Cotton Reform and Cotton Boost: an Empirical Analysis in Burkina Faso

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Abstract: Over the last 10 years, Burkina Faso experienced a reform of its cotton sector, and is now the first African cotton producer and exporter. The cotton boost consisted of a fast expansion of cotton areas through the growth of land shares allocated to cotton (and new producers), together with a global increase in total cultivated land. In this paper, we present an empirical setting to determine the contribution of total farmland changes in the increase of land dedicated to cotton, where both processes are represented by ordered endogenous variables. We apply this setting to the data that we collected in rural Burkina Faso in March 2006. From observed and subjective variables about the evolution of farming systems, we are able to identify both direct and indirect effects of the cotton reform on the extensive growth of cotton seed production: mechanization and technical assistance, labour intensification, enhanced managerial abilities (learning by doing and better environment for farmers), production incentives arising from the new local organizations of producers, guarantees and confidence stemming from the sector and an easier access to agricultural inputs.

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

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1. Introduction

The story of cotton growth throughout Sub-Saharan Africa is a very particular one, as described in the historical survey of Basset (2001). In contrast to a successful top-down implementation, the development of the cotton economy has been supported by small-scale peasant farmers and by a "peasant cotton revolution" (evolution of farming techniques and social organizations). Often quoted as one of the few success stories of agricultural development in Sub Saharan Africa, the cotton sector is now one of the economic growth leading factors (Azam & Djimtoingar, 2004) and one dominant cash crop for farmers in Sahelian regions. It is also one of the major strategies in poverty reduction for rural zones and the major source of cash inflows and export earnings for those countries (Goreux, 2003). Thus, an important arising issue is the sustainability of cotton sectors in Sub-Saharan Africa and the conditions provided for it.

Since the beginning of the 1990s, most of Sub Saharan African cotton economies have undertaken a huge process of reforms, replacing old public monopolies, official boards or parastatals, which were mainly organizing cotton markets, by private investors, cotton unions and relying more on market forces and competition (Akiyama et al., 2001). This has been supported by changes in economic and social institutions from local to national scales, in the organization of markets (input sales, cotton purchases, ginning, marketing, input and rural credits) with a process of partial to full privatization of the industry and in the relationships between producers, investors and governments. This process is believed to overcome the financial insolvencies and inefficiencies arising from the management of the old centralized cotton ginning firms and to raise the competitiveness of cotton sectors in a context of low world cotton prices (see Baffes 2004 for the explanations of this phenomenon). In Western African French-speaking countries, the reform pace has been slower with a greater involvement of the public sector than in Eastern and Austral African English-speaking countries. Each country has adopted its own scheme of reform, with progressive adjustments. Evolution of production and cotton firm's profits are very heterogeneous across countries, depending on the way institutions have been designed and on the evolution of production incentives for farmers. A key point has to be emphasized about the design of input credit schemes for cotton growers, and about their repayment incentives. Many studies from the cotton reforms (see for example, Brambilla and Porto 2006) show that cotton boost and financial clearing for the ginning firms are conditioned on the well functioning of input credit schemes and good rates of repayments. Hence, a central issue in cotton reforms throughout Africa lies in the design of input credit schemes and their related institutions.

Akiyama et al. (2001) and Goreux (2003) have examined cotton reforms in African countries. They have noted the positive effect of the privatization of cotton sectors on prices paid to producers and on the financial situation of cotton firms. However, these studies show that some level of regulation may be desirable with the involvement of producers in the industry as well as a new institutional design. Indeed, Poulton et al. (2004) pointed out that there is a trade-off between competition and coordination in the liberalized African cotton markets, which can lead to a coordination failure when no regulatory scheme is at work. This has led to the collapse of input credit schemes, with low repayment rates, because of poaching (strategic defaulting in credit repayment due to the opportunities for cotton growers to borrow inputs from one ginning company and to sell cotton seed to another firm). It is noteworthy that the coordination of activities within the industry is a significant issue in an economic environment of interlinked rural markets. Whenever unregulated liberalization occurred, cotton production has plunged drastically after a short-term boom caused by the increase in investments and new entrants. Regulatory schemes with new institutions have been established to cope with this issue as in Benin or in Zambia. The effects of the reform on national production are very heterogeneous and specific to each country (political environment, macroeconomic policies, ethnical conflicts, investment outlook, other commodity markets, agro-climatic shocks). What is relevant to emphasize is the importance of regulation and institutions in privatized cotton markets with sustainable input credit schemes. The cotton reforms are expected to impact mostly on the productivity of producer households (inputs, research, extension services, seeds…) and on the growth of areas planted in cotton. Brambilla and Porto (2006) have studied the effects of the cotton reform on productivity in Zambia. In this paper, we focus on the effects of the cotton reform in Burkina Faso on the growth of cotton areas. Why we have focused solely on this effect will be motivated below.

In Burkina Faso, the reform consisted of setting a new institutional design before privatizing the industry, creating a partnership between ginneries and producers, and new local organizations of cotton growers to cope with input credit. The resulting large increase in repayment rates of input credit and more bargaining power for producers (Kaminski, 2007) led to more production incentives for cotton production, attracting new farmers and new land to cotton seed production. Burkina Faso has become the first African cotton producer (production has been multiplied threefold in the last five years) partly because of the cotton reform but also because of the Ivorian Crisis in 2002 that resulted in a massive inflow of Burkinabe farmers formerly settled in Côte d'Ivoire. In Kaminski (2007), it is mentioned that the Ivorian Crisis has not led to a significant cotton evasion from Côte d'Ivoire to Burkina Faso, but that the massive inflow of labour force in rural areas is likely to have contributed significantly to the growth of national cotton production. However, this labour force has been oriented towards the cotton sector because of new incentives generated by the sector's reform.

In this paper we present an empirical study of the determinants of cotton growth in Burkina Faso, which is supported by a survey of producers conducted in March 2006, in representative cotton areas. 300 households of cotton growers were interviewed in order to understand how their agricultural choices of production have evolved during the reform. Our goal is to determine whether the cotton growth can be explained by the reform of the cotton sector, and what production incentives were at work during the reform. To this end, we estimate the joint probability of changes in land allocated to cotton and in total farm land under several specifications. From our cross-sectional data (containing some recall variables), the information that we gather on these processes is available through discrete, binary and ordered variables. An appropriate econometric specification is called for because of the possible endogeneity of the explanatory variable representing changes in total farmland. We rely on the use of subjective variables that support the observed evolution of farming systems. It enables us to assess the determinants of the cotton boost and, indirectly, to match the reform's impacts to these evolutions (role of technical assistance, mechanization or the setting of GPCs for instance).

The first specification is the binary Probit model associated with large increases in land, compared to decreases or no change in land area. This is a special case of the ordered Probit model, in which these changes are classified into more than two possible values (large decrease, moderate decrease, no change, moderate increase, etc.). The probability of changes in land area is estimated in a single-equation framework, and in a bivariate model, for the binary and the ordered Probit cases. In each model specification, we control for the possible endogeneity of an increase in total farm land (resp. increase in land allocated to cotton) in the equation for land allocated to cotton (resp. increase in total farm land). Exogeneity of such explanatory variables is tested for, using in particular a Rivers-Vuong test statistic in the single-equation models. The estimation procedure will hence allow us to determine whether, once we control for observed components in the probability of land area variations, the increase in farm land and land allocated to cotton are joint processes of not.

The remainder of this paper is as follows. Section 2 presents the stages of the reform in the cotton sector of Burkina Faso and its effects on production. We then present the different hypotheses which will be tested from our survey data. Section 3 is devoted to the empirical setting which consists of the survey design, the description of available data and the estimation strategy. Section 4 presents the econometric estimation results and their interpretations. Section 5 concludes.

2. Ten years of changes in the cotton sector of Burkina Faso

The stages of the reform: institutional design, privatization of the cotton firm and establishment of a professional partnership

After the independence of Burkina Faso in 1960, the parastatal firm SOFITEX[1] held a monopsony in cotton seed, and a monopoly in input provision and distribution, input credit,

[1] The National cotton fibers company

ginning and marketing cotton. Production was organized with groups of village producers, the GVs[2], where group lending schemes established. Research and extension services were provided by the government, in addition to some public goods supplied by SOFITEX (rural road maintenance, education, transportation of cotton seed). Prices were posted by the SOFITEX every three years for the purchase of cotton seed, the sale of agricultural inputs and the credit interest rate. As in many countries in French-speaking West Africa, the share of world price given to producers remained low because of explicit or implicit taxation from SOFITEX and poor management performances. The system was performing well until the 1990s because of top-quality agronomic research (with the participation of the former French cotton company, the CFDT) providing seeds and chemical inputs adapted to local conditions and a good coordination between village groups, banks and SOFITEX. Unfortunately, an increasing number of weaknesses put forward the idea that there was a need for reforming the cotton sector. Large deficits were experienced by SOFITEX, with a decrease in the repayment rates of input credit from GVs (coordination failures, see hereafter) without credible sanctions and the increasing scopes for opportunities in rent seeking and corruption among parastatal's agents and GVs leaders (no efficient and transparent stabilization mechanism for prices while world prices declined). As a result, SOFITEX experienced difficulties in paying producers and providing them with inputs.

The reform of the cotton sector in Burkina Faso has been described at length in Kaminski (2007). The main features of the reform lie in the two following issues: producers have gained significant bargaining power in the management of the sector, and new local institutions for cotton growers have allowed for the design of new attractive outgrower schemes. The former joint liability system of GVs matched cotton to non-cotton growers for their input needs but the input cost was deducted from the value of cotton sales. In large groups, lack of peer monitoring led to opportunistic behaviour and less incentives for cotton production. The first step of the reform consisted in replacing GVs by GPCs[3], the new organizations of producers which were designed for cotton growers. Since 1996 in GPCs, producers are free to create their own group, to accept or reject new members, so that matching by affinities and self-selection are the core mechanisms of these new institutions. This design has allowed better peer monitoring abilities and resulted in more cooperative behaviour with more flexibility in group formation. Repayment rates have increased up to 99% and these institutions have attracted new producers.

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[2] *Groupements villageois*

[3] *Groupements de producteurs de coton*

The second step of the reform was the partial privatization of SOFITEX in 1999, when government transferred half of its capital shares to UNPCB[4], the national union of cotton growers and the partial withdrawal of the government from the industry. Research and extension services are now held by SOFITEX and cotton unions. Then, a professional agreement was established between SOFITEX, banks, UNPCB and the national agronomic research institute. Producers were involved in management and decisions on pricing, funds for research and extension services, input provision, management of input credit and so on. Cotton unions were in charge of the provision of cereal inputs instead of SOFITEX while the latter focused on cotton inputs.

The third step of the reform began in 2002, with the entry of new investors in the ginning market. The goal was to attract new capital in the sector without changing the market organization of the sector. Indeed, the monopsonistic system was maintained with the definition of exclusive zones of purchasing seed cotton for each ginning firm, and SOFITEX retaining the major production area in the West. The Centre of Burkina Faso was awarded to SOCOMA[5] and the East to FASOCOTON[6]. These two new firms were included in the professional partnership with SOFITEX, producers, government and banks. Today, prices are reported and decided upon within this partnership agreement as many other collective decisions. Input credit is supplied by SOFITEX only for cotton inputs and by UNPCB for cereal inputs. The last step of the reform was to set up a new pricing mechanism. Prices are now posted every year, based on forecasts of the world price and are associated with a more transparent "smoothing" fund[7], administered by the inter-professional partnership.

The pattern of production during the reform: main facts and explanations

The present subsection contains assertions and propositions which are supported by national data and censuses and by interviews with executives from the sector and local cotton experts (that we met in February 2006).

Until the 1990s, the national production has grown steadily, due to the joint effect of a rise in productivity (improvement in the quality of inputs and seeds) and in cotton areas (spreading of the cotton outgrower schemes with an increasing support from the banks to SOFITEX). Because of the

[4] *Union nationale des producteurs de coton du Burkina Faso*
[5] *Société cotonnière du Gourma* (owned by DAGRIS)
[6] *Société cotonnière du Faso* (owned by REINHARDT)
[7] This fund was previously managed by the government to subsidize the sector but has never worked efficiently; it is now managed by the professional partnership and its purpose is to attenuate the world price variability of cotton fiber

difficulties and the huge accumulated arrears faced by SOFITEX in the 1990s, there were bottlenecks to provide inputs to cotton growers and to pay them early after the harvest of cotton seed. As a result, production decreased in the 1990s until the currency devaluation[8] of 1994. This has allowed for a significant increase in the competitiveness of the cotton sector and in the payments for cotton growers but with an increase in imported input prices. However, the SOFITEX deficits were not solved with bad repayment incentives arising from the GVs.

After GVs were replaced by GPCs in 1996, the production started to increase again only in 1999. This result was obtained because of new monitoring schemes, more credible sanctions as well as more flexible operation (self selection, free association of members). These elements have led to new and better incentives as analysed in Kaminski (2007). The beginning of the production increase in 1999 is also the result of the privatization of SOFITEX with the entry of producers in its capital and the emergence of a strong integrated union of cotton growers. The management of the ginning firm has been improved and the rise of bargaining powers for producers has allowed increasing prices of purchasing cotton seed whereas world price of cotton declined. SOFITEX met new supports from the banks to contract with new farmers and supply them with inputs, sustaining the beginning of the cotton boost. The entry of new investors in 2003 brought new funds for the cotton sector, therefore participating to the cotton boost[9]. The partnership between ginning firms having local monopsonies and a strong integrated cotton union is significant in the successful implementation of the reform supported by collective decisions and cooperative behaviour. There has been a marked empowerment of producer unions allowed by the timing and the design of the reform. They have benefited from the reform, taking up a growing number of responsibilities thanks to the emergence of their political and bargaining power (World Bank, 2004).

The reform plan for cotton in Burkina Faso is largely accepted to be the most successful in West Africa, as input credit access has been improved and producer prices have been maintained and even increased in spite of the declining world price of cotton fiber. The impact on production is obvious even if we have to consider other phenomena. The devaluation of the CFA Franc was responsible for the competitiveness of Burkina cotton until the end of the1990s and the Ivorian crisis in 2002 has led hundreds of thousands of people to return to Burkina and, in particular, the traditional cotton area in the Southwest.

These latter two exogenous shocks can account for part of the production growth trend but they are not decisive (see above). For all actors of the industry and for Burkina's government, the

[8] In 1994, the CFA Franc was devaluated by half of its value
[9] See figure 1 in the appendix for the pattern of production over the ten last years

necessary condition to the reform success was the financial streamlining of the sector and more efficient credit institutions. The institutional shift from the GVs to the GPCs, and the new monitoring system allowed by the inter-professional partnership between producers and ginners, are the crucial elements of the high credit repayment rates of the last five crop seasons. Privatization and liberalization have improved information for producers and strengthened the inter-professional partnership. Some degree of confidence has emerged for producers with respect to cotton companies even though many contractual problems (measurement errors, arbitrary quality classifications, corruption...) remain. With reduced or inexistent deficits and a sustainable credit scheme, banks have raised their commitments with cotton companies, leading to more credit allowances for a growing number of producers[10].

According to the executives of cotton firms, officials and producers' representatives, the reform has not led to more intensive use of inputs (pesticides and fertilizers); this fact is confirmed by national agricultural census and surveys (DGPSA[11], INSD[12]). The cotton growth mostly relies on area extension caused by a rapid process of mechanization in cotton regions and more labour allocated to this crop. The latter effect can be explained by the rise in land shares allocated to cotton, demographic growth and migration to cotton zones. In fact, the rise in land shares allocated to cotton in agricultural systems often occurs in a significant way for new or recent producers (as their land share was small or non-existing before), so that the rise in land shares allocated to cotton is partly explained by the entry of new cotton growers. The private sector has been 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.

The privatization process has also changed the organization of such "critical" functions of the industry as research and extension services, funded jointly by cotton companies and producer unions (see above). Research is funded by the three companies and cotton unions, decided by the inter-professional agreement, and contributions by the government have declined substantially. For many executives of the sector, the reform has not been associated with a better concern for those "critical" functions. With the withdrawal of the government from the industry, funding research and extension services is more difficult with the declining cotton prices. Considered as commons, the delivery of these services can be jeopardized by the privatization process that may "disrupt the

[10] Unfortunately, it is not true anymore today because of new insolvencies and deficits from SOFITEX coming from the declining world prices whereas prices paid to producers have been kept relatively high.

[11] *Direction générale des prévisions statistiques agricoles*

[12] *Institut national des statistiques et de la démographie*

chain" (Barbier, 2005). Indeed, this author shows that a misuse of pesticides (with a lack of technical advices) can induce pest resistance and productivity decline, as experienced in Thailand with the privatization of national boards in the agricultural sector. Supporting these activities is a key issue for the young inter-professional association. The withdrawal of the government has also led GPCs to become involved in local public goods provision. Cotton revenues were sometimes reinvested by the government in public goods. But for now, only the largest and the best managed groups can afford to subsidize local educational or health programs.

With the decline in international cotton prices, cotton revenues and the provision of public goods have shifted downwards (lower margins, negative price effect) but it has been offset by the growth of cotton areas and production for the average producer and at the national level (positive quantity effect). It can be explained by the stability of domestic cotton prices, the result of the better management of the whole sector and the better supervision of the outgrower scheme. The latter was also responsible for a better access to cereal inputs, so the cotton reform has also benefited to producers with respect to grain production and food sufficiency concerns. After the reform, supply was less constrained by credit. So, we understand why the key point of the reform can be the institutional change of local groups and the establishment of the inter-profession agreement with a good representation of producers. Many interviews that we led with industry executives and farmer leaders and representatives have shaded some light on the importance of confidence elements in the successful results from the reform. Supply of cotton seed has increased because of more access to credit, guaranteed prices, inputs and outlets and payment dates. In brief, farmers are quite confident in cotton processors and in the commercial relationships with them. Former agrarian institutions were an important barrier for cotton production. For some experts (AFD, CAPES), price was not determinant in land allocation choices made by farmers[13]. So, cotton areas have grown substantially because of more confidence for cotton growers in the sector and more access to inputs.

Both the number of producers and mechanization have been responsible for the increase in production through the extension of cotton areas. According to national agricultural data, in spite of the rise of cotton areas, it was not at the expense of cereal production. Increases in land shares dedicated to cotton are correlated to a rise in total cultivated land. Indeed, some of the cotton revenues are often invested in animal drawn-farming and some credit programs have been

[13] Above 150 CFAF, cotton supply is believed to be quite inelastic.

designed for it. Average crop yield is stagnating due to limited soil fertility and limited potential of the seed varieties but the variability is even more important across producers. National data have shown that crop yield has improved on the best soils, with an important "learning-by-doing" effect but that new producers cultivate cotton on marginal lands sometimes with under-applications of inputs. However, input use by unit of land has not risen but can be associated with a better long-term management of soil fertility (organic applications), an improved planning of mineral fertilizer and pesticide applications. Unfortunately, soil fertility is not sufficiently taken into account by farmers because of a lack of land tenure security and of education, according to technical agents. So, only extensive growth factors explain aggregated cotton production: the number of producers, allocation choices and mechanization.

All these assertions have been supported by the interviews led with executives of the sector and some experts. Our empirical study is going to address these propositions, testing a set of hypotheses that we will state in the following of the paper.

Explaining cotton growth by the growth in cotton areas?

As pointed out in the previous subsection and as can be observed in figure 1 (see the appendix), the increase in national cotton production during the reform has followed the growth of cotton areas with a quasi similar pattern. Our empirical study focuses on the determinants of the growth in cotton areas as a proxy of cotton seed production. Indeed, explaining the growth of cotton production by the extension of cotton areas is justified when crop yields are stationary. At the national level, this is verified when inspecting aggregate data (see figure 1). However, the permanent census on Burkina Faso’s agriculture (using pseudo-panel data) allows us to examine what happened at the household level. The global trend is an improvement of crop yield at the household level (concerning the same land) with stationary input use. With the entry of new producers and more marginal lands (less fertile), yield variability has increased with a stationary aggregate yield at the national level. We can interpret these findings as a global improvement in the quality of cotton agricultural systems management (learning by doing, research and technical assistance) with an offsetting dynamic effect from the entry of less efficient producers and less fertile lands. Hence, all other things being equal, our empirical setting which focuses on the growth of cotton areas, will overestimate cotton production growth for more marginal lands and less experienced producers, while it will underestimate it for more experienced producers. However, the nature of our data (see hereafter) does not allow us to assess quantitative effects of the reform on production and on cotton areas extension. As we want to deal with the identification and the ranking of the factors that led to the growth of production through the extension of cotton areas, we will not address this issue of over and under estimation of cotton growth with respect to household and land types.

The major explanations for the growth of cotton production, given in the previous subsection will be tested on our data. We state these hypotheses in Table 1 and we will address them when we will interpret the estimates from our regressions in Section 4.

[Table 1 here]

3. Estimation strategy

A vast number of papers deal with agricultural reforms and their effects on production growth in developing countries. The empirical setting mostly consists in estimating production functions (with panel data or time series). Panel data are used with stochastic production frontier models in Fan (1991) to measure and separate the effects of technological change, institutional reform and input use on Chinese agricultural production growth. Concerning cotton reforms in Sub Saharan Africa, Brambilla and Porto (2006) used repeated cross sectional data which correspond to the reform period to measure impacts on productivity. They use difference-in-difference between cotton and maize productivities across farmers to control for farmer and crop heterogeneities. With the use of a relevant set of control variables, they are able to extract significant time dummies corresponding to the direct effect of the Zambian reform. They show that the first stage of the liberalization of the sector which has coincided with a failure of the outgrower scheme is significantly associated to the decrease in cotton productivity and then, that the second stage which has coincided with a recovery of efficiency of these schemes is significantly associated to the increase in cotton productivities.

Our empirical methodology is departing from this literature in several aspects. First, we work with cross sectional data and focus on the extension of cotton areas, disentangling cultivated land extension and evolution of land shares[14] dedicated to cotton. Second, we work with both subjective and objective variables to explain the driving forces that have led to the extension of cotton areas

[14] One model of land shares dedicated to cotton is presented in the paper of Brambilla and Porto (2006) but the availability of variables is restricted and they do not use any subjective variable.

during the reform. The diversity of available data allows us to identify the determinants of cotton areas extension with cross sectional data and a special designed questionnaire.

The survey design: Sampling strategy and data set

We interviewed 300 households of cotton producers located in five different areas in the South and Southwest of Burkina Faso. We focus on these zones because they belong to seven provinces that produce 45 % of total national cotton production. Moreover, they are very different because some provinces are part of the traditional area of production while others are new zones of production or zones characterised by less productive patterns. Then, the cumulative production dynamics of these zones follow the same pattern as the national production[15]. In figure 3, the sampling zone is shown in bold lines (see in the appendix).

From this area, five zones of close ethnological and linguistic characteristics were chosen with four villages (two important and two secondary) selected in each. Then, 16 households were randomly chosen from each of the largest villages and 14 in the smallest ones. This represents 60 households per zone. Farmer names were collected from updated lists of all GPCs of the village and classified into strata according to their cotton areas of the past crop season. Some households were then randomly chosen in each stratum, proportionally to the size of the stratum. The five zones are represented in figure 4, in the appendix.

The selection of villages does not reduce representativity seriously as villages are very heterogeneous in size, ethnic composition, number and experience of GPCs and cotton growers between and within the five zones (see descriptive statistics, figure 2 and the next section). Only households involved in cotton production, even a marginal one, were interviewed. Indeed, our empirical strategy aims at explaining why cotton growers have increased their cotton areas. Some farmers might have abandoned cotton production and we should have tried to understand why, as well. However, according to national statistics, these farmers are few and very hard to be taken a census within villages of cotton growers. Thus, our study overestimates the increase in cotton areas because we have only drawn our sample from lists of cotton growers but it is reasonable to think that the overestimation bias would be quite small. Moreover, we aim to qualify and identify the determinants of the observed cotton boost, so that including farmers that abandoned cotton production does not appear as a relevant issue in addressing this goal.

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[15] See figure 2 in the appendix for the production trend of each visited province where we selected villages for the survey.

An original questionnaire was designed with recall variables and variables about the evolution of agricultural systems and economic decisions within each household. These variables were added to basic variables informing living standards (housing, education, health, consumption, credit, savings, crops, cattle). In addition to objective variables, households were asked about the reasons and the determinants of their choices and of the evolution of their decisions during the reform, concerning agricultural management. The availability of both objective and subjective variables on the evolution of agricultural systems allows us to study empirically a dynamic process (increase in cotton areas) with cross sectional data. Detailed information on available data that we used in this paper is presented in the appendix in the two last tables.

The first goal in observing basic statistics from the data was to identify any selection bias in the sampling design because we have restricted the sample on a defined area. However, the sample was drawn on a stratified basis within selected villages according to the past cotton production of each household listed on GPCs' lists. In table 2, we observe that the sample corresponds to 0.2% of national cotton production of the 2005/2006 crop season. Compared to the data of DGPSA, average crop yields are the same in our sample with lower variance (small differences). Land distribution looks like the one of cotton zones (table 3, see in the appendix) and input use is also similar to the national average. According to technical assistants of SOFITEX, the variability in crop yields is due to the variability in mineral and organic fertilizers application and in input access. Moreover, there is significant variability in soil fertility and experience with the cotton crop. On average, farmers apply far more nitrogen on cotton than on other crops. In figure 2, we display the production pattern of each province where we have visited at least one village. The heterogeneity of production across these provinces is significant and the cumulative one follows the national pattern.

[Table 2 here]

Second, we display descriptive statistics on our variables of interest, evolution of land shares dedicated to cotton and evolution of total farmland for each household during the reform, in a cross table (table 4, see in the appendix). Two thirds of the sample corresponds to households which have increased their farmland during the reform or increased their land share dedicated to cotton and more than one half to households that participated to both phenomena. The correlation between these two variables is quite significant and appears clearly in the table so that the endogeneity and simultaneity problems that we stated before seems relevant to check and to control for if needed.

In the literature, such a correlation is often explained by the profitability-risk trade-off (Rosenzweig and Binswanger, 1993) and the risk aversion for farmers with respect to food needs endowed with low amount of land. The optimal strategy lies in a food self-sufficiency allocation choice of crops (Fafchamps, 1992; Jayne, 1994) when some markets are missing or isolated and land access is constrained. Hence, farmers endowed with small farmland areas will have less land shares allocated to cotton than those with larger plots of land or more fertile lands. In our empirical setting, it can be translated into the following assumption: the evolution of land shares dedicated to cotton is positively correlated with the evolution of total farmland. However, the reverse causality is more questionable since the allocation choice of crops compared to the access and the resources needed to farmland does not involve the same decisional process and the same kind of constraints. For crop allocation, the major constraints can arise from local institutions and credit groups (input access) and from lumpy investments with technology adoption for new cotton growers. The determinants of adoption are identified in the literature as human and social capital ones, as well as technical assistance and learning by doing plus neighbouring effects (Besley and Case, 1994; Foster and Rosenzweig, 1995; Conley and Udry, 2004). Adoption is also important in the process of land extension when shifting from traditional to animal farming. Concerning access to land, other constraints may involve ethnical background, soil fertility, availability of village and family labour. Moreover, there are different dynamic processes. While allocation choice of crops can differ every year, access to land can be slower and related to social interactions within the village. To end up with, growth in land shares dedicated to cotton would not be linearly correlated to growth in total farmland as, for a sufficient amount of land, more risk-averse farmers would prefer to diversify agro-climatic and price risks among more crops.

Estimation strategy

Our estimation strategy is focusing on two variables of interest: evolution of total cultivated land and evolution of land shares dedicated to cotton. Nevertheless, these two processes are not sequential in the decisions of households, so that these two components of the growth of cotton areas need to be somehow disentangled. The data we collected on the evolution of cotton areas are discrete and ordered (see the appendix tables 5 and 6) according to the level of increase or decrease in total cultivated land and land shares allocated to cotton per each household. We estimate simultaneously these two variables by a bivariate probit model. Before presenting this model, we will present the standard probit binary model and the bivariate one. Finally, we will introduce an ordered probit model to deal with all the available information to obtain refined results and derive marginal effects.

Consider the general simultaneous-equation model

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

i=1,2,…,N, where y_{1i}^{*} and y_{2i}^{*} are two latent variables that can be broadly defined as measures of profitability associated with two simultaneous decisions, and therefore are expected to be positive when corresponding decisions are observed. Vectors of explanatory variables x_{1i} and x_{2i} may have some common components; u_{1i} and u_{2i} are random normal variables with constant variances normalized to 1, and a correlation coefficient denoted ρ. We assume the following exogeneity restrictions apply: $E(x_{1i}u_{1i}) = E(x_{2i}u_{2i}) = 0, \forall i$.

In our case, latent variables are associated with decisions on the extension of cotton land and total farmland, the precise matching of y_{1i}^{*} and y_{2i}^{*} to these decisions in (1) and (2) above depending on assumptions made on the data generating process. We may assume that extension of land for cotton depends explicitly on total farmland extension given other explanatory variables, in which case the former would correspond to y_{2i}^{*}, the latter to y_{1i}^{*} and other explanatory variables to x_{2i}, or the opposite.

Latent variables can lie in the real line, to be consistent with the fact that profitability may be defined according to a set of non-overlapping intervals, typically from large negative values to large and positive values, and including areas where profitability is more uncertain (around 0 in particular).

Let $\{S_j^k = [c_{j-1}^k, c_j^k]\}$, $j = 1,2,\ldots,J_k$; $k = 1,2$ denote such 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 (1) and (2) we have

$$
\begin{aligned}
\Pr ob(y_{1i}^* \in S_j^1, y_{2i}^* \in S_k^2) &= \Pr ob(y_{1i} = j, y_{2i} = k) \\
&= \Pr ob(c_{j-1}^1 \le y_{1i}^* < c_j^1, c_{k-1}^2 \le y_{2i}^* < c_k^2) \\
= \ \Phi_2 \Big[c_j^1 - \delta_1 - x_{1i}\beta_1, \theta\big(c_k^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\big), \bar{\rho} \Big] \\
- \Phi_2 \Big[c_{j-1}^1 - \delta_1 - x_{1i}\beta_1, \theta\big(c_k^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\big), \bar{\rho} \Big] \\
- \Phi_2 \Big[c_j^1 - \delta_1 - x_{1i}\beta_1, \theta\big(c_{k-1}^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\big), \bar{\rho} \Big] \\
+ \Phi_2 \Big[c_{j-1}^1 - \delta_1 - x_{1i}\beta_1, \theta\big(c_{k-1}^2 - \gamma\delta_1 - \gamma x_{1i}\beta_1 - \delta_2 - x_{2i}\beta_2\big), \bar{\rho} \Big],
\end{aligned}
\tag{3}
$$

where $\Phi_2(\bullet,\bullet,\bullet)$ 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 (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). Parameters in the system (1)-(2) are identified only if exclusion restrictions are imposed, namely at least one variable in x_{1i} should be excluded from x_{2i}. A particularly interesting special case is the bivariate (binary) Probit model, which obtains under the restriction that $J_k = 2, k = 1, 2$. Such a restriction would be justified if for instance a single cut off value for each equation is significantly different from 0 in the bivariate ordered Probit model. This alternative model is considered in the following, when extension of land for cotton or total land farm is represented by a dichotomous dependent variable coded as "negative or moderate increase" versus "large increase".

Whether we consider the general model as the bivariate ordered Probit model, or the bivariate binary Probit specification, endogeneity of y_2^* as an explanatory variable in equation (2) has to be accounted for. If error terms u_{1i} and u_{2i} are correlated ($\rho \neq 0$), this implies that y_{1i}^* is correlated with u_{2i} and therefore the second equation in the system (1) 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 (1)-(2) above.

The first one is proposed by Rivers and Vuong (1988), and considers separate estimation of equations (1) and (2). The method is based on a first-stage OLS regression of the potentially endogenous variable (y_{1i}) on exogenous explanatory variables (x_{1i}). In the second stage, computed residuals of the first-stage regression are included in the Probit estimation of equation (2) together with y_{1i} and x_{2i} as regressors. If the estimated parameter on predicted residuals is significant, then exogeneity of y_{1i} in equation (2) is rejected. The advantage of this test procedure is that it only requires single-equation least squares and (ordered) Probit estimation steps.

The second possibility consists in estimating the structural system of equations by bivariate (ordered) Probit and then use a Wald Test of $\gamma = 0$ in equation (2). Sajaia (2007) provides a method for computing this test in the bivariate ordered probit model, with a Full Information Maximum Likelihood (FIML) approach.

It should be noted that we do not consider, for the sake of space limitation, an alternative estimation method, the bivariate Probit corresponding to the reduced form of the system (1)-(2). Although this model could be employed to yield consistent parameter estimates as long as exogeneity of y_2^* in the sense defined above is rejected, we are able to obtain structural parameter estimates directly by FIML with the bivariate ordered Probit procedure.

To summarize, our estimation strategy is as follows. We first consider the special case of the binary Probit model, where y_1 (resp. y_2) is a dummy variable equal to 1 if the corresponding land increase is large, and 0 if it is moderate or land decreases. This special case obtains, as described above, by restricting cut off values to 0. We then test for endogeneity of y_2 using the Rivers-Vuong test procedure. The binary Probit model is also estimated under the restriction that $\gamma = 0$, i.e., without the endogeneity issue, in a bivariate framework and with the same explanatory variables. Second, we turn to the estimation of the ordered Probit model, under its single-equation expression, and then its full structural form (by FIML). In the former model, we also test for the endogeneity of y_2 by extending the Rivers-Vuong procedure to the ordered Probit case. In the latter, FIML estimates are also computed under the restriction that $\gamma = 0$. For the ordered Probit, dependent variables correspond to multinomial variables with a wider range of possible changes in farm land (resp. land for cotton): large decrease, moderate decrease, no change, moderate increase, etc. Finally, from ordered Probit parameter estimates of the cut off values, we are able to test for the validity of the restricted model (binary Probit), against the alternative of the ordered Probit.

4. Econometric results

We first estimate equation (2) by Maximum Likelihood binary Probit, where $y_1 = 1$ stands for a large increase in total farmland, and $y_2 = 1$ stands for a large increase in land share dedicated to cotton. Estimation results are presented in Table 7a, where we also report parameter estimates in the bivariate case where equation (2) is jointly estimated with equation (1) under the restriction $\gamma = 0$.

The probability of increasing land shares dedicated to cotton is positively and significantly correlated with household's concerns for guarantee of selling their crops, access to inputs, and payment date of cotton, level of technical assistance before the reform and significant increase in total farmland. There is a negative correlation with the present level of technical assistance. Cotton growers who entered the production during the reform have increased their shares more than the most experienced ones on average, and except for cotton growers with one to three years of experience. However, the differences do not seem significant. When we do not account for the significant increase in total farmland (bivariate probit case) the price concerns become positive and significant as well as the aversion for crop price variability. It is noteworthy to observe that the quality of social relationships within GPCs does not influence the decisions of households in crop allocation. All these results have to be related to hypotheses H4, H5 and H6.

As can be seen from the Rivers-Vuong exogeneity test in the single-equation case, exogeneity of total farm land increase is strongly rejected, indicating that both land changes evolve jointly, even when controlling for (exogenous) observed components. It is related to hypothesis H1.

[Table 7a here]

In table 7b, we present estimation results for the binary Probit model, where the definition of dependent variables is reversed: $y_1 = 1$ for a large increase in land share dedicated to cotton, and $y_2 = 1$ for a large increase in total farmland. A large increase here is considered to be more than 2 ha. Households are more likely to have increased by more than 2 ha their farmland during the reform when the family labour force has increased, and when agricultural systems have been improved (through mechanization), which is in line with hypothesis H2. This probability is also correlated with the level of present technical assistance but not with the level of technical assistance that prevailed before the reform. We control that resident ethnic groups are more likely to have increased their farmland during the reform than migrant ones, which supports hypothesis H3.

We also control for cotton experience, showing that cotton growers which entered the growing activity of *Gossypium* during the reform are more likely to have increased their farmland than more experienced cotton growers. This has to be related with the fact that farmers already mechanized (animal farming) before the reform are more likely to have significantly increased their farmland before the reform than farmers having adopted this technology during the reform. Table 7b also displays that the likelihood of increasing farmland is undoubtedly greater for mechanized farmers than for traditional ones. Mechanization is correlated not only with cotton experience (and learning by doing) but also with technical assistance and learning from others (village effects in our setting). However, we have not included village effects in the tables because other parameters do not change[16] (except the mechanization dummies) and our conclusions remain the same. Finally, the occurrence of a large increase in land share dedicated to cotton has no significant impact on the likelihood of a significant increase in total farmland.

While increase in total farmland was tested as endogenous in the probability of increase in land share dedicated to cotton (Table 7a), the reverse does not seem to hold. Exogeneity of an increase in land share dedicated to cotton in the total farmland equation is not rejected by the Rivers-Vuong test. This indicates that the correlation between observed levels of both land changes is captured by technological change, evolution of available labour force and learning by doing, which supports hypothesis H1. At this stage, our hypotheses cannot be rejected, but we need to analyze the estimation results of the ordered models to confirm these first statements.

[Table 7b here]

We now turn to estimation of the ordered Probit model, where dependent variables are allowed to take on more than 2 values. The change in land dedicated to cotton is classified into 6 possible modes: 1 for large decrease, 2 for moderate decrease, 3 for no change, 4 for moderate increase, and 5 for large increase. Total land change has 6 possible values: 1 for decrease, 2 for no

[16] A Hausman test was performed to check there are no significant differences among the values of estimated parameters in the models of table 7 and 8 with or without village effects. These effects capture agronomic constraints, soil fertilities and other local conditions.

change, 3 for less than 1 ha increase, 4 for an increase between 1 and 2 ha, 5 for an increase between 2 and 5 ha, and 6 for an increase of more than 5 ha. Using more detailed information on the extent of changes in total land and land allocation to cotton allows us to go deeper into the analysis of the determinants of the evolution of household decisions and agricultural systems.

Table 8a presents the estimation results for the model where y_1 is associated with changes in total farmland, and y_2 corresponds to changes in land share dedicated to cotton. Equation (2) is estimated by ordered Probit under three different procedures: single equation ordered Probit, bivariate ordered Probit under the restriction $\gamma = 0$ (FIML I) and unconstrained bivariate ordered Probit FIML (FIML II). Parameter estimates confirm the basic results derived from table 7a with more emphasis on the role of the concern for input access and less on the concern for guarantee of selling in deciding crop allocation. Moreover, the concern for food needs (important when the farmer is a small land owner) appears significantly and negatively associated to the evolution of land share dedicated to cotton. Cotton extension would be more marginal for the smallest-scale farmers.

The endogenous nature of the change in total farmland is confirmed in the ordered Probit case, where the exogeneity assumption for total farm land is again rejected by the Rivers-Vuong test. Parameter estimates obtained with the single-equation ordered Probit or the bivariate ordered Probit (FIML) II are very similar, apparently more than the bivariate ordered Probit (FIML) I in which change in total farm land is not included as an explanatory variable. The fact that cutoff values are not all significantly different from 0 indicates that the restricted model (the binary Probit) is rejected in favour of the ordered Probit specification. In particular, the first and fourth cut offs are significantly different from 0 in all three cases, indicating that separation between “large decrease” and “moderate decrease”, and “moderate increase” and “large increase” is relevant. On the other hand, the distinction between “”no change” and “moderate increase” (cut off 3) is never significant. The correlation coefficient between unobserved random terms in the latent variable equations (1) and (2) is significant and negative (-0.291), indicating that once we control for observed components of changes in land shares allocation to cotton, the latter is negatively correlated with the change in total farm land.

[Table 8a here]

Table 8b presents the estimation results for the model where y_1 is associated with changes in land share dedicated to cotton, and y_2 corresponds to changes in total farmland. This table also confirms the results derived from table 7b, but with more information. First, the evolution of village labour force is now significant as a factor of land growth as well as more managerial abilities. In contrast, the level of technical assistance is no significant anymore. It should be related to the managerial ability variable that is collinear. Here, the subjective variable (more managerial abilities in explaining growth of farmland) becomes significant instead of the objective one (level of technical assistance). This leaves a room for insightful interpretations. Finally, the evolution of total farmland is now negatively correlated with the length of village residence. This is a control variable for the new migrants which are awarded new land. Again, as in the case of the binary Probit specification (Table 7b), we do not reject exogeneity of land dedicated to cotton in the equation for changes in total farm land. Parameter estimates obtained with the single-equation ordered Probit or the bivariate ordered Probit (FIML) I and II are very similar. The estimated correlation coefficient in bivariate ordered Probit models estimated by FIML are naturally the same as in Table 8a. Finally, contrary to the estimation of land change for cotton, cut off estimates are significantly different from 0 in almost all cases (the only exception being cut offs 1 and 2 in the single-equation ordered Probit). This confirms the interest of modelling changes in total farm land by more than a discrete-choice binary specification.

[Table 8b here]

Our estimation results can be used to identify the components of the cotton reform that matched household concerns in deciding crop allocation and land extension. First, the institutional reform which established the GPCs is believed to have attracted new growers because of less opportunistic behaviours in credit repayment and more input access. Second, with the privatization of SOFITEX and the improvement of the firm's management, we know that farmers are more respected for their payment date for cotton seed sales and that guarantees of selling are more significant for cotton growers as the rating of cotton qualities is less arbitrary and as there are more transparency within the industry and between GPCs and SOFITEX. These elements shed light on the channels through which the reform has affected the production incentives for farmers. More confidence arising from better designed local agrarian institutions and more transparent relationships with their commercial partner, as well as more access to agricultural inputs, provided farmers with incentives to enter or increase cotton in their land allocation. The more the farmers are concerned with these elements, the more they were likely to have increased their land share dedicated to cotton, once we control for their changes in farmland during the reform and for their cotton experience. Moreover, no significant differences among different experienced cotton growers can be interpreted as the fact that former cotton growers have increased their land share dedicated to cotton in the same way than farmers which entered during the reform period.

Second, no impact resulted from different qualities in the relationships within GPCs on crop allocation decisions. Indeed, the institutional reform allowed GPCs to be freely created on a co-opt basis so that every disappointed farmers is now free to switch from one GPC to another and, even to create its own group. Hence, the possibility of switching group relaxes some constraints arising from local organizations as internal relationships which can restrict access to inputs, for instance.

Third, the reform has also changed the design and the management of technical assistance, shifting from public to private sector with an involvement of cotton unions in the advisement of GPCs. While technical assistance today is limiting the increase in land share dedicated to cotton (preventing farmers from "all-cotton" to avoid financial insolvencies from input credit schemes and to incite them to spray some risk among different crops), it was the reverse before the reform. It is likely that former agricultural technical services tried to push farmers doing cotton for national goals even if the financial situation of SOFITEX worsened with low repayment rate from GVs and when incentives for cotton production were low. The technical assistance is today more efficient and more adapted to cotton growing so that the positive impact should be identified on productivity. In contrast, technical assistance is correlated to the increase in total farmland for each household. It is likely that learning externalities have fostered the adoption of animal farming. However, technical assistance had no significant role before the reform in helping farmers to increase their proficiencies and their abilities in mechanization. Moreover, the result stated in the analysis of figures from table 8b indicates that there is a link between the present level of technical assistance and the rise of managerial abilities of farmers in the process of evolution of total farmland. Technical assistance has a significant role in the improvement of farmers' skills.

Indeed, the global farmland extension in cotton areas has to be related to the diffusion of animal farming and mechanization, as well as more rural labour inflow. There are no direct effects of the reform in these interpretations, but the new incentives arising from the reform that we made explicit before, are likely to have attracted both labour and capital to cotton areas. This indirect mechanism has been amplified by the Ivorian crisis with the arrival of hundreds of thousands farmers in South Burkina Faso. Both family and village available labour are responsible for the observed farmland growth as subjective explanations given by households in the survey. Less labour constraints have allowed households to increase both land shares dedicated to cotton and total farmland as cotton is the most labour intensive crop. Mechanization is correlated to cotton experience and national data (INSD) confirm that the cotton areas are the most mechanized throughout the country.

All our hypotheses stated in Table 1 have been examined empirically and cannot be rejected either by binary models, or by ordered ones. Indeed, the examination of the estimates and the Rivers-Vuong tests presented in tables 7a, 7b, 8a and 8b confirms that the extension of cotton areas is a joint process of increasing both land shares dedicated to cotton and total farmland where the latter is endogenous in the determination of the change in cotton areas (H1). While total farmland change depends largely on the evolution of familial labour force and the process of mechanization with constraints arising from ethnical background (H2 and H3), the change in land shares dedicated to cotton is driven by confidence effects and guarantees stemming from the sector as well as concerns for input access (H4). There is an associated significant role for technical assistance in restraining the growth of land shares dedicated to cotton to control for agro-climatic and financial risks (H5). Finally, the setting of GPCs has allowed more farmers to enter cotton growing (H6) with less institutional constraints (role of institutional design in the new incentives led by the reform).

We also wish to compare the performance of our models in terms of goodness of fit, by evaluating in particular the proportion of correct predictions. In Tables 9 and 10 (see in the appendix), we present goodness of fit statistics for the binary and ordered models. For binary models, the predictive power is very reasonable for all models and quite similar for the estimation of large increase in land share dedicated to cotton (correct predictions between 59 and 78 percent). However, the bivariate probit model is performing better for the estimation of significant increase in total farmland (more than 90% correct predictions compared with 67% for the single-equation Probit model). Table 10 shows that ordered models are quite equivalent in their predictive power, whatever criterion is chosen. We use three different criteria to deal with the predictive power of ordered models: the estimated probability corresponding to the observed categorical value of each independent variable is above 50%, this estimated probability is the max of all estimated probabilities for all categorical values, and the estimated probability is above the sample probability of appearance. For the evolution of land share dedicated to cotton, all models predict between 20 to 25% of observations according to the first criterion (the stricter one), around 45% for the second one and around 70% for the third one. For the evolution of total farmland, more than

50% of observations are well explained according to the first criterion, more than 60% according to the second one and 84% for the third one. These figures put forward the idea that our models can be use as predictive tools.

In Tables 11 and 12 (see in the appendix), we display marginal effects of explanatory variables computed for the single equation ordered Probit models of land share dedicated to cotton and the evolution of total farmland, respectively.

Concerning the evolution of land share dedicated to cotton, we see that the concern for food needs only to play a role in limiting the trend of increasing cotton in crop allocations as well as the concern for technical advices while it was the reverse for guarantee of selling, input access and payment date concerns. The level of present technical assistance also limits the scope of increasing land shares dedicated to cotton while in the past, the effect was concentrated on the big increase regime. For each regime, the strongest effect comes from the concern for payment date, then the concern for guarantee of selling and equivalently concerns for input access, technical advices, food needs, and levels of technical assistance. Evolution of total farmland is correlated with the likelihood of having experienced a big increase in the share, and negatively correlated with the other regimes. For the role of cotton experience, there are no significant differences between experienced and less experienced cotton growers in regimes of increase in the land share allocated to cotton. In contrast, new cotton growers are less likely to have their land share stagnated or decreased (as they entered production recently).

Concerning the evolution of total farmland, as expected, the increase in both family and village labour force availability is correlated with regimes of increases in total farmland as well as the evolution of agricultural systems. The family labour force is the most important factor, followed by the change in agricultural system and village labour force. Farmers who adopted animal farming during the reform are more likely to have increased their farmland but less than farmers who adopted it before the reform. However, for farmers who adopted animal farming recently, we should add to the dummy variable of mechanization, the subjective one of change in agricultural system so that, in total, it is likely that some recently mechanized farmers have increased their farmland more than already mechanized ones. Cotton groups belonging to resident ethnical groups are more likely to have increased their farmland than those who belongs to migrant ethnical groups but this effect is less strong than the one of mechanization or rise in labour availability.

Less labour and institutional constraints as well as more access to capital (inputs, mechanization) with technology adoption have allowed farmers to increase their cotton areas. In brief, cotton has oriented labour force and mechanization to rural areas, thus participating to the extensive growth of agriculture, with a growth of households' land share allocated to cotton led by new incentives coming from the cotton reform. However, the situation seems much unsecured because of the low ability of cotton firms to pay and finance cotton growing through contract farming and outgrower schemes in a very low world price environment.

5. Conclusion

The empirical study of the determinants of the extension of cotton areas in Burkina Faso has highlighted the role played by direct incentives led by the reform in crop allocation decisions made by households: confidence effects and input access. These factors are acknowledged to be the positive consequences from the cotton reform, with a new institutional design both for producers and for the organization of the industry. While new institutions of producers have allowed them to reach at some substantial bargaining power and at more efficient local organizations for outgrower schemes to be established, the new organization of the industry arising from the privatization process has been responsible for a more transparent and coordinated system, with a significant empowerment of producers. This gave rise to greater financial commitments from banks and cotton firms and more available inputs and credit for producers, facing less institutional constraints and more production incentives[17].

While the new institutional design has allowed producers to benefit from the privatization process, being responsible for a growing number of responsibilities, the cotton boost has to be associated to other externalities, as indirect consequences from the cotton reform: mechanization, rise of available labour force in cotton areas, technological and managerial improvements (learning externalities and learning-by-doing), that participated to the global agricultural extension growth and to the setting of a more professional farming . However, the channel whereby the reform has fostered these externalities remains unclear, even if the new production incentives are likely to have attracted capital and labour to cotton areas with more efficient extension services to make farmers able to adopt new technologies and to better manage their organizations.

[17] See Kaminski (2007) for the formalization of the impact of the institutional design on production incentives for farmers.

However, the spectrum of new difficulties faced by the Burkinabe cotton sector fronting declining world cotton prices and increasing input prices unveils that this cotton boost is not sustainable in the long-run if cotton firms and banks are not able to recover their loans anymore. New challenges involve the development of new technologies to improve productivities, new marketing strategies to build a strong reputation of Burkina Faso's cotton quality and to access cheaper inputs and investing in research and extension services. Then, it seems clear that an interesting strategy lies in the improvement of the parallel market (local and industrial textile industries) to reduce the risk arising from the world market and in new efforts to improve the organization of the sector. The new deficits experienced last years by cotton firms, that resulted in new difficulties to pay farmers (with bad agro-climatic conditions), have led to a stop of the cotton boost this year[18]. Moreover, the inter-professional partnership has decided upon a strong reduction in the price of cotton paid to farmers for the new crop season. The future of the Burkinabe cotton sector appears very uncertain.

The dependence of the Burkina Faso economy on its cotton sector is a substantial issue as no significant alternatives appears to be able to constitute a relevant substitute solution for farmers so that the cotton boost is not a panacea in poverty reduction strategies. It becomes urgent to find other solutions for agriculture with the involvement of research and investors to develop cash crop markets and to improve food security. Finally, there is a need to develop the management and implementation of soil conservation schemes (organic applications, fallowing, new soil techniques, crop associations...) and the struggle against desertification, with an adequate control of agricultural input use.

This paper has focused on production issues and the role of the cotton reform in the observed cotton boost. However, we may wonder whether this cotton boost has been associated to poverty reduction and improved living standards and how farmers have perceived it. This analysis is left for future research.

[18] The figures of production for 2006/2007 are 660,000 tons of cotton seed.

References

Akiyama, T., Baffes, J., Larson, D., Varangis, P., 2001. Commodity Market Reforms: Lessons of two Decades. World Bank, Washington.

Azam, J.P., Djimtoingar, N., 2004. Cotton, War and Growth in Chad (1960-2000), AERC "Explaining African Economic Growth Experience" Project.

Baffes, J., 2004. Cotton: Market Setting, Trade Policies, and Issues. World bank working paper.

Barbier, B., Deybe, D., 2005. Consequences and Alternatives for Input Supply in the Context of Privatization of Cotton Marketing Board in Burkina Faso, CIRAD.

Basset, T., 2001. The Peasant Cotton Revolution in West Africa, Côte d'Ivoire, 1880-1995. Cambridge University Press.

Binswanger, H., D., Sillers, 1983. Risk Aversion and Credit Constraints in Farmer' Decision-Making: A reinterpretation. Journal of Development Studies, 20, pp. 133-140.

Besley, T., A., Case, 1994. Diffusion as a Learning Process: Evidence from HYV Cotton, mimeo, Princeton University.

Brambilla I., G.G. Porto, 2006. Farm Productivity and Market structure: Evidence from cotton reforms in Zambia. World Bank, WPS3904.

Conley, T. and C. Udry, 2004. Learning about a New Technology: Pineapple in Ghana, mimeo, Yale University.

De Janvry, A., M. Fafchamps and E. Sadoulet, 1991. Peasant Household Behaviours with Missing Markets: Some Paradoxes explained. Economic Journal, 101, pp. 1400-1417.

Deaton, A, 1997. The Analysis Of Household Surveys. A Microeconometric Approach to Development Policy. World Bank, Washington.

DGPSA (*Direction générale des prévisions statistiques agricoles)*. Données des enquêtes permanentes agricoles 1993-2005. Ouagadougou, Burkina Faso.

Fafchamps, M., 1992. Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World. American Journal of Agricultural Economics, pp. 90-99.

Fan, S., 1991. Effects of technological change and institutional reform on production growth in Chinese agriculture, American Journal of Agricultural Economics, pp, 266-275,

Foster, A., M., Rosenzweig, 1995. Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. Journal of Political Economy, vol. 103, no. 6, pp.1176-1209.

Goreux, L., 2003. Reforming the cotton sector in Sub-Saharan Africa. World Bank working paper. World Bank, Washington.

Gray, L.C., M. Kevane, 2001. Evolving Tenure Rights and Agricultural Intensification in Southwestern Burkina Faso. World development, Vol.29, No.4, pp. 573-587.

INSD (*Institut National des Statistiques et de la Démographie*). Données des enquêtes nationales démographiques et de conditions de vie. Ouagadougou, Burkina Faso.

Jayne, T., 1994. Do High Food Marketing Costs Constrain Cash Crop Production? Evidence from Zimbabwe. Economic Development and Cultural Change, XXX, pp. 387-402.

Kaminski, J., 2007. Interlinked Agreements and the Institutional Reform in the Cotton Sector of Burkina Faso. TSE ARQADE Working paper.

Poulton, C. et al., 2004. Competition and Coordination in Liberalized African Cotton Market Systems. World Development, Vol.32, No 3, pp 519-536.

Rivers, D., Q., Vuong, 1988. Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models. Journal of Econometrics 39, 347-366.

Rosenzweig, M., H. Binswanger, 1993. Wealth, Weather Risk and the Composition and Profitability of Agricultural Investments. The Economic Journal, vol. 103, No. 416, pp. 56-78.

Sajaia, Z., 2007. Maximum Likelihood Estimation of a Bivariate Ordered Probit Model: Implementation and Monte Carlo Simulations. Draft Version, World Bank.

Townsend, R.F., 1999. Agricultural Incentives in Sub-Saharan Africa, Policy Challenges. World Bank technical paper No. 444.

World Bank, 2004. Cotton Cultivation in Burkina Faso, a 30 years success story. Scaling up Poverty Reduction, a Global Learning Process, Shanghai.

Appendix

Table 1: Hypotheses to be tested

H1	Evolution of total farm land and change in land allocated to cotton are joint processes, and the change in total farm land is endogenous in the determination of change in cotton area
H2	Evolution of total cultivated land depends mainly on mechanization process and evolution of family labour force
H3	Ethnical background influences the evolution of total cultivated land
H4	Evolution of land shares dedicated to cotton depends more on concerns for confidence and guarantees from the cotton sector, and input and credit access, than on price concerns.
H5	There is a significant role of technical assistance in the efficiency and choices of cotton growers, that has evolved during the reform
H6	The setting of GPCs has given incentives for farmers to rise their land shares allocated to cotton

Table 2: Descriptive Statistics of the Sample

Observations: 300 **Cotton**	Total	Mean	Median	Std. deviation	Min	Max	National level
Cotton seed output (kg)	1206266	4034.33	2373	5083.97	201	49640	710.10^6
Yield (kg/ ha)		1037.17	1002	359.94	201	2073.33	1050
Urea (kg/ ha)		68.85	50	52.13	0	533.33	62.4
Chemical fertiliser (kg/ ha)		110.77	100	60.53	0	600	103.7
Organic fertiliser (kg/ ha)		13.40	0	65.43	0	1000	-
Pesticide (litre/ ha)		5.39	6	2.36	0	24	4.92
Planted Area (ha)	1092.75	3.67	2.5	3.52	0.5	25	675.10^3
Other crops							
Urea (kg/ ha)		18.32	0	34.58	0	250	7.2
Chemical fertiliser (kg / ha)		27.17	0	52.07	0	400	12 .8
Organic fertiliser (kg/ ha)		21.67	0	105.78	0	1600	-
Pesticide (litre/ ha)		0.15	0	0.77	0	8.67	0.0
Area (ha)	985.95	3.29	3	1.33	1	15	-

Note: National data are estimates computed from the permanent agriculture survey data of DGPSA.

Figure 1: Cotton areas and production during the reform

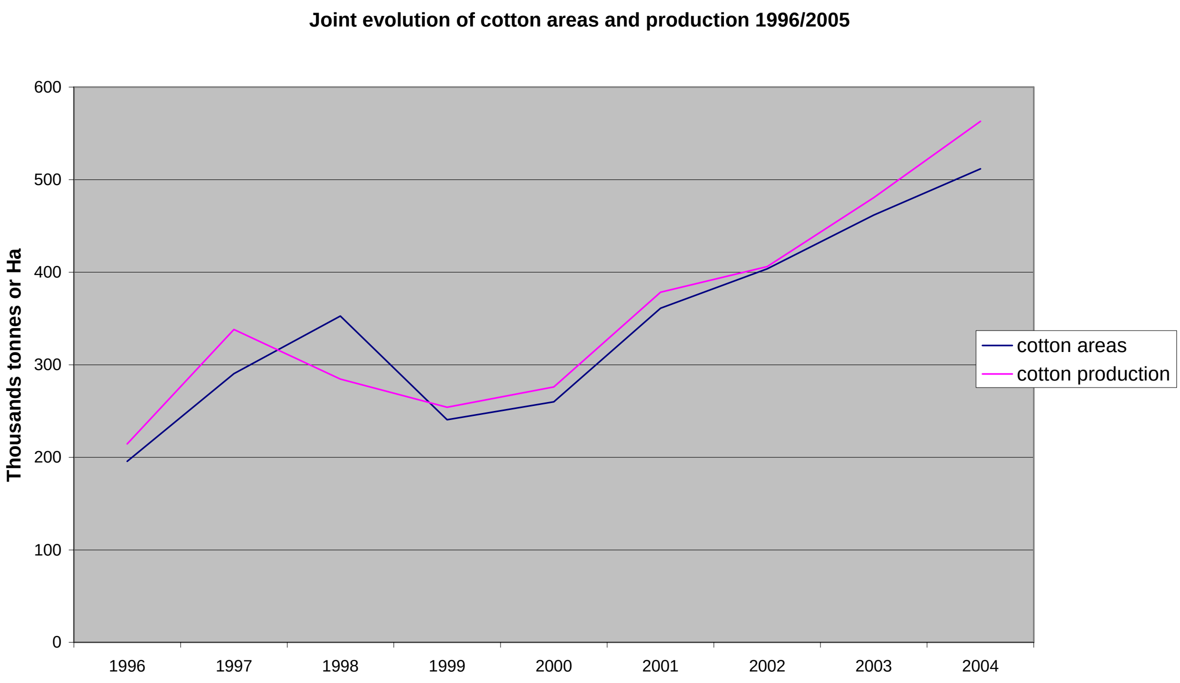
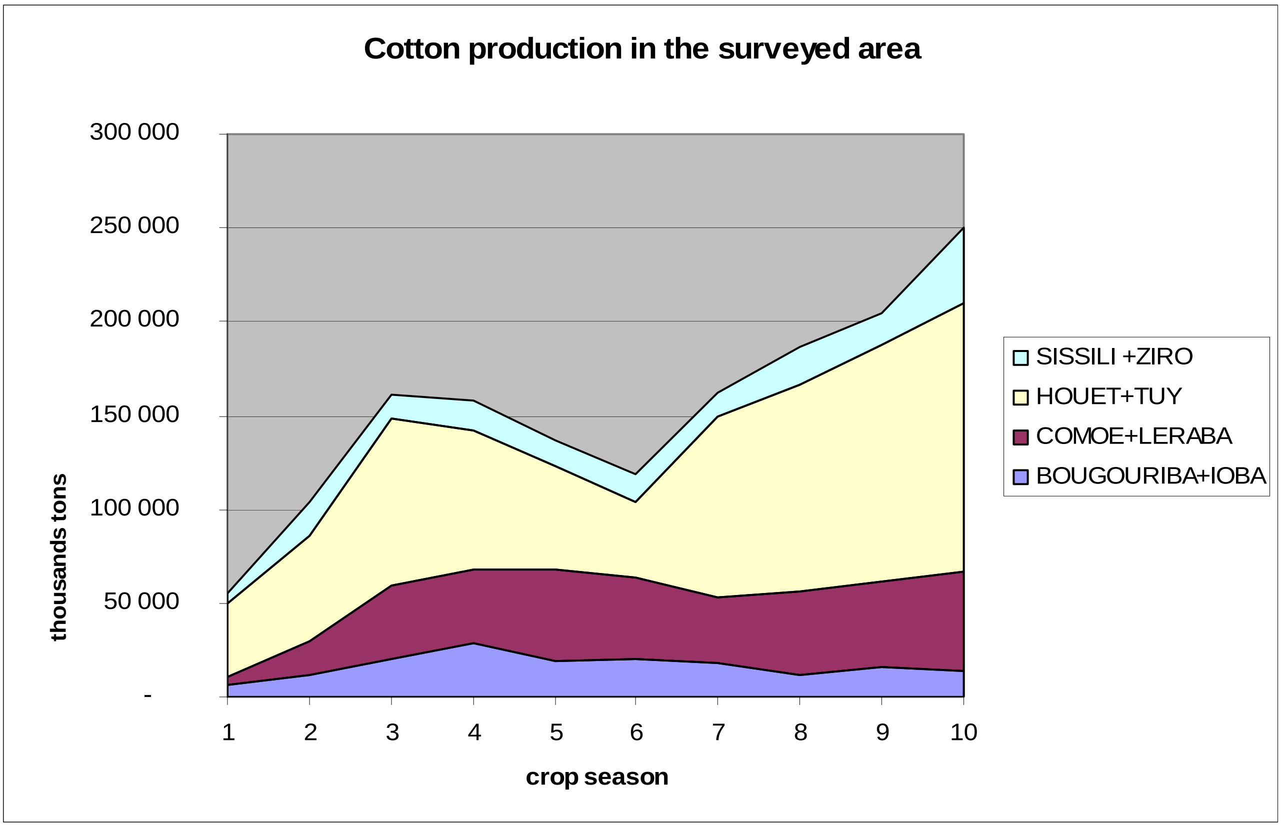
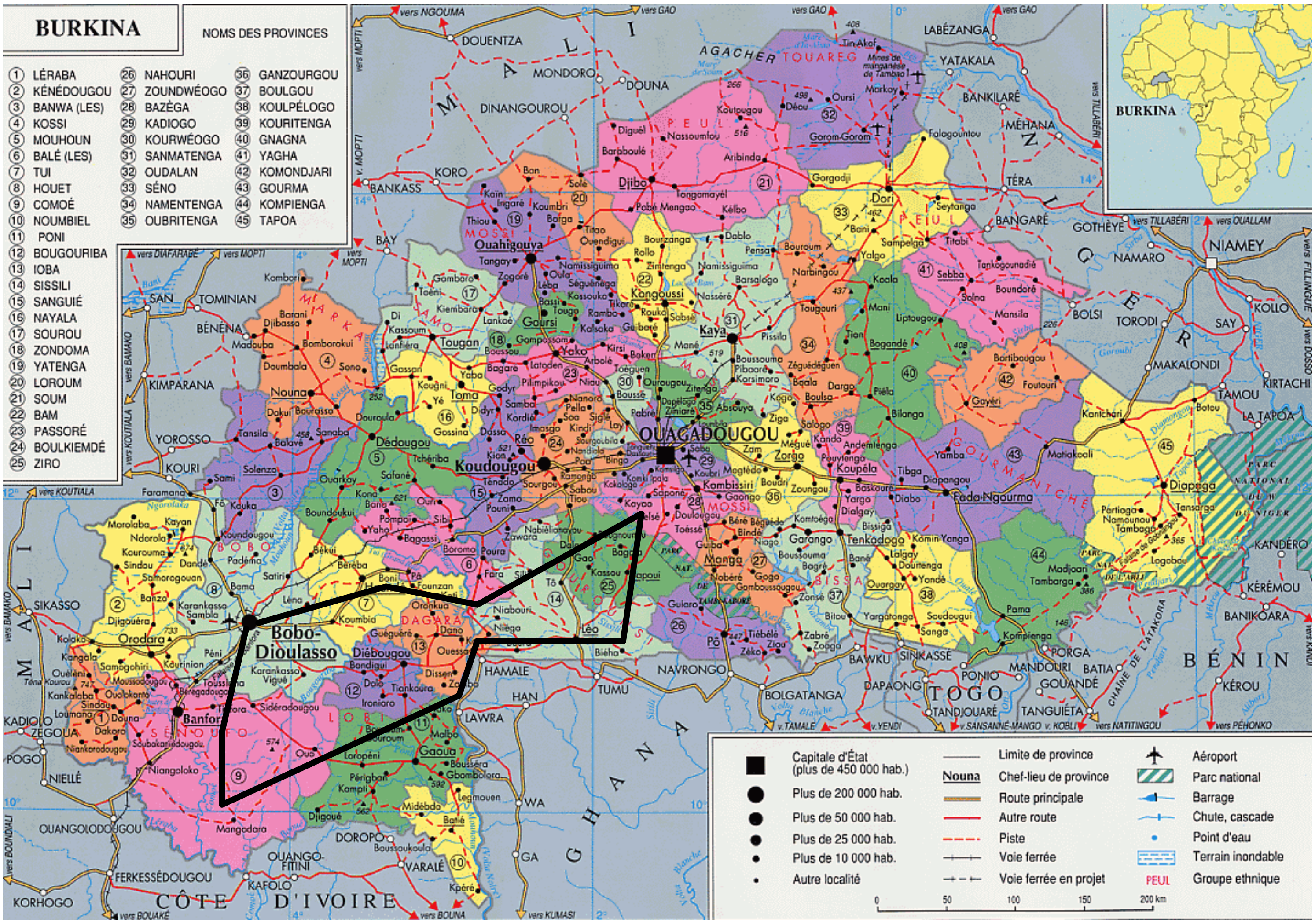


Figure 2: Representativity of the surveyed area: Cumulative and regional production patterns between 1995 and 2005





Source : Division Géographique du Ministère des Affaires Etrangères de France.

Figure 3: Sampling area

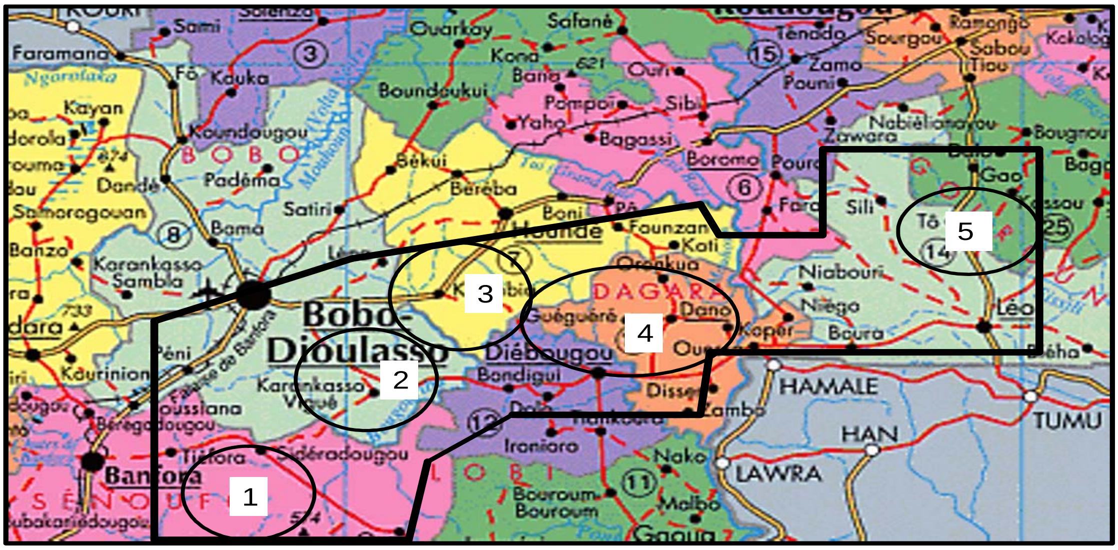


Figure 4: Sampling map

Table 3: Evolution of total cultivated land versus present farmland

Present total farmland / Total farmland (over the 10 last years)	Less than 2 ha	Between 2 and 5 ha	Between 5 and 10 ha	Between 10 and 15 ha	More than 15 ha	Number of Households
Decreased	2	6	5	0	0	13
Remained constant	5	49	25	5	1	85
Has increased < 1 ha	8	59	40	10	3	120
Has increased [1, 2] ha	1	11	16	7	3	38
Has increased [2, 5] ha		2	8	8	4	22
Has increased > 5 ha		1	6	7	8	22
Total	16	128	100	37	19	300

Table 4: Evolution of total cultivated Land versus Evolution of land share allocated to cotton

Evolution of land share allocated to cotton / Evolution of farm Land	Much increased	Slightly increased	Remained constant	Slightly decreased	Much decreased	Total
Decreased	3	7	2	1	0	13
Remained constant	23	26	30	5	1	85
Has increased by less than 1 ha	56	41	19	4	0	120
Has increased between 1 and 2 ha	18	15	3	2	0	38
Has increased between 2 and 5 ha	13	5	0	4	0	22
Has increased by more than 5 ha	14	6	1	1	0	22
Total	127	100	55	17	1	300

Table 5: Description of continuous variables

Variable name	Description	Mean	SE
Length of village residence	Length of village residence for the household in years	19.45	15.29
Technical assistance level	Number of visits of technical agents last year	2.95	5.69
Past technical assistance level	Number of visits of technical agents 10 years ago	1.95	2.84
Family labour force	Importance of increase in family labour force during the reform to explain farmland growth[19]	3.24	3.53
Village labour force	Importance of increase in village labour force during the reform to explain farmland growth	2.03	2.81
Agricultural system	Importance of the evolution in agricultural system (mechanization, animal farming) during the reform to explain farmland growth	3.02	3.75
Technical abilities	Importance of increase in technical abilities during the reform to explain farmland growth	1.22	2.36
Managerial abilities	Importance of increase in management abilities during the reform to explain farmland growth	0.94	2.14
Price	Importance of prices in deciding crop allocation	4.12	3.81
Price fluctuation	Importance of prices fluctuations in deciding crop allocation	2.3	3.17
Financial needs	Importance of financial needs in deciding crop allocation	3.57	3.69
Food needs	Importance of food needs in deciding crop allocation	2.61	3.18
Guarantee of selling	Importance of guarantee of selling crops in deciding crop allocation	2.78	3.44
Input access	Importance of access to inputs in deciding crop allocation	2.95	2.53
Animal farming access	Importance of access to animal drawn farming systems in deciding crop allocation	1	2.42
Long term soil management	Importance of long term land management in deciding crop allocation	0.37	1.46
Risk diversification	Importance of risk diversification strategies in deciding crop allocation	0.64	1.96
Payment date	Importance of dates of crop payments in deciding crop allocation	0.36	1.49
Trust	Importance of trust in trade relationships in deciding crop allocation	0.38	1.49
Family pressure	Importance of family influences in deciding crop allocation	0.65	1.93
Technical advices	Importance of advices from technical agents in deciding crop allocation	0.91	2.13
Cooperative	Importance of advices from the cooperative in deciding crop allocation	0.59	1.87

[19] All the variables described from here to the end of this table are taking values on a scale of [0, 10].

Table 6: Description of categorical, ordered and dummy variables

	Variable type and description	Mean
Big increase in land share dedicated to cotton	Dummy variable on the growth of land share for cotton during the reform,	
	=1 if the household has experienced a big increase in land share devoted to cotton crop	0.423
Significant increase in total farmland	Dummy variable on farmland growth during the reform,	
	=1 if the household has experienced a farmland growth more than 2 ha over the last ten years	0.273
Evolution of land shares dedicated to cotton	Ordered variable on the evolution of land share for cotton during the reform,	
	=1 if land share for cotton has much decreased	0.003
	=2 if land share for cotton has slightly decreased	0.057
	=3 if land share for cotton has remained constant	0.183
	=4 if land share for cotton has slightly increase	0.33
	=5 if land share for cotton has much increased	0.423
Evolution of total farmland by household	Ordered variable on the evolution of farmland areas during the reform,	
	=1 if farmland areas have decreased	0.043
	=2 if farmland areas have remained constant	0.283
	=3 if farmland areas have risen by less than two Ha	0.4
	=4 if farmland areas have risen by less than three Ha	0.127
	=5 if farmland areas have risen by less than five Ha	0.073
	=6 if farmland areas have risen by more than five Ha	0.073
Mechanization system	Categorical variable on the mechanization of agricultural systems,	
	=1 if the household has adopted animal drawn farming during the reform	0.607
	=2 if the household has a traditional technology	0.197
	=3 if the household has adopted animal drawn farming before the reform	0.197
Cotton experience	Ordered variable on the household experience with cotton growing,	
	=1 if one year experienced with cotton growing	0.033
	=2 if less than three year experienced with cotton growing	0.093
	=3 if less than five year experienced with cotton growing	0.143
	=4 if less than ten years experienced with cotton growing	0.24
	=5 if more than ten years experienced (growing cotton before the reform)	0.49
Resident ethnical group	Dummy variable on the ethnical group type of the household,	
	=1 if the household belongs to a resident (in contrast to a migrant) ethnical group	0.603
GPC relationships	Categorical variable on the quality of relationships within the cotton group,	
	=1 if good	0.347
	=2 if correct	0.55
	=3 if unpleasant	0.09
	=4 if very bad	0.013

Table 7a: Binary Probit estimates of a large increase in land shares allocated to cotton

Large increase in land shares allocated to cotton	Single-equation binary Probit	Bivariate binary Probit
Explanatory variables		
Price	.034 (.026)	.072 (.025)***
Price fluctuation	-.042 (.031)	-.062 (.030)**
Financial needs	-.015 (.024)	.002 (.023)
Food needs	-.035 (.024)	-.033 (.024)
Guarantee of selling	.098 (.030)***	.102 (.030)***
Input access	.050 (.027)*	.055 (.026)**
Animal farming access	.014 (.040)	.043 (.039)
Long term soil management	.018 (.060)	.034 (.060)
Risk diversification	-.055 (.056)	-.074 (.056)
Payment date	.158 (.074)**	.135 (.071)*
Technical advices	-.075 (.046)*	-.074 (.043)*
Technical assistance level	-.044 (.014)***	-.039 (.013)***
Past technical assistance level	.049 (.029)*	.061 (.028)**
Excellent GPC relationships	.180 (.683)	.296 (.740)
Correct GPC relationships	.007 (.676)	.078 (.732)
Unpleasant GPC relationships	-.101 (.722)	.003 (.771)
Bad GPC relationships	reference	reference
New cotton grower	.977 (.426)**	.616 (.445)
Cotton experience <3 years	-.192 (.345)	-.673 (.337)**
Cotton experience <5 years	.536 (.281)*	.098 (.263)
Cotton experience < 10 years	.332 (.195)*	.131 (.184)
Cotton grower >10 years	reference	reference
Significant increase in total farmland	1.571 (.382)***	-
Rivers-Vuong endogeneity test	-1.687 (.425)***	-
Constant	-1.060 (.685)	-.799 (.739)
Wald Chi²	70.51***	158.11***
Pseudo R^2	.177	.226
Correlation coefficient ρ	-	-0.167 (.142)
Observations	300	300

Note: Robust Standard errors in parentheses, * is significant at 10%, ** is significant at 5%, *** is significant at 1%. The first set of explanatory variables contains subjective ones (see the text and Tables 5 and 6 for a description of variables). The Rivers-Vuong test is used to test for the endogeneity of a significant increase in total farmland.

Table 7b: Binary Probit estimates of a large increase in total farmland

Large increase in total farmland	Single-equation binary Probit	Bivariate binary Probit
Explanatory variables		
Family labour force	.105 (.028)***	.105 (.027)***
Village labour force	.044 (.035)	.044 (.035)**
Agricultural system	.071 (.030)**	.072 (.029)**
Technical abilities	.070 (.045)	.071 (.044)
Managerial abilities	.005 (.043)	.007 (.043)
Technical assistance level	.024 (.014)*	.022 (.013)*
Past technical assistance level	-.004 (.031)	-.001 (.031)
Adopt animal farming < 10 years	.679 (.342)**	.673 (.340)**
Traditional farming	reference	Reference
Already animal farming (>10 years)	1.615 (.373)***	1.597 (.372)***
Length of village residence	-.004 (.006)	-.005 (.006)
Resident ethnical group	.524 (.238)**	.549 (.228)**
New cotton grower	-.608 (.689)**	-.535 (.702)
Cotton experience <3 years	-.762 (.517)	-.819 (.590)*
Cotton experience <5 years	-.875 (.322)**	.883 (.323)***
Cotton experience < 10 years	-.101 (.222)	-.089 (.219)
Cotton grower >10 years	reference	reference
Big increase in land shares allocated to cotton	.306 (.532)	-
Rivers-Vuong endogeneity test	-.562 (.570)	-
Constant	-2.570 (.480)***	-2.446 (.431)***
Wald Chi^2	93.13***	158.11***
Pseudo R^2	.348	.226
ρ (bivariate probit)	-	-0.167 (.142)
Observations	300	300

Note: Robust standard errors are in parentheses. * is significant at 10%, ** is significant at 5%, *** is significant at 1%. The first set of explanatory variables contains subjective ones (see Tables 5 and 6 for a description of variables). The Rivers-Vuong test is used to test for the endogeneity of a big increase in land allocated to cotton.

Table 8a: Ordered discrete choice models and estimates for the evolution of land shares dedicated to cotton over the last ten years

Evolution of land shares allocated to cotton	Single-equation Ordered Probit	Bivariate Ordered Probit (FIML) I	Bivariate Ordered Probit (FIML) II
Explanatory variables			
Price	.022 (.022)	.052 (.020)***	.022 (.021)
Price fluctuation	-.026 (.023)	-.038 (.025)	-.027 (.024)
Financial needs	-.009 (.020)	.008 (.020)	-.006 (.019)
Food needs	-.057 (.022)***	-.054 (.021)***	-.055 (.020)***
Guarantee of selling	.083 (.025)***	.091 (.025)***	.080 (.024)***
Input access	.056 (.023)**	.062 (.023)***	.054 (.022)**
Animal farming access	.013 (.034)	.030 (.034)	.009 (.033)
Long term soil management	-.074 (.057)	-.037 (.054)	-.062 (.053)
Risk diversification	-.066 (.047)	-.085 (.045)*	-.065 (.044)
Payment date	.166 (.052)***	.147 (.062)*	0.157 (.060)***
Technical advices	-.066 (.038)*	-.060 (.038)	-.058 (.036)
Technical assistance level	-.040 (.012)***	-.042 (.012)***	-.038 (.012)***
Past technical assistance level	.054 (.022)**	.065 (.027)**	.053 (.027)*
Excellent GPC relationships	-.021 (.437)	.094 (.566)	.014 (.552)
Correct GPC relationships	-.011 (.428)	.069 (.558)	.032 (.544)
Unpleasant GPC relationships	-.035 (.468)	.126 (.592)	-.001 (.577)
Bad GPC relationships	reference	reference	Reference
New cotton grower	.591 (.476)	.395 (.412)	.530 (.413)
Cotton experience <3 years	-.297 (.199)	-.532 (.231)**	-.323 (.236)
Cotton experience <5 years	.338 (.216)	.175 (.203)	.296 (.204)
Cotton experience < 10 years	.009 (.174)	-.013 (.166)	.003 (.166)
Cotton grower >10 years	reference	reference	Reference
Evolution of total farmland	.389 (.093)***	-	.326 (.079)***
Rivers-Vuong endogeneity test	-.417 (.119)***	-	-
Constant 1	-1.758 (.616)***	-2.650 (.672)***	-1.791 (.692)***
Constant 2	-.491 (.481)	-1.378 (.578)***	-.577 (.600)
Constant 3	.524 (.488)	-.380 (.571)	.394 (.590)
Constant 4	1.617 (.503)***	.661 (.571)	1.442 (.591)***
Wald Chi^2	98.75***	64.71***	85.09***
Pseudo R^2	.119	.194	.204
ρ (bivariate probit)	-	-.004 (.080)	-.291 (.098)***
Observations	300	300	300

Note: Robust standard errors are in parentheses. * is significant at 10%, ** is significant at 5%, *** is significant at 1%. The first set of explanatory variables contains subjective ones (see Tables 5 and 6 for a description of variables). The Rivers-Vuong test is used to test for the endogeneity of the evolution of total farmland.

Table 8b: Ordered choice models and estimates for the evolution of total farmland over the last ten years

Evolution of total farmland	Single-equation Ordered Probit	Bivariate Ordered Probit (FIML) I	Bivariate Ordered Probit (FIML) II
Explanatory variables			
Family labour force	.198 (.024)***	.198 (.023)***	.198 (.023)***
Village labour force	.091 (.028)***	.091 (.027)***	.093 (.027)***
Agricultural system	.118 (.024)***	.117 (.022)***	.113 (.022)***
Technical abilities	.048 (.035)	.048 (.032)	.048 (.031)
Managerial abilities	.056 (.035)*	.056 (.035)*	.064 (.034)*
Technical assistance level	.006 (.011)	.008 (.012)	.006 (.011)
Past technical assistance level	-.006 (.022)	-.007 (.024)	-.008 (.024)
Adopt animal farming < 10 years	.571 (.185)***	.571 (.193)***	.589 (.187)***
Traditional farming	reference	reference	Reference
Already animal farming (>10 years)	1.071 (.270)***	1.074 (.233)***	1.114 (.226)***
Length of village residence	-.012 (.004)***	-.011 (.005)**	-.012 (.004)***
Resident ethnical group	.390 (.166)**	.386 (.155)**	.448 (.151)***
New cotton grower	-.140 (.370)**	-.147 (.373)	-.155 (.373)
Cotton experience <3 years	-.085 (.239)	-.070 (.257)*	-.054 (.256)
Cotton experience <5 years	-.158 (.207)	-.157 (.213)***	-.151 (.212)
Cotton experience < 10 years	.217 (.171)	.219 (.171)	.216 (.171)
Cotton grower >10 years	reference	reference	reference
Evolution of land shares allocated to cotton	-.036 (.190)	-	-
Rivers-Vuong endogeneity test	.032 (.203)	-	-
Constant 1	-1.042 (.838)	-0.895 (.254)***	-0.829 (.247)***
Constant 2	0.930 (833)	1.076 (.247)***	1.115 (.240)***
Constant 3	2.851 (.855)***	2.997 (.292)***	3.034 (286)***
Constant 4	3.520 (.858)***	3.666 (.306)***	3.720 (.300)***
Constant 5	4.113 (.859)***	4.259 (.323)***	4.324 (.318)***
Wald Chi^2	232.97***	64.71***	85.09***
Pseudo R^2	.292	.194	.204
ρ (bivariate probit)	-	-0.004 (.080)	-.291 (.098)***
Observations	300	300	300

Note: Robust standard errors are in parentheses. * is significant at 10%, ** is significant at 5%, *** is significant at 1%. The first set of explanatory variables contains subjective ones (see Tables 5 and 6 for a description of variables). The Rivers-Vuong test is used to test for the evolution of land shares allocated to cotton

Table 9: Goodness of fit of binary Probit models

Variable	Outcome	Sample frequency (proportion)	Single-equation Probit	Bivariate Probit
			% Correct predictions	
Big increase in land share dedicated to cotton	1= Yes	0.423	0.591	0.598
	0 = No	0.577	0.786	0.751
	Total	-	0.704	0.686
Significant increase in total farmland	1 = Yes	0.273	0.585	0.634
	0 = No	0.727	0.674	0.917
	Total	-	0.650	0.840
Joint processes:	[1,1]	0.15	-	0.2
[Big increase in land	[1,0]	0.273	-	0.280
share dedicated to	[0,1]	0.123	-	0.189
cotton, significant	[0,0]	0.453	-	0.618
increase in total farmland]	Total	-	-	0.410

Note: The percentage of correct predictions is the proportion of observations (for each mode) corresponding to the criterion of a correct prediction by the model, here when the estimated probability is above 0.5.

Table 10: Predictive power of ordered models

Variable	Outcome	Sample frequency (proportion)	Single-equation Ordered Probit	Bivariate Ordered Probit (FIML) I	Bivariate Ordered Probit (FIML) II
			% correct predictions		
Evolution of land share dedicated to cotton	1= Large decrease	0.003	0	0	0
			0	0	0
			1	1	1
	2= Decrease	0.057	0	0	0
			0	0	0
			0.706	0.765	0.647
	3= No change	0.183	0	0	0
			0.218	0.2	0.2
			0.836	0.8	0.855
	4= Increase	0.333	0	0	0
			0.4	0.34	0.35
			0.75	0.72	0.68
	5= Large increase	0.423	0.567	0.488	0.528
			0.701	0.732	0.701
			0.677	0.669	0.646
	Total	-	0.240	0.206	0.223
			0.470	0.459	0.450
			0.732	0.716	0.696
Evolution of total farmland	1= Decrease	0.043	0	0	0
			0	0	0
			0.769	0.769	0.769
	2= No change	0.283	0.894	0.894	0.871
			0.941	0.929	0.906
			1	1	1
	3= increase by less than 1 ha	0.4	0.65	0.642	0.642
			0.817	0.825	0.792
			0.808	0.808	0.8
	4= increase between 1 and 2 ha	0.127	0	0	0
			0	0	0
			0.658	0.632	0.658
	5= increase between 2 and 5 ha	0.073	0	0	0
			0	0	0
			0.818	0.818	0.818
	6= increase by more than 5 ha	0.073	0.227	0.227	0.227
			0.409	0.409	0.409
			0.818	0.818	0.818
	Total	-	0.530	0.526	0.520
			0.623	0.623	0.603
			0.842	0.839	0.839

Notes: The percentage of correct prediction is the proportion of observations (for each mode) corresponding to the criteria of a correct prediction by the model. There are three criteria for ordered models; they are respectively when the estimated probability is above 0.5, when this is the maximum value of all estimated probabilities, and when it is above the sample appearance probability. Obviously, these three respective criteria are less and less strict (for most cases).

Table 11: Marginal effects (in 10^{-3}) for the ordered probit model of the evolution land share dedicated to cotton

Evolution of land shares allocated to cotton	Big decrease	Decrease	Stagnation	Increase	Big increase
Explanatory variables					
Price	-.066 (.08)	-1.485 (1.5)	-4.608 (4.63)	-2.425 (2.48)	8.583 (8.52)
Price fluctuation	.076 (.1)	1.716 (1.57)	5.327 (4.71)	2.803 (2.57)	-9.922 (8.73)
Financial needs	.027 (.06)	.606 (1.35)	1.879 (4.14)	.989 (2.19)	-3.500 (7.7)
Food needs	.169 (.2)	3.827 (1.84)**	11.878 (4.65)**	6.250 (2.61)**	-22.124 (8.34)***
Guarantee of selling	-.247 (.27)	-5.592 (2.13)***	-17.355 (5.35)***	-9.132 (3.55)***	32.326 (9.55)***
Input access	-.164 (.19)	-3.739 (1.72)**	-11.603 (4.97)**	6.206 (2.96)**	21.613 (8.94)**
Animal farming access	-.039 (.11)	-.878 (2.32)	-2.726 (7.04)	-1.434 (3.71)	5.078 (13.13)
Long term soil management	.218 (.28)	4.953 (4.09)	15.372 (12.04)	8.089 (6.35)	-28.632 (22.06)
Risk diversification	.196 (.23)	4.450 (3.36)	13.812 (9.97)	7.268 (5.39)	-25.726 (18.26)
Payment date	-.492 (.54)	-11.154 (4.36)**	-34.615 (11.73)***	-18.215 (7.04)***	64.475 (20.29)***
Technical advices	.195 (.24)	4.430 (2.9)	13.748 (7.96)*	7.235 (4.36)*	-25.608 (14.65)*
Technical assistance level	.118 (.12)	2.680 (1.02)***	8.316 (2.55)***	4.376 (1.65)***	-15.490 (4.48)***
Past technical assistance level	-.160 (.18)	-3.639 (1.78)**	-11.293 (4.77)**	-5.947 (2.68)**	21.036 (8.51)**
Excellent GPC relationships	.061 (1.32)	1.382	4.270 (91.18)	2.222 (46.86)	-7.934 (169.03)
Correct GPC relationships	.032 (1.26)	.723	2.244 (88.98)	1.183 (46.99)	-4.183 (165.87)
Unpleasant GPC relationships	.107 (1.51)	2.382	7.255 (98.65)	3.627 (46.75)	-13.371 (179.93)
Bad GPC relationships	reference	reference	reference	reference	reference
New cotton grower	-.821 (.95)	-24.200 (11.14)**	-100.456 (61.86)*	-106.683 (111.1)	232.160 (280.21)
Cotton experience <3 years	1.308 (1.78)	24.706 (19.84)	64.566 (45.81)	19.893 (8.87)**	-110.474 (70.26)
Cotton experience <5 years	-.711 (.84)	-18.309 (9.89)*	65.182 (38.71)*	-49.118 (39.45)	133.320 (85.59)
Cotton experience < 10 years	-.025 (.05)	-.571 (11.59)	-1.778 (36.17)	-0.943 (19.37)	3.317 (67.73)
Cotton grower >10 years	reference	reference	reference	reference	reference
Evolution of total farmland	-1.148 (1.29)	-26.033 (8.01)***	-80.792 (21)***	-42.514 (15.09)***	150.488 (36.06)***
Observations	300	300	300	300	300

Note: Robust standard errors in parentheses, * is significant at 10%, ** is significant at 5%, *** is significant at 1%.

Table 12: Marginal effects (in 10^{-3}) for the ordered probit model of the evolution of total farmland

Evolution of total farmland	Decrease	Stagnation	+ [0,1] ha	+ [1, 2] ha	+ [2, 5] ha	+ > 5 ha
Explanatory variables						
Family labour force	-1.583 (.79)**	-54.653 (7)***	12.914 (7.18)*	26.694 (4.79)***	11.728 (2.93)***	4.901 (1.8)***
Village labour force	-.734 (.39)*	-25.330 (7.68)***	5.985 (3.86)	12.372 (4.09)***	5.435 (1.83)***	2.217 (.92)**
Agricultural system	-.940 (.51)*	-32.430 (6.82)***	7.663 (4.43)*	15.840 (3.87)***	6.959 (2.19)***	2.908 (1.15)**
Technical abilities	-.386 (.33)	-13.330 (9.66)	3.150 (2.74)	6.510 (4.89)	2.860 (2.17)	1.195 (.98)
Managerial abilities	-.451 (.34)	-15.552 (9.55)*	3.675 (3.08)	7.596 (4.66)*	3.337 (2.16)	1.394 (.99)
Technical assistance level	-.052 (.09)	-1.810 (3.07)	.428 (.76)	.884 (1.51)	.388 (.67)	.162 (.27)
Past technical assistance level	-.049 (.18)	1.678 (6.08)	-.392 (1.44)	-.819 (2.99)	-.36 (1.32)	-.150 (.54)
Adopt animal farming < 10 years	-5.880 (3.55)*	-163.263 (54.47)***	52.043 (27.59)*	72.788 (25.08)***	31.291 (12.43)**	13.019 (6.02)**
Traditional farming	reference	reference	reference	reference	reference	reference
Already animal farming (>10 years)	-4.730 (2.33)**	-218.893 (37.07)***	-87.480 (66.99)	152.488 (40.63)***	96.618 (37.2)***	61.997 (31.35)**
Length of village residence	.092 (.06)*	3.174 (1.15)***	-.75 (.47)	-1.550 (.6)***	-.681 (.3)**	-.285 (.14)**
Resident ethnical group	-3.636 (2.76)	-11.054 (48.43)**	32.425 (20.18)*	50.827 (22.67)**	21.885 (10.99)**	9.038 (5.14)*
New cotton grower	1.348 (4.24)	40.515 (111.67)	-13.399 (46.59)	-17.989 (45.09)	-7.499 (17.93)	-2.976 (6.75)
Cotton experience <3 years	0.751 (2.33)	24.103 (69.33)	-6.935 (23.19)	-11.194 (30.87)	-4.781 (12.83)	-1.943 (5.07)
Cotton experience <5 years	1.483 (2.44)	45.314 (61.85)	-14.412 (24.37)	-20.389 (26.32)	-8.568 (10.58)	-3.429 (4.07)
Cotton experience < 10 years	-1.501 (1.19)	-57.2385 (43.12)	8.276 (7.86)	30.275 (24.3)	14.007 (12.42)	6.181 (5.82)
Cotton grower >10 years	reference	reference	reference	reference	reference	reference
Evolution of land share allocated to cotton	0.289 (1.53)	9.986 (52.55)	-2.360 (12.46)	-4.878 (25.66)	-2.143 (11.32)	-.895 (4.72)
Observations	300	300	300	300	300	300

Note: Robust standard errors are in parentheses, * is significant at 10%, ** is significant at 5%, *** is significant at 1%.