Who benefits from the adoption of Bt cotton in Burkina- Faso?

COMLANVI KONOU
Department of Economics, University of Nebraska- Lincoln, USA
konous2004@yahoo.fr

Abstract

The objective of this paper is to assess the effect of Bt (*Bacillus thuringiensis*) varieties on cotton yield and the amount of insecticides used in cotton field in Burkina- Faso upon the adoption of Bt cotton after 2005. In the paper, we use a simple version of a Muth model to assess the welfare effect of the adoption of Bt cotton in Burkina- Faso. Using the survey data from SOFITEX, SOCOMA and Faso Coton, we consider a single output and five inputs under the conditions of competitive markets. The results show a rise in yield and a reduction in the amount of insecticides used upon the adoption of Bt cotton in Burkina-Faso. In terms of welfare effect , an increase in the consumer surplus, in the producer surpluses of Seed company, fertilizer and herbicide supplier, workers and " land owners"; but a decrease in the producer surplus of the insecticides suppliers are found.

Keywords: Bt technology, Burkina-Faso, Welfare effect.

Background

From the literature, there are so many studies that have been done to evaluate the impact of the adoption of Bt crops on the yield and on the use of pesticides. Specifically, the issue of the adoption of Bt cotton has been commonplace for more than a decade and has been addressed in a variety of papers with different methods. De Janvry and Qaim (2005), in order to estimate the effect of the adoption of Bt cotton on insecticide use, regress the amount of insecticide use on explanatory variables such as Bt as dummy variable, insecticide/ cotton price ratio (P), cumulative Helicoverpa Armigera density (a pest) and agro ecological and entomological conditions of the cotton field in Argentina and India. In their paper, the impact of Bt adoption on the yield was econometrically estimated by regressing the yield of raw cotton on a Bt dummy variable and X, a vector of inputs used which are the same explanatory variables mentioned above. But since the insecticides are also dependent on other factors of production, there is potential endogeneity of inputs which brought the use of instrumental variables approach. Recent studies show that upon the adoption of Bt cotton there were significant pesticides and cost saving in most cotton-producing regions in the USA and China (Carpenter et al., 2002; Pray et al., 2002; Huang et al., 2002a). We provide the description of the results of some studies that evaluate the adoption of Bt cotton in some cotton producing countries in Table 1.

Theoretical Model

We use a transparent model to approximate the welfare impacts of a new technology **(**Perrin**,** 2011**)**. The simple case considered is a competitive industry producing a single output with *m* inputs, describing the technology with a cost function rather than a production function, expanding substantially on the approach of Richard Muth.

Represent the per hectare technology with the dual cost function, C(y,$\mathbf{w}$, t), where y is output (sold at price p), and $\mathbf{w}$ is an $mx1$ vector of prices for the input vector $\mathbf{x}$, and t represents technological change. Assume this cost function exhibits constant returns to scale and homotheticity in the vicinity of equilibria considered. Land in number of hectares N is supplied to the cotton industry at price r. The initial zero-profit equilibrium in product and factor markets can be expressed by the following system of equations.

Output demand a. $Ny = f(p)$, with demand elasticity ε,

cost = revenue b. $C+r = yp$,

MC=price, b'. $C_y = p$

(1) input demand c. $C_{\mathbf{w}} = x$, (from Shepard's lemma)

input supply d. $N\mathbf{x} = g(\mathbf{w})$ with supply elasticity matrix Σ,

Land Supply d'. $N=h(r)$ with supply elasticity σ.

Following the logic of comparative statics, total differentiation of this system of equations, converted to natural logarithms, can be expressed as:

(2)

$$a.d\ln N + d\ln y = \varepsilon d\ln p$$

$$b.\ (1\text{-}k)[sd\ln w - \delta dt] - kd\ln y + kd\ln r = d\ln p$$

$$b'.kd\ln w - \mu d\ln y + \delta dt = d\ln p$$

$$c.ld\ln y + E_{xw}dlw + (B - l\delta) = d\ln x$$

$$d.ldnN + d\ln x = \sum d\ln w$$

$$d'.d\ln N = \sigma d\ln r$$

Where:

s =input share

δ = dual rate of the technical change

k = share of land

μ = elasticity of marginal cost

E_{xw} = output- constant derived demand elasticity matrix

Σ = output Supply elasticity matrix

B =input bias vector of technological change

ι = unit vector

Results for (2) are derived using the following relationships and definitions

$$C_y = p\text{, by Hotelling's lemma}$$

$$\mathbf{C}_w = \mathbf{x}\text{, by Shepard's lemma}$$

(3) $\mathbf{C}_{wy} = \mathbf{C}'_{yw} = \hat{\mathbf{x}}\mathbf{E}_{xy}y^{-1}$, where $\mathbf{E}_{xy}$ is elasticity of derived demand for $\mathbf{x}$ wrt y,

under CRS, $\mathbf{E}_{xy} = \iota$ (the unit vector) $\Rightarrow \mathbf{C}_{wy} = \mathbf{x}y^{-1}$, the input intensity vector

$\mathbf{C}_{ww} = \hat{\mathbf{x}}\mathbf{E}_{\mathbf{xw}}\hat{\mathbf{w}}^{-1}$, where $\mathbf{E}_{xw}$ is the output - constant derived demand elasticity matrix

$$\delta(\text{w, y, t}) \equiv -\frac{\partial}{\partial t}\ln \text{C} = -\frac{\partial}{\partial t}\ln \text{AC},$$
$$= -\text{C}^{-1}\text{C}_t\text{, (the dual rate of technological change),}$$

and

(4)
$$\beta_i(\text{w, y, t}) \equiv -\frac{\partial}{\partial t}\ln k_i = -\frac{\partial}{\partial t}\ln \text{x}_i(\text{w, y, t}) - \delta(\text{w, y, t})\text{, or in matrix notation,}$$
$$\mathbf{B}(\text{w, y, t}) = \hat{\mathbf{x}}^{-1}\mathbf{C}_{wt} + \delta(\text{w, y, t})\iota\text{, (the input bias vector of technological change).}$$

The dual rate of technological change is shown on the figure 1 and the input bias vector of technological change is shown on the figure 2

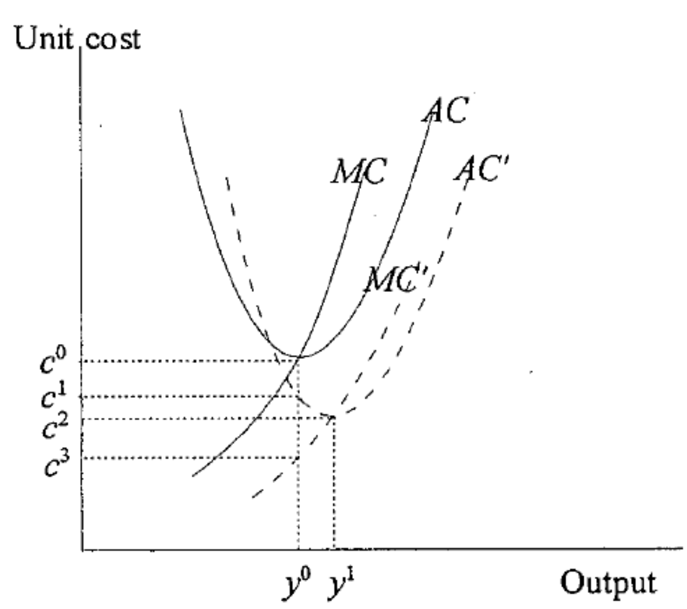


Figure 1. Rate and size bias of technological change

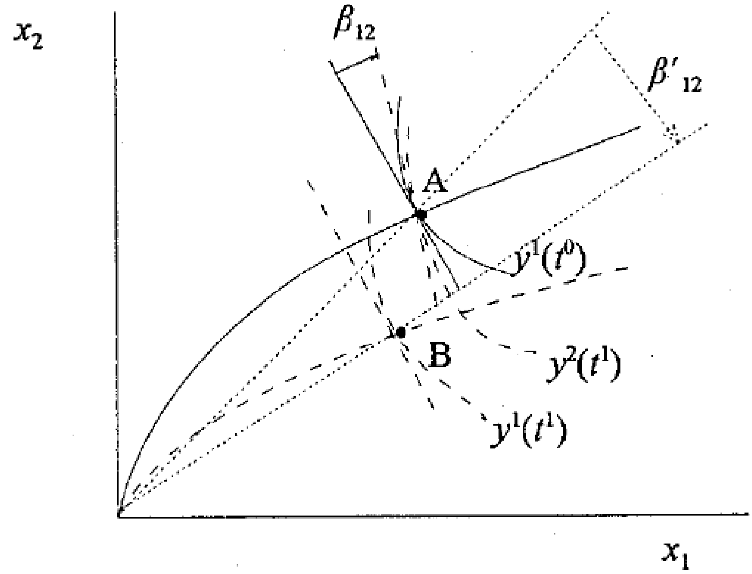


Figure 2. Input bias of technological change

Moving endogenous variables to the left and detaching coefficients, the log-differential comparative statics equations in (2) could be represented in matrix notation as

(5)

$$\begin{pmatrix} 1 & -\varepsilon & 0 & 0 & 1 & 0 \\ -k & -1 & k & (1-k)s & 0 & 0 \\ -\mu & 1 & k & 0 & 0 & 0 \\ l & 0 & 0 & Exw & 0 & -I \\ 0 & 0 & 0 & -\Sigma & I & I \\ 0 & 0 & -\sigma & 0 & I & 0 \end{pmatrix} \begin{bmatrix} d\ln y \\ d\ln p \\ d\ln r \\ d\ln \mathbf{w} \\ d\ln N \\ d\ln \mathbf{x} \end{bmatrix} = \begin{bmatrix} 0 \\ (1-k)\delta \\ -\delta \\ -(B-l\delta) \\ 0 \end{bmatrix} \mathrm{dt}$$

with solution

(6)
$$\begin{bmatrix} d\ln y \\ d\ln p \\ d\ln r \\ d\ln \mathbf{w} \\ d\ln N \\ d\ln \mathbf{x} \end{bmatrix} = inv \begin{pmatrix} 1 & -\varepsilon & 0 & 0 & 1 & 0 \\ -k & -1 & k & (1-k)s & 0 & 0 \\ -\mu & 1 & k & 0 & 0 & 0 \\ l & 0 & 0 & Exw & 0 & -I \\ 0 & 0 & 0 & -\Sigma & I & I \\ 0 & 0 & -\sigma & 0 & I & 0 \end{pmatrix} \begin{bmatrix} 0 \\ (1-k)\delta \\ -\delta \\ -(B-l\delta) \\ 0 \end{bmatrix} \mathrm{dt}$$

Here the equilibrium displacements resulting from the technological change are approximated based on parametric characteristics of the technological change. While parametric evaluations of the inverse are possible (Perrin, 1997) in general it is more practical to solve the system numerically in a spreadsheet.

Welfare impacts can be approximated by changes in simple consumer and producer surplus. Change in product consumers' surplus due to the technological change is the sum of the rectangle measured by the change in equilibrium product price times initial quantity plus the triangle measured by half of the change in price times the change in equilibrium quantity. Change in producers' surplus in each of the input markets is measured by a comparable trapezoid under the new price for that input. Thus, the welfare impacts of the technological change can be expressed as:

$$\Delta CS = -p^0 d\ln p\ y^0 \left[1 + \left(p^0 d\ln p\right)\left(y^0 d\ln y\right)/2\right] = -p^0 y^0 d\ln p(1 + d\ln y/2),$$

(7) and for each input i,

$$\Delta PS_i = w_i^{\ 0} d\ln w_i\ x_i^{\ 0}\left[1 + \left(w_i^{\ 0} d\ln w_i\right)\left(x_i^{\ 0} d\ln x_i\right)/2\right] = w_i^{\ 0} x_i^{\ 0} d\ln w_i (1 + d\ln w_i/2)$$

These welfare measures are expressed essentially as a fraction of the initial market value of the commodity (then multiplied by that value), which is often a more comprehensible measure than the dollar value itself. Because this is modeled as a zero profit industry, all receipts are paid out to inputs, so there is no surplus to firms in the industry, either before or after the technological change. Residual claimants on revenues, such as landowners or farm managers, must be included among the *m* inputs for the model to be complete.

Data Description

To characterize the change in cotton technology we use the survey data from SOFITEX, SOCOMA and Faso Coton provided in the research conducted by Vitale et al (2010). The surveys were conducted on 160 households in 10 villages the summer and the fall of 2009 by the Institute National Environment et Agricole (INERA). The inputs that are considered are seeds, insecticides, labor and fertilizer& herbicide. Other inputs were considered constant like in Vitale's paper (2010) but we include land among the inputs because we think the cost of land may have some effects on the surplus changes. More light will be shed on this later in the paper. We approximate the nature of the technology and the technological change using simple budget data presented in Table 2. Initial input shares of non-land costs are about 2.29% for seeds, 14.98% for insecticides, 36.68% for labor and43.46% for fertilizer& herbicide. Percentage changes in these shares identify the input biases of the technological change B, and the change in unit cost identifies the rate of technical change δ. This dual rate of technological changes equal to 0.17 and the biases of seeds, insecticides, labor and fertilizer&herbicide are 3.410; -0.9.07; 0.004 and -0.005 respectively.

Elasticities

The elasticities of output demand is assumed to be high (ε=10) because Burkina-Faso exports 100% of the cotton produced, with little if any effect on the world price. As for μ marginal cost elasticity, we assume that it is between zero 0 and 1, but in the context of this analysis we chose μ to be equal to 0.5.

The elasticity of land supply σ =10 is expected to be large because in Burkina-Faso farmers own their land or some farms belong to the whole family through inheritance. However, since land is an input, we value it at the rental rate of Cameroun which is r =$10.04/ha (ICAC, 2010) because there is no information on land for Burkina- Faso. By including land in this study, our goal is to use sensitivity analysis to test whether the elasticity of land supply do have some effect on the change of its producer surplus due to the adoption of Bt cotton.

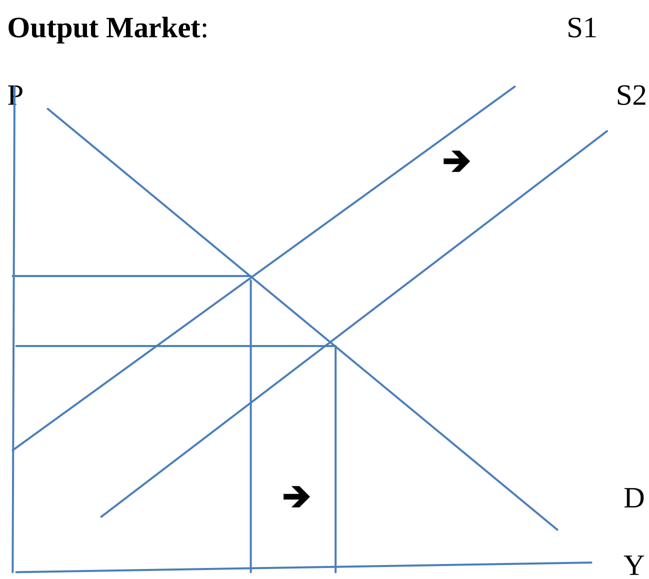
Table 3 shows the derived demand elasticity matrix of seed, insecticides, labor and fertilizer&herbicide. By imposing the cost function to be homogenous of degree one, the inputs derived demand from Shepard's lemma is homogenous of degree zero. Therefore; the elasticities of inputs derived demand should sum to zero assuming that reciprocity is imposed. Table 4 shows the elasticities of inputs supply assuming that the cross elasticities are zeros in the sense that the change in the price of seeds for example does not have any impact on the quantity supplied of the herbicides. Similarly, the change in the price of insecticides for example has no effect on the quantity supplied of labor

The solution to our model is depicted in Equation (6) which allows us to express the changes in the endogenous variables in terms of the parameters characterizing the effect of the technological change. The adoption of Bt technology in the cotton field has impact on both output market and inputs markets. From row four of the solution, we could see that the impacts on the inputs prices are dependent upon the inputs elasticities (E_{xw}), inputs biases of technological change (B) and the dual rate of technology (δ). In addition, from row three of the solution, it is obvious that the output price is reduced by the dual rate of technological change plus the share-weighted average of these inputs price changes upon the adoption of Bt technology.

Moreover, the fifth row of the solution shows that the amount of inputs is dependent upon the output-constant input supply elasticities. From table 5, cotton yield increases by 45.74% per hectare and the amount of insecticides has declined by 68.22% per hectare. In addition, the quantity demanded of the remaining inputs has increased due to Bt technology which requires a large amount of those inputs. In other words, the technology requires more of non-insecticides inputs for the yield to rise. The graphs of output depicted below describe the effect of Bt technology on the output supply curve which shifts to the right causing the price of the cotton output to fall and the quantity supplied of cotton to rise. We should note that the changes in the output and its price are dependent on the output demand elasticity. We presumed this elasticity to be high (ε=10) because Burkina- Faso as a small country can only have slight effect on the world price of cotton and since it exports almost 100% of its cotton produced the large output demand elasticity is quite consistent. In addition, in the markets of insecticides, the adoption of Bt technology has caused both prices and quantity demanded of insecticides to fall. The solutions of the system are closely related to all the elasticities that were guessetimated but following the theory on the output and inputs markets, the results are quite consistent.

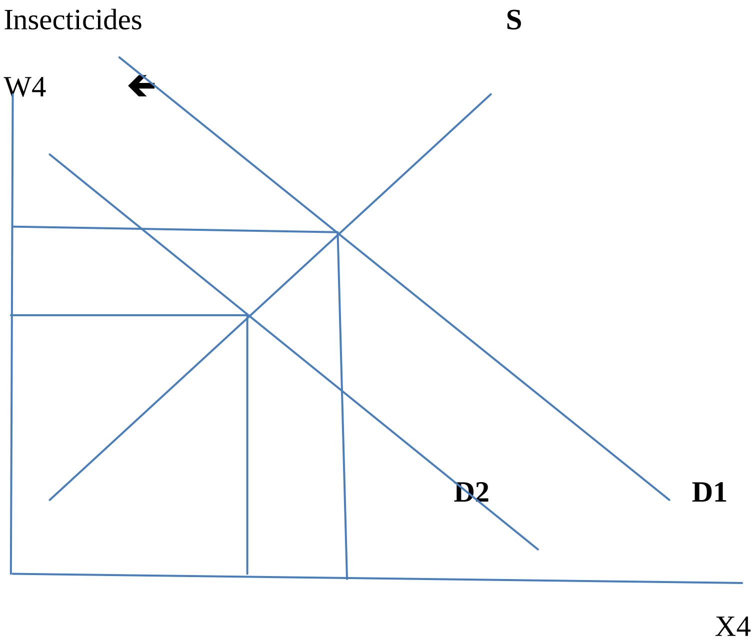
Graphs

Output Market:

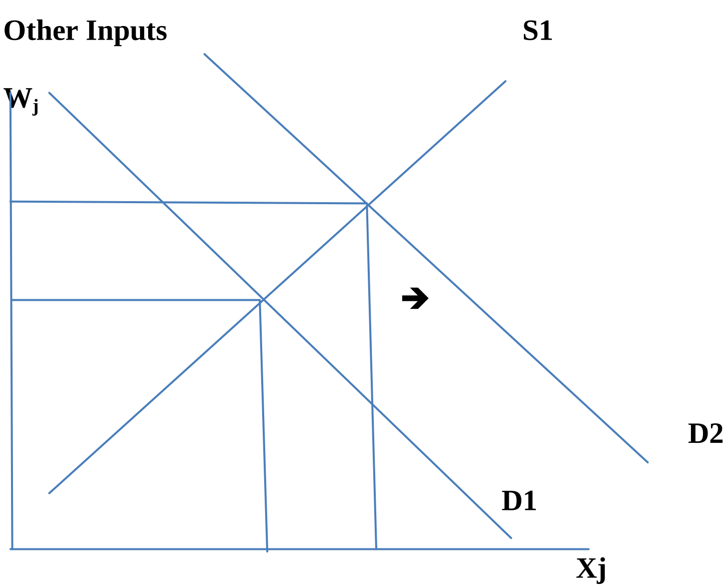


Inputs Market

Insecticides



Other Inputs



Welfare effect

The consumer surplus has increased by 7% as percent of crop value upon the adoption of Bt cotton. Since Burkina-Faso exports almost 100% of its cotton produced, the importers of cotton will benefit from this high level of exports. In this analysis, we are more interested in the effect on producer surplus. From table 6 we express the producer surplus on each input in terms of the cost of the inputs before the adoption of Bt cotton. For example, the change in producer surplus on seed has increased by 175% of initial seed cost, 12% of initial wage, 20% of initial cost of fertilizer/ herbicide and 1% of the original land rent.

As a result, the seed company (Monsanto) is making more benefit than any other stakeholders involved in cotton production in Burkina- Faso. The increase of 12% of initial wage was accrued to the local farmers. Also since the cotton production is labor intensive in Burkina- Faso, there is an increase in the labor demand due Bt technology. As economic impact the unemployment rate in the cotton producing regions will decline. Fertilizer/Herbicide companies are also going to make profit from the adoption of Bt cotton. The reason that the change in land- owner surplus is small, is explained by the high supply elasticity of land (σ =10). Since the farming-land markets are not that active in Burkina-Faso, there is a smaller change in the price of farming- land compare with the change in quantity supplied of farming-land.

We examine the sensitivity of the results to different values for land elasticity, ranging from 1 to 10. As table 7 shows, our estimates of welfare impacts are strongly insensitive to alternative assumptions within this range. The change in producer surplus on insecticide has decreased by 20% of the initial cost of the insecticides which is a loss for the insecticides companies. However, the decreases in both prices and the amount of insecticides used on cotton have been a benefit for the farmers in the sense that farmers are saving the cost on insecticides.

Conclusion

To sum up, the adoption of Bt cotton in Burkina-Faso has increased not only yield and decreased the use of insecticides but also has generated some losers and gainers. Obviously, there are more gainers than losers from Bt adoption in Burkina-Faso. Even though, our results were based on guessing the elasticities, they are quite consistent with the theory and we have some faith to provide more accurate results by having access to the data both for all the regions and for all the inputs used. The results show that the gainers are the seed suppliers (Monsanto), workers in the cotton field since they are being employed and also the producers of the fertilizers/herbicides. Similarly, the producers of insecticides used in the cotton field are the losers since the reduction of insecticides use is the key objective of the technology. We consider these results as preliminary because of the fact that we could not estimate the elasticities due to the lack of data. In terms of robustness of our results, we could econometrically estimate the elasticities from the cost function. Our work could be extended by assessing the health and environmental effect of the adoption of Bt cotton.

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Appendix

Table 1: Summary of Bt cotton adoption studies

Countries	Year of adoption[1] and rate[1]	Author and methods used	Dependent Variables	Explanatory Variables	Findings
Argentina	1995 (0.7%) 1998 (3.6%) 2000(5.4%) 2001/02(5%)	De Janvry and Qaim (2002) IV estimates in Insecticide and Quadratic specification of yield function	1-Insecticide 99/00;00/01 2-Insecticide reduction 2000 3- Yield (1 & 2 are explanatory variables) 1.(n=358) 2.(n=70) 3.(n=358) 4-Damage control specification Y= F(X)G(Z) Z is the pest agents G(Z) is the damage control function X inputs	Bt (dummy) Insecticide/cotton price ratio Bollworm pressure Leafworm pressure Other lepidopteran pressure Plant bug pressure Sucking pest pressure Irrigated (dummy) Climate (1–5 scale) Good soil quality (dummy) Farm size (owned land) Education Age Adjusted R2 :0.434	1.a Bollworm pressure is highly significant 0.199(5.53);.0.2(6.33) 1.b Bt – 1.171 (-5.85) 2.Bollworm pressure is significant 0.181(2.99) 3.a Insecticide predicted 216.79(3.46) 3.b Bt 506.29(6.66) 4. a Seeds 293.47(3.65) 4.b Irrigated 241.36(1.94) 4.c Bt 2.42 (1.93)
India	March 2002 25% in 2005	Matin Qaim (2003) Productivity effect with damage control specification Generalized Cobb – Douglas of yield function	1. Estimated pesticide use(n=471) 2. Yield(n=455) 3.Damage control Specification	Bt (dummy) Bollworm Season length (days) Soil quality Education Age Madhya Pradesh Tamil Nadu Adjusted R2 : 0.344	1.a Bt -0.379 (-10.27) 1.b Bollworm 0.093 (2.19) 2. bt-insecticide -0.346(-1.53) 3.bt 2.199(1.93)

China	1997 year of adoption 80% in 2000 Shandong 97% in 2000 in Hebei	<--James Clives, 2001 Pray et al.,2002→	The average saving in formulated insecticide was 4.3kg/ha equivalent to 67% reduction in insectides	Bt varieties yielded about 10% more than non-Bt varieties(James Clives,2001)	
Australia	8% 1996-1997 30% 2001-2002	<--James Clives ,2001	The average number of sprays required by Bt cotton is 40% less than that required by non-Bt	*The average yield of Bt cotton 1996 - 2000 was 7.8, and bales/ha for non-Bt cotton (Clives,2001)	
South Africa	1998 10% in 1998 45% in 2000/2001 In Makhathini 10% in 1998 to 92 % in 2002	Kirsten et al., 2002	In Makhathini 1998-2000 Yield + 24% Pesticide saving + 32% Seed cost -67% Ismael et al.,2001		
USA	1996 14% in 1996 34% in 2001 (Edge et al, 2001)		Insecticide reduction 907 MT in 1998; 1,224 MT in 1999 and 848 MT in 2001(Carpenter and Gianessi, 2001; Gianessi et al.,2002)	Production increases by 80704 MT in 1998;117935 MT in 1999 and 84085 MT in 2001	
Mexico	1996	1% in 1996 15% in 1998 35% in 2001.(James Clives, 2001	Yield increase by 3% in 1997 and 20% in 1998 (Traxler et al.,2001)	2.26 and 3 sprays saved in 1997 and 1998 respectively	

Table2. Budget data for calculation of input shares and technical change parameters

	Non-Bt				**Bt**	Share	Input Biases
Item:		value	%		value	%	**3.410**
seeds		8.88	0.02354126		62.36	0.16418303	**-0.970**
Insecticide		58	0.1537605		5.42	0.01426992	**0.004**
labor		142.04	0.37655417		143.75	0.37846875	**-0.005**
fert&herb		168.29	0.44614406		168.29	0.4430783	
Cost per ha		377.21	1		379.82	1	
Land		10.04	0.0259264		10.04	0.02575283	
Total Inputs Cost		387.25			389.86		
yield		997			1213		
Cost per kg		0.378345			0.313124		
price		0.35			0.35		
Gr Rev		354.32			418.83		
Net Rev		213.549			503.039		
delta δ		**0.17**					

Table2 source: Vitale et al, 2010

a Land for cotton per ha in Cameroun: ICAC, Cost of production of raw cotton, September 2010

Table 3: Input Derived Demand Elasticities

	dlnwSeed	dlnwINS	dlnwLab	dlnwFert/herb
dlnSeed	**-0.005**	**0.0016**	**0.002**	**0.0014**
dlnINS	**0.0013**	**-0.004**	**0.0017**	**0.001**
dlnLab	**0.002**	**0.003**	**-0.006**	**0.001**
dlnFert/herb	**0.001**	**0.0015**	**0.0005**	**-0.003**

Table 4: Input Supply Elasticities

	dlnwSeed	dlnwINS	dlnwLab	dlnwFert/herb
dlnSeed	**3.4**	**0**	**0**	**0**
dlnINS	**0**	**2.5**	**0**	**0**
dlnLab	**0**	0	**3.5**	**0**
dlnFert/herb	**0**	**0**	**0**	**2.25**

Table 5: The effects of Bt technology on the dependents variables of the system

dlny/dt	**45.74%**
dlnP/dt	-5.81%
dlnrLand/dt	1.23%
dlnwSeed/dt	112.12%
dlnwINS/dt	-22.36%
dlnwLab/dt	11.79%
dlnwFert&herb/dt	17.93%
dlnLand/dt	12.32%
dlnSeed/dt	368.89%
dlnINS/dt	**-68.22%**
dlnLab/dt	28.96%
dlnFert&herb/dt	28.03%

Table 6: Summary of Welfare effect on the stakeholders

Consumer Surplus						
P0*y0	348.95					
dlnp	-0.058053					
dlny/2	0.228681					
(1+dlny/2)	1.228681					
	-24.890123					
ΔCS	**24.890123**					
ΔCS/P0*y0	**7%**					
Producer Surplus		**Seed**	**Insecticide**	**labor**	**Fertilizer/herbicide**	**Land**
share non- Bt		0.022931	0.149774048	0.366791	0.434577147	0.025926404
Total cost non-Bt		387.25	387.25	387.25	387.25	387.25
w0*x0		8.88	58	142.04	168.29	10.04
dlnw		1.121195	-0.223612398	0.117947	0.179333144	0.012316804
1+dlnw/2		1.560598	0.888193801	1.058973	1.089666572	1.006158402
ΔPS		**15.53765**	**-11.51944644**	**17.74115**	**32.88610976**	**0.124422263**
ΔPS/w0*x0		**175%**	**-20%**	**12%**	**20%**	**1%**

Table 7: Sensitivity Analysis

			Surplus changes			
		Seed	insecticide	Labor	Fertilizer&Herb	land
(σ=1;μ=0.5;ε=-10)		175%	-20%	12%	19%	12%
(σ=2;μ=0.5;ε=-10)		175%	-20%	12%	19%	6%
(σ=3;μ=0.5;ε=-10)		175%	-20%	12%	19%	4%
(σ=4;μ=0.5;ε=-10)		175%	-20%	12%	19%	3%
(σ=5;μ=0.5;ε=-10)		175%	-20%	12%	20%	2%
(σ=6;μ=0.5;ε=-10)		175%	-20%	12%	20%	2%
(σ=7;μ=0.5;ε=-10)		175%	-20%	12%	20%	2%
(σ=8;μ=0.5;ε=-10)		175%	-20%	12%	20%	2%
(σ=9;μ=0.5;ε=-10)		175%	-20%	12%	20%	1%
(σ=10;μ=0.5;ε=-10)		**175%**	**-20%**	**12%**	**20%**	**1%**