		(0.03)
Extension Services Last Year		−0.39		0.08
		(0.29)		(0.46)
Negative Experience with Joint Liability		0.60**		1.42**
		(0.31)		(0.55)
Constraint to Performance				
Pricing Mechanism			1.17**	1.60**
			(−0.22)	(0.64)
Input Supply			−0.22	−0.54
			(0.56)	(0.96)
Access to Credit			1.81***	1.73**
			(0.64)	(0.77)
Joint Liability			0.06	−0.81
			(0.57)	(1.05)
Quality of Extension Services			0.27	−0.49
			(0.65)	(1.10)
Country				
Burkina Faso	−1.14**			−1.64*
	(0.54)			(0.97)

Table 4
(*Continued*)

Determinants of Production Frontier	West Africa			
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Benin	−1.40**			−1.64*
	(0.64)			(0.86)
Loglikelihood	−121.13	−118.20	−115.97	−101.87
Prob > χ^2	0.00	0.00	0.00	0.00

Notes: Statistically significant at the *90%, **95% and ***99% confidence levels.
Mali is the omitted country. The results remain broadly similar if the one-sided error is derived from an exponential distribution rather than a half-normal distribution.

0.8%. In this context, extensification remains an important option to increase production.[6]

The average TE score for West African cotton producers is 80%, ranging from 15% to 98% (Table 5). These results appear comparable with other recent TE studies on the cotton sector (Table 6). Average TE scores of 85% and of 66% were estimated for non-Bt cotton producers in North India and South Africa, respectively (Thirtle *et al*., 2003; Mal *et al*., 2011). Using a non-parametric approach, Gul *et al*. (2009) calculated an average TE score of 72% and 89% for Turkish cotton farmers, based on the assumption of constant and variable returns to scale, respectively. Earlier studies found lower TE for cotton growers (Bravo-Ureta and Evenson, 1994; Stessens, 2002; Audibert *et al*., 2003;). Differences in farmers' technical inefficiency scores are now examined through the use of institutional environmental factors.

The country dummies for Burkina Faso and Benin are negative and statistically significant. In comparison with Malian farmers, Burkinabe and Beninese farmers are more technically efficient in producing cotton. The TE scores also support this finding. As seen in Table 5, the average TE scores for Burkina (84%) and Benin (85%) are statistically higher than for Mali (72%), suggesting that farmers from the latter

Table 5
Technical efficiency scores of West African cotton farmers

	TE ≤ 0.50 # Obs.	0.50 < TE ≤ 0.70 # Obs.	0.70 < TE ≤ 0.90 # Obs.	TE > 0.90 # Obs.	TE Score	TE Range
West Africa (*n* = 222)	12	28	136	46	0.80	0.15–0.98
Mali (*n* = 85)	10	19	50	6	0.72	0.15–0.93
Burkina Faso (*n* = 56)	0	5	35	16	0.84	0.58–0.97
Benin (*n* = 81)	2	4	51	24	0.85	0.41–0.98

[6]In this paper, the traditional definitions of intensification and extensification are used. Intensification refers to 'increasing production per unit area' and extensification refers to 'increasing production through extension of the area under cultivation while maintaining or reducing aggregate input levels per unit area' (Erenstein, 2006, p. 133; Pretty *et al*., 2011).

Table 6

Review of cotton technical efficiency studies in developing countries

Authors (year)	Country	Method	# Obs.	TE Score	TE Range
Mal *et al*. (2011)	India	SFA	160*	0.88	0.63–0.97
			40†	0.85	0.62–0.92
Gul *et al*. (2009)	Turkey	DEA	79	CRS = 0.72	0.23–1.00
				VRS = 0.89	0.55–1.00
Demont *et al*. (2007)	Ivory Coast	DEA	21	0.74	…
			34	0.74	…
			35	0.60	…
Thirtle *et al*. (2003)	South Africa	SFA	35	0.53	…
			18*	0.88	0.80–0.92
Audibert *et al*. (2003)	Ivory Coast	DEA	82†	0.66	0.15–0.89
			75‡	0.54	0.02–1.00
			167§	0.47	0.03–1.00
Stessens (2002)	Ivory Coast	SFA	41	0.53	0.30–1.00
Shafiq and Rehman (2000)	Pakistan	DEA	120	…	<0.40–1.00
Bravo-Ureta and Evenson (1994)	Paraguay	SFA	87	0.58	0.19–0.85

Notes: DEA = data envelopment analysis, SFA = stochastic frontier analysis, CRS = constant returns to scale, VRS = variable returns to scale.
*Bt cotton.
†Non-Bt cotton.
‡Low malaria density infection.
§High density malaria infection.

country are further away from their production efficiency frontier. In our sample, the most inefficient farmers (TE scores < 50%) are found to be cultivating cotton in Mali (Table 5). However, Malian producers are better-equipped than their West African fellows in our sample (Table 2). This is consistent with previous work by Fok (2008, p. 199), who stated that 'Mali distinguishes itself by the popularisation of animal-drawn so that only a small share of the peasants is strictly conducting manual farming;. With better access to equipment, the production frontier shifts outward. One possible explanation is that the decline in equipment provisioning programme following market-reforms combined with financial constraints have recently reduced Malian producers' ability to properly maintain their farming equipment (Tefft, 2004; IRIN, 2008). If equipment in Mali is relatively older than in other countries, and since our data do not allow for annual depreciation costs for equipment (see Stessens, 2002; Demont *et al*., 2007), it may also be that our estimates are overestimating the true value of equipment used on Malian farms, making farms with old equipment look more inefficient than they really are. Another possible explanation is that the country dummy captures other aspects of the institutional environment in Mali, such as longer delays in farmer's payment and more intense input deviation, which may potentially explain the higher level of inefficiency.

The human capital factors, education[7] and cotton farming experience, are not statistically significant. Findings from previous studies on the influence of human capital

[7]Note that findings do not change if a secondary education dummy variable is used instead of a primary education dummy variable. Results are available upon request.

on farmers' TE in developing countries are mixed. Some studies found literacy to be efficiency reducing (Audibert *et al*., 2003; Berkhout *et al*., 2010), others to be efficiency enhancing (Keil *et al*., 2007; Gebremedhin *et al*., 2009) and others, like this study, did not find any statistically significant relationship (Battese and Coelli, 1995; Haji, 2006; Gul *et al*., 2009; Reddy and Bantilan, 2012). The absence of a significant relationship between basic level of education and efficiency has been explained by the potential presence of a stage of development threshold below which the expected positive relationship is not found (Bravo-Ureta and Evenson, 1994). Moreover, previous work on cotton farmers in West Africa showed that illiteracy did not restrain farmer management ability in terms of proper use of farm inputs and scouting programmes to deal with cotton pest problems (Michel, 2000; cited by Fok, 2008, p. 200). Gul *et al*. (2009) also found that farmer experience on cotton farming positively influences efficiency, which we do not find here.

The cereal hectare coefficient estimate is positive and highly significant, meaning that cultivating more hectares of cereals, including maize, millet and sorghum, contributes to higher technical inefficiency in growing cotton. This result supports the hypothesis of a competitive relationship between cash (cotton) and food (cereals) crops. Likewise, Demont and Stessens (2009) found that cotton and food crops are in direct competition on non-mechanised cotton farms in Ivory Coast due to major labour bottlenecks during field activities. Lack of timeliness in ploughing, seeding and weeding activities, due to labour constraints, is likely to have an efficiency reducing effect on cotton production. Storey (1986) argued that failures in the institutional environment are at the core of the competitive nature between food and cash crops, such as limited access to cereal inputs on credit and failure of contract farming to adequately provide high quality extension services to both food and cash crops. Interestingly, how much is spent on cereal inputs does not seem to explain differences in farmers' efficiency. Due to financial constraints, the purchase of cereal inputs remains low. Farmers have coped with limited access to cereal inputs by diverting some of their cotton inputs, such as fertilisers, to cereals, which is consistent with our previous result. Farms with more cereal hectares are more likely to apply sub-optimal levels of inputs to cotton, negatively impacting efficiency.

The estimated coefficient for extension services received during last crop season is statistically insignificant. This finding is consistent with recent research demonstrating that visits by and/or advice from extension agents does not significantly affect productivity (Binam *et al*., 2004; Ragasa *et al*., 2012). In developing countries, expectations regarding the performance of agricultural extension services remain low since their delivery faces many limitations (Poulton *et al*., 2010). Furthermore, high performance in extension service delivery may not lead to improved outcome, such as greater efficiency, unless the dissemination of information influences farmers to adopt better agricultural practices (Cohen and Lemma, 2011).

The coefficient for the joint liability variable is positive and highly significant, suggesting that farmers who have had issues with the joint liability programme prevailing inside their organisations are less efficient in producing cotton. This may be interpreted in two ways, not mutually exclusive. Farmers who have experienced reimbursement difficulties due, among other things, to limited financial resources and assets, or their inability to cope with climatic and financial shocks, may be less efficient. It could also be that farmers who would be able to put their inputs to maximum use, have less incentive to do so (thus showing up as being less efficient), if they belong to groups where peer monitoring and pressure have not functioned well, and where more successful farmers are obliged to pay the loans of farmers who face losses.

These explanations are well supported both by evidence from qualitative fieldwork among cotton cooperatives in these countries (Kaminski *et al*., 2010; Kone and Serra, 2010; Yerima *et al*., 2010) and studies from other contexts. Looking at the determinants of moral hazard in different joint liability programmes, Simtowe *et al*. (2006) found that mismanagement, natural disasters and low profits, were the main reasons for loan defaulting among cotton groups, followed by wilful default.

Likewise, farmers who identify the price mechanism and access to credit as the main constraint to performance are found to be less efficient in growing cotton. Using a dynamic supply model, based on adaptive expectations and partial adjustment, Theriault *et al*. (2013) found that low farm-gate prices and late payment negatively impacted cotton supply in Mali in the 2000s. The decline of cotton production in Zaire was also attributed to low farm-gate prices combined with policy failure to acknowledge the integrating farming system, in which cotton is cultivated (Ames and Tonyemba, 1990)[8]

7. Conclusions

This paper contributes to the literature on agricultural production efficiency in the context of West African cotton sectors by augmenting traditional production efficiency models with factors that the institutional literature suggests are important in affecting cotton sectors. The paper examines, using a stochastic frontier model, how variables proxying the institutional environment affect farmers' TE in Benin, Burkina Faso and Mali, which are major African cotton producer countries.

Our findings confirm that all key production factors – labour, equipment, land and inputs – have a positive sign and significant impact on cotton output, as found by most other studies. Furthermore, greater cotton production would be achieved through extensification rather than intensification according to the large estimated elasticity parameter for cotton hectares. This result quantitatively confirms what has been found in other analyses of cotton production in West African contexts (Fok, 2008). On average, TE is 80% among West African farmers, which appears consistent with other studies on cotton sectors in Africa and elsewhere.

More importantly, and in light of the hypothesis motivating this study, our findings show the importance of considering institutional environment factors in stochastic frontier production and TE analyses. Having more hectares of planted cereals is efficiency reducing, supporting the argument that cereal and cotton crops are directly in competition for the allocation of production factors. We interpret this as being due more to the failure of the institutional environment, than to the intrinsic competition between cereal and cotton crops – given studies have amply showed the potential complementarity between crop and cotton cultivation if used on a rotational basis and respecting the best extension advice. Bottlenecks in access to labour, incomplete credit markets for cereal inputs and sub-optimal extension services, especially following recent market reforms and cuts to agricultural budgets, imply instead that farmers use lower quantities of organic fertilisers (which require labour) and divert chemical

[8]To uncover differences in the institutional environment as well as to check the robustness of our results, a stochastic frontier production function, which incorporates technical inefficiency effects, is also regressed at the country-level. See the additional supporting information in the online version of this article at the publisher's website.

fertilisers destined for cotton to their cereal crops. They do so to buttress their food security but at the expense of overall production efficiency.

Another aspect of the institutional environment that our model has been able to capture is the effect of joint liability clauses within producers' cooperatives. We find that a variable capturing farmers' negative opinion of the joint liability programme in their group has an efficiency reducing effect on cotton production. This suggests that farmers who have themselves experienced problems with their loan repayment or who are unhappy with paying on behalf of others, are unable, respectively unwilling, to use their inputs to the most efficient use. Furthermore, farmers who identify the pricing mechanism or access to credit as the major constraint to higher performance also appear to be technically more inefficient. These findings suggest that when cotton cooperatives are unable to limit their members' indebtedness, when farmers are not paid on time and/or are given a too low price, and when access to credit is limited, then cotton farmers' TE is reduced.

The country dummies capture some of the differences in efficiency. The evidence suggests that farmers cultivating cotton in Benin and Burkina Faso are more technically efficient than in Mali. One reason may be that Malian farmers have the highest equipment count per capita in the region, a fact which in itself pushes the efficiency frontier upward – although our data may overestimate the value of farming equipment, since they do not account for capital depreciation. Other factors mentioned above may also corroborate the inefficiency gap interpretation, by pointing to a period of crisis in the Malian cotton sector, rife with high liquidity and management problems, from the top level down to the cooperative level. Serra (2012b) confirmed high levels of dissatisfaction among Malian farmers during 2008/09: farmers complained about high levels of opportunistic behaviour within many cooperatives, whose leadership was unable to avoid default by farmers. Farmers were paid very late the previous year and the debt levels of cooperatives were at an all time high.

Technical assistance and human capital factors – primary education and farming experience – do not statistically explain differences in inefficiency among cotton producers. The absence of a significant relationship between these variables and efficiency has also been found in previous research.

Ultimately, our analysis aims to highlight the need for a better understanding of local realities that cotton farmers face. The implementation of reforms that are in line with such realities is required to enhance efficiency in cotton production and, by this means, to revitalise West African cotton sectors, while inducing economic growth and poverty alleviation. Agricultural development policies focusing on reducing the inefficiency at the farm level should give special attention to the fact that cotton growers in the West African region have typically operated in integrated farming systems, where livestock production, cotton and cereal crops are strongly interconnected through crop rotation and interchangeable use of inputs. Interventions that improve access to cereal inputs on credit for cotton farmers are a necessary first step to revitalise the cotton sector, by reducing the incentives to divert inputs from cotton to cereals (Tschirley *et al.*, 2010). Improvement in the credit market would require a higher level of engagement from governments, financial institutions and leaders of farmers' associations. However, access to credit is a necessary but not a sufficient solution to high performance. Nurturing farmer management skills via functional and well-staffed extension services to ensure efficient delivery of information and adoption of better agricultural practices is as important as is the establishment of adequate pricing mechanism, which ensure reasonable prices and on-time payment to farmers.

Further research is clearly needed along these lines to shed more light on these findings and on the differences across African cotton sectors. It would be especially interesting to examine differences in the determinants of farmers' technical inefficiency between more regulated markets, as in West Africa with those in more competitive markets, as in East Africa. Other relevant institutional variables, such as date of payment to farmers, input quality, timeliness in input delivery and quality and modalities of agricultural extension services should also be included in future TE work

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Production function and technical inefficiency estimates per country.

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