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Institutional factors and farmers' adoption of conventional, organic and genetically modified cotton in Burkina Faso

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ABSTRACT

Organic farming and genetically modified (GM) crops technologies are currently being promoted as alternatives to conventional farming that is seen as unsustainable. However, institutional constraints can impede the adoption of even the most sustainable technology. This paper analysed the effect of institutional factors on farmers' adoption of conventional, organic and GM cotton in Burkina Faso. Building on the expected utility model and institutional theory, a multinomial logistic regression was performed using farmers' survey data from the 2014–2015 production season. The results showed that subsidies on fertiliser and credit for cereals production, the power of farmers' association and that of the cotton company favoured the adoption of conventional and GM cotton at the expense of organic cotton. In order to succeed, organic cotton projects need to include components that help farmers to access organic fertilisers for cereals production. They also need to involve the cotton companies that are the most powerful stakeholders of the cotton sector. Extension services are necessary for both organic and GM cotton adoption. Other important factors to consider include farmers' education, the potentials of the technologies, the good agro-ecological conditions, the continued involvement of women, the availability of virgin lands and the closeness of farmers to their farms.

KEYWORDS
Adoption; Burkina Faso; cotton; GM crops; institutional factors; organic farming

Introduction

Relying on the intense use of synthetic agrochemicals (fertilisers and pesticides) promoted under the Green revolution, conventional farming is increasingly considered unsustainable (UNEP, 2011; Wheeler, 2008). The main reason is that the high use of these synthetic agrochemicals is costly financially and detrimental to the environment and health. Among the alternatives to conventional farming, organic farming and genetically modified (GM) crops technologies are among the top competing ones for agricultural sustainability (Pretty & Bharucha, 2014; Wheeler, 2008). As a radical alternative, organic farming avoids the use of synthetic agrochemicals, while proposing the use of farming methods based on ecological principles. As an improved version of conventional crops, GM crops rather allow to reduce the use of detrimental pesticides according to its proponents.

Despite the promises of organic and GM crops farming for agricultural sustainability, the adoption of both technologies over conventional farming remains a challenge, partly because of institutional constraints. Typically, most agricultural policies support conventional farming, the business-as-usual (UNEP, 2011). In 2015, only 28 countries approved GM crops worldwide, 3 of them being African: South Africa, Burkina Faso and Sudan (James, 2015). The reluctance of countries to approve GM crops is mainly due to the uncertainty about their risks. Nevertheless, once GM crops are approved in a country, they

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are likely to gain policy support provided they yield better economic returns than conventional farming. Unlike GM crops farming, organic farming is practiced almost everywhere in the world; however, its development is very slow (Willer & Lernoud, 2014). As it is a radical proposal with low economic return in the short-term, organic farming has limited policy support, which impedes its adoption by farmers.

The case of conventional, organic and GM cotton in Burkina Faso illustrates the statements made above. Until 2003, only conventional cotton was produced in Burkina Faso. After field trials, commercial production of GM cotton was authorized in the country in 2008 (Traoré, Héma, & Traoré, 2014). In partnership with Monsanto, GM cotton was then being promoted by the Government and the Inter-professional Cotton Association of Burkina (AICB) that comprises the three cotton companies (SOFITEX, SOCOMA and FASO COTON) and the National Union of Cotton Producers of Burkina (UNPCB). As a result, GM cotton production expanded rapidly from 31% in 2009 to about 70% of the country's total cotton production by 2013 (Dowd-Uribe & Schnurr, 2016; Traoré et al., 2014). However, cotton companies have decided to stop GM cotton since the 2016/2017 cropping season, due to the low quality of GM cotton fibre (Dowd-Uribe & Schnurr, 2016).

Organic cotton was first introduced in Burkina Faso in 2004 by HELVETAS Swiss Intercooperation, a Swiss non-governmental organisation (NGO), through an Organic and Fairtrade cotton project. After a pilot implementation between 2004 and 2008, the project was expanded (HELVETAS Swiss Intercooperation, 2011). Another organic cotton project (SYPROBIO) was initiated in 2011 by the Research Institute of Organic Agriculture (FiBL) based in Switzerland. Starting with Benin, Burkina Faso and Mali, SYPROBIO aims to develop organic production systems in order to increase farmers' income and reduce food insecurity in West Africa (Research Institute of Organic Agriculture FiBL, 2011). In Burkina Faso, the SYPROBIO project has been aligned to the Organic and Fairtrade cotton project (HELVETAS Swiss Intercooperation, 2011). The main actors that are currently promoting the organic cotton initiatives in Burkina Faso are their initiators and UNPCB. However, organic cotton production remains very low in the country. According to data obtained from AICB and UNPCB, the total national production of cotton was 701,602 tonnes in 2015, of which 699,200 tonnes (99.66%) was conventional and GM cotton, while organic cotton was only 2402 tonnes (0.34%).

Some studies attempted to explain the fast adoption of GM cotton and the slow uptake of organic cotton in Burkina Faso. They emphasized the role of institutional factors such as political will (Lankoandé, Maradan, Sanon, Thiombiano, & Zein, 2011; Traoré et al., 2014), the governance structure of the cotton sector and the power of cotton companies (Bassett, 2010; Coulter, 2011; Dowd-Uribe, 2014), and the provision of subsidized synthetic fertilisers to farmers on credit (Dowd-Uribe, 2014). However, they are only exploratory, and did not use a formal adoption framework to provide a comprehensive understanding of how farmers integrate these factors in their decision to adopt the different cotton technologies. The present paper is aimed at analysing the effect of institutional factors on farmers' adoption of conventional, organic and GM cotton in Burkina Faso, using an economic framework that involves institutional theory.

The most popular framework for analysing farmers' decision to adopt technologies is the expected (or random) utility approach (Hellegers, Zeng, & Zilberman, 2011; McFadden, 1974). This approach suggests that farmers' decision is influenced by the factors that influence the utility (return) that they expect from adopting the technologies. These factors include farmers' characteristics, agro-ecological conditions, the characteristics of the technologies and institutional factors (Feder, Just, & Zilberman, 1985; Hellegers et al., 2011; Sunding & Zilberman, 2001). In a discrete choice setting, the farmer adopts the technology from which he/she expects the highest return, given these factors.

Institutional factors generally considered in studies on the adoption of agricultural technology are access to credit, land tenure, access to information and extension services, membership in farmer-based organisations (FBOs), input subsidies, output price supports and market conditions (Latruffe & Nauges, 2014; Mwangi & Kariuki, 2015; Sunding & Zilberman, 2001). From institutional theory, these factors are the result of various institutions that can be favourable or unfavourable to the adoption of some technologies (Zhang & Dhaliwal, 2009). Institutions relate to the general habits of action and thought, the rules, laws, regulations and policies; the modes of governance; the forms of collective action; the ways of organizing work; the kinds of markets; etc. (Nelson & Nelson, 2002; Ruttan & Hayami, 1984).

In Burkina Faso, the institutional arrangements among the government, cotton companies, cotton farmers and other partners were more favourable to conventional and GM cotton than organic cotton. It is therefore plausible to hypothesise that these arrangements were key drivers of GM cotton adoption and inhibiters of organic cotton adoption by farmers. However, testing this hypothesis requires accounting for the other determinants of adoption of conventional, organic and GM crops technologies.

The rest of the paper is organized as follows. The second section describes the institutional aspects that are likely to shape the adoption of conventional, organic and GM crops farming technologies in Burkina Faso. The third section reviews previous literature on the determinants of adoption of conventional, organic and GM crops technologies. The fourth section presents the materials and methods used for the study. The fifth section presents and discusses the results and the sixth section concludes the study with policy recommendations.

The institutional context of cotton farming in Burkina Faso

Cotton is the most important cash crop in Burkina Faso. As the second export commodity of the country after gold since 2009, it contributed 18.7% to export revenues in 2013 (INSD, 2014). Due to its economic importance, the cotton sector is subject to strong interventions by the government that is the biggest shareholder of the biggest cotton company, SOFITEX. Initially biased towards conventional cotton, the government support partially shifted towards GM cotton since its introduction (Lankoandé et al., 2011), before going back to conventional cotton since the 2016/2017 cropping season. This bias is the source of the institutional factors that can explain farmers' adoption of conventional, organic and GM cotton in Burkina Faso. These factors include mainly the provision of subsidized inputs on credit to conventional and GM cotton farmers for both cotton and cereals production, the power of the cotton companies and that of the farmers' association.

The basis of these institutional issues is the division of the country into three cotton zones, allowing each of the three cotton companies to operate alone in a given zone. SOFITEX operates in the Western zone that is the biggest cotton zone with more than 80% of the country cotton production, FASO COTON operates in the Central zone and SOCOMA operates in the Eastern zone. All the three companies are interested only in conventional and GM cotton, and the zoning arrangement allows them to have an important power over the farmers. On the one hand, each company contracts with agrochemical companies in order to acquire cotton inputs (synthetic fertilisers, insecticides, herbicides and fungicides). Some of these inputs, especially synthetic fertilisers, are subsidized by the government. Then, these inputs and seeds are supplied to farmers on credit by the cotton company in its operating zone as a monopoly, except herbicides that can be obtained on credit from the cotton company and the national union of cotton producers (UNPCB), and on cash from traders. In addition to fertilisers for cotton production, conventional and GM cotton farmers can also obtain subsidized synthetic fertilisers on credit for cereals production (especially maize).

On the other hand, both conventional and GM cotton farmers in a given cotton zone can sell their production only to the cotton company operating in that zone as a monopsony. The latter decides, in collaboration with UNPCB, the type of cotton (conventional or GM) farmers should grow (Coulter, 2011). In case farmers are given the opportunity to decide and report to the company the type of cotton they prefer, this is most often done through a democratic voting within the groups of cotton producers (GPCs) that have been organized by the cotton company and UNPCB in the communities/villages. Farmers whose preference is not met by the company or GPC decision may join other GPCs in neighbouring communities where their preference is met. But this can be costly: for example, transportation of inputs and cotton over longer distance; fee for membership to the new GPC; etc. These costs may tend to discourage farmers from leaving their initial GPC. Therefore, the decision of the individual farmers to choose between conventional and GM cotton is more dependent on the decision of their cotton company and that of their GPC. Nevertheless, there are situations in which farmers of the same GPC are allowed to choose either conventional or GM cotton according to their individual preferences.

Another option for farmers whose preference is not met by the decision of their cotton company or GPC is to join a group of organic cotton producers (GPCB). However, in addition to the costs mentioned above, they will not benefit from subsidized fertilisers on credit for cereals production. Yet, they may not be able also to buy these fertilisers that are rarely available on the markets. Even if they were available, subsidized fertilisers provided on credit would always be preferred because most farmers do not have enough cash to buy them. Therefore, if farmers want fertilisers for cereals production they have to produce conventional or GM cotton (Dowd-Uribe, 2014). However, an important requirement for organic farmers is that they should not produce conventional and GM cotton at the same time. Otherwise they will fail to get their organic cotton certified as such. This can discourage potential adopters of organic cotton who need synthetic fertilisers for cereals production.

The issues discussed above serve as background information for deriving key institutional variables in modelling farmers' adoption of the three cotton technologies in Burkina Faso. Other adoption variables are identified through a survey of previous literature.

Survey of previous studies

Factors that influence farmers' adoption of conventional, organic and GM crops farming technologies have been investigated in several studies. Feder et al. (1985) provided the first extensive review of literature on adoption of Green revolution technologies (including conventional farming methods) in developing countries. Focusing on the initial stages of adoption, the authors found that the most important factors affecting adoption decisions included farm size, risk and uncertainty, education, labour availability, credit constraints, wealth, land tenure and access to information. The impact of these variables depends on the characteristics of the technology and the institutional setting. Feder and Umali (1993) updated the work of Feder et al. (1985), emphasizing later stages of technologies adoption including Green revolution technologies. Many factors that Feder et al. (1985) cited as important for early adoption were no longer significant. These include farm size, tenure, education, extension and credit. Agro-climate, access to markets, roads, fertilisers and irrigation were key determinants of adoption of high-yielding varieties.

Regarding the factors that influence the decision to convert from conventional to organic farming, Kallas, Serra, and Gil (2010) and Latruffe and Nauges (2014) provided extensive reviews. They identified farmer characteristics (e.g. gender, education, age, experience, etc.), farm characteristics (e.g. location, farm size, soil type), exogenous (or institutional) factors (e.g. output and input prices, market size, subsidies, social learning and information access, policy reforms), and farmers' attitudes and opinions about the characteristics of the technology (e.g. acceptance within the rural community, health and environmental issues, etc.). In Burkina Faso, Bassett (2010) and Coulter (2011) were concerned about the slow uptake of organic cotton. They pointed out the power of the cotton companies (monopsony), the preference of these companies for conventional and GM cotton, and then their support to these technologies over organic cotton.

Qaim (2005) reviewed the adoption GM crops in developing countries. He emphasized the factors that inhibit GM crops adoption, including the limited availability of GM technologies and the protracted biosafety procedures. Kiresur and Ichangi (2011) and Mal, Reza Anik, Bauer, and Schmitz (2012) analysed the determinants of *Bt* cotton adoption at the farmer level in India. Focusing on northern Karnataka state and using a logistic regression, Kiresur and Ichangi (2011) showed that *Bt* cotton adoption was affected negatively by the costs of seed and pesticides, and positively by yields gain. In northern India, Mal et al. (2012) used a Cragg's double-hurdle model to show that the number of information sources, membership in a club, access to credit, and health costs had positive effects on adoption of *Bt* cotton, while farmers' experience, farm size and land fertility had negative effects. In Burkina Faso, Dowd-Uribe (2014) discussed how input credit provisioning, the governance of the country's cotton sector, and agro-ecological conditions shaped the fast adoption of GM cotton. Lankoandé et al. (2011) noted that policies are biased towards the promotion of GM cotton because of the associated financial benefit to the actors of the cotton sector. Traoré et al. (2014) argued that political will has been the key driver of the introduction and fast diffusion of GM cotton in Burkina Faso.

In the studies reviewed above, institutional factors were identified among the various determinants of conventional, organic and GM technologies. The studies in Burkina Faso have the merit of discussing institutional issues that are not common in adoption studies: political will and governance structure of the cotton sector. However, they are exploratory and do not show how individual farmers integrate these factors in their decision. Moreover, they are reductionist regarding the potential determinants of agricultural technologies adoption.

Methods and materials

Conceptual and analytical framework

Two economic frameworks are used in the literature to model individuals' adoption behaviour: the random (or expected) utility approach (McFadden, 1974) and the constrained entropy maximization approach (Anas, 1983). The two approaches are equivalent (Anas, 1983). The present paper applies the former one that is the most popular.

Consider that the three cotton farming technologies (T) are available to all cotton farmers: $T = 1$ for conventional cotton (CC), $T = 2$ for organic cotton (OC) and $T = 3$ for GM cotton (GMC). They are institutionally made exclusive for any cotton farmer. Let, Q^*_{i1}, Q^*_{i2} and Q^*_{i3} represent the aggregate net benefit any farmer i expects to gain from adopting conventional, organic and GM cotton, respectively. The farmer, assumed to be rational, chooses the technology T if the expected aggregate net benefit (or return) from this technology is the highest. In other words the farmer chooses the technology T if:

$$\max(Q^*_{i1},\ Q^*_{i2},\ Q^*_{i3}) = Q^*_{iT}, \quad T = 1,\ 2,\ 3. \tag{1}$$

The return expected from each technology (Q^*_{iT}) is unobservable (latent), but can be modelled as a linear function of the set of its determinants for which information is available (Z_i) and others that are unknown but captured by the error term (η_{iT}):

$$Q^*_{iT} = \beta_T Z_i + \eta_{iT}, \quad T = 1,\ 2,\ 3, \tag{2}$$

where β_T is a vector of parameters. The known determinants include farmer's demographic and socio-economic characteristics (Z_{1i}); farm characteristics and agro-ecological conditions (Z_{2i}); characteristics of the technologies (Z_{3i}) and institutional factors (Z_{4i}). Institutional factors affect the outcomes directly, or indirectly through the characteristics of the technologies (Figure 1).

The adoption behaviour (D_i) of any farmer i towards the technologies is a discrete choice problem described as follows (Bourguignon, Fournier, & Gurgand, 2007):

$$D_i = \begin{cases} 1 & \text{if } \max(Q^*_{i1},\ Q^*_{i2},\ Q^*_{i3}) = Q^*_{i1}, \\ 2 & \text{if } \max(Q^*_{i1},\ Q^*_{i2},\ Q^*_{i3}) = Q^*_{i2}, \\ 3 & \text{if } \max(Q^*_{i1},\ Q^*_{i2},\ Q^*_{i3}) = Q^*_{i3}. \end{cases} \tag{3}$$

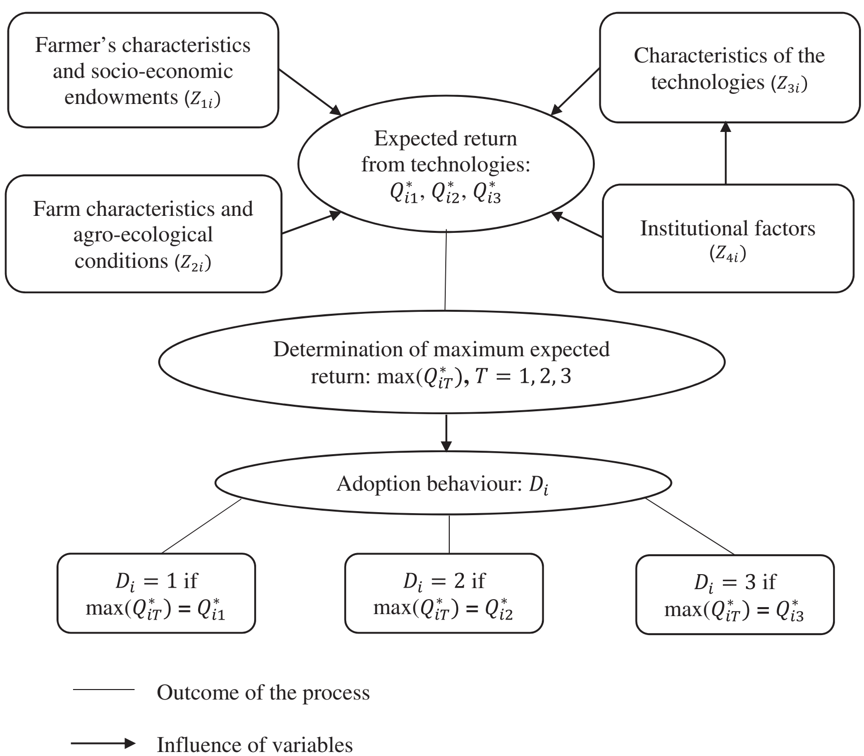

Figure 1. Conceptual framework for the determinants of conventional, organic and GM cotton adoption. Source: Authors.

The technology adoption variable (D_i) is defined as a categorical variable taking the modalities 1, 2 or 3. As it depends on Q^*_{iT}, which in turn depends on Z_i,D_i is a function of Z_i. D_i can be transformed into the probability that farmer i chooses technology T as follows:

$$\Pr(D_i = T|Z_i) = F(\beta_T Z_i), \quad (4)$$

where F is the cumulative distribution function for the error term η_{iT}.

Two competing econometric models for Equation (4) are the multinomial logit (MNL) model and the multinomial probit (MNP) model, depending on whether the distribution of F is Gumbel or normal respectively (Greene, 2003). The MNL model (McFadden, 1974) is the most used (Bourguignon et al., 2007; Greene, 2003). Generally considered as valid and powerful under the Independence of Irrelevant Alternatives (IIA) property (McFadden, 1974), the MNL model still yields better results even if it does not satisfy this property (Bourguignon et al., 2007). An MNL form is therefore specified for model (4) as follows:

$$\Pr(D_i = T|Z_i) = \frac{\exp(\beta_T Z_i)}{\sum_{K=1}^{3} \exp(\beta_K Z_i)}. \quad (5)$$

This model is estimated using the maximum likelihood method (McFadden, 1974). The quality of fit is evaluated based on the value of the McFadden's pseudo R-squared and the significance of the Likelihood Ratio (LR) Chi-Square statistic. The sign and significance of the coefficients β_T tell whether the corresponding explanatory variables have positive or negative effects on the probability of choosing technology T over a reference technology. Conventional cotton ($T = 1$) that is the old technology is used as the reference in this study. This is consistent with the tradition of studies on the adoption of organic and GM crops farming (e.g. see Mal et al., 2012; Mzoughi, 2011). Therefore, β_2 and β_3 are estimated and represent the vectors of parameters associated with the variables that affect the probability of adopting respectively organic and GM cotton over conventional cotton. For robustness check, a MNP model is also estimated.

Definition of the empirical explanatory variables

The explanatory variables are based on the literature review and the context of cotton production in Burkina Faso. Key institutional variables (Table 1) relate to the provision of subsidized synthetic fertilisers on credit (Dowd-Uribe, 2014), the power of the cotton company and that of the farmers' association (Bassett, 2010; Coulter, 2011).

The application of synthetic fertilisers (NPK and/or urea) in maize production (SYNTFERTINMAIZ) is used as a proxy of the provision of subsidized synthetic fertilisers on credit to farmers. Indeed, maize is the main food crop to which fertilisers are applied in Burkina Faso. Because farmers need fertilisers for maize production and cannot access them on the market, they grow conventional or GM cotton in order to benefit from synthetic fertilisers that are subsidized and provided on credit (Dowd-Uribe, 2014). In other words, a famer who is applying synthetic fertilisers in maize production is more likely to adopt conventional or GM cotton than adopting organic cotton.

Farmers may perceive that the decision of the cotton company (COMPANYDECIMP) and that of the GPC (GPCDECIMP) are important or not for their adoption of a given cotton technology. These two variables reflect respectively the power of the cotton company (Coulter, 2011) and farmers' collective action.

Other institutional factors that can encourage farmers' adoption of technologies are extension services in terms of advices and training. Farmers

Table 1. Potential institutional determinants of adoption.

Variable name	Variable definition and measurement	*A priori* expected effect[a] Organic	GM
SYNTFERTINMAIZ	The farmer uses synthetic fertilisers in maize farming (1 if yes; 0 if no)	−	0
COMPANYDECIMP	The decision of the cotton company is an important aspect in the choice (1 if yes; 0 if no)	0	+
GPCDECIMP	The decision of the GPC is an important aspect in the choice (1 if yes; 0 if no)	0	+
ADVGROWCC	The farmer was advised to grow conventional cotton (1 if yes; 0 if no)	−	−
ADVGROWOC	The farmer was advised to grow organic cotton (1 if yes; 0 if no)	+	−
ADVGROWGMC	The farmer was advised to grow GM cotton (1 if yes; 0 if no)	−	+
TRAINING	The farmer received training on cotton production during the past five years (1 if yes; 0 if no)	+	+

Source: Adapted from Bassett (2010), Coulter (2011) and Dowd-Uribe (2014).
[a]0 means there is no effect.

advised to adopt a given cotton technology are likely to adopt that technology at the expense of the other technologies. The related variables are ADVGROWCC, ADVGROWOC and ADVGROWGMC respectively for advice to grow conventional cotton, organic cotton and GM cotton. Training for farmers on the two new technologies (TRAINING) can also enhance their adoption.

Non-institutional factors that can explain the adoption of organic and GM cotton over conventional cotton are included as covariates: farmer's demographic and socio-economic characteristics, farm characteristics and agro-ecological conditions, and the characteristics of the technologies (Table 2).

The characteristics of the cotton farmer include his/her age (AGE), gender (GENDER), level of education (SECEDUC), and position in the household in terms of decision making (HHHCFMR). Younger and more educated farmers are more open to innovations and are more likely to adopt them. Women empowerment is a major component in organic cotton projects, while conventional and GM cotton in Burkina Faso are mainly grown by men. Therefore, female farmers are more likely to adopt organic cotton, while no gender effect is expected for GM cotton adoption over conventional cotton. Cotton farmers who are household head (HHHCFMR) may have a longer experience in conventional cotton farming which they are more familiar with and would prefer to continue with it. Nevertheless, they may delegate a member of the household to adopt the new technologies.

Farmers' socio-economic endowments commonly considered as adoption determinants are the number of active household members (ACTIVE) and livestock holding (LIVESTOCK) in terms of Tropical Livestock Units (TLU). Having more active members can be an opportunity for labour-intensive technologies such as organic farming and may have a positive effect on their adoption. However, it can also be an opportunity for large-scale cotton farming that generally uses conventional or GM crops farming methods. Similarly, having more livestock is a source of manure and may encourage manure-dependent technologies such as organic farming.

The characteristics of cotton farm include farm size (CFARMSIZE), land ownership (LANDOWN), and distance from household to cotton farm (DISTFARM). It is difficult to practice organic farming on large-scale because of the limited availability of organic fertiliser. Therefore, farmers who used to produce cotton on large-scale are less likely to adopt organic cotton. Land security is generally expected to have a positive effect on the adoption of agricultural innovations (Feder et al., 1985). Being the owner of the land used to grow cotton is an indicator of land security. Therefore, organic and GM cotton are more likely to be grown on own land. Organic cotton is more likely to be grown on farms that are close to the household

Table 2. Other potential determinants of adoption.

		A priori expected effect	
Variable name	Variable definition and measurement	Organic	GM
Farmer demographic and socio-economic characteristics			
AGE	Age of the cotton farmer (years)	–	–
GENDER	Gender of the cotton farmer (1 if Female; 0 if Male)	–	+/0
SECEDUC	Level of education of the farmer (1 if secondary school; 0 if otherwise)	+	+
HHHCFMR	The farmer is the household head (1 if yes; 0 if no)	–	0
ACTIVE	Active members in the household (number)	+/–	0
LIVESTOCK	Livestock holding (TLU)	+/–	0
Farm characteristics and agro-ecological conditions			
CFARMSIZE	Cotton farm size (ha)	–	0
LANDOWN	Land ownership (1 if own land; 0 if otherwise)	+	+
DISTFARM	Distance to farm (1 if long; 0 if otherwise)	–	0
FERTLAND	Having fertile lands (1 if yes; 0 if no)	+	0
VIRGLAND	Having virgin lands (1 if yes; 0 if no)	+	0
FALLOWLAND	Having fallowed land (1 if yes; 0 if no)	+	0
LOCATION	Farm location (1 if Comoé province; 0 if otherwise)	+	+/–
Characteristics and potentials of the technologies as perceived by farmers			
EASYTECHIMP	The ease in the use of the technology is an important aspect in the choice (1 if yes; 0 if no)	–	+
PROFITIMP	The profitability of the technology is an important aspect in the choice (1 if yes; 0 if no)	+	+
POSITSOILEFFIMP	The positive soil effect of the technology is an important aspect in the choice (1 if yes; 0 if no)	–	0
REPESTATTACK	Pest attacks over the past ten years (1 if reduced; 0 if otherwise)	+	+

Source: Authors, based on literature review (see Feder et al., 1985; Hellegers et al., 2011; Kallas et al., 2010; Sunding & Zilberman, 2001).

because of the difficulty of transporting organic fertilisers over long distance. No farm size and distance effects are expected for GM adoption over conventional cotton.

Natural endowments that can affect the adoption of organic cotton relate to the possession of fertile lands (FERTLAND), virgin lands (VIRGLAND) and fallowed lands (FALLOWLAND) by the farmer. Farmers who perceive their lands as fertile are likely to adopt organic cotton that avoids the use of synthetic fertilisers for fertility management. Having virgin and fallowed lands can reduce constraints that farmers face in adopting organic cotton, especially the requirement of the three-year transition period required for converting from conventional to organic farming.

A specific agro-ecological factor is considered based on the discussion by Dowd-Uribe (2014): pest dynamics. Farmers who perceive a reduction in pest attacks at least over the past 10 years (REPESTATTACK) are more likely to adopt less insecticide-dependent technologies such as organic and GM cotton. However, since GM cotton is considered as a better approach for controlling pests, farmers who experienced reduced pest attacks may consider that they do not need to adopt it. Other agro-ecological factors such as agro-climatic conditions can be considered through a dummy variable for the province in which the cotton farm is located (LOCATION). Better agro-climatic conditions can reduce potential climatic risks associated with organic and GM cotton farming, and then favour their adoption.

Fourteen characteristics of the technologies were considered, including technical, economic, environmental and social aspects. Their importance in farmers' adoption decision was evaluated based on farmers' perception. Three characteristics that appear relevant to farmers are retained: relative ease, profitability, and positive effect on farm lands. Organic farming is generally reported to be more difficult than conventional and GM crops farming. Therefore, farmers who consider the ease of the technology as important aspect in their adoption decision (EASYTECHIMP) are likely to adopt conventional or GM cotton at the expense of organic cotton on the one hand, and GM cotton at the expense of conventional and on the other hand. As cotton is a cash crop, its profitability may be the aspect farmers are most interested in when adopting a given cotton technology. Cotton price and input costs may be confounded in profitability. Assuming that conventional cotton is the least profitable (Lankoandé et al., 2011), farmers who consider profitability as important aspect in their adoption decision (PROFITIMP) are likely to adopt organic cotton and GM cotton over conventional cotton. Lankoandé et al. (2011) evaluated the net revenue per hectare (excluding labour cost) at 85,005 francs CFA for conventional cotton, 108,892 francs CFA for organic cotton and 127,521 francs CFA for GM cotton. In addition to monetary income, cotton farming has some positive externalities for farmers. A relevant externality is the improvement of farm lands through the residuals of fertilisers (both synthetic and organic) applied in the previous production season. Farmers who consider the positive effects on soil as important aspect in their adoption decision (POSITSOILEFFIMP) are likely to adopt conventional and GM cotton at the expense of organic cotton because the availability of organic fertilisers is limited.

Study area and source of data

Burkina Faso is divided into 13 regions, 45 provinces, 350 departments and 8337 villages (MAFAP, 2013). In 2014/2015, cotton was produced in 12 regions and 36 provinces grouped into the 3 cotton zones (Western, Central and Eastern). These zones comprise respectively 18, 12 and 6 provinces. The 3 types of cotton were produced in 14 provinces: Balé, Bougouriba, Comoé, Ioba, Nayala, Poni, Sissili, Tuy and Ziro in the Western zone; Bazèga, Boulgou and Oubritenga in the Central zone; and Gourma and Koulpelogo in the Eastern zone.

A survey was conducted using a multistage sampling method, from June to August 2015, to collect primary data from individual cotton farmers for the 2014/2015 production season. The Western cotton zone was purposively selected because the three cotton farming systems existed there for long, and it is the biggest of the three cotton zones of Burkina Faso in terms of contribution to cotton production. In this zone, the two provinces with the longest experience of coexistence of the three systems were purposively selected: Comoé and Ioba. In Comoé, the two departments where the three cotton farming systems existed were all considered: Sidéradougou and Tièfora. In Ioba, there were three departments with the longest experience of coexistence of the three systems: Dano, Dissin and Koper. Dano and Koper were randomly selected. In each of the four departments, two villages were initially targeted, considering the presence and experience of the three types of cotton, as well as their accessibility. This allowed to select Djanga and Kotou in Sidéradougou; Libora and Tiéfora-village in the department of Tiéfora; Complan and Tambikpéré in Dano. In the department of Koper, the three types of cotton were produced in only one village: Kpaï. In addition to this village, two other villages were considered relevant for inclusion in the sampling process in order to increase the sample size without loss of representativeness: Babora where only conventional and organic cotton were produced; and Didogh where only organic and GM cotton were produced.

After identifying the nine representative villages, the lists of farmers for all the 46 cotton producers' groups (GPCs) and organic cotton producers' groups (GPCBs) in these villages were compiled. These lists were obtained from the representatives of the National Union of Cotton Producers of Burkina (UNPCB) and those of the cotton company that operates in the Western cotton zone (SOFITEX). They were combined into a list of 801 cotton farmers, including 321 conventional cotton farmers (40.07%), 118 organic cotton farmers (14.73%) and 362 GM cotton farmers (45.19%). Then, a stratified random and proportional sampling procedure was employed to select 50% of cotton farmers from this list using the Stata software. More precisely, the 50% of farmers were selected for each sub-population of farmers according to the type of cotton produced (conventional, organic and GM), the geographical location (provinces, departments and villages), the cotton producers' groups (GPCs)/GPCBs and the gender of the farmer. This ensures that the proportion of each of the above sub-population of farmers in the total population is maintained in the sample.

The initial sample comprised 429 cotton farmers, including 171 conventional cotton farmers (39.86%), 61 organic cotton farmers (14.22%) and 197 GM cotton farmers (45.92%). This sample size is actually larger than the 50% of 801 cotton farmers' population, i.e. 401 farmers. This is because the population contains sub-populations (according to type of cotton, location, GPC/GPCB and gender) of uneven size, and taking 50% of this size leads to rounded numbers that are greater than the actual decimal numbers. Farmers were interviewed face to face using well-structured and pre-tested questionnaires that were finalized in collaboration with representatives of SOFITEX and UNPCB. After cleaning the data, 384 cotton farmers who provided complete information in the questionnaire were finally retained for the analyses, including 152 conventional cotton farmers (39.58%), 55 organic cotton farmers (14.32%) and 177 GM cotton farmers (46.09%). This imbalance of sample reflects the imbalance of cotton farmers' population in the study area.

Results and discussions

Descriptive statistics on the potential determinants of adoption

The proportions of cotton farmers who used synthetic fertilisers in maize production were similar among conventional and GM cotton farmers (88% and 81% respectively), but higher than that of organic cotton farmers (47%) (Table 3). The need to use synthetic

Table 3. Descriptive statistics on institutional determinants of adoption.

	Observed mean values				Mean differences (Bonferroni's method)		
	Full sample ($n = 384$)	Conventional ($n = 152$)	Organic ($n = 55$)	GM ($n = 177$)	Organic vs. conventional	GM vs. conventional	GM vs. organic
Institutional factors							
SYNTFERTINMAIZ (%)	79.17	88.16	47.27	81.36	−40.89***	−6.80	34.08***
	52	61	02	59	−59.37***	−02.43	56.94***
COMPANYDECIMP (%)							
GPCDECIMP (%)	40	21	02	68	−19.89***	46.65***	66.54***
ADVGROWCC (%)	35	49	11	31	−38.43***	−18.83***	19.60**
ADVGROWOC (%)	26	24	51	21	27.22***	−02.78	−30.01***
ADVGROWGMC (%)	29	27	15	34	−12.43	7.49	19.92**
TRAINING (%)	19.01	19.08	36.36	13.55	17.28**	−5.52	−22.80***

Source: Authors' calculations based on survey data (June–August 2015).
***$p < .01$; **$p < .05$; *$p < .1$.

fertilisers for maize production may be the rationale for growing conventional and GM cotton. Conventional farmers who considered the decision of their cotton company as important in their adoption decision were as many as GM cotton farmers (61% and 59% respectively), but were more than organic cotton farmers (0.02%). As for the decision of the GPC, GM farmers who considered it as important in their adoption decision were more (68%) than conventional cotton farmers (21%) and organic cotton farmers (0.02%). Farmers growing the type of cotton they were advised to grow were relatively more than those who did not grow this type of cotton. It was among organic cotton farmers that the majority were advised to grow organic cotton. More organic cotton farmers also received training relative to conventional and GM cotton farmers.

For many of the other potential determinants of adoption, there were significant differences across the three groups of cotton farmers (Table 4). These differences may lead to differences in farmers' behaviour towards the adoption of the three technologies. Therefore, it is necessary to control for these variables when estimating the effect of institutional factors on the adoption of the three farming technologies and when comparing the performances.

Econometric results

The results are robust to the choice of the model. Indeed, they are similar for the two alternative models (MNL and MNP), in terms of overall adequacy of the models as well as sign and significance of the coefficients (Table 5 and Table A1). The values of the coefficients differ from a model to the other as it is usually the case for the two models, but are not of interest here as mentioned earlier. The findings presented below are based on the results from the MNL model, but also hold for the results from the MNP model.

Overall, the multinomial logistic model estimated is statistically appropriate for analysing the determinants of the adoption of conventional, organic and GM cotton in Burkina Faso. The value of the McFadden's pseudo R-squared is high (0.5582), meaning that the model has a very good fit (McFadden, 1974). Moreover, the LR Chi-Square statistic is significant at 1 per cent ($\text{Prob} > \text{chi}^2 = 0.0000$), indicating that some explanatory variables retained in the model have significant effect.

As expected, the use of synthetic fertilisers in maize farming had a negative effect on organic cotton adoption and no effect on GM cotton adoption compared to conventional cotton. This finding confirms that

Table 4. Descriptive statistics on other potential determinants of adoption.

	Observed mean values or proportions				Mean differences (Bonferroni's method)		
	Full sample (n = 384)	Conventional (n = 152)	Organic (n = 55)	GM (n = 177)	Organic vs. conventional	GM vs. conventional	GM vs. organic
Farmers' demographic and socio-economic characteristics							
AGE (years)	43.47	42.68	46.85	43.10	4.18*	0.42	−3.75
GENDER (%)	6.51	0.66	34.55	2.82	33.89***	2.17	−31.72***
SECEDUC (%)	9.90	3.95	14.55	13.56	10.60*	9.61**	−0.99
HHHCFMR (%)	86	93	47	91	−46.15***	−02.46	43.69***
ACTIVE (number)	5.70	5.50	5.56	5.92	0.0636	0.4209	0.3572
LIVESTOCK (TLU)	2.75	2.66	2.59	2.88	−0.0655	0.2171	0.2826
Farm characteristics and agro-ecological conditions							
CFARMSIZE (ha)	1.92	2.26	0.60	2.04	−1.6660***	−0.2254	1.4407***
LANDOWN (%)	86	91	51	93	−40.54***	1.21	41.75***
DISTFARM (%)	16	13	9	22	−3.41	9.53*	12.94*
FERTLAND (%)	27	33	27	21	−5.62	−11.43*	−5.80
VIRGLAND (%)	42	34	56	46	22.81**	12.21*	−10.60
FALLOWLAND (%)	18	14	25	18	10.98	3.61	−7.38
LOCATION (%)	48.96	61.18	45.45	39.55	−15.73	−21.64***	−5.91
REPESTATTACK (%)	29	20	29	37	8.70	16.89***	8.20
Characteristics and potentials of the technologies as perceived by farmers							
EASYTECHIMP (%)	21	16	36	21	20.57***	5.11	−15.46**
PROFITIMP (%)	38	26	56	42	30.05***	15.49**	−14.56
POSITSOILEFFIMP (%)	19	25	27	11	2.27	−13.70***	−15.97**

Source: Authors' calculations based on survey data (June–August 2015).
***$p < .01$; **$p < .05$; *$p < .1$.

Table 5. Estimates of the multinomial logistic regression.

Variables	Organic cotton	GM cotton	Variables	Organic cotton	GM cotton
Farmers' demographic and socio-economic characteristics			Characteristics and potentials of the technologies		
AGE	−0.0069	−0.0127	EASYTECHIMP	4.295**	−0.211
	(0.0522)	(0.0134)		(1.746)	(0.396)
GENDER	6.090**	1.656	PROFITIMP	2.355**	0.647**
	(2.759)	(1.247)		(1.156)	(0.321)
SECEDUC	4.792**	1.217**	POSITSOILEFFIMP	3.341*	−1.756***
	(2.234)	(0.566)		(1.823)	(0.414)
HHHCFMR	−2.446	−0.380	Institutional factors		
	(2.306)	(0.557)	SYNTFERTINMAIZ	−5.853***	−0.412
Farm characteristics and agro-ecological conditions				(2.173)	(0.410)
CFARMSIZ	−7.585***	0.0528	COMPANYDECIMP	−2.347*	−0.312
	(2.631)	(0.105)		(1.417)	(0.305)
OWNLAND	−1.654	0.234	GPCDECIMP	−5.393**	2.358***
	(2.240)	(0.553)		(2.506)	(0.310)
DISTFARM	−4.482*	0.852**	ADVGROWCC	1.106	−0.662*
	(2.520)	(0.422)		(1.523)	(0.345)
FERTLAND	1.666	−0.0926	ADVGROWOC	3.242**	−0.567
	(1.818)	(0.375)		(1.582)	(0.460)
VIRGLAND	3.562**	0.370	ADVGROWGMC	−1.634	1.286***
	(1.769)	(0.312)		(1.311)	(0.403)
LOCATION	5.152**	−1.065***	TRAINING	3.510**	−0.432
	(2.447)	(0.368)		(1.719)	(0.413)
REPESTATTACK	1.598	0.345	Constant	4.095	0.461
	(1.492)	(0.363)		(3.549)	(0.970)
			LR chi^2(42)	429.61	
			Prob > chi2	0.0000	
			Pseudo R^2	0.5582	

Source: Authors' calculations based on survey data (June–August 2015).
Note: Standard errors in parentheses; ***$p < .01$; **$p < .05$; *$p < .1$.

farmers have to grow conventional or GM cotton in order to have access to fertilisers for other crops (Dowd-Uribe, 2014). To date, the provision of subsidized synthetic fertilisers to farmers on credit is the best opportunity for farmers to access fertilisers for cereals production. Farmers then prefer conventional and GM cotton in order to benefit from this policy, at the expense of organic cotton whose promoters discourage the use of synthetic fertilisers.

The decision of the cotton farmer's association (GPC) and that of his/her company were not expected to influence the adoption of organic cotton. Yet, the results show that both factors had negative effect on organic cotton adoption. This finding is consistent with the argument that the power of cotton companies explains the slow uptake of organic cotton in Burkina Faso (Bassett, 2010; Coulter, 2011). Conventional and GM cotton farmers who reported these factors as important may be expressing their commitment to their cotton company and their association. This commitment makes farmers reluctant to abandon conventional cotton for organic cotton. The reason is that they have to be members of a GPC and produce conventional or GM cotton for the cotton company.

Though the decision of the cotton farmer's association (GPC) and that of his/her company were expected to have positive effect on GM cotton adoption, only the decision of the GPC had a significantly positive effect. This means that the decision at the GPC level about whether to grow conventional or GM cotton was in favour of GM cotton. This is because GM cotton was being promoted by the cotton company in collaboration with the representatives of cotton farmers' organizations since 2008. Therefore, the non-significance of the effect of the cotton company's decision is due to the fact that this decision is generally communicated by the leaders of the GPCs to farmers. From this perspective, the effect of the cotton company's decision can be seen as confounded in that of the GPC's decision. In any case, the recent decision of cotton companies to stop GM cotton, starting from the 2016/2017 season, is evidence that the decision of the cotton companies is central to the adoption of conventional and GM cotton.

In addition to the provision of subsidized fertilisers on credit and the power of cotton company as well as that of farmers' association, other institutional factors affected the adoption of organic and GM cotton over conventional cotton positively. These are extension services in terms of advices and training in favour of the two new technologies. In general, being advised to adopt a given technology had the expected effect. Being advised to grow conventional cotton had a negative effect on GM cotton adoption and no effect on organic cotton adoption. Being advised to grow organic cotton had a positive effect on organic cotton adoption and no effect on GM cotton adoption. Being advised to grow GM cotton had a positive effect on GM cotton adoption and no effect on organic cotton adoption. Training on cotton production also had a positive effect on organic cotton adoption, but no effect on GM cotton adoption. This is because the trainings were more related to organic cotton production methods than conventional and GM cotton.

Other factors such as being a female farmer, the attendance of secondary school, having virgin lands, being located in the Comoé province, as well as the perceived ease, profitability, and positive soil effect of the technology had positive effect on the adoption of organic cotton over conventional cotton. Cotton farm size had a negative effect on organic adoption. Most of these results were expected, except for the perception of the farmer about the ease and the positive soil effect of the technology. It was expected that farmers who perceive the ease of the technology as important in their adoption decision would tend to adopt conventional or GM cotton rather than organic cotton because organic farming practices are often seen as difficult. Yet, the present findings suggest that farmers growing organic cotton may find it easy. This may be related to the fact that organic cotton farming is less costly financially than conventional cotton. Organic cotton farmers may also perceive organic fertilisers as having more positive effect on soil than synthetic fertilisers. Education, distance from household to farm, and the perceived profitability of the cotton technologies had positive effect on GM cotton adoption, while location in Comoé province and the perceived positive soil effect of the cotton technologies had negative effect.

Conclusion and policy implications

This study sought to analyse the effect of institutional factors on farmers' adoption of conventional, organic and GM cotton in Burkina Faso. Institutional factors that have been discussed in previous studies were the focus: the provision of subsidized synthetic fertilisers to farmers on credit by the Government and cotton companies; and the power of the cotton company and the farmers' associations. The study showed that these factors favoured the adoption of conventional and GM cotton against the adoption of organic cotton. Other institutional factors such as extension services (advices and training to farmers) enhanced the adoption of both organic and GM cotton.

Non-institutional factors also affected the adoption of organic and GM cotton. For organic cotton, farmers' education, the involvement of women, the availability of virgin lands, the location in the Comoé province and the potentials of the technologies (ease, profitability and positive effect on soil) had a positive effect on its adoption. Farm size and the distance to the farm had negative effect. For GM cotton, farmers' education, the distance to the farm and the profitability of the technologies had a positive effect, while the location in the Comoé province and the effect of the technologies on soil had a negative effect on its adoption.

For farmers to adopt organic cotton, its promoters that are mainly NGOs need to facilitate farmers' access to organic fertilisers. This should be in partnership not only with the National Union of Cotton Producers of Burkina Faso (UNPCB), but also with the cotton companies. These companies are the most powerful direct stakeholders driving cotton policies in the country with the support of the government. Further advices and training on organic cotton are necessary for its adoption. Ensuring that people access secondary school education can enhance the adoption of organic cotton. Directing organic cotton projects towards farmers who still have virgin lands, have small farms and live close to their farms and in areas with better agro-ecological conditions such as rainfall and soil fertility will improve the adoption of organic cotton.

As for GM cotton whose production is now stopped in Burkina Faso, its acceptance by the cotton companies will be first needed for its eventual adoption by farmers in the future. In the extreme case, whether farmers adopt conventional or GM cotton will be completely decided by the cotton companies. In case farmers are given the opportunity to choose between conventional or GM cotton, the type of cotton they adopt will be primarily a group decision at the level of their community-based association (GPC). Nevertheless, some individual-specific factors should also be considered for the adoption of GM cotton: ensuring that people access secondary school education; ensuring that GM cotton is profitable; and targeting farmers who live far from their farms while facing worse agro-ecological conditions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Table A1. Estimates of the multinomial probit regression

Variables	Organic cotton	GM cotton	Variables	Organic cotton	GM cotton
Farmers' demographic and socio-economic characteristics			Characteristics and potentials of the technologies		
AGE	−0.0055	−0.0110	EASYTECHIMP	3.0982**	−0.1719
	(0.0366)	(0.0111)		(1.1982)	(0.3220)
GENDER	4.3196**	1.2750	PROFITIMP	1.9632**	0.5021**
	(1.8870)	(0.9685)		(0.8369)	(0.2611)
SECEDUC	3.2994**	0.9897**	POSITSOILEFFIMP	2.2111*	−1.4655***
	(1.4760)	(0.4392)		(1.2365)	(0.3324)
HHHCFMR	−1.5693	−0.3185	Institutional factors		
	(1.5194)	(0.4609)	SYNTFERTINMAIZ	−4.1283***	−0.3349
Farm characteristics and agro-ecological conditions				(1.4885)	(0.3359)
CFARMSIZ	−5.5331***	0.0378	COMPANYDECIMP	−1.7253*	−0.2543
	(1.7323)	(0.0863)		(1.0342)	(0.2484)
OWNLAND	−1.2838	0.2164	GPCDECIMP	−3.3843**	1.9847***
	(1.5337)	(0.4649)		(1.5758)	(0.2449)
DISTFARM	−3.0045*	0.6382**	ADVGROWCC	1.0008	−0.5214*
	(1.6870)	(0.3399)		(1.0467)	(0.2760)
FERTLAND	1.1074	−0.1012	ADVGROWOC	2.2057**	−0.5105
	(1.2375)	(0.2974)		(1.0955)	(0.3714)
VIRGLAND	2.5457**	0.3094	ADVGROWGMC	−1.1823	1.0757***
	(1.1797)	(0.2562)		(0.9337)	(0.3211)
LOCATION	3.7920**	−0.8889***	TRAINING	2.4084**	−0.3680
	(1.6711)	(0.3013)		(1.1075)	(0.3382)
REPESTATTACK	1.2224	0.2790	Constant	2.3135	0.4399
	(1.0630)	(0.2932)		(2.4232)	(0.8109)
			Wald chi^2(42)	124.27	
			Prob > chi^2	0.0000	

Source: Authors' calculations based on survey data (June–August 2015)
Note: Standard errors in parentheses; ***$p < .01$; **$p < .05$; *$p < .1$.