האוניברסיטה העברית בירושלים
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Discussion Paper No. 9.10

Land Use, Production Growth, and the Institutional Environment of Smallholders: Evidence from Burkinabe Cotton Farmers

by

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Land Use, Production Growth, and the Institutional Environment of Smallholders: Evidence from Burkinabè Cotton Farmers*

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Forthcoming in *Land Economics*

Accepted version, February 10th, 2010

Abstract

The cotton boom in Burkina Faso consisted of a growth in cotton land shares together with an overall increase in total cultivated land. This paper examines the impact of institutional changes in the cotton sector on the evolution of smallholders' land-use decisions. The empirical analysis is supported by a structural model that takes into account the specific institutional features of the Burkinabè cotton sector and builds upon household-level data collected in rural Burkina Faso. We attribute most of the change in land use to the newly established institutional arrangements between producers and stakeholders, mechanization, and slackening of the food-security constraint.

JEL Codes: N57, 013, O33, Q15, Q18

Keywords: Burkina Faso, Cotton, Land Use, Commodity Reform, Institutional Arrangements

* We are grateful to participants of the CSAE Annual Conference on "Economic Development in Africa" and the discussant of this paper, Andrew Zeitlin. We are indebted to Sylvie Lambert and participants of PSE Lunch Seminar, as well as to Stéphane Straub and Ayal Kimhi for their useful comments. We warmly thank ARQADE and Jean-Paul Azam for financial support. We are also grateful to Kimséyinga Savadogo for having hosted us in Burkina Faso in the spring of 2006 and having helped us conduct the survey in cotton areas. Comments from two anonymous referees are gratefully acknowledged.

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1. Introduction

Initiated in the late 1980s, commodity market reforms have generated one of the most controversial policy debates in Sub-Saharan Africa. Based on the premise that liberalized commodity markets would increase agricultural profitability, which in turn would stimulate farm investment and rural development, the dismantling of official boards and other parastatals was expected to raise both commodity output and supply-chain performance. Yet, significant increases in farm productivity have not generally been observed and the reform programs have produced mixed results, often due to the overlooking of commodity-specific and rural institutional frameworks (Jayne et al., 1997).

Often quoted as one of the few success stories of agricultural development in Sahelian countries, the cotton sector is now a leading contributor to economic growth (Azam and Djimtoingar, 2007) and the dominant cash crop for farmers in the region. It is also one of the major strategic components for poverty reduction in rural areas, and the major source of cash inflow and export earnings for those countries (Goreux, 2003). The cotton success story was not only driven by major technical advancements but also through institutional changes, supported by millions of smallholders (Bassett, 2001). Until recently in most West African cotton-producing countries, the sector was organized in a very integrated fashion, with parastatals involved in input provision, ginning, and marketing. Increasingly poor economic performance was experienced from the late 1980s however, associated with huge financial insolvencies, poorly managed boards, and a high tax burden on producers. The reform process—where it has been undertaken—has been supported by changes in economic and social institutions, including market reorganization (inputs, seed cotton, ginning, marketing, rural credit), partial to full privatization of the industry, and institutional arrangements between producers, investors and governments.

In Burkina Faso, the reform started in the early 1990s and consisted of a new institutional design prior to privatizing the industry, including partnership agreements between ginneries and producers, and new local organizations of cotton growers. Smallholder cotton production was handled by marketing cooperatives through specific contractual arrangements with agribusinesses (outgrower schemes). Burkina Faso became the African cotton leader in production and export in 2006 and 2007, partly thanks to an unprecedented growth of its cotton area. Even though observed growth in seed cotton production should not be attributed to internal factors alone (given the effect of the Cote d'Ivoire crisis that started in 2002 and cross-border cotton smuggling), such factors have played an essential role in the cotton growth pattern (see Kaminski et al., 2009).

In this paper, we explore the way institutional changes simultaneously affected land-use patterns and the attractiveness for cotton, at the level of the smallholder and in the course of the reform. Since small producers face a number of significant constraints, notably market incompleteness (rural credit, food, or land markets) and liquidity constraints, the institutional environment has a major influence on land-use decisions. Due to its focus on institutional innovations, the Burkinabè reform is a particularly relevant case in point.

The key empirical ingredient of the paper is the estimation of the joint probability of changes in cotton land share (land use) and in total cultivated land (land cultivation), under several econometric specifications allowing in particular for the treatment of endogeneity of land-use decisions. The econometric model of land-use changes is supported by a conceptual model which accounts for the institutional features of the Burkinabè cotton economy: social norms for land allocation, missing food and land markets, and constrained access to agricultural inputs. Our original sample of 300 cotton producers includes variables reflecting institutional constraints (access to inputs, payment date, outlet marketing) and farmers' objectives (income and food security), performance of their cooperatives, as well as their own endowments (human and capital stock). Both observed and retrospective (stated) determinants are used as explanatory variables of growth in agricultural land and in cotton land share at the household level over the period of the reform. To partially control for measurement errors associated with retrospective surveys, the dependent variables in the model are ordered discrete and describe past changes in total land and land for cotton. Reported ex post changes in land-use patterns by farmers are subjected to several checks and controls (use of control variables), to deal with selection bias and endogeneity of land-use decision explanatory variables.

The main contribution of this paper is to provide evidence for the key role of the upgrading of institutional arrangements in cotton production growth, in a context of agricultural market failures and limited scope of institutions. We show that, all else being equal, earlier cash payments, better access to inputs, and outlet guarantees explain the increase in cotton land share, together with a partial slackening of the food-security constraint thanks to increased land cultivation. Our analysis is in line with the economic literature on transaction costs in African markets (Fafchamps, 2004), regarding in particular the way institutional innovations help lower transaction costs on rural markets (e.g., through services provided by farmers' groups in terms of credit and rotating savings, see Van Bastelaer and Leathers, 2006; Van den Brink and Chavas, 1997).

This paper is organized as follows. Section 2 briefly reviews the main institutional changes under the cotton reform of Burkina Faso and in the environment of producers. Section 3 presents the empirical strategy followed in this paper, including a conceptual framework for land cultivation and land use and the estimation strategy. We consider several estimation procedures for the system of land-use equations and specification tests adapted to the case of ordered discrete dependent variables. The data sample and the construction of variables are discussed is Section 4. Estimation results are presented in Section 5 and Section 6 concludes.

2. Changes in the institutional environment of cotton smallholders

2.1. Institutional changes in the cotton sector and growth in cotton areas

From Burkina Faso's independence in 1960 to the early 1990s, the parastatal firm SOFITEX (national cotton fiber company) held a monopsony in seed cotton and a monopoly in input provision and distribution, input credit, ginning and marketing cotton fiber. Groups of village producers, the GVs (*Groupements Villageois*), managed input credit schemes and self-marketing of their seed cotton to the parastatal, while research and extension services were provided by the government. The system performed well until the 1990s[1] due to top-quality agronomic research and sufficient coordination between the GVs, the banks and SOFITEX. Increasing budget deficits were however experienced by SOFITEX, with a decrease in the repayment rates of input credit from GVs, and increasing opportunities for rent-seeking activities and corruption among parastatal's agents and GV leaders. As a consequence, a reform plan was agreed upon by the producers' representatives, SOFITEX, and the State in the early 1990s.

Burkina Faso became the largest African cotton producer in 2006 with production increasing threefold between 2001 and 2006, an achievement that was unprecedented in the entire region (FAO, 2007). As shown by Kaminski et al. (2009), the cotton reform was a decisive factor, amplified by the effect of the Ivorian Crisis in 2002 that resulted in a massive inflow of Burkinabè farmers, formerly settled in Côte d'Ivoire. This labor force was oriented towards the cotton sector by the new incentives generated by the sector's reform, which contributed to the process of land extension.

Instead of leading to a more intensive use of chemical inputs (pesticide and fertilizer), as confirmed by national agricultural censuses and surveys (DGPSA - *Direction générale des prévisions statistiques agricoles*, 2006; INSD - *Institut National des Statistiques et de la Démographie*, 2006), cotton growth has relied mostly on area extension[2] caused by a rapid process of mechanization in cotton regions, and more labor allocated to this crop (FAO, 2007). The latter effect can be explained by an increase in cotton land share, demographic growth and migration to cotton zones. According to French Cooperation, World Bank and INSD experts, the price of seed cotton did not influence land-use choices during the period of the reform. Rather, cotton areas increased substantially because of cotton growers' rising confidence in the sector and a better access to inputs. Three factors behind such greater confidence of farmers in the system can be put forward.

First, new local institutions for cotton growers allowed for the implementation of more attractive outgrower schemes. The former joint-liability system of GVs matched cotton with non-cotton growers from the same villages for their input needs, leading to opportunistic behavior and less incentives for cotton production. The first step of the reform, starting in 1996, consisted in replacing GVs with a new type of producer group specifically designed for cotton growers, denoted GPC (*Groupements de Producteurs de Coton*, Cotton Producer Groups). Matching by affinity and self-selection became the core mechanism of these new institutions, allowing for better peer-monitoring capabilities and resulting in more cooperative behavior (Kaminski, 2007). As a consequence, repayment rates increased by up to 95% and the GPCs have been continuously attracting new producers ever since they became operational in 2000.

Second, producers gained significant bargaining power in the management of the sector. The increase in production starting in 1999 was also a consequence of the privatization of SOFITEX—with producers as stakeholders—and the emergence of a strongly integrated union of cotton growers. In 1999, the government transferred half of its capital shares to the National Union of Cotton Producers (UNPCB, *Union Nationale des Producteurs de Coton du Burkina Faso*), the new national union for cotton growers, while research and extension services were delegated to SOFITEX and the cotton unions. Producers were involved in management and decisions on pricing, funds for research and extension services, input provision, management of input credit, etc. Cotton unions were in charge of the provision of cereal inputs instead of SOFITEX, while the latter focused on the delivery and credit for cotton inputs.

Third, the management of the ginning firm SOFITEX improved and the rise of producers' bargaining power enabled them to increase their share in the overall value added of the sector, obtaining a higher cotton price in a period where the world price was declining (Baffes, 2004). SOFITEX received new support from the banks to provide input credit to an increasing number of GPCs, hence sustaining the beginning of the cotton "boom". The entry of new investors in 2003 also brought new funds to the cotton sector, the private sector being encouraged to build ginneries and provide services to farmers in regions where the parastatal company was not operating effectively, thus expanding the cotton-producing area. Subsequent stages of the reform involved a more flexible price-setting mechanism, more in line with world price and supplemented by an independently-managed stabilization fund.

The partnership between ginning firms as local monopolies and a strongly integrated cotton union was significant in the successful implementation of the reform, thanks to effective vertical coordination. Farmers have benefited from the reform, taking on a growing number of responsibilities as their political and bargaining power increased (World Bank, 2004). With reduced or non-existent deficits and a sustainable credit scheme, banks have raised their commitment to cotton companies, leading to more credit allowances for a growing number of producers. This has also provided producers with better access to cereal inputs, so that the cotton reform has been beneficial for grain production and food-security concerns as well (Kaminski et al., 2009), allowing one third of cotton-producing households to become food-secure.

Concomitantly with this renewed confidence in the cotton sector, production increased continuously from 210,000 to 710,000 tons of seed cotton annually from 2001 to 2006. Given the difficulty to interpret aggregate (country-level) data, we now focus on the determinants of cotton extensive growth at the household level.

2.2. Institutional arrangements for accessing land and inputs

Social norms on access to land and access to inputs also play a role in farmers' land-use decisions, being part of their institutional and social environment,

There is no market for land in Burkina Faso, but land can be obtained through secured rights of usage (inheritance in the restricted lineage, clearing of bush, gift), or unsecured rights (loan, temporary letting), with the latter rights possibly becoming more secure over time (Stamm, 1994). Empirical evidence suggests that land rights do not matter much in the allocation of factors and land investment among households in Burkina Faso, because local peasants do not feel insecure about their usage rights (Sawadogo and Stamm, 2000; Brasselle et al., 2002). This differs from Udry and Goldstein (2008) and Udry (1996) where land allocation is inefficient among (more insecure rights) and within households (gender-differentiated rights).

Due to population growth and imigration, southwest Burkina Faso has been subject to high demographic pressure for land, resulting in higher uncertainty on land rights and lower soil quality (Gray and Kevane, 2001). Farmers responded by intensifying their farming systems and adopted more conservation-oriented practices, independently from their land tenure status. Over the course of the immigration process, farmers from migrant ethnic groups have been more and more willing to invest in soil quality. Claims over land from non-resident ethnic group members resulted in less fertile soils, and new migrants are sometimes denied access to land. Hence, in addition to other social and political considerations, ethnic origin matters in the patterns of households' cultivated land.

Input access has also improved because the GPC-based system has allowed better-connected individuals to gain access to inputs according to their experience and their land-use pattern (cotton is usually the only cash income source to repay input credit). Accessing inputs no longer depends on social status or ethnic origin but on overall management of the GPC.[3] Credit markets in rural areas are almost non-existent in Burkina Faso, and the only way to access input credit is often through GPCs, for both cotton and cereal cultivation.

3. The Model

To evaluate the role of institutional changes in the observed patterns of cotton areas, we first present a conceptual model of land use which accounts for market incompleteness and institutional arrangements with farmers.

3.1. A model of land use under incomplete markets and outgrower schemes

Decisions about land use for rural Sahelian households are often modeled by lexicographic preferences according to a primary income goal and a secondary food-security goal (Abdoulaye and Sanders, 2006). Because some markets are missing or poorly integrated, production decisions are not separable from consumption ones and a food self-sufficiency strategy can be optimal for a rural household (De Janvry et al., 1991; Fafchamps, 1992; Jayne, 1994). Hence, it is relevant to account simultaneously for food-security and income constraints in the optimization problem of the household. In our case, the cotton crop is institutionally favored compared to other crops, because input credit is available through outgrower arrangements for cotton and through GPC membership for cereals. Moreover, outgrower schemes ensure that farmers will have guaranteed outlets and early cash payment, a crucial feature for smallholders with cash constraints and low access to credit.

Consider a representative household allocating farm land L to two types of crops, food (*F*) and cash crops (non food, *NF*) with corresponding land areas L_F and L_{NF} so that $L_F + L_{NF} = L$. Each crop is associated with a farmer-specific technology, represented by the following profit level per unit of land:

$$\Pi_k = \pi_k(x_k) - C_k,\ \ k = F, NF, \tag{1}$$

where $\pi_k(\bullet)$ is random and concave, $x_k = (x_{k1}, x_{k2}, \ldots, x_{kJ})$ is a vector of *J* variable inputs, and C_k is the non-random cost (per unit of land) of cultivating land with crop *k*. We assume this cost is proportional to land for crop *k*: $C_k = c_k L_k = c_k l_k L$, where l_k is the land share of crop *k*, so that the total cost of land cultivation is implicitly quadratic. With this specification, profit is separable in variable and land costs, and the randomness of profit appears only through the profit component associated with variable costs, π_k. Given total arable land *L*, the problem of the household is to determine the optimal level of inputs x_{kj}, $k=1,\ldots, K\,;\, j=1,\ldots, J$, and land shares l_k , $k=1,\ldots,K$. As a local approximation to a more general utility function, we specify a mean-variance utility function of profit (see for example Chavas and Holt, 1990; and Coyle, 1999 on production models with uncertainty, where land is a decision variable), so that the farmer solves:

$$\begin{aligned} \underset{l_k, x_{kj}}{Max}\, V(l_k, x_k) &= L\, E\sum_{k=1}^{K} l_k \Pi_k - \gamma \operatorname{var}\left(L \sum_{k=1}^{K} l_k \Pi_k \right) \\ &= L \sum_{k=1}^{K} \left[l_k E\pi_k(x_k) - c_k L (l_k)^2 \right] - (L)^2 \gamma \operatorname{var}\left(\sum_{k=1}^{K} \left[l_k \pi_k(x_k) - c_k L (l_k)^2 \right] \right) \end{aligned} \tag{2}$$

$$\text{such that} \begin{cases} \sum_{k=F,NF} l_k \leq 1, \\ V(l_k, x_k) \geq \tilde{V}, \\ l_F \geq \tilde{l}_F(L, x_F, x), \\ x_F \leq \tilde{x}_F(l_{NF}), \\ x \leq \underline{x}, \\ L \leq \underline{L}, \end{cases} \tag{3}$$

where γ is a measure of relative risk aversion taking positive values, $\tilde{V}$ denotes the household goal in terms of income, $\tilde{l}_F(L, x_F, x)$ is the food-security goal, and $\tilde{x}_F(l_k)$ is the corresponding level of input available for food crops. Arable land and input access may be constrained or rationed by the aforementioned social mechanisms and by cotton firms, with $\underline{x}$ and $\underline{L}$ the corresponding upper bounds of inputs and land. Hence, the last five constraints in (3) capture the institutional environment of cotton farmers under incomplete markets. Once the income goal is achieved, the household tries to reach its food-security goal but may not maximize income. If the income goal is only achieved when the food-security goal is not, then the household allocates land and inputs so as to move closer to the latter.[4]

At the optimum, the first constraint in (3) is binding and, if the constraints on total land, total inputs, inputs and land used for food crop are not binding, the first-order conditions of problem (2)-(3) can be written explicitly as:

$$l_k^* = \frac{1 + \frac{1}{2L} \sum_{i=1}^{K} \frac{E\pi_k(x_k) - E\pi_i(x_i)}{c_i + \gamma\sigma_i(x_i)^2}}{\sum_{i=1}^{K} \frac{c_k + \gamma\sigma_k(x_k)^2}{c_i + \gamma\sigma_i(x_i)^2}} \quad \text{and} \quad \frac{\partial E\pi_k(x_k)}{\partial x_{kj}} = \gamma L l_k^* \frac{\partial \sigma_k(x_k)^2}{\partial x_{kj}}, \tag{4}$$

where $\sigma_k(.)^2$ is the variance of π_k. These optimal land shares and input use levels allow the farmer to reach the income and food-security goals, and entail unconstrained use of inputs and land. Optimal land use depends on the relative risk-profitability profiles of all crops, which are themselves functions of household-specific technologies and input use, and therefore indirectly of output and input prices, and risk aversion. Partial differentiation of (4) with respect to land and inputs reveals that land use and input allocation are positively correlated, that is, all else being equal, the bigger the land share, the more input applied to the crop (see the appendix for computational details). Relative profitability among crops matters less for land use when total cultivated land increases, whereas input use increases if we assume that input use reduces profit variability.

Accounting for other binding constraints, we obtain that

$$\forall k = F, NF, l_k = l_k^* \text{ if } V(l_k^*, x_k) \geq \tilde{V} \text{ and } l_F^* \geq \tilde{l}_F(L, x_F, x), \quad (5)$$

$$l_F = \tilde{l}_F(L, x_F, x) \text{ if } V(l_k, \tilde{l}_F, x_k) \geq \tilde{V} \text{ and } l_F^* < \tilde{l}_F(L, x_F, x), \quad (6)$$

$$l_F = l_F(\tilde{V}) \leq \tilde{l}_F(L, x_F, x) \text{ if } V(l_k, \tilde{l}_F\ x_k) < \tilde{V} \text{ and } l_F^* < \tilde{l}_F(L, x_F, x). \quad (7)$$

Thus, land use is not only affected by available land for cultivation because of risk aversion and risk-diversification opportunities, but also by food-security reasons, and constraints on land and inputs. Decisions about land use and land cultivation are not sequential, and the above insights therefore support the idea that land use and cultivation patterns should be considered simultaneous and interdependent processes.

3.2. Estimation Strategy

To derive a system of reduced-form equations for changes in land and cotton areas from the structural model above, several steps are required. First, optimal solutions for land shares are linearized through a first-order approximation around village means. Second, the model is transformed into an equivalent least-square dummy-variable representation (in levels). Third, a time-in-difference transformation is performed on model equations, to obtain the final system of equations with latent variables which can be estimated using a discrete-choice model specification.

Let us define *X* and *Y*, two vectors of all-crop and household characteristics, respectively. *X* is composed of crop prices and price-variability profiles, production risk and cost components. *Y* accounts for households' crop technologies, human and farm capital, risk aversion, labor force, social status, cotton experience, ethnic background, and non-farm opportunities. Let $W = (x_k, X, Y, L, \tilde{V}, \tilde{l}_F)$ denote the full vector of household and crop characteristics, and $\overline{W} = (\overline{x_k}, \overline{X}, \overline{Y}, \overline{L}, \overline{V}, \overline{l_F})$ the vector of village-specific means of the corresponding variables.

A first-order approximation of (4) around village-average characteristics such that (6) and (7) are feasible gives:

$$l_k(W) - l_k(\overline{W}) \approx \frac{\partial l_k(\overline{W})}{\partial \overline{W}} \times (W - \overline{W}) = D_k^{'} \Delta W_k, \quad (8)$$

where D_k is the vector of partial derivatives of l_k with respect to these characteristics, and ΔW_k is the vector of deviations of household characteristics from village averages, which can be written:

$$\Delta W_k = (W - \overline{W}) = (x_k - \overline{x_k}, X - \overline{X}, Y - \overline{Y}, L - \overline{L}, \tilde{V} - \overline{V}, \tilde{l}_F - \overline{l_F}).$$

Because markets are incomplete, as represented by constraints (3), optimal land-use and input-use choices are endogenously affected by household-specific characteristics, as represented in cases (6) and (7). Indeed, the specific income and food-security goals of each household, as well as their access to inputs and land may cause the constraints to be binding in (3). The impact of these constraints may be captured by introducing Lagrangian multipliers, which would modify the expression derived in (4) to (6) or (7). For that reason, these household-specific characteristics are introduced in vector *W*, since Lagrangian multipliers would then be implicitly part of vector $D_{k,}$ as shadow costs associated with these constraints.

As a first approximation, equation (8) gives rise to a linear expression when components of D_k are assumed constant across households. This linear form admits a fixed effects (within-group) representation where village-specific components of l_k and *W* are wiped out. It is well known (see, e.g., Krishnakumar, 2006) that an equivalent model obtains with variables in levels and village dummy variables introduced as additional explanatory variables. Access to input, input use level, income and food-security goals all depend on (endogenous) land access,[5] as well as on (exogenous) crop and household-specific characteristics. We can therefore explicitly represent endogeneity of total land by considering the following system of equations:

$$\begin{cases} l_k = a_0 + \alpha_k X + \beta_k Y + \gamma_k L + \lambda^v + \varepsilon_k, \\ L = a_1 + AX + BY + \eta^v + e, \end{cases} \tag{9}$$

where a_0 and a_1 are between-village averages and the regressors are both (through input use and access, food-security and income goals) direct and indirect effects of the characteristics on cultivated land and land use. λ^v and η^v are village fixed effects and ε_k and e are error terms.

To represent land changes between any two given years, we write the time-in-difference simultaneous model as:

$$\begin{cases} \Delta l_k = b_0 + \alpha_k \Delta X + \beta_k \Delta Y + \gamma_k \Delta L + \Delta\lambda^v + \mu_k, \\ \Delta L = b_1 + A\Delta X + B\Delta Y + \Delta\eta^v + u, \end{cases} \tag{10}$$

where $\Delta(.)$ is the in-difference operator between years t_0 and t, assuming transformed regressors are constant except for village effects.[6] This would typically be the case if cross dependence is present across villages, i.e., if initial effects λ^v and η^v are not time-independent (see, e.g., Baltagi and Pesaran, 2007). Error terms μ_k and u may be correlated, motivating the joint estimation of the system's equations.

Letting $i=1,2, \ldots, N$ denote the (producer's) household index, equation (10) can be written as the following simultaneous-equation model:

$$\begin{cases} y_{1i}^* = \delta_1 + x_{1i}\beta_1 + u_{1i}, \\ y_{2i}^* = \delta_2 + \gamma y_{1i}^* + x_{2i}\beta_2 + u_{2i}, \end{cases} \tag{11}$$

where y_{1i}^* and y_{2i}^* are two latent variables that can be broadly defined as measures of profitability associated with two simultaneous decisions. Vectors of explanatory variables x_{1i} and x_{2i} may have some common components (as in (10)); u_{1i} and u_{2i} are error terms with $corr(u_{i1}, u_{2i}) = \rho$. We assume that the following exogeneity restrictions apply: $E(x_{1i}u_{1i}) = E(x_{2i}u_{2i}) = 0, \forall i$.

In our case, latent variables correspond to changes in the allocation of cotton land and total cultivated land, the precise matching of y_{1i}^* and y_{2i}^* to these decisions in (11) above depending on assumptions made on the data-generating process. Our structural model implies that expansion of land for cotton depends explicitly on total cultivated land given other explanatory variables, so that the former corresponds to y_{2i}^*, and the latter to y_{1i}^*.

Estimation of the structural econometric model (11) can be performed with discrete variables as dependent variables instead of y_{1i}^* and y_{2i}^*, and corresponding to ordered changes in land use and land cultivation as reported ex post by farmers. Such retrospective discrete variables are preferred to continuous variables (i.e., corresponding to observed latent variables) because the latter are likely to be affected by measurement errors.[7] In addition, GPC records used to track the evolution of total cultivated land cannot be considered accurate. Furthermore, the reform implementation and its associated institutional changes took place in the mid-run as a very piecemeal and gradual process. For this reason, assessing the impact of the institutional environment on land use only requires information about the average pattern on the 1996-2006 period. This can adequately be captured by discrete retrospective variables through an ordered classification of the magnitude of farmers' decisional changes affecting land management.

We consider estimation of the system of ordered discrete variables by a bivariate Ordered Probit procedure (Sajaia, 2007). The derivation of the joint probability for the two latent variables is presented in the Appendix. Parameters in the system (11) are identified only if exclusion restrictions are imposed, namely at least one variable in x_{1i} should be excluded from x_{2i}. An interesting candidate in the determination of change in cultivated land that is not correlated with land-use change—and cotton land share—is ethnic origin, once experience in cotton growing is controlled for. The shift from GVs to GPCs allowed farmers to access inputs independent of their ethnic background, while this remained an important determinant for land access, as discussed in section 2.

Correlation between u_{1i} and u_{2i} implies that y_{1i}^* is correlated with u_{2i} and therefore the second equation in the system of equations (11) cannot be estimated independently. In our empirical analysis of joint determination of total farm land and land for cotton, this endogeneity issue is indeed crucial. There are two ways of testing for possible endogeneity of y_1^* in the equation for y_2^* in the system of equations (11) above, determining whether constraints in (3) are binding. The first one was proposed by Rivers and Vuong (1988) and only requires single-equation least squares and (ordered) Probit estimation steps. The second possibility consists in estimating the structural system of equations (11) by a bivariate (ordered) Probit and then using a Wald test of $\gamma = 0$ in the second equation of the system. Sajaia (2007) provides a method for computing such a test in the bivariate ordered Probit model, with a full information maximum likelihood (FIML) approach.

4. Data

In March 2006, we interviewed 300 cotton-producing households in the south and southwest of Burkina Faso. These regions represent 45% of the country's cotton production, are characterized by different historical backgrounds and heterogeneous production dynamics over the period of the reform. However, the dynamics of aggregate cotton output from these regions is similar to the national pattern.

Five zones with similar ethnological and linguistic characteristics were chosen, with four villages selected in each. Households were randomly selected in each stratum (according to cotton areas in the previous cropping season), proportional to the size of the stratum. Only households involved (even marginally) in cotton production were interviewed. Some farmers have abandoned cotton production over the period but, according to national statistics, these farmers are few and very hard to identify within villages of cotton growers. Thus, even though our study may overestimate the increase in cotton areas, the selection bias is expected to be fairly small, and we address this issue below.

The questionnaire was designed with retrospective questions about the evolution of agricultural systems, the institutional and technical environment, and economic decisions within each household in the period 1996-2006. The empirical analysis applies to a dynamic process (changes in cotton area and cultivated land) but with cross-sectional data collected 10 years after the reform started in the cotton sector. As discussed above, in order to limit the impact of measurement errors and recall problems inherent to retrospective questions, we consider ordered discrete variables as proxies for the changes in total cultivated land and in cotton land share.[8]

Farmers were first asked about total cultivated land and land for cotton, both before the reform and for the year 2006. This information was compared to the GPC records and discussed before validation. Two ordered discrete variables were then constructed with non-overlapping intervals for the magnitude of changes in cotton land share (5 classes, from large decrease to large increase) and total cultivated land (6 classes, from decrease to increase by more than 5 ha). Data were also obtained on agricultural production for the year 2006 (planted area and yield for most crops including cotton, seed, fertilizer and pesticide), with some variables also available at the country level for comparison (DGPSA, 2006).

[Table 1 here]

Descriptive statistics on the changes in cotton land share and total cultivated land are presented in Table 1, and on crop yields and inputs in Table 2. Two-thirds of the households[9] increased their cultivated land during the reform and/or increased their cotton land share. Average crop yields and input use for cotton are fairly close to country-level data (DGPSA, 2006). The variability in crop yields is mostly due to heterogeneity in fertilizer application rates, access to inputs, soil fertility and experience with cotton production. On average, farmers apply far more nitrogen fertilizer on cotton than on other crops, which partly reflects the relative profitability of cotton with respect to other crops, and the facts that input access is conditioned on growing cotton and that input diversion to other crops has become more difficult. However, input use for other crops is larger than the country average, because GPCs are now able to provide their members with cereal input credit. The average cotton land share is slightly more than 50%, compared to around 30% before the reform in the same region (DGPSA, 2006).

[Table 2 here]

Households were then asked about the determinants of their decisions, in particular, the degree to which income and food-security goals mattered. First, they reported the three most important determinants to them of land use, and rated each determinant on a *[0,10]* scale. Farmers were then asked whether other determinants were also significant and if it was the case, they were asked to rate them according to their stated ordered preferences.[10] Determinants of decisions include profitability of agricultural production, financial and food needs, guarantee of selling crops, input access and payment date. We now present the motivation behind the introduction of these determinants and we discuss the construction of the corresponding explanatory variables. Some are obtained from observed variables for the year of the sample (*revealed* determinants), while others are reported retrospectively by farmers and are denoted *stated* determinants. Stated determinants therefore refer to the perception of households at the period of the survey, about the leading factors that affected their production choices over the past 10 years, i.e., since the beginning of the reform. Combining stated and revealed determinants enabled us to use the most relevant information pertaining to the contractual environment of farmers and to institutional performance, as well as eliciting income and food security constraints affecting land-use choices.

The first two determinants are related to the profitability of cotton production, and are captured by the (stated) households' concern about the relative price of cotton with respect to cereals on the one hand, the (revealed) present intensity of mineral fertilizer use on cotton compared to other crops on the other. For the first one, both the level of the price ratio and its variability were considered, to capture farmer attitudes toward risk. For the second determinant, we consider both the absolute and the relative input use. While absolute input use is supposedly correlated with land-use through profitability incentives such as identified in the (unconstrained) optimization problem of the conceptual model, constrained access to inputs may modify this relationship. Because input access is easier for cotton than cereals, relative input use will be used as a control variable for the two input-availability constraints in (3).

The profit-risk profile of crops is represented by exogenous characteristics such as climate variability (captured by village effects), technical knowledge and technical assistance, experience in cotton growing (revealed), input access, outlet guarantees, and payment date. We control for the social environment of farmers through dummies on the quality of relationships with the GPC (stated), and we introduce a dummy variable to control for household heads who did not have pre-reform experience (less than 28 years old in 2006). Technical knowledge and changes in agricultural labor and capital may also influence the pattern of land extension when adopting animal traction. We therefore consider variables reflecting changes in both familial and village labor force (revealed), as well as a technology dummy (revealed) for the adoption of animal-drawn farming. The opportunity cost of agricultural activity is proxied by off-farm income (revealed).

As the reform period covers 10 years, the answers to the recall questions may cover different periods of time, reflecting the farmers' particular experiences. To address this point, we control for age and education of the household's head (revealed) and for experience in cotton growing (also included in household characteristics for profit-risk profile of crops). The latter also enables us to isolate the effect of ethnic origin on land access as an instrument in the estimation strategy, and to control for the effects of experience on land-use evolution with respect to cotton growing. Experience in cotton growing (revealed) is a necessary and important control variable for cotton growers who started producing during the cotton reform, and at different moments from the time of the interview. As stated above, experience is also controlling for heterogeneous social group dynamics and input access.[11]

Two additional (revealed) variables are used as instruments in the equation of land-cultivation change: a dummy for households belonging to resident ethnic groups and duration of residence in the village. The latter enables us to distinguish between already-settled ethnic minorities and migrants. Other control variables include village fixed effects and an index of risk aversion. The relative risk aversion index is between 0 and 1 and is computed as follows. Farmers were asked to report the minimum monetary deposit they would request from an unknown trader in advance to sell him their harvest (arbitrarily set at a value of 100,000 FCFA). They had to choose between the lottery where they would be paid twice by this trader, with 50 percent probability of not being paid at all (only the deposit), and the one with their regular trader assumed to pay them with certainty.

[Table 3 here]

Table 3 presents descriptive statistics on qualitative variables representing changes in land use and land cultivation (total cultivated land, cotton land share) as well as agricultural production technology, cotton experience, resident ethnic group, relationships with GPC, and if the household's head is more than 28 years old. From the ordered discrete variables of land changes (total land and cotton land share), we constructed two dummy variables corresponding to a large increase in cotton land share (42 percent of the sample, corresponding to modality 5 of the ordered variable) and a large increase in total cultivated land (27 percent, corresponding to modalities 4, 5 and 6 of the ordered variable). Regarding production technology, most households in the sample have adopted animal traction during the period of the reform (60 percent). Half of them have more than 10 years experience in cotton growing, meaning that they were producing cotton before the reform. This is confirmed by the fact that 81 percent of the household heads were more than 18 years old when the reform started. The population of resident ethnic groups is larger than the migrant one in the sample (about 60 percent), and a large majority of households have a satisfactory to good relationship with the GPC (almost 90 percent).

Descriptive statistics on quantitative variables, including revealed and stated determinants of land-use choices, are presented in Table 4. The average farmer in the sample was already of working age when the reform started in 1996 but was born elsewhere (residence duration in the village less than age). Concerning agricultural inputs, farmers apply twice as much fertilizer on cotton than on other crops, and the family labor has been increased by more than 3 units on average over the period of the reform (10 years), to which one should add additional labor force from the village which increased by 2 units on average.

[Table 4 here]

5. Estimation results

5.1. Selection bias and specification tests

We estimate the system of equations (11) according to three different specifications: a) single-equation ordered Probit for each equation in the system; b) bivariate ordered Probit (FIML) I ; c) bivariate ordered Probit (FIML) II. In specification a), equations are estimated separately and all explanatory variables are assumed exogenous. The Rivers-Vuong test of the null assumption of exogeneity for the other ordered discrete variable (change in total land in the equation of change in cotton land share and vice versa) is performed. In specification b), the system is estimated under the same exogeneity assumption as in case a), and the correlation coefficient between random terms in both equations is estimated. Finally, specification c) entails joint estimation of both equations by explicitly accounting for the endogeneity of the other ordered discrete variable on the right-hand side. Estimation results are in Tables 5a (change in cotton land share) and 5b (change in total cultivated land). Before we discuss parameter estimates and specification test results in more detail, we need to address the issue of selection bias.

With about 50 percent of new entrants (who did not grow cotton prior to the reform), the induced change in the composition of cotton farmers might entail biased estimation of the system of equations (11). Controlling for cotton experience enables us however to account for the change in the distribution of cotton households during the reform and for newcomers to the cotton sector. Nevertheless, we do not have information on farmers who exited production, which could lead to a selection problem, as already stressed above (see Brambilla and Porto, 2005).

We now show that selection is not a significant issue for exiting farmers, accounting for a representative proportion of households (6 percent) who exited cotton production during the reform, on which we have information (from village visits and interviews with non-cotton households and local authorities). We introduce a new value for the cotton experience variable, which corresponds to the farmers who exited production,[12] and we estimate a Probit selection equation, controlling for the endogeneity bias with the Rivers-Vuong residuals. We show (see appendix Table A1) that the Heckman Probit estimates (Heckman, 1979) are not significantly different from the Probit estimates for two binary choices: significant increase in cultivated land and large increase in cotton land share. Thus, the selection problem is not really important here, as attested by the non-rejection (with a Wald test) of the assumption of independent equations of the two Heckman Probit models. We therefore conclude that exit more likely concerned households with older heads, higher off-farm current income, or troubles within their former GPCs.

Let us now turn to specification tests on the model, addressing the issue of endogeneity and correlation across land-use change equations. To address the endogeneity issue, we first compute the Rivers-Vuong test statistic from the single-equation ordered Probit specification a). We then compute the Wald test statistic under the null assumption of exogeneity of the change in land-use variable in the bivariate-ordered equations (FIML I). Both exogeneity test statistics allow us to reject the null assumption of exogeneity of the change in total cultivated land in the equation for cotton. Hence, our prediction of an endogenous change in cultivated land in (10) is supported by the data, meaning that (binding) constraints on land access effectively impact land-use decisions. In the case of the total cultivated land equation however, exogeneity of cotton land share is not rejected by both specification tests.

As can be seen in Tables 5a and 5b, correlation among residuals of the two equations of (10) is negative and significant, which gives support to the bivariate specification and to the simultaneous nature of data-generating processes. Concerning the ordered Probit specifications FIML I and FIML II, since more than two cut-off values are found to be significant in each case and for each equation, the ordered discrete specification is preferred to the binary discrete-choice model (as in Table A1). We therefore concentrate on the estimates of the bivariate ordered Probit specification with the change in total cultivated land as an endogenous variable in the determination of land-use changes for cotton (Bivariate Ordered Probit FIML II).

5.2. Bivariate ordered Probit estimation results

[Tables 5a and 5b here]

In our interpretation of the role of "statement of importance" variables on land-use decisions, we should keep in mind that we actually identify relationships between households' determinants including subjective concerns and reported agricultural production decisions in the form of land-use changes. Although we do not directly estimate the impact of institutional features on our variables of interest, analyzing the significance of these determinants is insightful to assess how farmers responded to institutional changes. Regarding the interpretation of stated importance variables in cotton and total cultivated land equations, we do not identify the actual impact of a particular determinant itself on land-use decisions, but we match variations in land-use decisions across farmers with variations in the stated importance of this determinant. Therefore, stated-importance determinants have to be interpreted differently from "revealed" ones (experience, etc.), from which the direct effect on land-use decisions can be identified.

Consider first the concern about the relative price of cotton with respect to cereals. Estimation results from Table 5a reveal that the stated importance of relative prices did not matter much for cotton land-use patterns over the reform period. In a process of land extension, price concerns matter less when cultivated land increases, according to (4). But we also know that all farmers experienced the same changes in the purchase price of seed cotton and in cotton inputs, so that little can be said about the true impact of prices on land-use decisions. However, cereal prices differ greatly across villages and cropping seasons, so that there is potential heterogeneity in the relative prices experienced by farmers. In this case, the non-significance of the "stated price" variable only means that the households' responsiveness to relative prices was not crucial when allocating land to cotton. In contrast, the stated concern about "relative price variability" is significant, meaning that households were sensitive to crop prices' volatility.

Input and land uses are expected to be positively correlated because of profitability incentives, as shown by the comparative statics of the conceptual model (see appendix). We can therefore proxy relative crop profitability by input use, everything else held constant. As can be seen from Table 5a, absolute input use (revealed) is not significant either in the equation for cotton land-use, but it is significant in the equation of total cultivated land (Table 5b). Furthermore, the non-significance of relative input use indicates that constraints on input access in (3) are not currently binding on average. Hence, we can conjecture that relative cotton profitability did not directly affect land use through incentives on crop allocation and input use.

All other things being equal, the impact of an increase in total cultivated land on cotton land share is positive and significant, so that the food-security constraint may be less likely to bind with land extension, and it is also consistent with cash-income goals once food security has been achieved, as in (5). The stated determinant “concern about financial goal” is not significant, which is interpreted as a non-binding income goal constraint in (3).

The most striking results in Table 5a are the role of the institutional environment of smallholders in accessing market and agricultural contracts through cotton, and the degree of technical assistance (measured by the number of visits by extension agents). The stated importance of accessing inputs in land-use choices, having guaranteed outlets (and thereby access to output markets) and the payment date are significant and positively correlated with increases in cotton land share. Hence, the improvement of contractual relationships in the cotton sector might explain the observed change in land use, having a greater impact on the most sensitive—and possibly formerly constrained (liquidity, access to input and output markets, and to land)—farmers. This supports the gradual establishment of better market arrangements among producers and between farmers and cotton firms, with the limitation of food needs as the key mechanism of cotton expansion. These arrangements would have, in turn, slackened the constraints on input credit access, income and liquidity, and food needs.

The date of payment for the seed cotton (early in the season, compared to other crops), the importance of accessing inputs and the guarantee of selling all production at once for a predetermined price appear to have been major determinants in land-use decisions for cotton. Multiplying the estimated coefficient by the average level of the corresponding explanatory variable, we can compare the average magnitude of farmers’ responsiveness to stated determinants regarding land use. The most important effect is due to outlet guarantees (0.183), followed by input access (0.147) and stabilized price of seed cotton (0.092), while payment date is far behind (0.04). Stated importance of food-security objectives was an important limitation (-0.12).

Under the financial streamlining that occurred within the cotton sector, the new institutional arrangements between ginners and farmers involved an earlier payment of the seed cotton and a more timely and accessible delivery of agricultural inputs. Increasing the share of family agricultural business under outgrower schemes reflects less risky strategies undertaken by farmers to satisfy their income goal, compared to other crops whose payments arrive later in the crop season. For those crops, marketing is more risky and involves many stakeholders with no guarantee of selling production at a good (and stable) price, resulting in a more difficult access to inputs. Hence, lower marketing risk for cotton might have driven part of the observed outcomes on land-use changes.

Technical assistance has limited an overly large increase in cotton land use, as a means of reducing financial risks for cotton firms and cotton-producing households, in the case of incomplete or missing rural insurance markets to cover production risks. It was the opposite in the past when extension agents were sent by the government under a national strategy of cotton promotion. The delegation of extension services to the private sector was associated with more concern about marketing profitability and the financial risks involved in the outgrower schemes for input credit. The quality of the GPC relationships is not significant in the evolution of land use. This may be why it has become easier to change groups for unsatisfied producers, thereby enabling input credit to be more equally distributed. Consequently, the GPC institutional innovation may have slackened the social constraint on land-use choices in favor of cotton.

Turning now to the change in total cultivated land (Table 5b), the evolution patterns of family labor force and mechanization appear to be strong determinants for households, as indicated by estimated parameters of technology dummies (traditional farming, adoption of animal-traction since less or more than 10 years). Already-equipped farmers were more likely to increase their cultivated land than those who became equipped during the reform, and much more than those who are still cropping in a conventional fashion (no animal traction). Note that the increase in the village labor force (slackening of labor shortage constraints) also plays a significant role in the general pattern of cultivated land increase, while technical assistance has no significant impact.

Ethnic origin also explains better access to land for resident ethnic groups than for other groups, when experience in cotton growing and the duration of village residence are accounted for. The use of ethnic origin as an instrument for endogenous change in total cultivated land is therefore justified. Among other control variables in Table 5b, absolute input use (on cotton) is negative and significant, while the stated effects of relative price of cotton and input access are positive and significant. Indeed, the relative price of cotton, application of inputs to cotton, and input access are also components of overall land profitability and risk profiles. In addition, the most efficient smallholders in terms of input use on cotton, and the most constrained in terms of input access may be less interested in land extension in general, for scale efficiency for the former (diversification prospects) and possible food-security reasons for the latter. Although relative prices and profitability components might not have mattered directly for land-use changes, it is likely that more profitable cotton contributed to cultivated land extension in general. Since land cultivation is positively correlated with the change in the cotton land share, relative profitability, in turn, affected land-use decisions through this channel.

6. Conclusion

This paper addresses the problem of agricultural land use by smallholders in a very constrained environment due to market incompleteness. Taking the case of cotton expansion during the Burkinabè cotton reform, we propose a structural model of land use accounting for incomplete or missing markets, as well as endogenous cultivated land, in the determination of optimal land use.

We show that market issues (price and inputs) may not matter directly for land-use decisions because of endogenous constraints internalized by households arising from market incompleteness: food security, income goal, social arrangements for land access, and restricted access to agricultural inputs. However, the profitability of cotton contributed to the growth of overall cultivated land, having a positive indirect effect on the growth of cotton land share. Controlling for household-specific characteristics, we point out that easier access to inputs, receiving early cash payments, and benefiting from outlet guarantees explain the direct and significant changes in land-use patterns in favor of cotton during the cotton reform in Burkina Faso.

Better institutional arrangements have driven the potential for cotton production in Burkina Faso, through more incentives for land use that favors cotton and also via indirect effects—through labor and capital investment, and better allocation of factors—for land cultivation. Our estimation results reveal that the free-adhesion principle for cotton groups (GPCs) has enabled farmers not to be constrained by the quality of their group when taking on their land-use decisions. Altogether, this has substantially decreased the risk profile of cotton relative to other crops, while the increase in total cultivated land has secured farmers in terms of their food-security objectives.

Recent difficulties faced by the Burkinabè cotton sector reveal however that extensive cotton production is not sustainable in the long run if cotton firms and banks can no longer recover their loans, and if governance is an issue (Kaminski and Bambio, 2009). Declining world cotton prices, increasing input prices, mismanagement of the smoothing fund, and poorer management of cotton firms were responsible for a lower institutional performance in the recent years. The deficits experienced by cotton firms have resulted in new difficulties in paying farmers (with adverse agro-climatic conditions) in a timely manner and in providing them with cereal inputs. This puts forth the idea that, under market incompleteness, marketing crops is highly sensitive to the institutional performance of the cotton sector. Further research efforts would be necessary to empirically analyze the underlying mechanisms of the recent drop in production.

Because it was achieved through extensive land use, the current growth in seed cotton production cannot be sustained in the long run. A policy-led intensification of farming systems is then expected, which could be based on the same institutional mechanisms as those of the cotton reform; namely, the involvement and empowerment of producers in the political process together with a sufficient degree of market coordination among stakeholders. Meanwhile, it will require improvements in governance and accountability of cotton executives and rural leaders (Kaminski et al., 2009).

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Table 1. Changes in total cultivated land and in cotton land share

Change in total cultivated land	Change in cotton land share: Large increase	Moderate increase	No change	Moderate decrease	Large decrease	Total number of households
Decreased	3	7	2	1	0	13
Remained constant	23	26	30	5	1	85
Increased < 2 ha	56	41	19	4	0	120
Increased [2, 3] ha	18	15	3	2	0	38
Increased [3, 5] ha	13	5	0	4	0	22
Increased > 5 ha	14	6	1	1	0	22
Total number of households	127	100	55	17	1	300

Table 2. Agricultural production statistics, 2006

Observations: 300

Cotton	Total	Mean	Std. deviation	Min	Max	Country level
Planted area (ha)	1092.75	3.67	3.52	0.5	25	675,000
Seed cotton output (kg)	1,206,266	4034.33	5083.97	201	49,640	710,000
Yield (kg/ ha)		1037.17	359.94	201	2073.33	1050
Urea (kg/ ha)		68.85	52.13	0	533.33	62.4
Chemical fertilizer (kg/ ha)		110.77	60.53	0	600	103.7
Organic fertilizer (kg/ ha)		13.40	65.43	0	1000	-
Pesticide (liter/ ha)		5.39	2.36	0	24	4.92
Other crops						
Planted area (ha)	985.95	3.29	1.33	1	15	-
Urea (kg/ ha)		18.32	34.58	0	250	7.2
Chemical fertilizer (kg / ha)		27.17	52.07	0	400	12.8
Organic fertilizer (kg/ ha)		21.67	105.78	0	1600	-
Pesticide (liter/ ha)		0.15	0.77	0	8.67	0.0

Note. Country-level data are obtained from the permanent agriculture survey data (DGPSA, 2006).

Table 3. Description of qualitative variables

Variable	Description	Relative frequency
Change in cotton land share	1 if cotton land share has greatly decreased (more than 15% of the current amount of cultivated land over all cultivated land) during the reform	0.003
	2 if cotton land share has moderately decreased (less than 15%)	0.057
	3 if cotton land share has remained constant	0.183
	4 if cotton land share has moderately increased (less than 15%)	0.33
	5 if cotton land share has increased by more than 15%	0.423
Large increase in cotton land share	1 if the household has experienced a large increase in the cotton land share during the reform: additional cotton land share represents at least 15% of the present cultivated land	0.423
Change in total cultivated land	1 if cultivated land area has decreased during the reform	0.043
	2 if cultivated land area has remained constant	0.283
	3 if cultivated land area has increased less than 2 ha	0.4
	4 if cultivated land area has increased between 2 and 3 ha	0.127
	5 if cultivated land area has increased between 3 and 5 ha	0.073
	6 if cultivated land area has increased more than 5 ha	0.073
Large increase in total cultivated land	1 if the household has experienced an increase in cultivated land of more than 3 ha during the reform	0.273
Agricultural technology	=1 if the household has adopted animal-traction farming during the reform	0.607
	=2 if the household has a traditional technology	0.197
	=3 if the household has adopted animal-traction farming before the reform	0.197
Cotton experience	1 if new cotton grower	0.033
	2 if less than three years experience with cotton growing	0.093
	3 if less than five years experience with cotton growing	0.143
	4 if less than ten years experience with cotton growing	0.24
	5 if more than ten years experience (growing cotton before the reform)	0.49
Resident ethnic group	1 if the household belongs to a resident (in contrast to a migrant) ethnic group	0.603
Relationship with Group of Cotton Producers (GPC)	1 if good	0.347
	2 if satisfactory	0.55
	3 if unpleasant	0.09
	4 if very bad	0.013
More than 28	1 if the household's head is more than or 28 years old (i.e., more than 18 years old at the beginning of the reform)	0.81

Note. 300 observations.

Table 4. Description of quantitative variables

Variable	Description	Mean	Standard deviation
	Objective ("revealed") determinants		
Age	Age of the household's head	34	8.08
Duration of residence	Duration of residence in the village (in years)	19.46	15.29
Technical assistance level	Number of visits of technical advisors in 2005/2006	2.95	5.69
Past technical assistance level	Number of visits of technical advisors in 1996	1.95	2.84
Risk aversion	Relative risk aversion index for a harvest value of 100,000 FCFA	0.71	.021
Off-farm income	Household off-farm income in thousands FCFA per head	13.5	29.0
Transfers	Household received transfers in thousands FCFA per head	.48	2.54
Absolute input	Quantity of total mineral fertilizers in Kg applied per cultivated hectare of cotton	179.02	86.26
Relative input	Ratio of total mineral fertilizers applied on cotton/other crops per hectare	2.07	1.24
Change in family labor force	Increase in family labor force during the reform (full-time working units)	3.24	3.53
Change in village labor force	Increase in village labor force units working at the household's plots during the reform (full-time labor units)	2.03	2.81
	Subjective ("stated") determinants (rated by importance)		
Relative price	Importance of prices in deciding crop allocation to land	4.12	3.81
Relative price variability	Importance of price fluctuations in deciding crop allocation to land	2.3	3.17
Financial needs	Importance of financial needs in deciding crop allocation to land	3.57	3.69
Food needs	Importance of food needs in deciding crop allocation to land	2.61	3.18
Guarantee of selling	Importance of guarantee of selling crops in deciding crop allocation to land	2.78	3.44
Input access	Importance of access to inputs in deciding crop allocation to land	2.95	2.53
Payment date	Importance of crop payment dates in deciding crop allocation to land	0.36	1.49

Note. 300 observations. "Stated" determinants are rated by households in order of importance on a scale [0, 10].

Table 5a. Ordered discrete-choice model estimates for the change in cotton land share

Change in cotton land share	Single-equation ordered Probit	Bivariate ordered Probit (FIML) I	Bivariate ordered Probit (FIML) II
Relative price	.026 (.023)	.033 (.022)	.008 (.022)
Relative price variability	-.030 (.026)	-.029 (.025)	-.040 (.022)*
Financial goal	-.010 (.023)	-.006 (.023)	-.006 (.024)
Food-security goal	-.061 (.023)***	-.058 (.026)**	-.052 (.024)**
Guarantee of selling	.054 (.026)**	.057 (.026)**	.066 (.026)***
Input access	.057 (.022)***	.062 (.022)***	.050 (.025)**
Payment date	.100 (.052)**	.112 (.050)**	.118 (.052)**
Technical assistance level	-.038 (.012)***	-.039 (.013)***	-.041 (.013)***
Past technical assistance level	.088 (.027)***	.084 (.026)***	.077 (.027)***
Change in family labor force	-.036 (.034)	-.027 (.025)	.003 (.037)
Change in village labor force	.013 (.036)	.052 (.030)*	.039 (.037)
Adopted animal traction < 10 years	.149 (.259)	.386 (.230)*	-.050 (.205)
Traditional farming	Reference	Reference	Reference
Adopted animal traction (>10 years)	-.050 (.352)	.550 (.269)**	.135 (.306)
Change in total cultivated land	.458 (.204)**	-	.323 (.121)***
Off-farm income	-.002 (.003)	-.002 (.003)	-.001 (.003)
Risk aversion	-.486 (.508)	-.398 (.501)	-.355 (.504)
Absolute input	-	-	.001 (.001)
Relative input	-.116 (.091)	-.110 (.086)	-.123 (.084)
Age	.002 (.009)	.001 (.009)	.002 (.011)
More than 28	-	-	-.045 (.231)
New cotton grower	744 (.452)*	585 (.464)	.590 (.472)
Cotton experience <3 years	-.090 (.268)	-.175 (.264)	-.173 (.272)
Cotton experience <5 years	.425 (.232)*	.403 (.229)*	.352 (.223)*
Cotton experience < 10 years	.135 (.190)	.205 (.182)	.095 (.186)
Cotton grower >10 years	Reference	Reference	Reference
Village effects	Included	Included	Included
Education dummies	Included	Included	Included
GPC dummies	Not significant	Not significant	Not significant
Rivers-Vuong endogeneity test	-.523 (.220)**	-	-
Cut-off 1	-1.606 (833)**	-2.085 (.779)***	-1.535 (.859)**
Cut-off 2	-.272 (.751)	-.752 (.725)	-.260 (.777)
Cut-off 3	.743 (.745)	.366 (.718)	.716 (.756)
Cut-off 4	1.858 (.746)***	1.371 (.719)**	1.786 (.748)***
Wald Chi²	136.83***	131.39***	148.35***
Pseudo R^2	.142	.226	.248
ρ (correlation between equations)	-	.024 (.081)	-.243 (.115)**

Notes. 300 observations. Robust standard errors are in parentheses. *significant at 10 %, **significant at 5 %, ***significant at 1 %. The Rivers-Vuong test is used to test for endogeneity of the change in total cultivated land.

Table 5b. Ordered-choice model estimates for the change in total cultivated land

Change in total cultivated land	Single-equation ordered Probit	Bivariate ordered Probit (FIML) I	Bivariate ordered Probit (FIML) II
Relative price	.044 (.027)*	.027 (.025)	.051 (.025)**
Relative price variability	.011 (.032)	.030 (.027)	-.012 (.026)
Financial goal	.006 (.019)	.005 (.021)	.011 (.021)
Food-security goal	.034 (.030)	.044 (.024)*	.038 (.024)
Guarantee of selling	-.042 (.031)	-.019 (.024)	-.029 (.024)
Input access	.036 (.029)	.072 (.022)***	.065 (.022)***
Payment date	-.103 (.047)**	-.056 (.054)	-.070 (.057)
Technical assistance level	.013 (.017)	.008 (.008)	.009 (.008)
Past technical assistance level	-.047 (.032)	.009 (.025)	.014 (.025)
Change in family labor force	.208 (.024)***	.190 (.025)***	.190 (.025)***
Change in village labor force	.129 (.027)***	.136 (.026)***	.148 (.025)***
Adopted animal traction < 10 years	.771 (.187)***	.663 (.207)***	.703 (.213)***
Traditional farming	Reference	Reference	Reference
Adopted animal traction (>10 years)	1.200 (.266)***	.953 (.302)***	1.049 (.295)***
Change in cotton land share	.415 (.403)	-	-
Off-farm income	-.002 (.002)	.000 (.002)	-.001 (.002)
Risk aversion	-.192 (.381)	.004 (.489)	.033 (.486)
Absolute input	-	-	-.003 (.001)***
Relative input	.001 (.009)	.011 (.010)	.034 (.097)
Age	.001 (.009)	.005 (.010)	.000 (.011)
More than 28 years old	-	-	.132 (.228)
New cotton grower	-.229 (.398)	-.081 (.355)	-.212 (.363)
Cotton experience <3 years	-.191 (.287)	-.268 (.259)	-.265 (.269)
Cotton experience <5 years	-.049 (.221)	.047 (.230)	.067 (.232)
Cotton experience < 10 years	.174 (.184)	.392 (.203)**	.351 (.208)*
Cotton grower >10 years	Reference	Reference	Reference
Duration of residence	-.012 (.004)***	-.011 (.004)***	-.012 (.004)***
Resident ethnic group	.509 (.183)***	.230 (.232)	.447 (.196)***
Village effects	Included	Included	Included
Education dummies	Included	Included	Included
GPC dummies	Not significant	Not significant	Not significant
Rivers-Vuong endogeneity test	-.365 (.422)	-	-
Cut-off 1	-.313 (1.782)	-1.658 (.752)***	-2.219 (.784)***
Cut-off 2	1.658 (1.798)	.328 (.752)	-.167 (.782)
Cut-off 3	3.540 (1.815)*	2.327 (.775)***	1.826 (.808)***
Cut-off 4	4.260 (1.824)***	3.078 (.786)***	2.600 (.819)***
Cut-off 5	4.900 (1.831)***	3.733 (.796)***	3.262 (.829)***
Wald Chi²	233.65***	131.39***	148.35***
Pseudo R^2	.294	.226	.248
ρ (correlation between equations)	-	.024 (.081)	-.243 (.115)**

Notes. 300 observations. Robust standard errors are in parentheses. *significant at 10 %, **significant at 5 %, ***significant at 1 %. The Rivers-Vuong test is used to test for endogeneity of the change in cotton land share.

Appendix

Derivation of the structural land equations

To obtain equations (3), we maximize the expression (2) with respect to each land share l_k of crop *k*, and each input quantity applied to this crop x_{kj}. With respect to the land share, we have:

$$\frac{\partial V(l_k, x_k)}{\partial l_k} = L[E\pi_k(x_k) - 2c_k L\left(l_k\right)] - 2L^2\gamma l_k \sigma_k(x_k)^2 = \lambda \qquad \text{(A.1)}$$

where λ is the Lagrange multiplier associated to the constraint of (2), and

$$\frac{\partial V\ (l_k, x_k)}{\partial x_{kj}} = Ll_k \frac{\partial E\pi_k(x_k)}{\partial x_{kj}} - \left(L\, l_k\right)^2 \gamma \frac{\partial \sigma_k(x_k)^2}{\partial x_{kj}} = 0\,, \qquad \text{(A.2)}$$

with respect to the input quantity applied to crop *k*. Rearranging terms yields:

$$l_k^{\,*} = \frac{1}{2L}\frac{E\pi_k(x_k) - \lambda}{c_k + \gamma\sigma_k(x_k)^2} \text{ and } \frac{\partial E\pi_k(x_k)}{\partial x_{kj}} = \gamma L l_k^* \frac{\partial \sigma_k(x_k)^2}{\partial x_{kj}}\,. \qquad \text{(A.3)}$$

Assuming that profit variance decreases with input application implies that more risk-averse farmers are willing to apply more input, everything equal. Because $\sum_k l_k = 1$ at the optimum (binding constraint), λ is different from 0. From (A.3) we get: $\sum_k l_k^{\,*} = \frac{1}{2L}\sum_k \frac{E\pi_k(x_k) - \lambda}{c_k + \gamma\sigma_k(x_k)^2} = 1$ and we can have an explicit form of λ such as:

$$\lambda = \frac{\sum_{i=1}^{K} \frac{E\pi_i\ (x_i)}{c_i\ + \gamma\sigma_i\ (x_i\ )^2} - 2L}{\sum_{i=1}^{K} \frac{1}{c_i\ + \gamma\sigma_i\ (x_i\ )^2}}\quad . \qquad \text{(A.4)}$$

Plugging this expression into (A.3), we obtain an explicit form of the optimal land share of crop *k*:

$$l_k^{h*} = \frac{1}{2L}\frac{E\pi_k(x_k)}{c_k + \gamma\sigma_k(x_k)^2} - \frac{1}{2L^h}\frac{\sum_{i=1}^{K} \frac{E\pi_i\ (x_i)}{c_i\ + \gamma\sigma_i\ (x_i\ )^2} - 2L}{\sum_{i=1}^{K} \frac{c_k + \gamma\sigma_k(x_k)^2}{c_i\ + \gamma\sigma_i\ (x_i\ )^2}} = \frac{1 + \frac{1}{2L}\sum_{i=1}^{K} \frac{E\pi_k(x_k) - E\pi_i\ (x_i)}{c_i\ + \gamma\sigma_i\ (x_i)^2}}{\sum_{i=1}^{K} \frac{c_k + \gamma\sigma_k(x_k)^2}{c_i\ + \gamma\sigma_i\ (x_i)^2}}\,,$$

which is a measure of the relative risk-profitability of crop *k* with respect to all crops.

Partial differentiation of (3) gives the following expressions:

$$
\begin{cases}
\dfrac{\partial l_k^{\ *}}{\partial x_{kj}} = -\dfrac{1+\dfrac{1}{2L}\sum_{i=1}^{K}\dfrac{E\pi_k(x_k)-E\pi_i\ (x_i)}{c_i\ +\gamma\sigma_i\ (x_i)^2}}{[\sum_{i=1}^{K}\dfrac{c_k+\gamma\sigma_k(x_k)^2}{c_i\ +\gamma\sigma_i\ (x_i)^2}]^2}[\sum_{i=1}^{K}\dfrac{1}{c_i\ +\gamma\sigma_i\ (x_i)^2}-\dfrac{1}{c_k+\gamma\sigma_k(x_k)^2}]\gamma\dfrac{\partial\sigma_k(x_k)^2}{\partial x_{kj}} \\
\dfrac{\partial l_k^*}{\partial x_{kj}} = \dfrac{1}{\gamma L}\dfrac{\dfrac{\partial^2 E\pi_k(x_k)}{\partial x_{kj}^{\ 2}}\dfrac{\partial\sigma_k(x_k)^2}{\partial x_{kj}}-\dfrac{\partial E\pi_k(x_k)}{\partial x_{kj}}\dfrac{\partial^2\sigma_k(x_k)^2}{\partial x_{kj}^{\ 2}}}{[\dfrac{\partial\sigma_k(x_k)^2}{\partial x_{kj}}]^2}
\end{cases}
\qquad \text{(A.5)}
$$

Profit variance is decreasing and convex with input use, so both expressions are unambiguously positive. Land shares and input uses are thus positively correlated, everything being equal. Note that when the total amount of cultivated land L^h is very large, then:

$$
l_k^{\ *} \approx \frac{1}{\sum_{i=1}^{K}\dfrac{c_k+\gamma\sigma_k(x_k)^2}{c_i\ +\gamma\sigma_i\ (x_i)^2}} \quad \text{and} \quad \frac{\partial l_k^*}{\partial x_{kj}} \approx 0 \qquad \text{(A.6)}
$$

that is, land use only depends on relative land cultivation costs and relative profit variance among crops. The land use/input use correlation is also weakening with cultivated land.

The Bivariate Ordered Probit Model

Let $\left\{S_j^k = [c_{j-1}^k, c_j^k]\right\}$, $j = 1,2,\ldots,J_k$; $k = 1,2$ denote a series of sets, with $\bigcup_j S_j^k = \mathbb{R}, \forall k = 1,2$, and such that $c_0^k = -\infty, c_{J_K}^k = \infty, \forall k,$ and $c_{j-1}^k \le c_j^k, \forall k, \forall j$. We observe the following ordered dependent variables:

$y_{1j} = 1$ if $y_{1i}^* \in S_j^1$ and $y_{2k} = 1$ if $y_{2i}^* \in S_k^2$, $j = 1,2,\ldots,J_1$, $k = 1,2,\ldots,J_2$.

From the structural model (11), we have:

$$\begin{aligned}
\Pr ob(y_{1i}^* \in S_j^1, y_{2i}^* \in S_k^2) &= \Pr ob(y_{1i} = j, y_{2i} = k) = \Pr ob(c_{j-1}^1 \le y_{1i}^* < c_j^1, c_{k-1}^2 \le y_{2i}^* < c_k^2) \\
&= \Phi_2\left[c_j^1 - \delta_1 - x_{1i}\beta_1, \theta\left(c_k^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\right), \bar{\rho}\right] \\
&- \Phi_2\left[c_{j-1}^1 - \delta_1 - x_{1i}\beta_1, \theta\left(c_k^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\right), \bar{\rho}\right] \\
&- \Phi_2\left[c_j^1 - \delta_1 - x_{1i}\beta_1, \theta\left(c_{k-1}^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\right), \bar{\rho}\right] \\
&+ \Phi_2\left[c_{j-1}^1 - \delta_1 - x_{1i}\beta_1, \theta\left(c_{k-1}^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\right), \bar{\rho}\right],
\end{aligned}$$

where $\Phi_2(.,.,.)$ is the bivariate standard normal cumulative distribution function, and $\theta = \left(1 + 2\gamma\rho + \gamma^2\right)^{-1/2}$, $\bar{\rho} = \theta(\gamma + \rho)$. The formula for the probability of any pair *(j, k)* can be used to construct the log-likelihood of the sample, and to obtain consistent maximum likelihood estimates of the bivariate ordered Probit model (see Sajaia, 2007). $J_1 + J_2 - 2$ cut-off values (c_j^k) are estimated together with parameters $(\beta_1, \beta_2, \gamma, \rho)$, but intercept terms δ_1 and δ_2 are not identified (equivalently, cut-offs are only identified up to a constant term).

Table A1. Binary Probit estimates with selection effect

Dependent variable	Large increase in cotton land share = Y1		Significant increase in total cultivated land = Y2	
	Binary Probit 1	Heckman Probit 1	Binary Probit 2	Heckman Probit2
Relative price	.025 (.029)	.024 (.029)	.018 (.046)	.015 (.057)
Relative price variability	-.047 (.035)	-.049 (.035)	.066 (.048)	.061 (.047)
Financial goal	-.024 (.028)	-.021 (.027)	.049 (.033)	.043 (.033)
Food-security goal	-.037 (.025)	-.037 (.025)	.057 (.043)	.052 (.042)
Guarantee of selling	.062 (.032)**	.065 (.032)**	-.086 (.058)	-.090 (.068)
Input access	.056 (.029)**	.054 (.029)*	.102 (.041)***	.090 (.046)**
Payment date	.048 (.065)	.050 (.064)	-.288 (.105)***	-.272 (.103)***
Technical assistance	-.046 (.016)***	-.047 (.016)***	.058 (.028)**	.060 (.028)**
Past technical assistance	.074 (.033)**	.080 (.033)**	-.021 (.049)	-.029 (.049)
Change in family labor force	-.010 (.037)	-.015 (.037)	.071 (.033)**	.068 (.084)
Change in village labor force	.004 (.042)	-.001 (.041)	.090 (.037)**	.083 (.062)
Animal traction< 10 years	-.004 (.320)	-.018 (.318)	1.038 (.428)***	1.141 (.513)**
Traditional farming	Reference	Reference	Reference	Reference
Animal traction > 10 years	-.612 (.542)	-.614 (.540)	1.635 (.483)***	1.651 (.511)***
Y2 or Y1 (resp.)	2.349 (1.054)**	2.468 (1.063)**	1.735 (1.419)	1.784 (1.398)
Ethnic resident group	-	-	.433 (.249)*	.112 (.585)
Duration of residence	-	-	.003 (.007)	.001 (.008)
Off-farm income	-.002 (.003)	.001 (.003)	.003 (.003)	.004 (.005)
Risk aversion	-1.033 (.638)*	-1.010 (.638)	.581 (.876)	.560 (1.486)
Relative input	-.138 (.106)	-.142 (.105)	-.036 (.133)	-.005 (.158)
Age	.007 (.012)	-.002 (.012)	.014 (.014)	.026 (.016)*
New cotton grower	1.210 (.480)***	1.198 (.468)***	-.633 (.733)	-.622 (.559)
Cotton experience <3 y	.030 (.447)	.003 (.446)	-.426 (.646)	-.301 (.743)
Cotton experience <5 y	.789 (.318)***	.776 (.321)**	-.621 (.413)	-.478 (1.409)
Cotton experience < 10 y	.547 (.218)***	.550 (.217)***	-.012 (.273)	.003 (.318)
Cotton grower >10 y	Reference	Reference	Reference	Reference
Village effects	Included	Included	Included	Included
Education dummies	Included	Included	Included	Included
GPC dummies	Not significant	Not significant	Not significant	Not significant
Rivers-Vuong endogeneity test	-2.577 (1.064)**	-2.672 (1.072)***	-1.976 (1.450)	-1.966 (1.338)
Constant	-1.533 (1.536)**	-1.171 (1.040)	-4.186 (1.194)***	-3.375 (3.236)
Wald Chi^2	118.75***	124.14***	119.45***	176.69***
Pseudo R^2	.258	.408	.494	.507
Observations	300	318	300	318

Selection equation: Growing cotton in 2006 (no exit during the reform)	Heckman Probit 1	Heckman Probit 2
Resident ethnic group	.683 (.139)***	.786 (.441)*
Off-farm income	-.006 (.003)*	-.006 (.005)
Transfers	-.088 (.051)*	-.090 (.197)*
Age	-.062 (.023)***	-.059 (.036)*
GPC relationships: very good	7.790 (1.902)***	7.790 (3.902)
GPC relationships: satisfactory	2.086 (.0336)***	2.030 (3.516)
GPC relationships: not good	.969 (.401)**	.820 (3.170)
GPC relationships: very bad	reference	reference
Constant	2.410 (1.018)**	2.311 (2.304)
Wald-test of independent equations	0.49	0.19

Notes. Robust standard errors are in parentheses. *significant at 10 %, **significant at 5 %, ***significant at 1 %. The Rivers-Vuong tests are used to test for endogeneity of the change in total cultivated land and cotton land share.

End Notes

[1] For a full review of the cotton story and the cotton reform in Burkina Faso and a comparative analysis with its neighboring countries, See Kaminski et al. (2009).
[2] Average crop yield has stagnated at around 1.05 tons of seed cotton per hectare during the reform period, as the positive trend of individual crop productivity was outweighed by the entry of less productive farmers and land (see DGPSA, 2006; and Kaminski et al. 2009).
[3] The functioning of these market-oriented village groups has been shown to exhibit no elite capture once elaborated governance rules have been set up (Bernard et al., 2008).
[4] It means that the income goal dominates the food security one, that is, interior solutions exist as soon as the income goal is achieved while the food-security one needs not to be. Obviously, the food-security goal is endogenous since it depends on expected agricultural income unless there is no food market at all.
[5] Note that land has only an exogenous effect in the optimal land and input use decisions in (4). The endogeneity comes from the constraints in (3), and are captured by the shadow costs of these constraints. Testing for the endogeneity of land cultivation in land use is then of key importance in the empirical results to determine whether constraints in (3) are binding.
[6] This is to control for different crop prices histories (local markets) and other social and natural characteristics: soil management, land tenure systems, natural constraints on land extension, micro-level climatic changes, evolution of communities and ethnic/religious composition or fractionalization, and so on.
[7] Changes in land use are difficult to assess accurately since many farmers intercrop several crops together, so measures of land shares are only gross measures.
[8] Ideally, one would use panel data on observed yearly land-use changes to estimate the model (11). Unfortunately, many existing panels (like DGPSA) lack part of the information needed to identify (11) under the necessary controls to be consistent with our conceptual framework.
[9] Including cotton growers who started to produce cotton after 1996 (50% of the sample, see Table A2).
[10] The questionnaire was designed to minimize strategic and framing biases. In particular, we spent a considerable amount of time with farmers to establish their stated preferences, making sure their own ordering was consistent with their decisions. We also avoid justification and cognitive biases by asking the questions about land-use decisions and land cultivation much later during the interviews.
[11] That is, the less experienced farmers might have to join a group with more constraints on production choices or input access. This could be related to their ethnic background, but as time goes by, they can make a better match or even form their own group.
[12] The cotton experience variable has five categories, according to the date of entry in cotton production (see Table A2 for the five dummies). The value 0 is attributed to those who exited cotton production during the cotton reform. The selection equation for the exit/non-exit choice is estimated by Probit.

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