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Economic Consequences of Different Institutional Structures for the Cotton Sector in West and Central Africa: Evidence from Burkina Faso

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In West and Central Africa, vertical coordination is used by governments to control both input and output markets. This article assesses the potential economic effects of different institutional structures for parastatals using a structural model of smallholder cotton farms in Burkina Faso. A structural system is developed to measure the potential economic outcomes of three market alternatives in terms of a parastatal company (state-owned cotton company) exercising market power. Results demonstrate that, when a parastatal is allowed to exercise market power, it is incentivized to extract rents from the farmers maximizing the parastatal's economic surplus. The primary beneficiaries of the privatization of the cotton sector are smallholder farmers, a result of the higher prices received in output markets. The parastatal extracts more from the output market than from the input market. With partial privatization, farmers are better off either in output or input markets.

***Key words**:* Burkina Faso, Cotton Production, Market Structure, Parastatals, Smallholder Farmers, Vertical Coordination

Cotton is one of the most important cash crops in sub-Saharan Africa. In many of these countries, growing cotton is the primary source of employment in rural areas, accounting for a substantial share of the cash income (Elbehri and Macdonald, 2004; Sodjinou et al., 2015). Additionally, it is the prime export commodity in the region, accounting for 15% of world cotton exports, ranking third behind the United States and Uzbekistan (Baffes, 2001). The Cotton-4 (C-4) countries—Benin, Burkina Faso, Chad, and Mali—alone account for 8% of world cotton exports. However, they have no significant influence on world cotton trade (Alston, Sumner, and Brunke, 2007). Cotton sectors in West and Central African (WCA) countries are dominated by smallholder farms that produce it for cash income alongside food crops (cereals and vegetables) to satisfy family consumption needs. Many of the WCA cotton sectors experienced rapid growth over the past four decades and significantly contributed to the economic growth of the sub-Saharan African

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region (Elbehri and Macdonald, 2004; Falck-Zepeda, Horna, and Smale, 2007; Bassett, 2014; Theriault and Serra, 2014).

The WCA cotton market is a prime example of an imperfectly competitive market dominated by state-owned cotton companies (parastatals). The cotton sector in this region has traditionally been vertically coordinated although recent reforms have created alternative institutional arrangements among countries. A single parastatal company in each country retains legal monopoly on the input market, providing farmers with many of the necessary non-labor inputs (i.e. seed, pesticides, urea, extension education services) and also legal monopsony on the output market, requiring producers to sell to the parastatal. This parastatal vertical coordination system (Figure 1) has allowed the parastatals to set the input and output prices, extracting significant rents from the farmers (World Bank, 2000; Tumusiime, Brorsen, and Vitale, 2014).

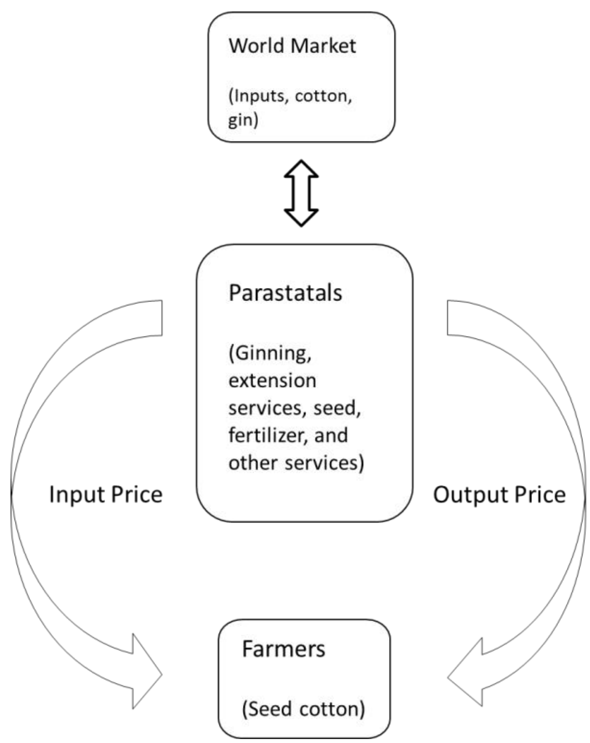


Figure 1. Parastatal vertical coordination system in West and Central Africa.

The pricing system used in this region was similar in nearly all the countries until recent reforms created more latitude in cotton pricing. Cotton prices were the same across the growing area (panterritorial), fixed throughout the growing season (panseasonal), and were set and publicly announced by the parastatal before the beginning of the planting season (Badiane et al., 2002; Elbehri and Macdonald, 2004; Baffes et al., 2009; Vitale, Ouattarra, and Vognan, 2011; Tumusiime, Brorsen, and Vitale, 2014). This pricing system, while guaranteeing an anticipated and equal price among the farmers, penalized the most efficient and productive ones. Moreover, extracting these rents restrained the parastatal from potential reinvestments in research and the farmers from adopting new technology to reduce production costs and counter declining prices. Combined, the system is constraining the overall growth of the cotton sector. The parastatal system, despite these inequities, enabled rapid growth of cotton production and exports from the early 1960s until the mid-1990s when declining performance of the parastatals coupled with high volatility in world cotton markets led to calls for reforms (Baffes, 2007; Onal, 2012).

Recent evidence shows that this vertical coordination system has reached its performance peak and it is less likely to survive in this current scenario of increasing competition and globalization (World Bank, 2000; Vitale et al., 2010; Onal, 2012). The proposed reforms aim to break down the existing vertical coordination and allow for privatization of the sector in order to increase competitiveness and overall performance (Baghdadli, Cheikhrouhou, and Raballand, 2007; Tumusiime, Brorsen, and Vitale, 2014). While this vertical coordination structure continues to prevail in many WCA countries, where the government still controls the cotton trade, some have undertaken reforms that partially or completely liberalized the sector, allowing for the entrance of a limited number of ginning companies. However, monopsony power in the output market continues to exist (Falck-Zepeda, Horna, and Smale, 2007; Vitale et al., 2010; Delpeuch and Leblois, 2013; Theriault and Tschirley, 2014; Tumusiime, Brorsen, and Vitale, 2014). Although many previous studies suggest alternative systems for the current parastatal vertical coordination, they did not encompass all alternatives for possible market structures which might give a gradual change of vertical system rather than radical complete privatization. So it needs analysis of how partial change to privatization from vertical coordination can affect production, farmers ‘shares and the input industry.

This article assesses the potential economic consequences of allowing possible market structures—monopoly, monopsony, and a competitive market—in terms of parastatal companies' market power in the cotton sector in WCA by developing a structural economic model to compare the potential economic outcomes of departing from the current parastatal vertical coordination into more competitive alternatives. More specifically, the objective is to determine the prospective gains in the producer's surplus of migrating from the current parastatal vertical coordination to more competitive market structures, using the features of the cotton sector system in Burkina Faso.

Historical Background: Cotton Production in West and Central Africa

Cotton was introduced in West and Central African French colonies during the colonial era to supply the French textile industry with seed cotton (World Bank, 2000). Cotton production and marketing were secured by a French, state-owned company Compagnie Française pour le Developpemnent des Fibres Textiles (CFDT). Following independence in 1960, CFDT remained as a small shareholder while a number of national cotton companies (parastatals) were created in different countries of the region with local governments retaining the majority of shares (Gerley and Poulton, 2009). Since that time, the cotton sector has been dominated by a parastatal company in each country and it exerts vertical control from farm to ginning. The parastatals, until the pre-reforms era, retained legal monopoly power in input supplies (seed, pesticides, urea, extension services, and others); marketing; cotton ginning; and monopsony power in cotton buying, extracting considerable rents from the farmers (World Bank, 2000; Baffes, 2007; Vitale et al., 2010**).** The parastatal vertical coordination system increased the cotton-farming area and significantly contributed to the economic growth of the region (Baffes, 2007). From 1961 to 2000, WCA cotton yields increased four-fold and production more than 20-fold (Elbehri and Macdonald 2004).

There are four important and distinguishable phases of incentives to the cotton farmers in the WCA region. In the first phase, ranging from 1970-1984, cotton farmers received roughly one-third of the world cotton price. In the second phase, from 1985-1993—which was well known for poor world cotton prices, high inflation, financial crises in a majority of cotton companies, and heavy financial aid to these companies to face the crises—the farmers earned up to 55% of the world price. The third phase, from 1994-1997, was marked by a decline in world commodity prices as a result of a financial crisis in East Asia and farmers received about 42% of the world price. During the last phase, from 1998 until the early 2000s, world cotton prices declined, a majority of the cotton companies experienced another financial crises, yet farmers captured a considerably greater portion of the world price (around 59%) than historically getting (Baffes, 2007). Reforms of the cotton sector to increase competition and boost the share of the world price received by the local farmers have been proposed. These reforms aimed to limit government intervention in price setting and subsidies to the cotton market. These reforms, accompanied by improvements in the efficiency of the ginners, were expected to increase income to farmers, boost cotton production, and improve the region's world export share. However, in Burkina Faso and Mali, the vertical coordination still prevails owing to the historic benefits it brought to the sector in those countries (Badiane et al., 2002; Baffes, 2007; Gerley and Poulton, 2009; Tumusiime, Brorsen, and Vitale, 2014).

Theoretical Framework for Cotton Market Structures

This study is based on the concept of economic surplus (total welfare), as described by Alston, Norton, and Pardey (1995) and Alston, Sexton, and Zhang (1997), where the producer's surplus is defined as the total revenue minus total costs of production of the good.

Extracting rent from the output under subsidizing an input by parastatal companies

The quantity produced (*S*) in the competitive market is derived using the producer's marginal cost, and a comparison to the world market quantity with the quantity produced in the local market is used to attain a ginning efficiency ratio of 40%, the industry standard.

In Figure 2a, *S* denotes the original cotton supply under competitive conditions; *a* is the reservation price for cotton, which is defined as the minimum price required to entice farmers to engage in cotton production; p_w is the cotton lint world price (under competitive conditions); p_p is the demand price the parastatal pays farmers for the cotton; Q_l is the aggregated cotton (lint equivalent) quantity supplied by the local market under monopsony power; and Q_w is the cotton lint equilibrium quantity under competitive conditions. The reservation price is a function of the prices of other food crops (cereals and vegetables).

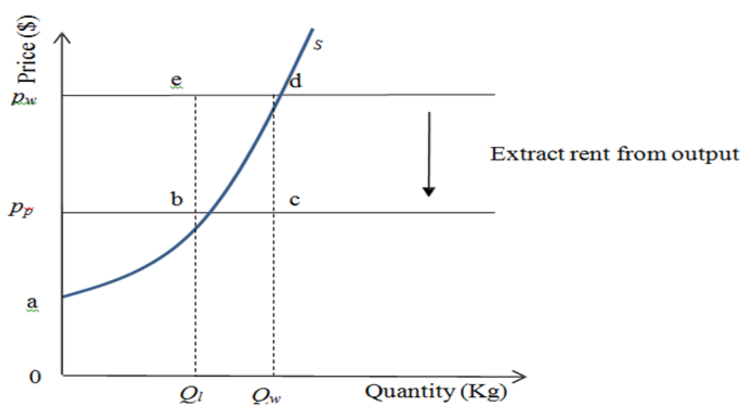


Figure 2a. Rent extraction on the output market under monopsony by Parastatals.

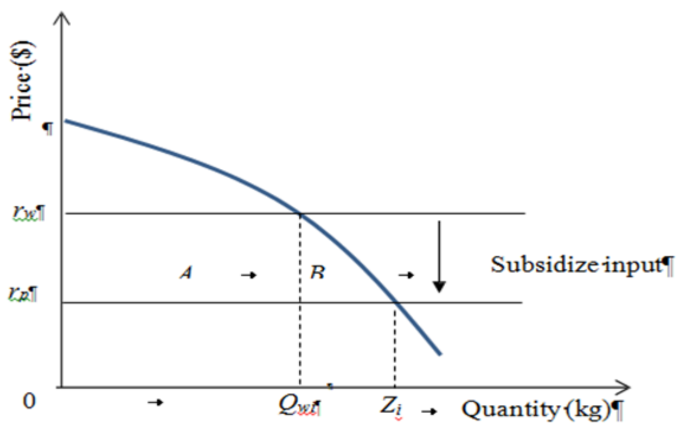


Figure 2b. Parastatal subsidy on the input market.

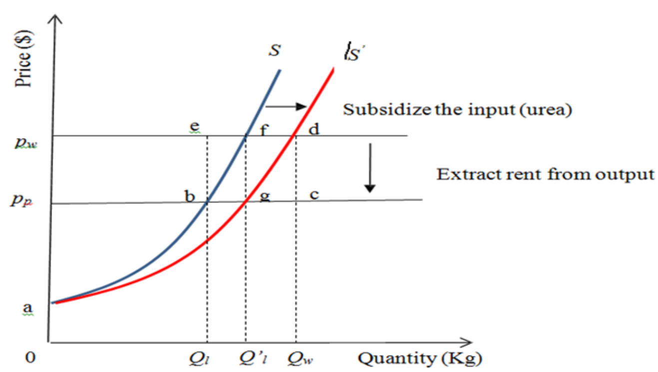


Figure 2c. Supply shift due to subsidy on the input (urea) market.

If farmers received the cotton competitive market price (p_w), the producer's surplus would be equal to the area *adp*$_w$. However, the parastatal company exercises monopsony power in the output market and sets the price (p_p) below the competitive market price, extracting rent from the farmers. This results in a change in the producer's surplus equal to the difference between the areas *adp*$_w$ and *abp*$_p$. The area $p_w ebp_p$ is the rent the parastatal extracts by enforcing its pricing power on the output market, and the area *bed* is the deadweight loss generated as a result of the parastatal monopsony buying cotton.

Using the illustrative example of a single input, in this case urea with 46% nitrogen, the parastatals could induce cotton production by subsidizing the price of the urea. The subsidy lowers the urea price paid by farmers from r_w (world urea price) to r_p (urea price the parastatal charges the farmers), boosting the quantity used from Q_{wi} to Z_i which is the profit-maximizing level of urea for the farmers receiving a subsidy (Figure 2b). The increased quantity of urea used will have a positive effect on the cotton output by increasing the quantity produced from Q_l to Q'_l, and shifting the cotton supply to the right from *S* to *S'*, assuming the cotton lint price in the local market is maintained at the same level (p_p) below the world price (p_w) (Figure 2c). This supply shift will increase the rent extracted by the parastatal by adding the area *ebgf* to the area p_pbep_w (rent extracted under the original cotton supply). The change in the producer's surplus is given by the difference between the areas p_pga and p_pba (Figure 2c).

The parastatal subsidy in urea is equal to the sum of the areas *A* and *B* (Figure 2b). The parastatal companies will only subsidize urea if the expenditure with the subsidy is less than the rents extracted in the output market, $A+B < p_wfg\ p_p$.

Extracting rent from the input

If the parastatal extracts rent from the input market by selling urea at a price (r'_w) higher than the world market price (r_w), the quantity of urea used will decrease from Q_{wi} to Q'_{wi} (Figure 3a). This decrease in urea used will negatively impact output by decreasing the quantity of cotton produced from Q_w to Q''_c, shifting the cotton supply curve to the left from *S* to *S''*. The rent extracted by the parastatal is equal to the area p_pjip_w, and the change in the producer surplus is given by the difference of the areas p_pca and p_pja (Figure 3b).

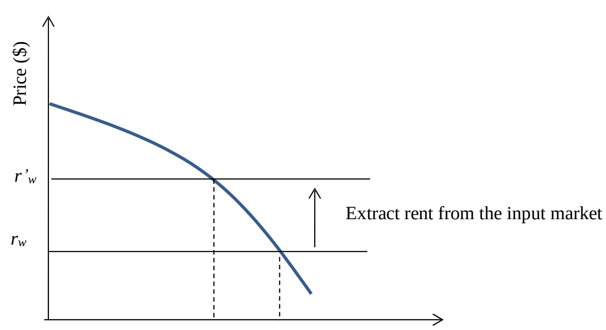


Figure 3a. Extract rent from the input market.

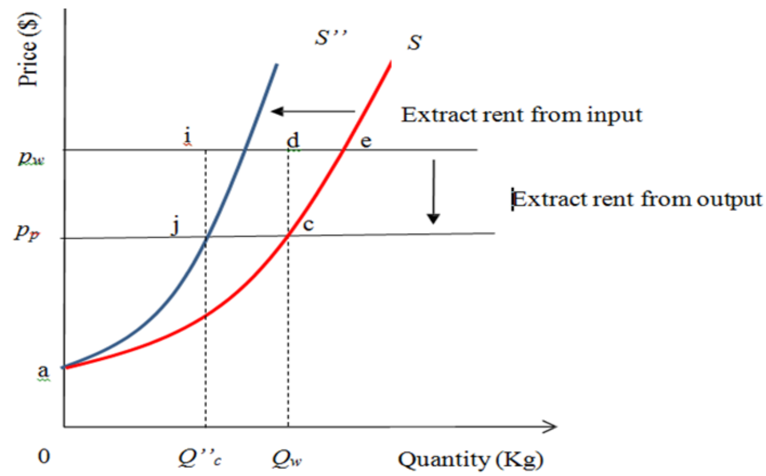


Figure 3b. Supply shift due to rent extraction on the input.

No rent extraction by the parastatal

Within the current parastatal vertical coordination, the surplus distribution in the cotton sector is unequal. If a more competitive market is permitted by privatizing the cotton sector and allowing more companies to enter the market, different streams of rents would be extracted and the farmers would benefit from the higher output prices and lower input prices. In this competitive market, the welfare is greater than with the parastatal system and the farmers capture the surplus generated so the parastatal profit is zero (Vitale et al., 2010).

The Structural Model for Alternative Market Structures

National cotton companies (parastatals) maximize profit by purchasing cotton from smallholder farmers, and contractual agreements require farmers to sell all their cotton to the parastatals at announced pre-planting prices. With vertical control over the cotton sector, the parastatals set both input and output prices and, through extension educational services, are able to act as the primary technology provider (Badiane et al., 2002; Elbehri and Macdonald, 2004, Baffes, 2007). Those features are established in the theoretical model through decision variables for input and output prices, and their influences on aggregate supply. Farmers are price takers, but cotton competes with food crops for resources. To measure parastatals' rents (profit) and farmers' surpluses as described previously, we used the following structural model under four different market structures: Opportunity cost of land, labor, and capital establish a minimum price for cotton.

Aggregate supply is obtained by summing over the farming population, which varies across region and farm type (Vitale et al., 2010). Given the large number of cotton farmers, aggregate supply is modeled as a continuous function. The aggregate cotton production quantity (Q_l) and the aggregated input (Z_i) cost are calculated respectively as:

(1) $$Q_I = \sum_{i=1}^{n}(Y_i * X_i)$$

(2) $$Z_i = \sum_{i=1}^{n}(z_i * X_i)$$

where Y_i is the cotton yield for i^{th} farmer in kg/ha; X_i is the area of cotton grown by i^{th} farmer in hectares; z_i is the quantity of the urea used by i^{th} farmer in kg/ha; and n is the total number of farmers.

The parastatals exert their vertical control over the cotton market and choose both the input (r_p) and output (p_p) prices to maximize their profits according to Equation (3).

(3) $$\underset{p_p, r_p}{Max}\, PI = 0.4 * (p_w - p_p) * Q_l(p_p, r_p, \tau, p_m) - (r_w - r_p) * Z_i(p_p, r_p, \tau, p_m)$$

where 0.4 is the ginning efficiency ratio, PI is the parastatal profit, p_w is the cotton lint price in the world market in \$/kg, r_w is the urea price in the world market in \$/kg, τ is a vector of food crop prices (cereals and vegetables), and p_m is the price of maize (corn) in \$/kg. Maize is included because farmers can choose to either plant cotton or maize.

Those prices (r_p and p_p) are subject to the farmers maximizing their profits as described by Equation (4). Given the urea (r_p) and cotton lint (p_p) prices, the farmers choose the amount of area to plant into cotton (X_i) and maize (X_{im}), and the level of input (z_i) to maximize their profits as described by the following relationship:

(4) $$\underset{X_{ie+}X_{im}, z_i}{Max}\, FI = p_p * Y_i(z_i) * X_i(p_p, r_p, \tau, p_m) + P_m * Y_{im}(z_i) * X_{im} - r_p * z_i(p_p, r_p, \tau, p_m) + \lambda_{land}\,(Land - \rho_i * X_i - \rho_{im} * X_{im})$$

where FI is the farmer's profit, Y_{im} is the maize yield for i^{th} farmer in kg/ha, X_{im} is the area allocated to maize by i^{th} farmer in hectares, $\lambda land$ is the shadow price of the land constraint, $Land$ is the level of land available for i^{th} farmer, and ρ_i and ρ_{im} are the levels of land required to produce X_i and X_{im} for i^{th} farmer, respectively.

For the farmer to engage in growing cotton, the farmer's model has to satisfy a break-even condition that is defined by the following equation (5):

(5) $$BE_i = (0.4 * Y_i * p_p) + p_m * Y_{im} - (r_p * z_i) \geq 0$$

where BE_i is the break-even point for i^{th} farmer and 0.4 is the ginning efficiency ratio.

The structure of the output supply and input demand equations are determined by the prices set by the parastatals. In general, parastatals can choose to either subsidize or extract rents in a market. Using an illustrative example, with a single input (urea), there are four possible combinations from alternatively subsidizing (or extracting) rents in the input and output markets. The optimal choice depends on both the size of the market and the shape (elasticity) of the supply and demand curves. The exact relationships are obtained from the first order conditions (FOC). The first order derivatives of the parastatal profit function, with respect to p_p and r_p results, are in Equations (6) and (7):

(6) $$\frac{\partial PI}{\partial p_p} = -Q_l(p_{p,} r_{p,} \tau, p_m) + p_w * \frac{\partial Q_l(p_{p,} r_{p,} \tau, p_m)}{\partial p_p} - (r_w - r_p) * \frac{\partial Z_i(p_{p,} r_{p,} \tau, p_m)}{\partial p_p} = 0$$

(7) $$\frac{\partial PI}{\partial r_p} = Z_i(p_{p,} r_{p,} \tau, p_m) - r_w * \frac{\partial Z_i(p_{p,} r_{p,} \tau, p_m)}{\partial r_p} + (p_w - p_p) * \frac{\partial Q_l(p_{p,} r_{p,} \tau, p_m)}{\partial r_p} = 0$$

The first term in Equation (6) is the marginal loss in revenue when the cotton lint domestic price (p_p) is increasing, equaling the aggregated quantity transacted Q_l. This loss in revenue occurs since higher demand prices (p_p) reduce the parastatal price margin, decreasing the parastatal profit. The second term represents the marginal increase in revenue on the output market. When the cotton price (p_p) increases the aggregated quantity of cotton supplied (Q_l), it increases the parastatal profit. A more elastic supply enables greater pricing power. The third term is unique to the vertical coordination issue. It represents how enacting pricing power on the output market has effects on the input market. When the parastatal increases the price paid (p_p) to farmers, the level of subsidy on urea decreases.

In Equation (7), the first term represents the marginal increase in revenue when the input price is subsidized, equaling the aggregated quantity transacted Z_i. This increase in revenue is due to the increase in cotton output as a result of the increased quantity of urea used. The second term represents the decrease in revenue as a result of subsidizing urea, with a magnitude proportional to the slope of the urea supply curve. Similar to Equation

(6), the third term is also unique to the vertical coordination issue: it represents how enacting pricing power on the input market has positive effects on the output market. When the parastatal subsidizes urea, the farmers use the optimal level of urea and produce at the physical optimum level, increasing the quantity of cotton produced.

Taking the first derivatives of the farmer's profit maximizing equation with respect to X_i, X_{im}, z_i, and λ_{land}, yields, the following equations result:

(8) $$\frac{\partial FI_i}{\partial X_i} = p_p * Y_i - \lambda_{land} * \rho_i = 0$$

(9) $$\frac{\partial FI_i}{\partial X_{im}} = p_m * Y_{im} - \lambda_{land} * \rho_{im} = 0$$

(10) $$\frac{\partial FI_i}{\partial z_i} = -r_p + p_p * \frac{\partial Y_i}{\partial z_i} X_i + p_m * \frac{\partial Y_{im}}{\partial z_{im}} X_{im} = 0$$

(11) $$\frac{\partial FI_i}{\partial \lambda_{land}} = Land - \rho_i * X_i - \rho_{im} * X_{im} \geq 0$$

In Equation (8), the first term represents the marginal increase in revenue when the domestic cotton price increases, stimulating the production of cotton bringing in more productive growers. The second term is the loss in revenue when the shadow prices of land increase. Similar to Equation (8), the first term in Equation (9) represents the marginal increase in revenue when the domestic price of maize increases, encouraging farmers to increase the area of maize planted in place of cotton, and the second term is the marginal loss in revenue when the shadow prices of land increase. For Equation (10), the first term is the marginal loss when the level of subsidy decreases meaning that the farmers have to pay a higher price for urea, and the second and third terms represent the increase in revenue when the cotton and maize output increases as a result of increases in the use of urea. Equation (11) is the land constraint.

The Vertical Coordination (Monopsony-Monopoly) Case

With vertical coordination, farmers and the parastatal are linked by contractual agreements. The parastatal maintains a legal monopoly when selling fertilizer in the input market and legal monopsony when purchasing on the output market, setting both the urea price (r_p) charged to the farmers and the cotton lint price paid to the farmers (p_p).

Under this arrangement, the parastatal surplus is maximized by solving the following objective function:

(12) $$\underset{p_p, r_p}{Max\ PI} = 0.4 * (p_p - p_w) * Q_l - \sum_{i=1}^{n}[(r_w - r_p) * X_i * z_i]$$

With vertical coordination, the parastatal profit maximization objective function is subject to farmers satisfying the break-even condition. The farmer break-even condition requires that growers' revenues must be greater than or equal to production costs in order to continue producing cotton. The break-even condition is given by the following function under an exponential yield response function[1]:

(13) $$BE_i = 0.4p_p * Y_i(N(z_i)) - r_p * z_i - OC \geq 0$$

where Y_i is yield response function for type of i^{th} farm.

The level of urea used is a function of both urea and the cotton lint prices, given the urea (r_p) and cotton lint (p_p) prices set by the parastatal and the level of urea used by the farmer is determined by resolving the following equation induced from Equation (14). To obtain the optimal level of urea, take the derivative from Equation (13) with respect to z_i when BE_i equals zero, which results in the following:

(14) $$Z_i = \frac{Y_i * p_m}{0.4 * \frac{\partial Y_i}{\partial Z_i} * r_p}$$

The farmers are assumed to be price takers; the surplus by farmer type is determined by maximizing the equation at the following Equation (15), which is the difference between total revenue and total cost for farm i

(15) $$\underset{X_i, z_i}{Max\ FI_i} = (p_p * Y_i - r_p * z_i - OC_i) * X_i$$

The total farm surplus is determined by summing the farm surplus across the total number (n) of farms as described in Equation (16),

(16) $$Total\ FI = \sum_{i=1}^{n} Max\ FI_i$$

[1] As shown, producers use two types of fertilizer: urea and a complex fertilizer mixture of 15% NPK (15-15-15). Econometric results found only urea to be significant so only urea is included in the math equations.

The marginal cost is calculated as shown in Equation (17):

$$(17) \qquad MC_i = \frac{Q_l * p_p - Total\ FI}{Q_l}$$

The Monopoly-Competition Case

The first alternative to the parastatal vertical coordination is to allow for the parastatal to keep monopoly control of the input market, while the farmers are allowed to sell their cotton production at the competitive market price. With monopoly control, the parastatal sets the urea price, and the cotton price received by the farmers is linked to the competitive market price. The parastatal surplus in the Monopoly-Competition Case is determined with Equation (18):

$$(18) \qquad \underset{r_p}{Max\ PI} = 0.4 * \sum_{i=1}^{n}[(r_w - r_p) * X_i * z_i]$$

where r_w is the urea price ($/kg) in the competitive market.

Under the Monopoly-Competition Case, the parastatal also maximizes the surplus subject to the farmers satisfying the break-even condition. In this case, the break-even condition is given by the following function as in Equation (19):

$$(19) \qquad BE_{it} = 0.4 * p_w * Y_i(N(z_i)) - r_p * z_i - OC \geq 0$$

Given the cotton lint competitive market price (p_w) and the urea price set by the parastatal (r_p), the level of urea used is determined in Equation (20):

$$(20) \qquad Z_i = \frac{Y_i * p_w}{0.4 * \frac{\partial Y_i}{\partial Z_i} * r_p}$$

Under the Monopoly-Competition Case, the farmers sell their cotton at the competitive market price (p_w) with the urea price being set by the parastatal. The farmers' maximum surpluses are given by the following equation:

$$(21) \qquad \underset{X_i, z_i}{Max\ FI_i} = (p_w * Y_i - r_p * z_i - OC_i) * X_i$$

The total farm surplus is determined by summing the farm surplus across the total number (n) of farms, and is calculated following Equation (22):

(22) $$Total\ FI = \sum_{i=1}^{n} Max\ FI_i$$

The marginal cost is determined by following Equation (23):

(23) $$MC_i = \frac{Q_l * p_w - Total\ FI}{Q_i}$$

The Monopsony-Competition Case

The second alternative to vertical coordination is to allow the parastatal to remain as a monopsonist in cotton buying while the farmers can procure urea on the competitive market. Under this arrangement, the farmers' urea prices are linked to the competitive market price while the parastatal sets the cotton lint price (p_p) it pays to farmers. The parastatal exercises market power in the output market and has to set a cotton price (p_p) that satisfies the farmers' break-even conditions in order to make it attractive for the farmers to grow cotton rather than maize.

The parastatal surplus under the Monopsony-Competition Case is maximized by solving the following:

(24) $$\underset{p_p}{Max\ PI} = 0.4 * (p_w - p_p) * Q_l$$

where 0.4 is the efficiency ginning ratio, and it is used to compare the local market cotton quantity and the competitive market cotton quantity; p_w is the cotton lint price in the competitive market in \$/kg; p_p is the cotton lint price in \$/kg farmers receive from the parastatal; Q_l is the aggregated expected cotton quantity supplied by farmers in kg.

A farmer's break-even condition in this case is given by the following:

(25) $$BE_i = 0.4 * p_p * Y_i(N(z_i)) - r_p * z_i - OC \geq 0$$

where BE_i is the break-even point for farmer i; p_p is the demand price in \$/kg the parastatal pays the farmers for cotton lint; a_t is the intercept term of the yield response function for type of farm size t when no urea is used to grow cotton; b_t is the coefficient of the linear term of the yield response function for type of farm size t; c_t is the coefficient of the quadratic term of the yield response for type of farm size *t;* z_i is the urea price in $/kg in the competitive market; and *OC* is the average marginal cost in $/ha for growing cotton, excluding the urea cost.

Given the cotton lint price set by the parastatal (p_p) and the urea price in the competitive market (r_w), the level of urea used is determined as follows:

$$(26) \qquad Z_i = \frac{Y_i * p_p}{0.4 * \beta_1 * r_w}$$

where Z_i is the level of the urea in kg/ha used by farmer *i*, b_t is the coefficient of the linear term of the yield response equation for type of farm size *t*, c_t is the coefficient of the quadratic term of the yield response for type of farm size *t*, p_p is the monopsonistic demand price in $/kg the parastatal pays the farmers for the cotton lint, and r_w is the urea price in $/kg in the competitive market.

Under the Monopsony-Competition Case, farmers procure the inputs in the competitive market and are required to sell the cotton to the parastatal, show as

$$(27) \qquad \underset{X_i, z_i}{Max\ FI_i} = \left(p_p * Y_i - r_w * z_i - other\ cost\right) * X_i$$

where *Max* FI_i is the maximum surplus for farmer type *i;* p_p is the cotton lint price in $/kg the parastatal pays the farmers; Y_i is the cotton yield in kg/ha for farmer *i*; X_i is the area allocated to grow cotton by farmer *I;* z_i is the urea price in $/kg in the competitive market; and other cost is the average marginal cost in $/ha of growing cotton, excluding the urea cost.

The total farm surplus is determined by summing the surplus across the total number (*n*) of farms and is calculated by Equation (16).

The marginal cost is determined by the following equation:

$$(28) \qquad MC_i = \frac{Q_I * p_p - Total\ FI}{Q_i}$$

where MC_i is the marginal cost of growing cotton for farm *i*, p_p is the cotton lint price in $/kg the parastatal pays the farmer, *Total FI* is the total maximum surplus for farmers, and Q_I is the aggregated expected cotton quantity in kg supplied by farmer *i.*

The Free Market-Competition Case

The last option is to allow for a competitive market where the farmer's prices are directly linked to the competitive market prices, with the farmer's surplus being directly affected by changes in the competitive market price. Hence the parastatal profit is equal to zero. It is assumed that, under these conditions, the farmers are free of credit constrains, being able to participate in the competitive market.

The farmer's surplus is determined by the following equation:

$$(29) \qquad \underset{X_i, z_i}{Max\ FI_i} = (p_w * Y_i - r_w * z_i - OC) * X_i$$

where *Max* FI_i is the maximum surplus for farmer type *i;* p_w is the cotton lint price in $/kg in the competitive market; Y_i is the cotton yield in kg/ha for farmer *i*; *X* is the area allocated to grow cotton by farmer *i;* z_i is the urea price in $/kg in the competitive market; and OC is the average marginal cost in $/ha of growing cotton, excluding the urea cost. In a similar manner, the total farm surplus is determined by summing the surplus across the total number (*n*) of farms and is calculated in Equation (16).

In the competitive market case, the urea use is a function on the cotton lint price and urea price in the competitive market; it is given by the following:

$$(30) \qquad Z_i = \frac{Y_i * p_p}{0.4 * \frac{\partial Y_i}{\partial Z_i} * r_w}$$

where Z_i is the level in kg/ha of urea used by farmer *i*, b_t is the coefficient of the linear term of the of the yield response equation for type of farm size *t*, c_t is the coefficient of the quadratic term of the yield response for type of farm size *t*, p_p is the competitive demand price in $/kg the parastatal pays the farmers for the cotton lint, and r_w is the urea price in $/kg in the competitive market. Equation (17) determines the marginal cost.

Data and Procedures

Data

The price data used in this article were obtained from two different sources. The cotton world price is taken from the National Cotton Council of America economics data center and converted from cents per pound to dollars per kilogram. An average for the period of 2005-2013 of the "A" index price is used (Table A2-1). The "A" index price is not adjusted to transportation and other transfer costs. The cotton parastatal price was obtained from SOFITEX, the main parastatal ginning company in Burkina Faso. Farm data were taken from three years of producer surveys (2009-2011) developed and administered by the national agricultural institute Institut de l'Environnement et de Recherches Agricoles du Burkina Faso (INERA). Each year, a sample of approximately

180 cotton farmers were randomly selected and surveyed. The sample was taken from 10 villages encompassing the three major cotton-growing areas in Burkina Faso. The surveys identified the three farm types: large farms, where at least two draft animals were used in the field operations; small farms, with only one draft animal; and manual farms, where all the field operations were performed by people. Survey data were then averaged across the three different farm types in the three cotton-growing areas (Table A2-2 and A2-3). To obtain an aggregate measure of each marketing outcome, the three farm types were scaled up to the national level. In 2013, Burkina Faso harvested 1.2 million hectares of cotton and this area was used in the aggregate analysis.

Yield response function

Yield response function coefficients were estimated based on fertilizer applications observed from the producer data set. An exponential yield function was used to characterize diminishing marginal physical products of nitrogen. Since the majority of acreage was grown on Bt cotton during the study period, the yield equations were estimated using Bt cotton data. Conventional cotton and Bt cotton respond identically to fertilizer since they both are based on the same genetic materials. Yield performance is primarily distinguished by differences in pest damage, independent of nitrogen applications. The regression equations were structured as stochastic efficiency frontiers with exponential response to fertilizer input (Battese and Coelli, 1995). The general form of each yield regression equation is:

(31) $$ln\,Y_i = ln\,\beta_0 + ln\,\beta_1 + ln\,\beta_2 + \sigma_i$$

where β_0 is the intercept term, β_1 is the regression parameter for the complex fertilizer, β_2 is the regression parameter for urea, and σ_i is an error term for the stochastic frontier. The regression models were estimated in SAS using the QLIM procedure and solved with the maximum likelihood approach (Table 2). The model identified urea as having a significant effect in the regression equations for the small and large producers (Table 2). Although urea was not significant in the manual yield regression, it was maintained in the economic analysis since a plot of the yield identified a response adequate to demonstrate the underlying functioning of the economic model. Specifically, all three yield regression equations are consistent with the production literature that identified cotton's response to nitrogen as varying between 2 and 7 kg of cotton per kg of applied nitrogen (Kelly, 2005). The complex fertilizer was not significant and was not included as an endogenous variable in the economic analysis.

World cotton and urea prices in the competitive scenarios

The world cotton price and the price of urea are presented in Table 1 for the competitive market scenarios. In the other cases where parastatals establish non-competitive pricing, i.e. monopoly or monopsony, the General Algebraic Modeling System (GAMS) model was used to determine those price levels. The world cotton price was taken as the average of the Cotlook ”A” index between 2005 and 2013, and the input price is given by the historical average of the urea price for WCA. Under the world market, cotton lint is bought at \$1.90/kg and the input, urea, is sold in at \$0.50/kg.

Table 1. Input and Output Prices as Determined by GAMS or Observed Data Across Four Alternative Market Structures (\$/kg).

		I/P Price Levels[a]			O/P Price Levels[b]	
Market Structure	**Input Markets**	r_p	r_w	**Output Market**	P_p	P_w
Vertical Coordination	Monopoly	2.01	0.5	Monopsony	1.5	1.9
Monopoly-Comp	Monopoly	2.75	0.5	Free Market	1.9	1.9
Comp.- Monopsony	Free Market	0.5	0.5	Monopsony	0.61	1.9
Competition	Free Market	0.5	0.5	Free Market	1.9	1.9

[a] *The input price of the Competition cases, r_w, is the average market price of urea (2005-2013). Monopoly price, r_p, is obtained from the GAMS model (see above equations). b The output price of the Competition case is the average world cotton price (2005-2013). Monopsony price, pp, is obtained from the GAMS model (see above*

Procedures: Price setting in four different market structures

To demonstrate the effect of the three alternatives to the parastatal vertical coordination in the total surplus distribution, the economic models of alternative institutional structures were programmed in the GAMS software package. Each of the four cases used Equation 12 as the objective function that was maximized, subject to the *Breakeven* constraint given by Equation 13. A separate equation was used in GAMS to determine the cotton supply (Q_l) by summing overall the corresponding supply from each farm type. The individual supply response equations used the cotton yield response to the nitrogen function given by Equation 30 and Table 2. To distinguish each case, additional equations were used in the GAMS to fix price levels at competitive levels, as appropriate. For example, in the Monopoly-Competition Case, the price of cotton bought by the parastatal was held at \$1.9/kg while the producer price of urea (r_p) was treated as an endogenous variable solved by GAMS. Likewise, in the Monopsony-Competition Case, the price of urea sold by the parastatal to producers was held at

\$0.50/kg, while the purchase price of cotton (p_p) was treated as an endogenous variable solved by GAMS. An additional land constraint was included to maintain the total area of cotton within its limit of 1.2 million hectares. Since the empirical yield response functions never reach a physical maximum, an upper limit of \$500/kg/ha was included in the model. This level corresponds to the highest levels of urea applied on fields under ideal agronomic conditions (Luo et al., 2018). The equations were solved in GAMS using a nonlinear programming algorithm (MINOS) in the GAMS IDE software environment.

Table 2. Econometric Results of Nitrogen Yield Response Functions.

		Farm Type	
Item	**Manual**	**Small**	**Large**
Parameter			
β0	6.1794	5.820216**	5.96705**
β1	-0.0926	-0.02242	0.06593
β2	0.26316	0.30926**	0.18927*
σ	0.570697**	0.392767**	0.350459**
Log-likelihood	-62.63376	-198.6077	-124.46346
AIC	135.26	407.21541	258.92693
N	55	301	219

Single asterik (*) indicates regression parameter significance at the 5% level and double asterisk (**) at the 1% level.

Results and Discussion for Four Market Structures

The vertical coordination (Monopsony-Monopoly) case

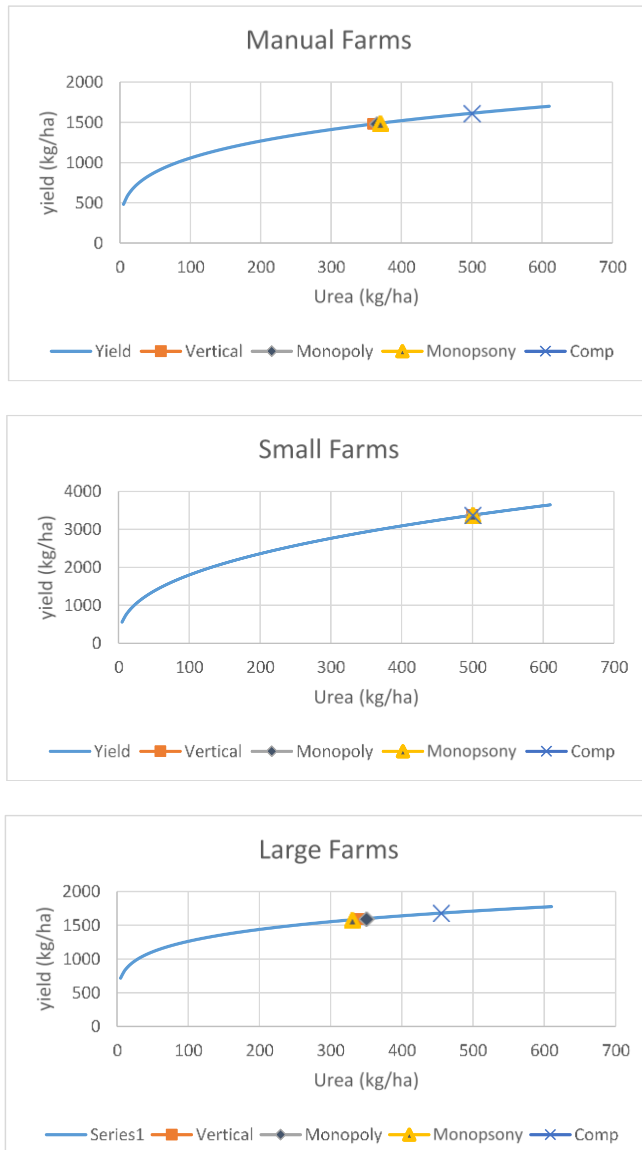
Contractual agreements in this case require cotton farmers to solely procure inputs provided by parastatal marketing channels and sell all their output exclusively to the parastatal. The area of cotton planted varies across farm types and remains constant across the four different market structures. The manual and large farms plant 180,000 hectares of cotton each, while the small producers plant 840,000 hectares and account for the largest share of the area planted (70%). Model results found that the parastatal would set the cotton lint price at \$1.50/kg, \$0.40 below the world market price (Table 1). Additional rents are extracted from selling urea above the world price. According to the model results, urea would be sold at \$2.01/kg, \$1.51 above the world price (Table 1). Parastatals typically subsidize inputs and extract rents by undercutting producers when purchasing cotton. The difference is explained by the empirical yield response that, due to the limited data, resulted in much greater urea productivity than expected. We maintained the yield functions to provide for a more general view of how pricing would be established for inputs such as genetically modified (GM) crops that could provide for dramatic gains in productivity. Likewise, the price markup of urea is also unexpectedly high. Under actual conditions, producers would be able to avoid such high markups through bargaining and or self-help organizations since urea is a basic commodity. For proprietary inputs such as hybrid and GM crops, however, technology fees and premiums would likely be commensurate with the price markups found in the model results.

The model predicts the distribution of total economic surplus among the parastatals and cotton farmers, which is uneven along the four market structures considered (Table 3). Results show that a total economic surplus of $1.234 million is generated per year, and the parastatal collects the largest share of the benefits at $1.135 million (91.98%). Manual farmers break even, but do not receive any surplus (0%). The small farmers receive $61.7 million (5.31%), and the large farmers get $33.4 million (2.71%) of the total economic surplus (Table 3). The high share collected by the parastatals under this case reflects the fact that the parastatals establish the input and output prices to extract rents from the output market by setting the cotton price paid to the farmers at $1.5/kg, 21.0% below the competitive market price ($1.9/Kg). Furthermore, Equation (7) of the first order condition for the parastatal profit maximization suggests that the parastatal can enforce market power on the input market and, in this case, extract rents from urea. Parastatals are able to charge the high urea price due to the high productivity found in the yield response functions.

Table 3. Estimates of Economic Surplus ($ million) and Distributions across Stakeholders Under Four Alternative Market Structures.

Market Structure	Surplus	Parastatal	Manual	Small	Large	Total
Vertical Coordination	Total	1,135.00	0	65.5	33.4	1,234
	Percent (%)	91.98	0	5.31	2.71	100
Monopoly-Competition	Total	769	26.9	316.2	122	1,234
	Percent (%)	62.32	2.18	25.62	9.89	100
Competition-Monopsony	Total	1,125.00	0	67.7	41.2	1,193
	Percent (%)	91.17	0	5.49	3.34	100
Competition	Total	0	131.2	853.4	249.3	1,483
	Percent (%)	0	10.63	69.16	20.2	100

With this case, in which the total farm surplus is the smallest compared to the other market structures (Table 3), the farmers use the least amount of urea (Figure 4). The manual farms use 358 kg/ha, which is rather distant from its maximum level of 500 kg/ha applied in the competitive outcome. The small farms, with the most productive yield responses, use the maximum rate of 500 hg/ha.



Note: Values in parenthesis are the level of urea used (kg/ha).

Figure 4. Yield and urea use by farm type across the four different market structures.

The Monopoly-Competition case

One alternative to a parastatal vertical coordination arrangement is to liberalize marketing conditions, allowing farmers to directly market their production on world markets. In this case, producers receive the competitive cotton price ($1.90/kg) while the parastatal retains monopoly control of the input market. Given this arrangement, the parastatal would charge producers $2.25 above the urea world price ($0.50/kg) resulting in a price of $2.75/kg (Table 2). The higher markup in this case is achieved by the parastatal since the price received by producers is $40/kg higher compared to vertical coordination. Despite the higher urea price charged by the parastatal, the higher cotton price in the competitive market ($1.90/kg) makes growing cotton attractive to farmers (Table 1).

With this institutional arrangement, the total economic surplus generated remains the same as compared to vertical coordination, $1.234 million (Table 3). When inputs are productive, the modeling results suggest that substantial markups on urea enable the parastatal to re-create the same type of outcome as in the vertical coordination case with an identical overall surplus. The distribution of the surplus remains inequitable as it was in the prior vertical coordination case. The parastatal captures less surplus than under the vertical coordination since the parastatal no longer exercises market power on the output market. Farmers increase their share of the total economic surplus as a result of the higher competitive cotton price ($1.90/kg) received. The parastatal share decreases from 91.98% to 62.32%, and the total farm surplus increases from 8.02% to 37.68%. The larger beneficiaries of the higher cotton price ($1.90/kg) received in the competitive market are the manual farmers with their share of the surplus increasing from 0% to 2.18% relative to the vertical coordination case (Table 2). The small and large farmers capture 25.62% and 9.89% of the total surplus, respectively.

Under this arrangement the parastatal maximizes its surplus by extracting rents from the input market that has implications on input use. Urea use in this case is similar to the vertical coordination case (Figure 4). Manual farms apply 370 kg/ha and the large farmers use 350 kg/ha. As in the vertical case, the small farms with the most productive response function apply the maximum urea rate of 500 kg/ha.

The Monopsony-Competition case

In this case, farmers procure inputs on the world market at the competitive price of $0.50/kg while the parastatal exerts monopsony control in purchasing cotton. In theory, with monopsony power, farmers expect to receive less than the competitive world market cotton price of $1.90/kg (World Bank, 2000). Modeling results found that, under these conditions, the parastatal purchases cotton at $0.61/kg, considerably less than the $1.50 received under monopsony control in the vertical coordination case (Table 1). Although farmers receive a lower cotton price in this case, they are substantially better off since there are no price markups on urea.

The total economic surplus decreases slightly from $1.234 million in the previous two cases to $1.193 million, corresponding to a 3.3% decline (Table 3). The parastatal captures the largest share of the surplus (91.17%), and the remainder of the total economic surplus shared among the small (5.49%) and the large (3.34%) producers, with the manual farmers being penalized the most by the parastatal monopsonist without any surplus. The results of the model show that the parastatal surplus is higher when it is allowed to exercise market power and extract rents on the output market, rather than on the input market, because the output market is larger than the input market.

In this case, farmers buy urea at the competitive market price ($0.50/kg) and modeling results suggest that the relative profitability of fertilizer does not fundamentally change across the first three cases. Fertilizer use in this case is only marginally different than the prior two cases despite there being underlying differences in market structure. Hence, under the modeling assumptions used in the analysis, divesting parastatals from just one of the markets would not have a substantial effect. By optimally exerting their market control, parastatals can extract substantial rents whether their control is upstream or downstream of the farm gate. As with the two prior cases, small farmers produce at the physical maximum production level of urea use (500 kg/ha) considered in the analysis (Figure 4). Manual farms apply 370 kg/ha of urea, 130 kg/ha below their maximum production level, and the large farms apply 330 kg/ha (Figure 4).

The Free Market-Competition case

The third alternative to the parastatal vertical coordination is to completely liberalize the cotton sector. This institutional arrangement allows farmers to procure inputs and sell their production in competitive markets. In a competitive market where the farmers benefit from higher price incentives—receiving $1.90/kg for cotton lint and purchasing urea at $0.50/kg—the total economic surplus is maximized with all of the benefits accruing to the farmers. Essentially a reversal of the distribution found in the vertically controlled case. The total economic surplus reaches a maximum of $1.483 million, of which 10.63% accrues to the manual farmers, 69.16% to the small farmers, and 20.2% to the large farmers. The parastatal surplus is zero (Table 2). In competitive conditions, the manual and small farm types apply urea levels at the physical maximum (Figure 4). The large farms apply more urea in this case as well, 457 kg/ha, only 8.3% less than the maximum rate (Figure 4).

Comparisons Across Four Different Market Structures

The results of this paper show that the parastatal captures the largest share of the total economic surplus when allowed to enforce market power on both inputs and outputs, or each one of them separately. An unanticipated modeling result is that the parastatal extracts rents from both the input and output markets relative to the input market. For example, under vertical coordination, the parastatal adjusts the input and output prices to extract rents from both the input and output marketing channels. Under the modeling conditions analyzed, farmers are no better off with partial market privatization. This result is not consistent with Poulton et al. (2003) and Gergely and Poulton (2009). They show that, through partial or total privatization of cotton, sectors generated positive results that increased investments in African cotton production and farmers received a higher share of the world price. Tumusiime, Brorsen, and Vitale (2014) also show that with two market structures—competition and vertical coordination—competitive markets give farmers a higher market share. The differences in market outcomes is likely due to the empirical yield responses used in this study that found an unexpectedly high level of urea productivity providing incentives for extracting rents from inputs rather than subsidizing them.

The result also shows that farmers' shares by farm size depended on different market structures. Manual farmers are the most sensitive to the cotton lint price. For instance, they lose substantial surplus when the parastatal acts as a monopsonist and pays the producers poor prices compared to competitive market prices.

Urea application rates vary across the four market structures. Farmers tend to use the optimal level of urea (Figure 4) motivated by different incentives across the different market structures proposed. In the vertical coordination case, urea has a substantial price markup and only one of the producer types, the small farms, apply the maximum urea rate. Under more conventional wisdom, vertical control is expected to result in the subsidy of fertilizer to promote higher yields upon which monopsony rents are extracted. The modeling results of this paper highlight that other alternatives are possible and that, with the likely development of more productive technologies in the future, the prospects for market control, both upstream and downstream, are likely to increase.

Conclusion

This paper assessed the potential economic consequences of different market structures for the cotton sector in WCA using a structural model parameterized with a sample of 180 farms from Burkina Faso. The modeling results show that the primary beneficiaries of departing from the current parastatal vertical coordination in favor of alternative competitive market structures are the farmers by reason of the higher prices models who they can receive for cotton lint. The model results show that the economic surplus distribution among the farmers and the parastatal is unequal across the four market structures analyzed. Privatization of the WCA cotton sector has been proposed to remove market power and other market distortions to increase the sector welfare (World Bank, 2000). However, the current unstable economic conditions in several WCA countries might create difficulties in withdrawing parastatal companies' market powers. A gradual movement to privatization could be the solution since it would ease the transition to more producer control.

The results from the model establish that both the share of the cotton price and urea price markups affect farmers' surpluses. Even when receiving a higher share of the cotton price, farmers' surpluses are reduced by urea price markups in the vertical and monopoly cases. For instance, when it comes to partial privatization, the farmers are not any better off with a monopoly-competitive structure in which they are allowed to sell their production at the market price with the parastatal maintaining monopoly control of the input market when compared to a monopsony structure where the parastatal is allowed to act as a monopsonist and farmers procure urea at the competitive market price. Manual farmers are the ones who benefit the most among the three producer types. Unlike the other farm types under monopsony cases, manual farmers simply break even and do not generate any surplus, but the scenario inverts when they are allowed to receive the competitive cotton price and generate surplus.

The modeling results serve as a reminder to policy makers and stakeholders that, as farming in regions such as West Africa becomes more productive, the ability of parastatals to exert market power will also increase. Our modeling results found how the nature of market power changed completely when the more productive and correspondingly intensive use of a chemical fertilizer was available. Parastatals switched from a presumed subsidy on fertilizer to substantial markups in a marketing environment with substantially more productive fertilizer. More research will be needed to explore how more productive inputs such as irrigation, GM crops, and hybrid varieties would be priced under the same alternative range of marketing conditions considered in this paper.

One limitation of our analysis is that it did not directly address the performance or the degree of inefficiencies associated with the parastatal, nor the destiny of parastatal profits since corruption and poor management have been an issue identified in prior research (Bourdet, 2004; Kaminski, 2011). It would be expected that, in a competitive market, the share of the parastatal surplus under vertical coordination would be transferred to the farmers; however, this is less likely to happen in WCA countries due to other institutional constraints (Vitale et al., 2010; Tumusiime, Brorsen, and Vitale, 2014). We suggest a gradual move towards complete privatization could be beneficial to cotton farmers.

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APPENDIX

Table A2-1. World and Parastatal Cotton Prices Used in Marketing Structure Analysis (average prices).

Year	Cotlook "A" Index Price	Parastatal Price ($/kg)[b]
2005	1.26	0.398
2006	1.33	0.335
2007	1.64	0.348
2008	1.35	0.366
2009	1.72	0.337
2010	3.64	0.339
2011	2.20	0.386
2012	1.94	0.480
2013	1.98	0.500
Average	1.90	-

[a] The Cotlook "A" index price is a proxy measure of the world cotton price. b Producers' received price by parastatal companies in Bukina Faso. Source: National Cotton Council of America.

Table A2-2. Summary Statistics of GM Cotton Producer Surveys (2009-2011) Comparing Household Demographics, Income, and Farm Size across Farm Types and Production Zones.

Item	SOFITEX[a]				SOCOMA				Faso Cotton				All Zones
	Large[b]	Small	Manual	Average	Large	Small	Manual	Average	Large	Small	Manual	Average	Average
GM cotton Households Surveyed[c]													
2009	48	29	3	80	15	25	-	40	11	27	2	40	160
2010	88	56	7	151	14	24	-	38	3	22	4	29	218
2011	66	31	12	109	23	42	8	73	14	61	0	75	257
Total	202	116	22	340	52	91	8	151	28	110	6	144	635
Household Size (persons)	16.7[e]	11	11	13.9	24.1	10	-	18.7	11.5	9.5	11	10.1	14.1
Household Farm Labor (persons)	10.1	6.4	3.8	8.3	21.6	6.1	-	14.3	5.5	4.4	3.5	4.6	8.6
Area in GM Cotton (ha)	5.1	2.9	2	4.1	4.1	2.1	1.5	2.8	2.5	1.7	1.3	1.8	3.3
Area in Conventional Cotton (ha)	4.1	2.6	1.9	3.3	2.8	1.5	1.7	2	1.5	0.7	-	0.7	2.6
Distance to GM Cotton Field (km)	3.7	3.7	8	3.6	2.9	2.8	-	2.8	5.8	5	9	5.4	3.8
Experience Growing Cotton	31.9	25.5	13	28	9.1	11.1	-	9.8	10.8	10.8	13	10.2	20.4
Household Income ($ per year)[f]	924	513	-	780	575	280	-	455	471	471	-	520	655

[a] Cotton production zone refers to the areas of operation of the three national cotton companies: SOFITEX, SOCOMA, and Faso Cotton. [b] Farm types are defined as follows: Large are farms with 2 or more animals for assistance in field operations, Small are farms with 1 animal for assistance in field operations, and Man. are farms where everything is done manually without any assistance of animals. [c] Sample size reports the total number of GM cotton producers surveyed. Observations with missing data resulted in different sample sizes for each of the variables. [d] Missing data is represented by "-" and required adjusting the weights used in calculating averages (see footnote e.) [e] Weighted averages are used when calculating averages across farm types and zones. Weights were determined based on the number of usable observations, i.e. adjusted for missing data. The variables Household Size, Experience Growing Cotton, Distance to GM Cotton Field, and Household Income were collected in 2009, the first year of the survey. [f] Household Income included farm income from crop and livestock sales, non-farm income, and remittances.

Table A2-3. Summary of Cotton Production Input Use Averaged Over Three Farm Types Across Three Production Zones, 2009-2011 (N=180).

Item	Large Farms	Small Farms	Manual Farms
		Bollgard 11	
Insecticide (litre/ha)	2	2.1	3
Seed (kg/ha)	19.7	20.8	25.4
Household Labor (persons/ha)	2.2	3	2.6
Labor (hours/ha)			
Plowing	23.1	23	28.1
Seeding	18.1	20.4	32.7
Weeding	31.6	58.4	61.9
Harvesting	126.6	176.4	147.2
Fertilizer			
Complex NPK (kg/ha)	125.2	114.1	103
Urea (kg/ha)	48.2	47.5	43
Herbicide	1.7	2	2.2
		Conventional Cotton	
Insecticide (litre/ha)	3.5	5.1	1.6
Seed (kg/ha)	48.6	44	47.5
Household Labor (persons/ha)	N/A	N/A	N/A
Labor (hours/ha)	N/A	N/A	N/A
Fertilizer			
Complex NPK (kg/ha)	127.2	133.9	105.4
Urea (kg/ha)	50.5	51	43.3
Herbicide	1.2	1.6	0.8

A Household Labor and Labor for conventional cotton were not recorded. Source: INERA, the national agricultural institute of Burkina Faso.

Table A2-4. Summary of Annual Mean Production Costs Averaged Over Three Farm Types Across Three Production Zones, 2009-2011 (N=180).

Item	Large Farm ($/ha)	Small Farm ($/ha)	Manual Farm ($/ha)
	Bollgard 11		
Insecticide	10.81	12	15.86
Seed Cost	60.07	61.19	58.25
Labor	147.92	142.08	138.83
Fertilizer and herbicide	154.54	149.91	133.26
Total Cost	373.34	365.18	346.2
	Conventional Cotton		
Insecticide	55.55	49.02	52.35
Seed Cost	12.1	12.43	12.87
Labor	140.48	139.13	132.92
Fertilizer and herbicide	152.47	151.55	136.97
Total Cost	360.59	352.13	335.11

Source: INERA, the national agricultural institute of Burkina Faso.

Table A2-5. Annual Mean Cotton Yields (n = 180).

Yield (kg/ha)	**Farm Type**		
	Large	**Small**	**Manual**
Gene Type			
		2009	
BG11	1189	848	550
Conventional	1045	661	168
		2010	
BG11	1692	1964	1259
Conventional	791	1007	816
		2011	
BG11	1222	1153	1202
Conventional	983	969	974
		Average (2009-2011)	
BG11	1368	1321	1004
Conventional	940	879	653

Source: INERA, the national agricultural institute of Burkina Faso.