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Policy and Institutional Factors and the Distribution of Economic Benefits and Risk from the Adoption of Insect Resistant (Bt) Cotton in West Africa

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Abstract: Some countries in West Africa are considering the potential adoption of insect resistant cotton. Burkina Faso has already approved commercial cultivation of this technology. This paper presents the results of a socio economic impact assessment of the potential adoption of insect resistant cotton in West Africa using an augmented economic surplus model to consider risk and parameter uncertainty. Model considers changes in parameters such as technology fees, regulatory lags, and adoption patterns. Results show these are important in shaping the average response but also its distribution. Countries in West Africa definitively loose from not adopting Bt cotton. Adoption with reduced or no technology fees gathered the most gains to producers and for society as a whole. The paper develops a discussion of the potential policy and institutional factors affecting adoption outcomes.

Keywords: Bt Cotton, Economic Surplus Model, West Africa, Benefits, Risk, Biotechnology

Introduction

Burkina Faso approved in 2007 the commercial cultivation of genetically modified Bt (*Bacillus thuringiensis* kurstaki) cotton. The main trait of Bt cotton is the expression of insect resistance to specific lepidopteran insects. Cotton growers in West Africa (WA) and other regions of Africa may gain access to Bt cotton as this product is undergoing biosafety evaluation in Kenya and Uganda, and has been approved for commercial

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cultivation in South Africa. Yet, the potential adoption of Bt cotton by West African nations has generated conflicting points of view about the uncertain impacts of genetically modified technologies on the economy and the environment.

In this paper, we describe an *ex ante* assessment of the potential adoption impact of Bt cotton by major cotton-producing countries in West Africa. These countries include Benin, Burkina Faso, Mali, Senegal and Togo. Recognizing the risk and uncertainty associated with the technology and the limitations of existing data, we expand the economic surplus model with a stochastic analysis. We develop five scenarios to highlight the effects of policies and institutional factors on the distribution of benefits and risks that lend insights into policy and institutional issues that are critical for the proper deployment of crop biotechnology in West Africa.

To ensure proper discussion of policies and institutional issues, we first review background information and previous studies related to the economic impact of Bt cotton at the industry level in West Africa. Then, we briefly describe the model, scenarios and findings.[1] Finally, we discuss institutional and policy issues related to the potential adoption of Bt cotton in order to address the potential limitations that may arise from the adoption and use of Bt cotton technology in Africa.

Cotton production has significant implications for the livelihood of resource poor farmers in West Africa. Approximately 1-2 million smallholder farmers produce most of the cotton in the region (SWAC Secretariat OECD 2005). Cotton production creates significant direct and indirect employment opportunities in the region. Smallholder cotton producers in West Africa are usually well diversified in terms of crops, employing mostly household labour for their cultivation.

West African governments view cotton as an alternative cash crop for smallholder producers that can support income creation and that can generate hard currency from exports. West Africa currently accounts for approximately 10 per cent of world cotton exports and is the third largest cotton producer in the world. (*FAO Statistics* 2005). For a long time, West Africa as a region has had a comparative advantage over other cotton producing countries in terms of lower production costs, high quality fiber, and a solid institutional infrastructure (Baffes 2004).

Cotton responds well to environmental conditions in the region, characterized by frequent droughts and variable rainfall. Insect damage, however, limits cotton production in West Africa. Without chemical control, yield damage from lepidopteran insects[2] can vary from 23 to 34 per cent (Oerke, *et al.* 1995). Lepidopteran and other insect damage to cotton production, coupled with increased resistance to commonly used pesticides, may help explain the loss in the region's competitive advantage. (Martin *et al.* 2002). Efforts to control lepidopteran damage add to approximately 194 million dollars annually with increasingly lower success (CAB International (2001).

Ajayi *et al.* (2002) reports that cotton yields have declined in West Africa with a concurrent increases in pesticide use partly due to increased resistance of pests, such as cotton bollworm. Integrated pest management practices have been proposed to improve pest control, reduce pesticide applications and reduce farmers' costs (Ochout et al. 1998). Yet, these practices have not been widely adopted in the region (Silvie *et al.* 2001). Bt cotton is an alternative for controlling target lepidopteran pests and thus may contribute to cotton productivity improvements in West Africa. The need exists for credible information related to the potential impact of Bt cotton and other modern biotechnologies. Economic practitioners have used economic surplus models in both *ex ante* and *ex post* situations to provide decision makers with robust information about adoption impacts.

Background on Bt Cotton

The first gene used in Bt cotton (commercial name Bollgard™), known as *Cry1Ac*, was developed by Monsanto in the 1980s from the soil micro-organism, *Bacillus thuringiensis* kurstaki. Scientists long know that this microorganism produces a protein that is toxic to a limited number of Lepidopteran insects when ingested. The range of control of the technology has been extended through the introduction of two or more Bt genes inserted into the plant or by the expression of new chemistries. Bt cotton was first sold in the United States in 1996 and was developed through a strategic alliance between Monsanto and the dominant U.S. seed cotton firm, Delta and Pineland (D&PL).

Bt cotton has been approved for commercial cultivation in nine countries including Argentina, Australia, Brazil, Colombia, China, India, Mexico, South Africa and United States (James 2007). In these countries, the developer has either entered into licensing agreements with local seed companies or as in India and China has developed and directly commercialized the innovation. In all countries, the innovator has charged producers a fee for using the technology beyond the regular seed cost. The ability to charge a technology fee or premium is possible due to the temporary monopoly granted by intellectual property protection and/or the fact that the innovator may be the sole supplier of this particular product.

From the standpoint of the private sector, West Africa may be an attractive sizable market, provided there are proper IP protection and market penetration. Table 1 presents gross income estimates of the value of the technology fee under varying adoption assumptions. At an expected level of 20 per cent adoption for the whole region, the market value of the Bt technology fee runs from 8.5 and 45 million dollars for the $15 and $80 per hectare technology fee. If we add the combined potential markets of Burkina Faso, Benin, Mali, Côte d'Ivoire, and Togo, the value of the technology fee ranges from 4.6 to 24.5 million dollars annually. This may represent an attractive market for a technology whose R&D costs have been paid elsewhere through deployment in other countries. So far, the apparent release plans are for the technology to be commercialized in close collaboration with national research organizations and thus there may not be a technology fee charged to farmers. This may change in the course of transferring the technology to producers in Burkina Faso and other countries in West Africa.

Literature on Bt Cotton Impact Assessment in West Africa

A significant share of the existing adoption impact assessment literature is on Bt cotton. Of the published peer reviewed literature, the largest share examines the impact of farmer adoption (Smale *et al.* 2006b). Of the published studies, only three address the potential economic impact of Bt cotton in West Africa. Cabanilla *et al.* (2003) estimated aggregate *ex ante* benefits from the adoption of Bt cotton in West Africa by utilizing a linear programming model to derive benefits for a representative farm resulting from estimating optimal allocations for land, output, profit and whole farm income. Linear programming estimates used detailed field studies data to estimate farm level outcomes, which where aggregated to the national level. Authors estimate that aggregate benefits annually accruing to farmers were $68 million in Mali, $41 million in Burkina Faso, $53 million in Benin, $39 million in Côte d'Ivoire and $8 million in Senegal. In summary, Cabanilla et al. (2003) showed that the region would forego significant benefits from not adopting Bt cotton.

Table 1. Annual Gross Income to Gene/Germplasm Innovator from Charging a Per Hectare Technology Fee Assuming 100%, 60% and 20% Adoption Levels in West Africa

Country	Income from technology fee with 100% adoption		Income from technology fee with 60% adoption		Income from technology fee with 20% adoption	
	Tech fee= 15 ($/ha)	Tech fee= 80 ($/ha)	Tech fee= 15 ($/ha)	Tech fee= 80 ($/ha)	Tech fee= 15 ($/ha)	Tech fee= 80 ($/ha)
Benin*	5.4	29.1	3.3	17.4	1.1	5.8
Burkina Faso*	4.8	25.8	2.9	15.5	1	5.2
Mali*	6	32.2	3.6	19.3	1.2	6.4
Senegal*	0.4	2.4	0.3	1.4	0.1	0.5
Togo	2.3	12	1.4	7.2	0.5	2.4
Sub-total countries in study	18.9	101.5	11.5	60.8	3.9	20.3
Cameroon	3	16.2	1.8	9.7	0.6	3.2
C. African Rep.	0.5	2.7	0.3	1.6	0.1	0.5
Chad	4.4	23.4	2.6	14	0.9	4.7
Congo, D.R.	1	5.5	0.6	3.3	0.2	1.1
Côte d'Ivoire*	4.5	23.9	2.7	14.3	0.9	4.8
Gambia	0	0.1	0	0	0	0
Ghana	0.5	2.8	0.3	1.7	0.1	0.1
Guinea	0.7	3.7	0.4	2.2	0.1	0.7
Guinea-Bissau	0.1	0.3	0	0.2	0	0.1
Mauritania	0	0.2	0	0.1	0	0
Nigeria	8.5	45.1	5.1	27.1	1.7	9
Sub-total rest of West Africa	23.2	123.9	13.8	74.2	4.6	24.2
Total West Africa	42.3	225.3	25.4	135.2	8.5	45.1

Note: Based on FAOSTAT data on area planted in West Africa.

Elbeheri and Macdonald (2005) utilize a multi-region general equilibrium model to estimate the likely impacts – especially on trade- of adoption and non-adoption of Bt cotton in West Africa. In the case of non-adoption in West and Central Africa, but with adoption in other countries, the authors estimate that social welfare in the region will decrease by US$ 88 million annually. In contrast, adoption of Bt cotton technology increases social welfare, as the change in producer surplus induced by the expansion in cotton supply is larger than the expected concomitant cotton price reduction.

Vitale *et al.* (2007) examines the potential adoption of Bt cotton and maize in West Africa with an emphasis in Mali. Dual cultivation of maize and cotton is a common production system in Mali. The authors make use of confined and large-scale field trials in Burkina Faso to draw performance data that was used in their simulations. The paper use an economic surplus model augmented with a farmer decision-making component. Adoption decisions are thus endogenous to the model. Due to the nature of the markets for cotton and maize, simulation results diverge significantly. In the case of cotton, with a strong export market, farmers capture a large share of benefits. In contrast, as maize is mainly a subsistence crop, consumers capture the larger share of economic surplus generated from the adoption of Bt maize. Estimates show that aggregate benefits from Bt cotton adoption would surpass those associated with Bt maize by $10.3 million per year.

Many *ex ante* (and *ex post*) assessments of GM crops use the approach presented in Falck-Zepeda *et al.* (2000a, 2000b) as foundation for their implementation. The approach considers of an adjustment to the standard economic surplus model described by Alston et al. (1995),that accounts for temporary monopolies derived from the intellectual property protection endowed to most GM crops (Moschini and Lapan 1997). A major disadvantage of the economic surplus approach is that it relies on underlying parameters. In those cases where there is very little or no information or where information is not reliable, usually the situation with *ex ante* assessments, estimates may not be as robust as desired. Impact assessment practitioners may gather information from other countries (such as Vitale *et al.* 2007 or Cabanilla *et al.* 2005) or may elicit information from local experts. Furthermore, conventional economic surplus models do not incorporate risk or uncertainty typical of agricultural production and smallholder producers in developing countries.

We now discuss a modification to the conventional economic surplus model that incorporates a stochastic component allowing the examination of risk arising from the adoption of Bt cotton in West Africa. One of the advantages of using a stochastic simulation is the ability to evaluate the variability of simulation outcome and the risk. We present five scenarios that will examine a portfolio of policy and institutional factors issues relevant in West Africa.

Studies examining Bt cotton adoption in countries such as South Africa (Gouse *et al.*2005), Mexico (Traxler *et al.* 2003) and Argentina (Qaim and Janvry 2005), demonstrate the need to examine institutional and policy issues as they may have an impact on the level and distribution of economic benefits accruing to farmers. Institutional and policy issues include legal frameworks, credit availability, production contracts, the technology premium fee level, and the degree to which seed, input and product markets are competitive. Therefore, we proceed to discuss policy and institutional issues related to the adoption of Bt cotton in West Africa.

The Model

Most *ex post* or *ex ante* analyses of the size and distribution of national economic benefits from adopting GM crops have been conducted with adaptations or versions of the economic surplus approach detailed by Alston and Pardey (1999). This approach is also termed a partial equilibrium displacement model because it considers only the effects of the technology change in the market where the technical change occurs. The model disregards the effects in other markets, such as input markets. We based the economic surplus model used in this study on a set of equations that depict the cotton market in West Africa from which a set of formulas are derived to estimate consumer, producer surplus and innovator surplus.

We augment the model with the inclusion of probability distributions that replace individual parameters. The idea behind this replacement is to perform a rigorous sensitivity analysis of model parameters and to introduce risk considerations into the model as described in Falck Zepeda *et al.* (2008). Then, we estimated annual producer, consumer and innovator surplus for the period of the simulation and for each scenario. In addition, we estimated the Net Present Value (NPV), and when appropriate, the Internal Rate of Return (IRR) for each year of the simulation and sum to a total value.

The countries of Benin, Burkina Faso, Mali, Senegal and Togo were included as standalone countries in the estimations. We group the rest of the cotton producing countries in West Africa and other regions under Rest of the World (ROW) category. In most cases, we used triangular distributions to reflect a distribution of outcomes. The triangular distribution is parsimonious at the minimum, most likely and maximum values, fully describe the distribution. Furthermore, the triangular distribution approximate the normal distribution over repeated sampling draws. The distribution is widely used in production economics and the finance literature for modeling risk. The values for the distribution of the model parameters where compiled from the literature (Hardaker et al. 2004).

We inputted the model into a spreadsheet and then ran Monte Carlo simulations using the programme @Risk™. The program calculates and saves output variables designated in advance by drawing quasi-randomly from the distributions included in the model. After the program estimates and saves output, the program repeats this process for a designated number of times by the user. The @Risk™ program saves results, and when all iterations are done, calculates statistics over all simulation results for the output variables. In this paper, output variables are producer, consumer, innovator, and total surplus, and net present value and internal rates of return.

The formulas for changes in domestic and ROW producer and consumer surpluses used in our study were:

$$\Delta CS = P_0\, C_0\, Z\, (1 + 0.5\, Z\, h_a),$$
$$\Delta PS = P_0\, Q_0\, (K - Z)\, (1 + 0.5\, Ze_a\,),$$
$$\Delta IS = A_t\, (P_{Bt} - P_{Conv}) = At * TF_t$$
$$\Delta TS = DCS + DPS + DIS - DC_{Dep}$$
$$K = \left[\frac{(\Delta Y}{\varepsilon a} + \frac{\Delta C}{(1+\Delta Y)} - \frac{TF}{TC} \right] \times A \times R \times S$$

where ΔCS= Change in consumer surplus, ΔPS=Change in producer surplus, ΔIS=Change in innovator surplus, ΔTS= Change in Total surplus, P_0 is the price without the innovation, C_0= Quantity consumed without the innovation, Q_0= Quantity produced without innovation, K is the proportional size of the supply shift, Z = is the price change associated with the supply shift, P_{Bt} is the price of Bt cotton, P_{Conv} is the price of conventional varieties and C_{Dep} are the costs necessary to develop

Table 2a: Assumptions Used in the Estimation of Economic Surplus Model for the Adoption of Bt Cotton in West Africa

Assumptions	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Source(s) of assumptions
Maximum adoption rates (%)	0% in WA 20% ROW	30% in WA 20% ROW	60% in WA 20% ROW	50% in WA20% ROW	Fluctuating adoption in Benin and Mali, 30% in rest of WA,20% ROW	Based on Cabanilla,et al. 2005.
Total R&D & Biosafety lag (years)	0	6 Burkina Faso, 9 other WA countries	5	6 Burkina Faso, 9 other WA countries	6 Burkina Faso, 9 other WA countries	Own (subjective) assumption
Adoption lag (years)	0	5 Burkina Faso, and other WA countries	5	5 Burkina Faso, and other WA countries	5 Burkina Faso, and other WA countries	Own (subjective) Assumptions
Year at maximum adoption level	7	7	7	7	7	Own (subjective) Assumptions
Years to dis-adopt	0	5	5	5	5	Own (subjective) assumptions
Total years simulation	23	24	23	24	24	Sum of all components of adoption pattern

Notes: WA = West Africa, ROW=Rest of the World, Scenario 1=No adoption in West Africa, adoption in the rest of the world, Scenario 2 =WA adopts available private sector varieties, Scenario 3 =WA uses West African varieties backcrossed with private sector lines, Scenario 4 =WA uses West African varieties backcrossed with private sector lines plus a negotiated premium Scenario 5= WA uses West African varieties backcrossed with private sector lines with irregular adoption.

and deploy the technology including biosafety regulatory compliance costs, ΔY is the expected yield difference between Bt and conventional cotton, e_a is the elasticity of supply of cotton, ΔC is the cost difference between Bt and conventional cotton, TF is the technology fee, TC is the Total costs of production, A is the adoption rate, R is the probability of R&D success (assumed in this paper to be 100 per cent), and S is the share of the hectares planted to Bt cotton in each country.

Simulations were conducted over a set period, then output variables were calculated for each year and then the results were transformed to net present values. Note that the values for elasticities, yield and cost differences, prices and quantities, and other parameters are specific to the country and region groups, unless specified differently.

Modelling Scenarios

Scenario 1: No country in West Africa adopts Bt cotton, while cotton-producing countries in the ROW adopt at a constant rate of 20 per cent. Maximum adoption rates are achieved in the ROW in year seven. The total time simulated is 23 years. For the ROW countries, we assumed a triangular distribution with a minimum, most likely and maximum technology fee of US$15, US$ 32, and US$ 56 per hectare respectively. Note that these estimates from the literature are relatively high as they correspond to the technology fees charged for both developing and industrialized countries and thus the results of our simulations will tend to be conservative estimates.

Scenario 2: Adopting countries in West Africa use Bt cotton but after backcrossing to local varieties. This policy increases the lag time to deploy the technology. Thus, there is a delay in terms of producers receiving the stream of benefits. Lags are extended to adopting countries by three years. Adapted local varieties may yield more than foreign varieties, while ensuring a higher acceptance by farmers in the region (Qaim et al., 2006). Therefore we have modified yield parameters to reflect potential yield advantage from adapted varieties. This is the most likely scenario for the case of Burkina Faso and the rest of countries in West Africa.

Scenario 3: adoption starts in 2012 in Burkina Faso, followed by the other countries three years later. The maximum adoption ceiling in the region is 60 per cent. Adopting countries use adapted local varieties. We assume a public release; therefore, there is no technology fee. Many countries in Africa are considering of the involvement of the public sector in the development and distribution of Bt cotton technology.

Scenario 4: Literature reviews have shown the importance of the technology fee levels in determining the gains from the adoption introduction of Bt cotton. Lower technology fees tend to increase gains by producers by reducing input costs and by providing incentives to increased adoption. Taking into consideration the significant negotiating power of farmer unions and marketing associations have in West Africa, we explore the possibility that they are able to negotiate a lower technology transfer fee compared to the three previous scenarios. We reduced the technology fee for by 40 per cent across all parameters of the triangular distribution to gain a sense of the potential impacts of such policy. The minimum, mode and maximum technology are then set to 9, 19 and 34 dollars per hectare, respectively. We also increased adoption rates slightly to a maximum of 50 per cent because of the lower price of Bt cotton seed. Other assumptions remain the same as those used in Scenario 3.

Scenario 5: Taking into consideration the experience with the adoption of modern varieties in Africa, we allowed for a pattern of adoption, dis-adoption and re-adoption in Mali and Benin. The purpose of this scenario is to emphasize the importance of addressing institutional and governance considerations and the farmer vulnerability to fluctuations in seed availability and hence farm income. Thus, this scenario illustrates the impact of fluctuating adoption rates and institutional issues on the level and distribution of benefits as documented in other countries in Africa (Gouse et al. 2005). We therefore modify the smooth sigmoid adoption curve used in the previous four scenarios to describe and somewhat irregular adoption path. We assume that a drastic fall in world cotton prices, a political turmoil, or a drought event could affect cotton production in general, but there may be a larger (and perhaps faster) reduction could be expected in Bt cotton areas, given the higher seed costs. Except for the irregularity in adoption rates, all other assumptions in Scenario 5 are the same as those made in Scenario 3.

Discussion of the Parameters Considered

We present the parameters and the assumptions used in the model in Tables 2a and 2b, along with the literature consulted to obtain parameter values. We instructed the simulation programme to repeat the process 10,000 times for Scenarios 1-4 and 25,000 times for Scenario 5. A higher

Table 2.b: Assumptions for Probability Distributions used in the Estimation of Economic Surplus Model for the Adoption of Bt Cotton in West Africa. cont.

Assumptions	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Source(s) of assumptions
Technology fee (US$/ha)	Triangular (15, 32, 56) for ROW	Triangular (15, 32, 56) for WA and ROW	Public Sector release-no charge (15, 32, 56) Triangular for ROW	Triangular (9,19, 34) for WA and (15, 32, 56) for ROW	Triangular (15, 32, 56) for WA and ROW	Falck-Zepeda et al., 2000; Huang et al., 2003; Bennett et al., 2004; Huang et al., 2004
Supply eelasticity (Units)		Triangular (0.3,1,1.5)	Triangular (0.3,1,1.5)	Triangular (0.3,1,1.5)	Triangular (0.3,1,1.5)	Minot and Daniels 2005;Dercon 1993, Delgado and Minot 2000,Alston, Norton and Pardey, 1995
Yield advantage of Bt over conventional varieties (%)	Triangular (0, 0.2, 0.4) for ROW only	Triangular (0., 0.25, 0.45) for Burkina Faso and WA for ROW (0., 0.2, 0.4)	Triangular (0,0.2,0.4) for WA and ROW	Triangular (0,0.25,0.45) for Burkina Faso and WA for ROW (0., 0.2, 0.4)	Triangular (0,0.25,0.45) for Burkina Faso and WA 0., 0.2, 0.4) (for ROW	Falck-Zepeda et al., 2000; Huang et al., 2003; Bennett et al., 2004; Huang et al.,
Cost advantage of Bt over conventional varieties (%, net of technology fee)	Triangular (0, 0.06, 0.12) equivalent to a reduction of 0, 7, 14 applications for ROW only	Triangular (0, 0.06, 0.12) for ROW and (0, 0.13, 0.26) for WA equivalent to a reduction of 0, 7, 14 applications	Triangular (0, 0.06, 0.12) for ROW and (0, 0.13, 0.26) for WA equivalent to a reduction of 0, 7, 14 applications	Triangular (0, 0.06, 0.12) for ROW and (0, 0.13, 0.26) for WA equivalent to a reduction of 0, 7, 14 applications	Triangular (0, 0.06, 0.12) for ROW and (0, 0.13, 0.26) for WA equivalent to a reduction of 0, 7, 14 applications	Cabanilla et al. 2005; Bennett et al., 2004; Huang et al. 2004

Table 2.b continued

Table 2.b continued

Assumptions	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5 assumptions	Source(s) of
Adaptive R&D / Biosafety regulatory costs (US$ total)	0	$120,000 distributed over 4 years in BF, $90,000 distributed over 3 years rest adopting countries ion WA	$120,000 distributed over 4 years in BF, $90,000 distributed over 3 years rest adopting countries ion WA	$120,000 distributed over 4 years in BF, $90,000 distributed over 3 years rest adopting countries ion WA	$120,000 distributed over 4 years in BF, $90,000 distributed over 3 years rest adopting countries ion WA	Pray et al. 2005, Quemada 2003 and Falck Zepeda and Cohen, 2006

Note: The triangular probability distributions used in the simulations are fully described by minimum, mode and maximum values. In the table above values for these three parameters are included in parentheses in each cell of this table, when appropriate.

number of simulations in Scenario 5 were necessary as simulation results fluctuated significantly due to fluctuating adoption patterns in this scenario. We, therefore, wanted to ensure robust statistical summaries estimated for the aggregate results. A more in-depth description of the parameters is in Falck Zepeda, *et al.* (2008).

1) Time lags: time lags defined as the sum of the time required for adaptive research and development (R&D) and biosafety regulatory process in the innovating country.
2) Cost of compliance with of compliance with biosafety regulations and/or R&D: Since this is an ex-ante study, we used data from other developing countries including India and China (for example, Pray *et al.* 2005; Quemada 2003; Falck-Zepeda and Cohen 2006). When the cost of compliance with biosafety regulations is included, that benefit values to producers will most likely decrease.
3) Technology diffusion pattern: In the simulations, Burkina Faso took the leading role because this country has approved the commercial release of the Bt cotton. Other countries including Benin, Mali, Senegal and Togo, adopted after an evaluation period. The later assumption is controversial but reflects the experience of other regions of the world (i.e. the case of herbicide resistant soybeans in Brazil after approval in Argentina).
4) Model elasticities: Given the limited information concerning the supply elasticity of cotton in West Africa, the unitary elasticity was assumed as the most likely value. To set the range of the supply elasticity values, we consulted the literature. The final triangular distribution used took a minimum value of 0.5 and a maximum of 1.5, with a mode value of 1.0. We chose deliberately a more conservative minimum value ($\varepsilon = 0.3$) as seen in Table 2b.
5) Yield advantage: We drew values of the difference between Bt and conventional yields from existing literature. Note that the minimum value at 0 per cent allows for the possibility of no yield effect induced by the Bt trait. If there is no pest attack there is no reason to observe a yield difference between the Bt and conventional variety. The likelihood is that if there is still a difference this is unrelated to the trait but rather to the germplasm used.
6) Cost advantage: Refers to the per unit cost savings from reduced pesticide use resulting from the use of Bt varieties. As in the case of yield advantages, we consulted the published literature to obtain values for the triangular distribution that we use in our simulations. The minimum cost difference was set to zero since a Bt variety

does not necessarily reduce the need for insecticide applications. The experience in other countries has shown that even in the case of successful adoption of a Bt cotton technology and successful control of the primary pests, secondary pest populations can become economically significant and therefore may require pest applications. The cost of controlling secondary pests then could offset benefits from reduced applications of pesticides to control the target pest.

Notice that the simulations account for the possibility that farmers may be worse off by using the Bt cotton technology when there is no yield advantage and/or no costs advantage.

Results

Scenario results

Table 3 introduces results expressed in actual and present values. The overall result is that the change in economic surplus is positive with the adoption of a Bt cotton technology in West Africa. The results of the simulations show that producer surplus gains are qualitatively similar amongst all countries. On the other hand, the probability that consumers would gain with Bt adoption are very high. These overall results vary from one scenario to another. One of the benefits from using a stochastic simulation model is the ability to compare and analyze variability at different levels of analysis. We observed significant variability at the country level masked within the average simulation results.

Table 3 introduces average benefits for consumers, producers and innovators for the more realistic scenarios 2, 3, 4 and 5. It is also important to point out that in Scenario 3 there is no innovation surplus since there is no technology fee. In the case that West Africa would choose not to allow cultivation of Bt cotton (Scenario 1/Baseline), the results show that producers would unequivocally loose from this policy. These losses are a consequence of price reductions driven by supply shifts from technology adoption in the rest of the world. Price reductions do induce a gain by consumers; however, consumer gains do not match producer losses. Therefore, not adopting Bt technology would generate net losses for the region.

Comparing Scenarios 2 and 4, we see that both lowering technology fees and higher levels of technology adoption may improve the level of benefits but also its distribution. In almost all countries,

Table 3: Level and Distribution of the Present and Actual Value of Economic Surplus in West Africa and Burkina Faso, by Scenario (Millions US$)

Actors	Present Values					Actual Values				
	S 1	**S 2**	**S 3**	**S 4**	**S 5**	**S 1**	**S 2**	**S 3**	**S 4**	**S 5**
West Africa										
Producers	-28.1	32.9	30.6	33.6	20	-77.6	199.7	201.5	208.3	145.9
Consumers	0.5	0.6	0.7	0.6	0.5	1.4	1.56	1.9	1.7	1.5
Innovators	0	48.	0	28.8	37	0	219.3	0	131.5	188.7
Total Surplus	-27.7	81.1	31.0	62.8	58	-76.2	420.1	203.1	341.1	335.7
Burkina Faso										
Producers	-7.0	13.4	12.9	13.8	13.5	-19.3	56.7	53.5	58.6	51.2
Consumers	0.1	0.1	0.2	0.1	0.1	0.4	0.4	0.5	0.4	0.4
Innovators	0	14.7	0	8.9	14.7	0	54.9	0	32.9	54.9
Total Surplus	-6.9	28.3	13.0	22.7	28.3	-19.0	111.9	56.4	91.9	106.5

Note: 1) Source: Falck Zepeda et al. (2008), 2) The values for producer, consumer and innovator surplus do not add to the value for total surplus shown in the table because the values presented in each cell of this table are the average of the thousands of iterations undertaken in each scenario.

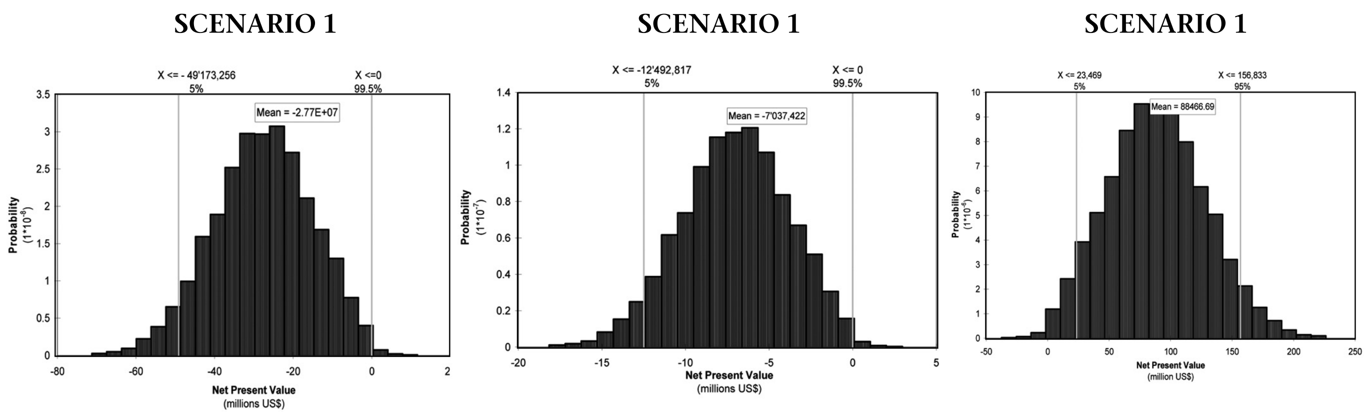
producers and consumers are better off with a reduction in technology fees as in Scenario 4. Certainly, innovators are worse off. Therefore the question of minimal technology fees to enter a market become relevant. Alternatively, the question could be framed as what is the minimal technology fee per area that induces a developer to invest in a market, as this will have an impact on profitability. Similar questions can be raised with regard to the public sector. One of the public policy considerations is whether developers –and innovation- will be affected by price reductions and how. In Table 4, we can also see the impact of not addressing institutional issues that may disrupt adoption processes. In Scenario 5, irregular adoption processes affect significantly producers in Benin and Mali, but they are not the only stakeholder affected as innovators are also affected.[3]

Figures 1 a-c introduces the distribution of net present values for the baseline scenario 1. The probability that West Africa in general and Burkina Faso a loose from not adopting Bt cotton is very high (99.5% certainty) as shown in Figures 1a and 1b. Similar results occur in other countries. As expected, with a price decrease, consumers gain from the use of Bt cotton. Senegal uses a large proportion of the cotton domestically produced, and therefore the change in consumer surplus due to the adoption of Bt cotton would most likely be high (Figure 1c). The probability of a negative change in consumer surplus is very low. The probability of having a negative change in total economic surplus is much lower in Scenario 2 (4 per cent) than in the baseline scenario (99.5 per cent).

The introduction of local adapted varieties makes a big difference in our modeling efforts. The core idea for this scenario is to examine the trade-off between using a variety available now versus a using a variety produced sometime in the future. This tradeoff needs to be compared to the additional cost involved with adaptive R&D necessary to introduce the Bt gene into local varieties. Results show that the use of a local variety with higher yield may compensate for the time and cost to develop the technology in the first place.

In scenario 4 in Table 3, benefit level increases for both consumers and producers in West Africa, with a concurrent reduction in innovator surplus. Consumer gain through output price decreases while producers increase their own gains from a reduction in input costs. Lowering the technology fee charge does benefit producers and consumers. The real questions are how much a reduction and what is the mechanism by

Figure 1. Distribution of Present Value of Total Surplus for Scenario 1



a. West Africa - Total surplus

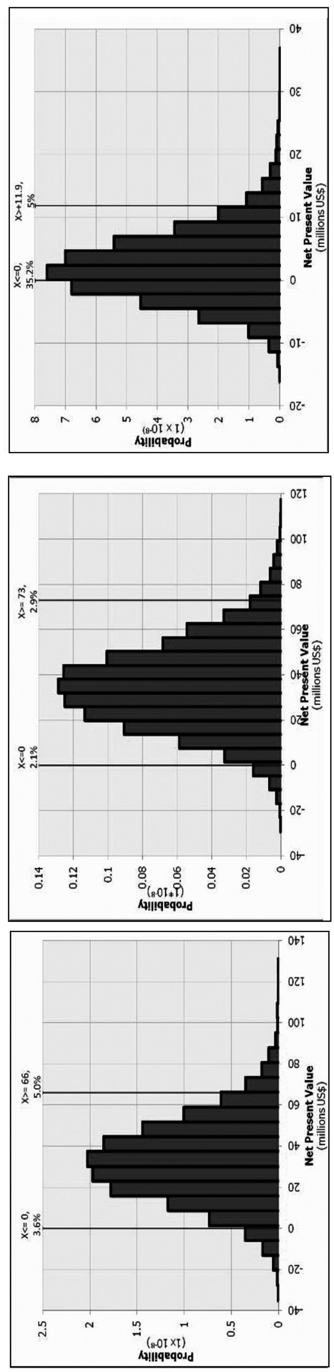
b. Burkina Faso - Producer surplus

c. Senegal - Consumer surplus

Source: Falck Zepeda, et al. 2008.

Figure 2. Distribution of Total Surplus Across Scenarios

SCENARIO 2 | SCENARIO 3 | SCENARIO 5



a. West Africa total surplus | b. West Africa total surplus | c. Benin producer surplus which farmers can negotiate price reductions in the region. Furthermore, reducing prices tends to decrease variability and downside risk. These results are indeed a reflection of a reduced financial risk in the cotton sector derived from driving input prices down, to get them a close to a competitive market price as possible. However, decision makers have to be conscious that there is a threshold under which developers will not deliver a product to a particular market as it becomes un-economical. The case of public sector product delivery free (or close to free) requires much more attention.

When we consider introduction of irregular adoption rates in countries such as Benin and Mali, as in Scenario 5, there is significant effect on outcomes. In both countries, irregular adoption rates reduce producer and total surplus compared to previous scenarios (Tables 3 and 4). This is not the only impact, as there is a concurrent increase in the level of downside risk. In comparison to Scenario 4, we observe a decrease in consumer surplus and increased innovator surplus. The probability distributions for the chance in producer surplus reveal that disrupted adoption causes a higher probability of negative producer surplus (Figures 2a and 2b). The probability of negative change in producer surplus can be as high as 35 per cent in Benin (Figure 2c). The country with lowest probability of a negative outcome is Senegal, with a still sizable 20 per cent probability. Interesting to note that consumer surplus is not affected much by irregular adoption as adoption in the ROW dampens potential losses from using the technology in West Africa.

The change in total surplus and consumer and producer surplus do not vary much between Scenarios 2, 3 and 4 (Table 4). Neither, the distribution of outcomes varies much among these scenarios (Figures 2a, 2b and 2c). The probability distribution of change in total economic surplus for West Africa under Scenario 3 (Figure 2b) corroborates this statement. In this case, a very small reduction in the probability of obtaining negative outcomes within total economic surplus is observed in Scenario 3 (2.6 per cent) with respect to Scenario 2 (3.86 per cent). An example at the country level, in Burkina Faso, the probability of a negative change in total economic surplus is reduced from 5.8 per cent in Scenario 2 to 4.1per cent in Scenario 3. Similar reductions are observed for total, producer and consumer surplus in all countries in the region.

Policy and Institutional Issues

A review of the impact of Bt cotton in the developing world has shown that the technology can have a positive impact in small-scale farmers (see Smale *et al.* 2008), but that "much attention needs to be focused on the development of local institutions" (Tripp, forthcoming). Furthermore, the economic literature on the adoption of GM cotton has underlined the importance of taking into account the institutions in analyzing the success of these technologies, particularly within the context of small-scale agriculture.

The initial success of Bt cotton adoption in South Africa, for example, was derailed by the weakness in the institutional framework under it was initially developed, approved and commercialized (Gouse 2005). In China, the higher yields observed with Bt cotton was not matched with the expected reduction in insecticides, given the lack of information of proper management in hands of farmers (Pemsl 2005) and the lack of transparency in seed markets. These cases, as well as others, pinpoint how critical is it to address and understand the institutional framework - including formal and informal institutions - and to assess the possible institutional barriers to the successful deployment of Bt cotton or any other GM technology.

A common conclusion of many GM studies is stating the need of having in place effective biosafety regulations and increased investment in biotechnology as key factors in the successful commercialization of GM crops (Smale et al. 2008). A recent study of Bt Cotton by Tripp (forthcoming) concurs with this assessment but shows that "broader institutional issues … need to be addressed if biotechnology is going to have an impact in most developing countries." From the experience of other developing countries that have already adopted Bt cotton, several lessons can be learned by implementing groups in West Africa.

Innovation system: Countries face alternative options to ensure farmers have access to appropriate technology. Options include using technology developed by multinational companies, or by the international research system, or alternatively to develop the technology by themselves. The appropriate choice will depend on the development of the country's own innovation system and the level of financial and human resources, available to address the creation or adaption of appropriate technologies. In all cases, the need exist to have a functional system to characterize, conserve and improve genetic resources for agriculture, as they are the backbone of all crop and animal improvement systems.

Local adaptation of cotton varieties: Some countries such as Mexico, Colombia, and South Africa used foreign Bt varieties directly

Table 4: Average Present Values of Economic Benefits to the Cotton Sector, by Sector Actor and Country (Values in US$)

Country	Producer surplus	Innovator surplus	Consumer surplus	Total surplus without innovator	Total surplus
			SCENARIO 2		
Benin	7,397,656	11,381,600	203,629	18,931,930	7,550,328
BF	13,452,700	14,778,650	139,729	28,303,260	13,524,610
Mali	8,416,729	15,339,090	102,146	23,811,640	8,472,551
Senegal	553,824	1,305,254	91,535	1,904,289	599,035
Togo	3,045,468	5,172,745	20,321	8,192,210	3,019,465
ROW	4,073,093,000	2,794,727,000	1,477,385,000	8,345,204,000	5,550,478,000
			SCENARIO 3		
Benin	6,839,931	-	250,147	7,039,122	7,039,122
BF	12,850,065	-	171,652	12,953,894	12,953,894
Mali	7,404,722	-	125,483	7,483,881	7,483,881
Senegal	494,871	-	112,447	560,993	560,993
Togo	2,988,217	-	24,964	2,966,857	2,966,857
ROW	4,536,370,920	2,794,726,929	1,813,242,661	9,144,340,511	6,349,613,581

Table 4 continued

Table 4 continued

Country	Producer surplus	Innovator surplus	Consumer surplus	Total surplus without innovator	Total surplus
SCENARIO 4					
Benin	7,579,815	6,828,961	223,300	14,581,120	7,752,158
BF	13,789,120	8,867,198	153,230	22,747,890	13,880,690
Mali	8,525,793	9,203,451	112,017	17,794,940	8,591,486
Senegal	560,684	783,151	100,379	1,397,890	614,739
Togo	3,167,267	3,103,650	22,284	6,246,877	3,143,227
ROW	4,441,543,000	2,794,728,000	1,619,545,000	8,855,815,000	6,061,088,000
SCENARIO 5					
Benin	2,307,335	7,415,446	202,151	9,873,975	2,458,529
BF	13,499,500	14,778,660	138,715	28,349,060	13,570,390
Mali	848,027	9,085,328	101,405	9,988,436	903,108
Senegal	557,971	1,305,253	90,870	1,907,769	602,517
Togo	3,065,317	5,172,746	20,174	8,211,913	3,039,167
ROW	4,078,755,000	2,794,726,000	1,465,509,000	8,338,990,000	5,544,264,000

Note: 1) Scenario 1 is not presented here due to space constraints, 2) The values for producers, consumers and innovators surplus do not add to the value for total surplus and total surplus without innovator shown in the table. Values for all the components of surplus presented in each cell of this table are the average of the thousands of iterations undertaken in each scenario.

in the first stages of the adoption process. The policy of allowing foreign varieties may not be feasible in West Africa as many countries have strict regulations regarding the use of planting of varieties. If adaptation of the trait (Bt gene) into local varieties is viewed as a necessary process, additional time and funding will be required.

Institutional limitations: Successful diffusion of GM cotton in developing countries depends very much on strong public institutions, including the clear support of the government, a dynamic research sector, and the availability of credit for funding investments in agricultural inputs. An area of particular importance is the information that farmers need to have for the adequate management of a GM crop and the flow of information to and from producers regarding the technology and its place in society.

Despite the adoption of Bt cotton, many adopting countries (i.e. China, India, Colombia and others) are still overusing insecticides, mainly due to the lack of proper information regarding the management of the technology. In other countries, pesticides are barely applied or are applied using the wrong dosage for controlling insects. The later may be the case in West Africa as there is a history of low chemical use by farmers (Horna *et al.* 2008). Therefore, there is the need to establish an efficient and enabling knowledge sharing mechanism to ensure that farmers get the right information at the right moment. This is, of course, connected to the idea of developing trust in the sources of information and the knowledge networks that operate in many countries.

Legal Frameworks including Biosafety and IP

a) Biosafety

A regulatory process is needed for GM cotton varieties to be officially release in most countries. The biosafety regulatory process involves a risk assessment steps. Several actors and stakeholders including regulators, decision makers, users, and developers interact to define, assess and decide the outcome. Actors involved in this process may contribute to ensure biosafety assessment, testing, and the development of genetically modified crops; and provide support in training, capacity building, regulatory strategies and policy development. In most countries, one of the first steps for the approval of GM varieties is the implementation on confined field trials (CFTs). CFTs provide the technology developer and decision makers with the opportunity to evaluate the performance of GM plants. The CFTs allow collecting data required for the biosafety assessment, as well as, variety testing, registration, and seed certification purposes. The regulatory agency will supervise the implementation of the CFTs after the application form has been approved, as well as analyze data submitted by the proponent, and determine the appropriate course of action after commercial release stage has been approved.

One of the potential post release strategies, in the case of cotton, is the establishment of an insect resistant management strategy including the creation of a refugia. Hence, one critical issue is to evaluate, and recommend, if needed, insect resistance management practices along with the introduction of Bt cotton variety. Bt expression introduces selective pressures on a pest population. Eventually, individual pests that are resistant to the Bt protein will survive and thrive, rendering the technology obsolete. Scientists devised various strategies to lengthen the time until resistance occurs. One successful strategy to date has been setting aside areas planted with non Bt cotton varieties where resistant individuals mate with non-resistant individuals, thus diluting the proportion of resistant individuals. The set aside is called a "refugia".

There are different variations in terms of whether farmers are allowed to spray for non-target insects in the refugia and the relative area dedicated to the set aside. As indicated before, the refugia have been successful so far in delaying the appearance of resistance to the Bt gene under field conditions. Bt cotton was introduced back in 1996 in the United States and so far, no case of resistance has been observed, mainly due to the effective management of the refugia. Nevertheless, refugia requirements for GM crops are much more difficult to comply in areas characterized by smallholdings, which is the case of most cotton farmers in developing country. Not only farmers have to understand the importance of the refugia strategies but also there must be effective mechanisms to regulate its compliance. The roles that the private sector - including ginneries - and the public sectors will play have to be clearly defined and financed. The case in China merits some careful consideration as the refugia in this country has not been deemed necessary due to the farming system in place that seems to act as alternative refugia.

If target pests are present at high densities or populations persist for an extended period, the need may exist for supplemental insecticide applications to prevent further yield losses. Furthermore, even when there is adequate control of the target pests, secondary pests that used to be controlled – albeit indirectly – when controlling the target pest may become economically significant. Secondary pest evolution is a well-known issue in breeding and managing plant genetic resistance, which needs to be addressed as early as possible through variety release plans and regulatory approval processes. Integrated Pest Management (IPM) practices, scouting techniques, and agronomic management practices must keep pace with a changing pest population.

Another critical issue is the possibility of incidental gene transfer to wild cotton populations. Although this possibility is remote, some countries have chosen to limit the areas where Bt cotton is planted. In the US, Bt cotton varieties are not permitted for cultivation in the Southern part of Florida, Hawaii, U.S. Virgin Islands or Puerto Rico. In Mexico, Bt cotton varieties are not permitted for cultivation in the southern states, as there are wild relatives of cotton in the region. Interestingly enough, the possibility that modern cotton varieties may be able to cross sexually with wild relatives is very low.

b) Intellectual property right

In many countries in West Africa, governments and state owned enterprises freely distribute seed to farmers. Many questions arise from this approach. For example, how will IP issues affect innovation and science and technology in West Africa? Will the public sector attempt to recuperate some of the investments made in adaptive research? How is the technology fee for using the Bt technology going to be recuperated? Are there institutions to guarantee that the seed won't be multiplied illegally?

The later situation has indeed occurred in other countries who have used Bt cotton in the past including India and China. The other issue is stewardship and liability. Even in the case where private sector "donates" the technology free for use by producers, the national and international regulatory regime has not evolved sufficiently to create a regime that would address the issues of liability. Furthermore, the need exists to provide incentives to stakeholders, to ensure product stewardship along the production chain. Certainly, the donor, which may be a private sector organization, has the interest of protecting its technology for misuse. In essence, the mechanisms to alleviate the need to manage liability and to ensure product stewardship need to be in place to ensure proper technology deployment.

Cotton sector organization and coordination: In West Africa, the cotton sector has been evolving over time. Actors, vertical and horizontal coordination and commercialization channels have evolved responding to internal and external realities of cotton production, especially subsidies by industrialized and some developing countries to their own cotton production systems.

For example, Benin has reduced the role of the quasi-state enterprise SONAPRA and has introduced competition in the distribution of inputs and marketing of cotton but the government is still subsidizing the farmers (Minot and Daniels, 2004). Mali has privatized the state owned cotton seed company HUICOMA, and has created a new price setting mechanism that ties producer prices to world market prices but the CMTD (85 per cent owned by the government) controls most of the production, ginning and marketing of cotton (Basset, 2006).

One the one hand, the vertical institutional coordination mechanism in place in West Africa can ensure deployment of the Bt cotton technology in the region. On the other hand, this same coordination mechanism may introduce inefficiencies due to lack of competition and may in turn derail the proper introduction of the technology. The need exists for the state owned enterprises to evaluate the marketing channels and to provide the proper technology transfer support to ensure the proper deployment of the Bt cotton technology in the region.

Alternative production methods: Alternative production methods, including organic cotton production, have been growing at a fast pace in many parts of West Africa and other developing countries, but remain a small proportion of total area planted (Falck Zepeda 2006). If farmers consider this alternative production sector important, especially for its foreign market potential, planting GM crops could pose a risk for their viability. Ginneries and exporters could lose their certification, as the main market for organic cotton is Europe. In most cases, certification for these markets requires zero percent use of GM seed. If this is the case, there is need to examine closely the benefits, costs, and risks of managing a co-existence system. In addition, the need exists to explore the different mechanisms to guarantee segregation, labelling and traceability, which can be expensive for implementation.

Landlocked economies: Some countries in West Africa are landlocked. Their exports must pass through neighbouring countries to reach export ports. Ratifying parties to the Cartagena Protocol on Biosafety have to comply with article 19(1) "each Party shall take necessary measures to require that living modified organisms that are subject to intentional transboundary movement within the scope of this Protocol are handled, packaged and transported under conditions of safety, taking into consideration relevant international rules and standards.".

Such a measure would compel any Protocol member to likely include advanced inform consent and the possibility to label each shipment with a detail on the nature of the GM events included in the shipment. If a country, especially those ratifying parties to the Protocol, introduces one or more types of GM cotton in the future, it may have to test each shipment of cottonseed to make sure the labelling is correct or alternatively develop segregation, traceability and identity preservation systems to ensure the transboundary movement of GM materials. The cost of such procedures would be significant, even if it the shipment is only destined for a neighboring member country that has approved the same GM cotton event when passing through country that has not approved the GM cotton event. The issue of asynchronous approvals needs to be addressed urgently in West Africa and thus the need exists to explore regional approaches to biosafety and biotechnology assessment and decision-making.

Concluding Remarks

Policy makers in West Africa have a difficult task in front of them. On the one hand, decision makers need to screen and assess competing claims on the benefits, costs and risks of these genetically modified technologies and decide on their role in terms of improving producer productivity, increasing their resiliency and creating prosperity; on the other hand, they have to promote agricultural productivity while protecting the environment and biodiversity. The overarching goal of this paper is to contribute to the empowerment of decision makers in West Africa by discussing results of economic simulations but also discussing the potential institutional issues related to the adoption of Bt cotton in West Africa. The discussion in this paper can help support decision makers understand policy options and their trade-offs, while empowering them to choose strategies for the cotton sector in their countries.

Results from our simulations and from other papers in the literature indicate that West African governments need to ensure long-term productivity gains to match international levels and to compete with subsidies and other government support programmes in place in other cotton producing countries. These results show that West Africa is worse off when facing other countries adopting productivity enhancing technologies such as Bt cotton. West African countries will need to adopt productivity enhancing technologies to compete in global markets.

Several factors shape the level and distribution of net benefits derived from the potential adoption of Bt cotton in West Africa. A major factor is seed prices that include the technology premium. The technology fee has to balance the value of the pest damage relative to other constraints, as well as the potential pest control alternatives and producers' ability and willingness to pay. The amount charged for this technology fee will be critical in the successful deployment of the technology in the region.

Burkina Faso has taken the first step in the region with the approval of Bt cotton commercialization. This fact determined the leadership role in terms of first adopter in our simulations. Burkina Faso is posed to capture a larger share of benefits from this technology. This fact contrasts with the relative low gains across all producing countries in West Africa from the adoption of the technology. As introduced in the discussion, we have used advanced risk simulation methods, plausible assumptions and have considered both negative and positive outcomes. We may think of our results as the most likely outcome from negative and positive outcomes in our simulations. In absolute numbers, the largest cotton consumption occurs in Senegal. However, our simulations indicate that Benin is the country where consumers could potentially gain from Bt cotton adoption in the region, as they have the highest consumption of locally produced cotton.

Published studies on the impact of Bt cotton in other countries indicate that a larger share of benefits accrue to adopting producers. These findings do not hold in our simulations. The innovator captures the largest shares of benefits compared to the actors in the cotton sector. These results directly relate to the conservative assumptions used in our simulations. Thus, they may be thought as the lower bound estimates of gains from the adoption of Bt cotton in West Africa. At the same times, these results are a call for West African countries to focus on the proper deployment strategies and to anticipate issues related their deployment, in order to minimize and/or mitigate these issues before they become binding constraints.

Our discussion on the policy and institutional factors serve to emphasize the role that these issues have in relation to technology adoption. Policy makers need to address all these factors to ensure the deployment of proper technologies to maximize societal gains arising from technology adoption. Scenario 5 (irregular adoption patterns) powerfully highlight the need to address institutional constraints and thus address irregular adoption pattern issues such as benefits increasingly accruing to innovators. This fact has serious implications for the practice of socio-economic impact assessments particularly those done *ex ante*.

Practitioners need to understand, in-depth, the institutional and policy context in which agricultural biotechnologies are being deployed by developers. These factors need to be included into estimations and simulations in order to ensure proper assessments. There needs to be significant advances in terms of identifying methods to model robustly these developments. Our initial simulations for the case of Bt cotton in West Africa show the need for modelling policy and institutions clearly.

Can producers in West Africa gain from the adoption of Bt cotton? Even when taking into consideration all the limitations and caveats from our study, producer can gain from having at least one more technology choice to choose from such as Bt cotton. This technology can help resolve one specific productivity constraint and thus contribute to the overall goal of poverty alleviation in the region. Proper deployment of the Bt cotton technology will need to be situated within the scope of overall economic development. A prudent course of action will evaluate options and give Bt cotton a proper role in the global economic development process. In essence, two distinct recommendations arise from our study. First, governments in West Africa need to identify and promote appropriate incentives to choose the best from technology alternatives and, second, the need exists to identify and mitigate policy and institutional constraints that may limit the proper technology deployment in West Africa.

Endnotes

1 For a in depth description of scenario results and findings see Falck Zepeda, Horna and Smale (2008)

2 The order Lepidoptera is the second most prevalent species order in the class Insect, including butterflies, moths and skippers. Members of the order are referred to as lepidopterans.

3 We also conducted a regression analysis using @RiskTM in order to examine the sensitivity of our results to the assumptions underlying the structural model. Results are similar for producer surplus for all countries in West Africa. The levels of expected producer surplus are most heavily influenced by yield performance in

ROW and by price elasticities, followed by yield performance in each country, cost and other parameters of the structural model. In addition, we performed and advanced sensitivity analysis of the simulation results. We allowed positive and negative changes of 10 per cent steps in key parameters and performed repeated simulations with these values. In general, the advanced sensitivity analysis showed that our results are robust to changes in distribution parameters.

References

Ajayi, O., M. Camara, G. Fleisher, F. Haidara, M. Sow, A. Troare, and H. van de Valk, (2002). "Socio-economic Assessment of Pesticide use in Mali". Special Issue Publication Series No.6. *Hannover*, Pesticide Policy Project.

Alston, J. M., G. W. Norton and P. G. Pardey (1995). "Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting". Ithaca and London: Cornell University Press.

Baffes, J., (2004). "The Cotton Problem". *World Bank Research Observer* 20(1): 109-143.

Bennett, R., Y. Ismael, and B. Shankar (2004). "Reductions in Insecticide use from Adoption of Bt Cotton in South Africa: Impacts One Economic Performance and Toxic Load to the Environment", *Journal of Agricultural Science* 142(6): 665-674.

Bennett, R., U. Kambhampati, S. Morse, and Y. Ismael (2006a). "Farm-level Economic Performance of Genetically Modified Cotton in Maharastra, India". *Review of Agricultural Economics* 28(1): 59-71.

Bennett, R. S. Morse, Y. Ismael (2006b). "The Economic Impact of Genetically Modified Cotton on South African Smallholders: Yield, Profit and Health Effects". *Journal of Development Studies* 42(4): 662-667.

Cabanilla, L., T. Abdoulaye, and J. Sanders (2005). "Economic Costs of Non-adoption of Bt-Cotton in West Africa: With Special Reference to Mali". *International Journal of Biotechnology* 7(1/2/3):46-61.

CAB International (2001). Crop Protection Compendium. Wallingford, UK: CAB International.

Delgado, C., and N. Minot (2000). "Agriculture in Tanzania since 1986: Follower or Leader of Growth". World Bank Country Study. The World Bank and the International Food Policy Research Institute, Washington, DC.

Dercon, S. (1993). "Peasant Supply Response and Macroeconomic Policies: Cotton in Tanzania". *Journal of African Economics* 2(2), 157–193.

Elbehlri, A., and S. MacDonald (2005). "Estimating the Impact of Transgenic Bt Cotton on West and Central Africa: A General Equilibrium Approach". *World Development* 32(12): 2049-64.

Falck Zepeda, J. B., D. Horna, and M. Smale (2008). "Betting on Cotton: Potential Payoffs and Economic Risks of Adopting Transgenic Cotton in West Africa". *African Journal of Agricultural and Resource Economics* 2(1):188-207.

Falck Zepeda, J. and J. Cohen (2006). "Biosafety Regulation of Genetically Modified Orphan Crops in Developing Countries: A Way Forward." in Richard Just, Julian Alston, David Zilberman (eds.) *Regulating Agricultural Biotechnologies and Policy*, Springer Editors.

Falck-Zepeda, J., G. Traxler, and R. G. Nelson (2000a). "Surplus Distribution from the Introduction of a Biotechnology Innovation". *American Journal of Agricultural Economics* 82: 360 - 369.

Falck-Zepeda, J., G. Traxler, and R. G. Nelson (2000b). "Rent Creation and Distribution From Biotechnology Innovations: The Case of Bt Cotton and Herbicide-Tolerant Soybeans in 1997." *Agribusiness* 16: 21-32.

FAO Statistics, (2005). "Imports and Exports of Selected Agricultural Commodities", Group III. Internet address: http://www.fao.org/es/ess/yearbook/vol_1_1/pdf/c16.pdf. Date of search July 2007.

Gouse, M., J. Kirsten, B. Shankar and C. Thirtle, (2005). "Bt Cotton in KwaZulu Natal: Technological Triumph but Institutional Failure". *AgBiotechNet* 7(134): 1-7.

Hareau, G. G., B. F. Mills, and G. W. Norton (2006). "The Potential Benefits of Herbicide-Resistant Transgenic Rice in Uruguay: Lessons for Small Developing Countries." *Food Policy* 31 (2): 162-179.

Huang, J., R. Hu, V. H. Meijl, and F. V. Tongeren (2004). "Biotechnology Boots to Crop Productivity in China: Trade and Welfare Implications". *Journal of Development Economics* 75(1): 27-54.

Huang J., R. Hu, C. Pray, F. Qiao, and S. Rozelle (2003). "Biotechnolgy as an Alternative to Chemical Pesticides: A Case Study of Bt Cotton in China". *Agricultural Economics* 29(1): 55-67.

ICAC (2004). "Survey of the Cost of Production of Raw Cotton". International Cotton Advisory Committee. Washington, DC. pp.106.

ICAC (2006). "World Cotton Trade 2005/06". International Cotton Advisory Committee. Washington, DC. pp. 209.

James, C. 2007. "Global Status of Commercialized Biotech/GM Crops: 2007". *ISAAA Briefs No. 37*. International Service for the Adquisition of Agri-Biotech Appplications : Ithaca, NY

Martin, T., F. Chandre, O. G. Ochu, M. Vaissayre, and D. Fournier (2002). "Pyrethroid Resistance Mechanisms in the Cotton Bollworm Helicoverpa Armigera from West Africa". *Pesticide Biochemistry and Physiology* 74:17-26.

Minot, N. and L. Daniels (2005). "Impact of Global Cotton Markets on Rural Poverty in Benin". *Agricultural Economics* 33, supplement 453–466

Moschini, G., and H. Lapan. (1997). "Intellectual Property Rights and the Welfare Effects of Agricultural R&D". *American Journal of Agricultural Economics* 79(4): 1229-1242.

Ochout, G. O., G. A. Matthews, J. D. Mumford (1998). "Comparison of Different Strategies for Cotton Insect Pest Management in Africa". *Crop Protection* 17(9): 735-741.

Oerke, E.C., H.W. Dehne, F. Schohnbeik, and A. Weber (1995). Crop Production and Crop Protection: Estimated Losses in Major Food and Cash Crops. Amsterdam: Elsevier.

Pemsl, D. E.,H. Waibel, A. P. Gutierrez (2005) "Why do some Bt-cotton Farmers in China Continue to use High Levels of Pesticides?." *International Journal of Agricultural Sustainability* (3):44 -56.

Pemsl, D., H. Waibel, and J. Orphal. (2004). "A Methodology to Assess the Profitability of Bt Cotton: Case Study Results from the State of Karnataka, India". *Crop Protection* 24(12):1249-1257.

Pray, C., D. Ma, J. Huang, and F. Qiao (2001). "Impact of Bt Cotton in China", *World Development* 29(5): 813 - 825.

Pray, C. E., P. Bengali, and B. Ramaswami (2005). "The Cost of Regulation: The India Experience. *Quarterly Journal of International Agriculture* 44(3): 267-289.

Qaim, M., and A. D. Janvry (2005). "Bt Cotton and Pesticide Use in Argentina: Economic and Environmental Effects". *Environment and Development Economics* 10(2): 179-200.

Qaim, M., E. J. Cap, and A. D. Janvry (2003). "Agronomics and Sustainability of Transgenic Cotton in Argentina". *AgBioForum* 6(1&2): 41-47.

Qaim, M., A. Subramanian, G. Naik, and D. Zilberman (2006). "Adoption of Bt Cotton and Impact Variability: Insights from India". *Review of Agricultural Economics* 28(1): 48-58.

Quemada, H. (2003). "Developing a Regulatory Package for Insect Tolerant Potatoes for African Farmers: Projected Data Requirements for Regulatory Approval in South Africa". Paper presented at the symposium Strengthening Biosafety Capacity for Development, June 9-11, Dikhololo, South Africa.

Smale, M., P. Zambrano, J. Falck-Zepeda, and G. Gruère (2006a). "Parables: Applied Economics Literature about the Impact of Genetically Engineered Crop Varieties in Developing Economies". IFPRI Environment and Production Technology Division Discussion Paper 158, IFPRI, Washington.

Smale, M., P. Zambrano, and M. Cartel (2006b). Bales and Balance: A Review of the Methods Used to Assess the Economic Impact of Bt Cotton on Farmers in Developing Economies. *AgBioForum*, 9(3): 195-212.

Silvie, P., J. P. Deguine, N. S. Michel, and M. Vaissayre(2001). "Potential of Threshold based Interventions for Cotton Pest Control by Small Farmers in West Africa", *Crop Protection* 20(4): 297–301.

SWAC Secretariat /OECD (2005). "Economic and Social Importance of Cotton in West Africa: Role of Cotton in Regional Development, Trade and Livelihoods". Sahel and West Africa Club (SWAC) Secretariat, OECD, SAH/D(2005)556.

Traxler, G., S. Godoy-Avila, J. Falck-Zepeda, and J. D. J. Espinoza-Arellano (2003). "Transgenic Cotton in Mexico: Economic and Environmental Impacts of the First Generation of Biotechnologies" in N. Kalaitzandonakes eds., *The Economic and Environmental Impacts of Agbiotec: A Global Perspectives*, New York: Kluwer- Plenum Academic Publishers.

Tripp, R. (ed). Forthcoming. Biotechnology and Agricultural Development: Transgenic Cotton, Rural Institutions and Resource-Poor Farmers. R. London: Routledge.

UNCTAD (2006). "Market Information in the Commodities Area: Cotton Chain", UNCTAD: http://ro.unctad.org/infocomm/anglais/cotton/chain.htm.

Vitale, J., T. Boyer, R. Uaiene, and J. H. Sanders (2007). The Economic Impacts of Introducing Bt Technology in Smallholder Cotton Production Systems of West Africa: A Case Study from Mali. *AgBioForum* 10 (2): 71-84.