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Full Length Research Paper

The assessment of economic indicators using GM cotton worldwide over time

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This paper reviews the evidence on the economic benefits using GM cotton with different patterns across space and time. To this end, we investigated the effects of GM cotton using global data from more than one decade of field trials and surveys. More specifically, the effects of GM cotton on crop yields, seed costs, pesticide costs, management and labor costs and finally net return were analyzed. Based on the literature searched, regression analysis was conducted to investigate and estimate the relationship between response variables and explanatory variables on these parameters. The results using regression analysis approach indicate that yield gain is the high expectation of cotton growers to optimize net returns. Put in another way, yield gain is the main factor influencing net return. As such, this study concludes that GM cotton is the technology which can lead to yield increases and capture higher net return. More so, lessons from this study may contribute to the assessment of this technology especially for poor-resource farmers in the developing countries.

Key words: Regression analysis, net return, yield, benefits.

INTRODUCTION

The development of GM cotton cultivars provides cotton produce more options for managing pests, but their value to producer depends not only on the cost savings that they may contribute to the pest management system employed, but also on the gross revenues from the sale of the crop produced. Economic benefit is the most important factor that can affect GM cotton technologies among the farmers worldwide, not only in developed countries but also in developing countries. GM cotton not only provide an effective tool for controlling target insects (Wu et al., 2008), but also provide many social, environmental and economic benefits, such as reducing the use of chemical insecticides, benefiting the environment and human health, and increasing farm income (Wang, 2007; Brookes and Barfoot, 2008; Choudhary and Gaur, 2011; Huang et al., 2010; Tabashnik, 2010).

There is a general belief that the GM technology will be a major factor in boosting productivity of agriculture, especially in developing countries. Several studies on GM cotton in developing countries claimed that its use brings benefits to smallholders because it decreased the number of pesticide sprayings and increased yields (Zhao et al., 2011). According to Kaphengst et al. (2010), there is substantial evidence that the adoption of Bt cotton provides economic benefits for farmers in a number of countries. For example, it is notable that in 2010, the biotech cotton area in India, which is the largest cotton growing country in the world, occupied 9.4 million hectares of approved GM cotton increasing by an impressive 12% gain between 2009 and 2010, despite almost optimal levels of adoption which reached 86% in 2010. The benefits of GM cotton hybrid in India are significant and the substantial increase in 2010 was due to the significant merits in production, economic, environmental, health, and social benefits (James, 2010).

Over a decade after GM crops such transgenic cottons were first commercialized among smallholders in the developing world, there now exist a considerable body of evidence to show that their impacts have been mixed,

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variable, differentiated and contingent on an array of agro-ecological, socio economic and institutional factors. The effect of a widespread application of GM cotton on sustainable development has been the subject of controversial discussion in terms of potential benefits. As a result, the literature on the impacts of GM cotton is already substantial, especially in terms of the socio economic impacts on farmers.

The aim of any agricultural enterprise is to maximize the profit, given limited resources or amount of inputs. The expenditure of using fertilizer, chemical matter, labor, management system and yield gain impact the net revenue of the cotton enterprise. Therefore, net income is a key measure for determining how successful a cotton grower operation has been historically, as well as an indicator of how the financial success of the farm might be in the future. What causes net returns to vary from year to year at the farm level, and more importantly, returns to vary between operations is important information for cotton producers to identify, so they can make good management decision. For instance, do agronomic aspect (yield) has a greater effect on net return variability or do economic factors such as seed cost, pesticide cost, management and labor cost have a greater effect on net income variability? In economic analysis, inputs are the essential factors influencing yield. As a result, yield can affect net return.

At this point, more specifically, it is important to point out that the objective of this paper is to employ regression analysis to test factors influencing net return in cotton enterprise worldwide over time. To determine which factors have a greater impact on net returns for cotton producers over time, historical returns were analyzed based on refereed journals, book chapters or non peer-reviewed conference proceedings through online searches from long-term studies in developed countries (USA and Australia) and developing countries (India and China). In this study, historical returns were identified from each individual study to look at variability in net returns across producers based on the input and output in economic analysis. A potential weakness of this study is that there are non-economic data evaluated in this data set (for example, variety, soil type, irrigation or non irrigation facility, rainfall data, etc.) which would help to better identify specific management styles of individual producers. Nonetheless, it is believed that results from this study can be useful for operations of all sizes as they think about what they need to focus on for long-term business survival.

MATERIALS AND METHODS

Data source

The data for this study were obtained from literature searched from many resources, set as the database. This study investigated the impact of GM cotton on crop yields at the global and country level and assessed the effect of GM cotton on farm level costs and benefits, and extends the existing literature by considering all countries and by focusing on a wide scope of literature. Four countries (USA, Australia, China and India) were considered to be chosen in terms of growing area and economic performance of GM cotton. The database included peer-reviewed scientific articles as well as non peer-reviewed sources from grey literature. Such non peer-reviewed sources were mainly official reports from governmental organizations or agencies/institutes funded by governments, official international and national statistics as well as conference proceeding, and also from academic, governmental, civil society or from a company.

Database contained peer-reviewed and non peer-reviewed between the publication year of 1998 and 2012. A total of 129 papers were successfully collected which at least consists of one of the economic indicators (yield, net return, seed cost, pesticide cost, management and labor cost and net return). 53 papers were successfully considered in the database then the data were tabulated and accounted for by using Microsoft Excel 2007. 16 samples (number of data tabulation) were taken based on the average data which consist of all economic indicators (yield, seed cost, pesticide cost, management and labor cost, and net return) for regression analysis. Furthermore, the data base included general information on the cotton trait (herbicide tolerance, stacked gene, Bt) from field survey and field trial.

Variable selection

This study examined the relationship of net return with multiple variables. To simplify, net returns refer to the return to farm operator for their labor, management system, pesticide and seed, after all production expenses have been paid. Production costs refer to the expenditure of using input during the production process to produce the cotton. The question is that are net returns dependent on the yield, seed cost, pesticide cost, management and labor cost? Therefore, the technique of linear regression and correlation was used, in which case should predict the value of net returns using independent variables.

Model establishment

Comparative statistics provide a broad overview about the agronomic and economic effects of GM cotton. However, such statistics become less effective in separating the effects of individual changes while controlling for the effects of other variables. Individual effects of variables while controlling for the effects of others can be estimated by employing a multiple regression (Bennett et al., 2004). In this regression, net revenue is taken as the dependent variable while yield, seed cost, pesticide cost, management and labor cost are taken as the independent variables. This model is

Table 1. Model summary and analysis of variance between response variable and explanatory variables of GM cotton.

Model Summary[b]					
Model	**R**	**R square**	**Adjusted R square**	**Std. error of the estimate**	**Durbin Watson**
1	0.767[a]	0.589	0.439	281.96047	1.446

ANOVA[b]					
Model	**Sum of squares**	**Df**	**Mean square**	**F**	**Sig.**
1 Regression	1251993.465	4	312998.366	3.937	0.032[a]
Residual	874518.759	11	79501.705		
Total	2126512.224	15			

a. Predictors (Constant), management and labor, seed, yield, pesticide. b. Dependent variable.

used to further explore the relationship between net return per hectare, yield and various production inputs, such as pesticide use, seed cost, management and labor cost. Based on the theoretical foundation, the regression model was established which can be written as:

$$Y = bo + b1X1 + b2X2 + \ldots + biXi + \varepsilon \qquad (1)$$

Where:
bi = partial slope coefficient (also called partial regression coefficient, metric coefficient); it represents the change in Y associated with a one-unit increase in Xi when all other independent variables are held constant.

It was observed that bo is the sample estimate of βo, bi is the sample estimate of βi, and βs are the parameters from the whole population in which the sampling was conducted.

The dependent variable and the explanatory variable must be specified as:

Y = Net return
X1 = Yield
X2 = Seed cost
X3 = Pesticide cost
X4 = Management and labor cost.

We performed SPSS 16.0 to determine the intercept and regression coefficients, after that we tested them for significance by doing the Analysis of Variance (ANOVA). ANOVA determines if regression coefficients that the probable model calculates should be present in the final model as a predictor or not. A *P*-value or sig-value for coefficients significance test was conducted. If *P*-value for a coefficient was less than 0.05 ($P<0.05$), the coefficient is statistically significant and the related variable should be present in the model as a predictor, but if it was higher than 0.05 ($P>0.05$), the coefficient is not statistically significant and the related variable should not be present as a predictor (Draper and Smith, 1981).

Coefficient of determination or R-square (R^2) shows how the model of predictors fits the dependent or independent variables (higher R^2, higher fit of the model and higher model goodness). Moreover, significant test for intercept (bo) is similar to regression coefficients (Kleinbaum et al., 1998). Significance test of the coefficient and R^2 helps researchers to decide what predictor is more important and must be presented in the model. Besides this, when the number of the predictors increased, usually most of the variables are strongly correlated with each other and it is not necessary to present all of these correlated variables in the model since they can be used in place of one another (Manly, 2001).

RESULTS

We employed a regression analysis in order to investigate the correlation between dependent variable (Y = Net Revenue) and predictor variable (X1 = Yield, X2 = Seed, X3 = Pesticide, X4 = Management and Labor).

Data reflected in Table 1 demonstrated that under the condition level, $\alpha = 0.05$, $F = 3.937$, and *p* value = 0.032 (<0.05). This means indicated that the goodness of fitting of the equation on this model is high. Because *p* value of F is smaller than 0.05, therefore the overall significance is good and it also indicated that there is no multicollinearity problem. This provides evidence of existence of a linear relationship between the net return and the four explanatory variables.

To express the quality of fit between a regression model and the sample data, the coefficient of multiple determinations (R^2) was used ranging in value from 0.0 to 0.1. Table 1 shows the value of R^2 as 0.589 indicating that the fitting degree is relatively high, and the linear relationship between predictors and dependent variable is significant. Higher value of R^2 indicates a better fit of the model to the sample observations. However, adding any regressor variable to this model, even an irrelevant regressor, yields a greater R^2. For this reason, R^2 by itself is not a good measure of the quality of fit. To overcome this deficiency in R^2, an adjusted value could be used. Therefore, the adjusted R^2 was used on this model which is a more reliable indicator of model quality. We found

Table 2. Correlation matrixes between predictors' variable and dependent variable of GM cotton.

Variable		Net return	Yield	Seed	Pesticide	Management and labor
Pearson Correlation	Net return	1.000	0.502	-0.210	0.313	-0.225
	Yield	0.502*	1.000	0.046	-0.229	0.387
	Seed	-0.210	0.046	1.000	0.035	-0.227
	Pesticide	0.313	-0.229	0.035	1.000	-0.565
	Management and labor	-0.225	0.387	-0.227	-0.565*	1.000
Sig. (1-tailed)	Net return		0.024	0.217	0.119	0.202
	Yield	0.024		0.433	0.197	0.069
	Seed	0.217	0.433		0.449	0.199
	Pesticide	0.119	0.197	0.449		0.011
	Management and labor	0.202	0.069	0.199	0.011	

* Correlation is significant at the 0.05 level (1-tailed).

Table 3. Multicollinearity test and model test of regression analysis of GM cotton.

Model	Unstandardized Coefficient		Standardized Coefficient	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (Constant)	-27.793	559.069		-0.050	0.961	0.848	
Yield*	360.243	106.464	0.710	3.384	0.006	0.934	1.179
Seed	-5.725	4.058	-0.282	-1.411	0.186	0.672	1.071
Pesticide	4.296	4.114	0.246	1.044	0.319	0.572	1.488
Management and labor	-0.486	0.292	-0.425	-1.661	0.125		1.747

* Significant at the 0.05 level.

that the value of adjusted R^2 is 0.439. As such, 44% of the variability in Net revenue in GM cotton can be predicted from the relation of the independent variable (yield, seed, pesticide, management and labor), while the remaining can be explained by the outlier beyond the model.

In the case of one explanatory variable, the coefficient of determination is simply the square of the coefficient of correlation namely r^2. Table 2 shows the relationship between the dependent and explanatory variables. This study performed Pearson correlation matrixes focused on the strong correlation (positive or negative) between the dependent and independent variables.

Table 2 demonstrated that the relationship between yield and net return indicated a strong positive correlation ($r = 0.502$) with r^2 significant level < 0.05 (0.024). Moreover, we found a significant positive effect between net return and pesticide ($r = 0.313$). In addition, a strong negative correlation ($r = -0.565$) was shown in terms of pesticide, whereas a positive correlation was shown in terms of management and labor cost with r^2 significance level < 0.05 (0.011). Although the two explanatory variables (seed cost, and management and labor cost) have a negative correlation, they are actually not statistically significant.

Table 3 performed the multicollinearity test and the model test for this study. What we found here is that all of our independent variables are not highly correlated (if a correlation is greater than 0.7 or less than -0.7).

The two values (F-ratio and t-ratio) indicate respectively whether there is a linear relationship between the response and explanatory variables taken together, and whether any given explanatory variable has an influence on the response variable over and above that of the other explanatory variables.

Table 3 depicts that for the independent variable yield (X1), the estimation of regression is 360.243, standard error is 106.464, t test value is 3.384, t test significance is 0.006, which is lower than 0.01. In other words, the independent variable yield is highly significant. Then, to predictors variable X2 (seed), X3 (pesticide) and X4 (management and labor), we can find that t test significance is 0.186, 0.319, 0.125, which is higher than 0.05, respectively. Therefore, these coefficients of independent variables are not significant. Overall, net return variability can be significantly affected by yield.

The obtained results demonstrated that the prediction equation for net return in GM cotton (Y) is formulated using the predictors as follows:

$$Y = -27.793 + 360.243\ X1 - 5.725\ X2 + 4.296\ X3 - 0.486\ X4$$

Another multicollinearity problem has been tested by using Variance Inflation Factor (VIF) which indicated that the overall result is lower than 10. That is this model has no multicollinearity problem. In addition, autocorrelation test on this model was carried out by Durbin Watson (DW) analysis which indicated that DW = 1.446. According to DW checking table, under 0.05 significant level, $Du < DW < 4 - Du$ ($n = 15$, $K = 4$) then $1.446<1.97<4–1.97$, that is this equation has no problem with autocorrelation.

DISCUSSION

Regression analysis reveals that net return mostly is affected by yield gain. That is yield gain is the main factor influencing farmers' income. The database depicts that yield gain varies from country to country, trait to trait, year to year due to the climatic conditions, site specific and geographical dependent. Moreover, the impact of yield difference on GM cotton was dependent upon the level of pest pressure, location, year, climatic factors, and time of planting. Another contributing factor of yield differences is the variety used as "background" in which Bt genes, for instance, is introduced (Kambhampati et al., 2006; Qaim et al., 2006).

A question commonly asked is whether one explanatory variable is more important than the other. The effect of any given explanatory variable depends on which other variables have been included in the regression model. The question cannot be answered by simply looking at the respective values of the β coefficients, because the value of the β coefficients depends on the unit of the explanatory variable. In this case, yield gain is measured by kg/hectare and the others (seed cost, pesticide cost, management and labor cost) are measured by USD/hectare. There can be no comparison between such disparate quantities; instead we look at the t-ratios between response variable and explanatory variables, in which 3.38 was for the yield which was higher than that of any other independent variables. Therefore, the effect of the yield gain is greater than that of other explanatory variables. A strong positive correlation between yield and net return indicates that increased yield of using GM cotton leads to higher revenue of cotton grower.

A negative t-ratio of seed cost showed by -1.411 indicating cotton growers with high seed cost was expected to have lower net return unless they will have higher yield that can offset higher seed expenditure to optimize the return. This result is consistent with the correlation between seed cost and net return which has a negative value. It means that the higher the expenditure of GM seed, the lower the net return they have. Therefore, cotton growers who paid for GM seed should have higher yield otherwise they could not get higher income. Moreover, the t-ratio of pesticide cost shows a positive value (1.044), while expecting cotton growers need more chemical spray to reduce the yield losses due to the pest pressure. In other words, when farmers expect to incur large yield losses from cotton bollworm, they spray more. That is, the more they spray, the higher the expected yield. However, the higher pesticide use was due to the differences in naturally occurring fluctuations in pest population which varied from country to country, county to county, year to year, site specific, climatic conditions and geographical dependent. The increased use of pesticide could also be due to the significantly greater planting of GM cotton worldwide over time.

The model test of regression analysis of GM cotton shows that the t-ratio of management and labor costs by -1.66 indicates negative relationship with net return. This is also consistent with the result of the correlation (-0.225). It means that when the management and labor cost increases, the net return decreases. There are several possibilities to this finding. One explanation is that due to the higher yield cotton, growers need more labor during the harvest season. Another explanation is that the increase of management and labor cost could also be due to the management system requirement of using GM seed such as irrigation facilities, consultant fee, etc., associated with management costs.

To sum up, increased yield lead to higher revenues and lower pesticide costs that in turn offset higher seed, management and labor costs. In China, where yield levels are already high, the main benefits of Bt cotton can be derived from costs saving due to lower pesticide use. While in India yield increases seem to correspond with a higher need to labor (for example, because of increased workload of harvesting), in China Bt cotton adoption leads to substantial reductions in labor and management costs due to more efficient crop management (Brookes and Barfoot, 2009).

In this study, statistical inferences of regression analysis reveal that yield, seed cost, pesticide cost, management and labor cost effectively influence net return in GM cotton. Other factors which determine relative economic profitability beyond those economic indicators have been ignored but should be considered and taken into account for the future research. It is a concern that this study relied on the individual studies. Thus, the data observed might not be adequately addressed to capture the effect of using GM cotton due to the fact that these studies might use totally different methodologies to assess the economic benefit of GM cotton. For instance, such assessment might be based on the impact different studies, using field trials or surveys, have on public research institutes or private companies which probably show presence of biases that can occur with different methodologies. The observed economic impacts of GM cotton in any 'place' will depend on the yield potential of crop varieties, the pest infestation, and general and seasonal dependent climate and weather conditions, as well as government intervention (Finger et al., 2011).

As a result of the aforementioned points, the analysis presented some interesting points that shed light on the diversity that can be observed in the literature and which helped fuel the divergent viewpoints held in the development of GM cotton. Thus, this study is a representative of the entire economic standpoint based on the literature searched with different goals and methodologies, as well as the study's purpose.

Conclusions

Regression analysis in this paper presented the relationship between net return, yield and production cost. The relationship is that cotton growers expect higher yield of GM cotton. Therefore, a significantly higher yield is needed to optimize the net return. Another relationship is due to the fact that the higher seed costs might lead to decreasing net return. Moreover, this study suggests that cotton growers rely on the chemical spray in order to increase yield and net return even if this crop (GM cotton) is resistant to the cotton bollworm. This also indicates that secondary pest might be a problem for cotton growers worldwide over time. Management and labor cost should be considered as the labor requirement during the harvest seasons and GM cotton require a good crop management system which leads to payment for consultant fee, irrigation cost, and other management costs.

The results presented here do support the development of GM cotton, and by adding-up individual studies through meta-data, there is the risk of comparing apples and oranges. Nonetheless, the analysis presented shows that GM cotton should be developed and deployed since it might contribute to poverty reduction and rural economic development, and all of these aspects should be considered in the assessment of this technology.

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