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ESTIMATING PRODUCTIVITY OF BT COTTON AND ITS IMPACT ON PESTICIDE USE IN PUNJAB (PAKISTAN)

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Abstract. The present study is designed to determine the impact of Bt cotton seed on pesticide use and cotton productivity in the Punjab province of Pakistan. Cross-sectional data for two cropping seasons of 2008 and 2009 are gathered from three districts of cotton growing region of the province. Modified exponential damage control production function is employed to estimate the effect of Bt cotton seed. Results of the production function show that farmers using Bt cotton seed obtain higher yield as compared to non-users of Bt cotton seed. Fertilizer and irrigation variables are positively related with cotton yield whereas location dummies indicate that cotton growers from Multan district have low productivity as compared to those from Rahim Yar Khan and Mianwali districts. Age, farming experience and farm size are found increasing cotton productivity. So, the study concludes that in addition to traditional inputs and socioeconomic factors, Bt cotton can fetch higher benefits to cotton growers, provided that farmers have access to quality Bt cotton seed in the market.

Keywords: Bt cotton, Damage control production function, Productivity, Pesticide use

JEL classification: Q15

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I. INTRODUCTION

Rising cost of cotton production, mainly due to pesticide use to control for cotton pests has induced farmers to adopt Bt cotton seed as Bt cotton seed has resistance against certain cotton bollworms in Pakistan, in addition to other factors. Bollworms are the major cotton pests in Pakistan. Although various options are suggested to control cottons pests, some of them are biological control, mechanical control, integrated pest management and using cotton seed having resistance against cotton pests. All options require certain level of research and development activates and dissemination strategies for wide spread adoptions. However, Bt cotton seed is the most suitable option when quality Bt cotton seed is available in the market. This is one of the reasons that adoption of Bt cotton seed is widely spread compared to other options as farmers allocate above 70 percent area to Bt cotton seed in the Punjab province (Bakhsh, 2013).

In Pakistan, farmers started planting Bt cotton seed at their farms many years ago before formal approval of the Government of Pakistan in 2010. Promotional strategies of private seed companies, results of Bt cotton in the neighboring countries, presence of the seed, etc. were motivational forces for farmers. Literature from the neighboring countries provided evidence of reduced pesticide use and increased yield (Bennett *et al.*, 2006; Kouser and Qaim, 2011; Qaim *et al.*, 2006; Subramanian and Qaim, 2010). The decline in pesticide use decreased cost of cotton production considerably in those countries, in addition to pesticide poisoning cases (Kouser and Qaim, 2011). Small landholders can receive higher income and profit by adopting Bt cotton seed as indicated by Ali and Abdulai (2010), Kathage and Qaim (2012) and Mulwa *et al.* (2013).

Presently two types of cotton are found at farmers' fields in Pakistani. They include traditional cotton and Bt cotton. Thus the need is to conduct the study in determining benefits of Bt cotton seed. Possible benefits of Bt cotton may include a change in pesticide use, cotton productivity and revenue whereas associated cost is seed cost. Many studies are conducted in Pakistan showing positive impacts of Bt cotton seed (Abedullah *et al.*, 2015; Ali and Abdulai, 2010; Kouser and Qaim, 2013, 2014; Nazli, 2009; Sheikh *et al.*, 2008) while using cross-sectional single year data. Researchers mostly raise questions employing cross-sectional single year data because of variations in weather conditions and insect pest infestation during different years (Bakhsh, 2013). Further, it is difficult to separate the effects of technology from these variations. Using data with a time series dimension is more appropriate to work out benefits of adopting new technology.

Considering this aspect, the present study was conducted to estimate the effects of Bt cotton seed on pesticide use and cotton productivity, employing data collected over a period of two cotton growing seasons from a large sample of farmers using Bt cotton and non-Bt cotton seeds.

II. MATERIALS AND METHODS

STUDY AREA AND DATA

Cotton is commonly grown in irrigated areas of Pakistani Punjab and the irrigated southern Punjab is famous for cotton production. Thus the present study was conducted in this region of Punjab province. Data were collected over a period of two cropping seasons-2008 and 2009. A three stage sampling technique was used for the selection of the respondents. First stage involved selection of three districts randomly. In the second stage, the list of the respondents growing cotton was prepared. For this purpose, the registered private seed companies/input dealers were contacted who sold cotton seed (Bt and non-Bt) to farmers during cotton growing season of 2008. In the third sampling stage, we selected the respondents using a systematic simple random sampling technique. A total of 96 respondents from one selected district were enumerated. The total sample size from all the selected districts was 288 respondents. The same respondents were interviewed for crop season, 2009. However, three respondents could not be interviewed due to death, migration, etc. Thus, a total of 573 respondents were interviewed during two crop growing seasons of cotton in the Punjab province. Since, data of the study include two types of farmers, one group of farmers growing only Bt cotton and the other one planting both types of cotton seeds, *i.e.* Bt and non-Bt cotton. Farmers belonging to the second category were asked to provide information on both types of cotton seeds. Thus, the number of observations on plot level is 801 used in the analysis.

EMPIRICAL ANALYSIS

Pesticides are used against cotton insect and pests and so its use is not similar compared to other inputs such as fertilizer, seed and irrigation which imply direct impacts on yield. The contribution of pesticide is, therefore, abating cotton pest pressure. Lichtenberg and Zilberman (1986) argue that production function treating pesticide as traditional input fails to capture the damage control nature of pesticides. For more details about damage control specification for pesticide use in agriculture, *see* Lichtenberg and Zilberman (1986) and Jha and Regmi (2009). Huang *et al.* (2002) employed damage control framework based on the framework of Lichtenberg and Zilberman (1986) in estimating productivity of pesticide. Bt cotton is considered as an alternative to pesticide use, since its use can substitute pesticides. So, farmers can control certain pests either through employing pesticide or Bt cotton seed.

Consider here the Cobb-Douglas type production function[1] of the cotton crop in order to estimate the impacts of pesticide use and Bt cotton seed on yield:

$$Y = \delta \sum_{i=1}^{n} X_i \quad (1)$$

where Y is the quantity of cotton yield and X includes vector of farm inputs, such as seed, fertilizer, pesticide, irrigation and labour. As discussed earlier, the unique nature of pesticide and Bt cotton having damage control characteristics call for specifying different non-linear functional form for these two inputs. Following the work of Lichtenberg and Zilberman (1986), equation (1) can be written as:

$$Y = \delta \sum_{i=1}^{n} X_i G(Z_i) \quad (2)$$

Now Z denotes a vector of damage control agents such as pesticide and Bt cotton and X includes other farm inputs. Above function in equation (2) is the joint production function incorporating the damage control function of pesticide and Bt cotton and $G(Z_i)$ lies $0 < G(Z_i) < 1$. It means the proportion of potential cotton yield loss from pest attacks in the range of zero and unity. When $G(Z_i) = 0$, it shows complete loss of the crop and $G(X_i) = 1$, it means perfect control of pests. Taking log of both sides in equation (2) and using modified exponential form[2] give the following form:

$$\ln Y = \delta + \beta \sum_{i=1}^{n} \ln X_i + \propto A_i + \left[1 - e^{\{-\gamma_1(Pest_{quantity}) - \gamma_2(Bt)\}}\right] \quad (3)$$

where $\ln Y$ is log of cotton yield in kg per hectare. X_i include a vector of farm inputs and A_i shows socio-economic characteristics of the farms and farmers and geographical variables.

[1]Other functional forms such as quadratic and translog were employed but these functional forms did not give the better results compared to Cobb-Douglas production function.

[2]Other forms such as logistic and Wiebull were also estimated but these forms did not give significant results for our data. Jha and Regmi (2009) also estimated damage control function using modified exponential form.

$Pest_{quantity}$ is log of the amount of pesticide use in cotton production in liter per hectare, Bt is the dummy variable for Bt cotton and it is 1 if farmers planted Bt cotton, 0 otherwise. Summary statistics of the variables is detailed in Table 1.

III. RESULTS AND DISCUSSION

Descriptive statistics given in Table 1 show that cotton growers operate at around 19 hectares of land growing cotton and other crops. Average age of 44 years indicates relatively younger farmers involved in farming which is also depicted by farming experience of the respondents. Pesticide use is 4.32 liter per hectare which is still too high. This may be the reason that farmers have to use plant protection to control sucking pests because two types of pests damage cotton. They include bollworms and sucking pests whereas Bt cotton has resistance against bollworms only. Bt dummy variable indicates that out of total plots, 71 percent plots are of Bt cotton seed, indicating intensity of Bt cotton at farmers' fields.

TABLE 1

Summary Statistics of Variables in the Production

Variable	Mean	SD	Minimum	Maximum
Age of the respondents (years)	44.20	11.85	19	72
Farming experience of the respondents (years)	19.74	11.19	2	55
Farm size (hec)	18.97	22.84	0.81	224
Seed (kg/hec)	18.68	4.93	9.38	32.12
Fertilizer (NPK kg/hec)	249.30	79.91	1.32	600.44
Irrigation (No.)	9.80	3.12	3	16
Pesticide (Liter/hec)	4.32	2.20	0.41	16.89
Labor (Rs/hec)	7754.28	2205.48	1086.40	18585.200
Yield (kg/hec)	2394.54	751.84	296.52	5930.32
Bt dummy	0.71	0.45	0	1
Cropping season 2009	0.47	0.49	0	1
R. Y. Khan	0.40	0.49	0	1
Mianwali	0.24	0.43	0	1
Number of observations	801			

Table 2 shows typical Cobb-Douglas production function, Hausman test to determine endogeneity of pesticide variable and modified exponential production function. In estimating production function, theoretical knowledge demands for explanatory variables as being exogenous variables, otherwise estimated coefficients are not consistent. This endogeneity problem is common for all farm inputs, it is more important for pesticide use, since farmers apply pesticide in response to insect and pest attacks. In order to solve this problem, instrumental variables are used when the problem is more severe. If endogeneity is less severe, the least square estimator is more efficient than instrumental estimator. A variant of Hausman test was used to determine endogeneity of pesticide. For this purpose, we estimate pesticide use function by regressing pesticide quantity on different variables, namely prices of output and pesticide, Bt dummy, cropping season, regional dummies and socioeconomic variables.

TABLE 2

Estimation of Cobb-Douglas, Pesticide Endogeneity Test and Modified Exponential function

Variable	Cobb-Douglas		Hausman		Modified Exponential	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	7.488	0.434***	7.516	0.452***	7.479	0.430***
Bt	0.179	0.030***	0.173	0.039***		
Pesticide	0.044	0.028	0.048	0.032		
Seed	0.048	0.047	0.049	0.047	0.048	–0.047
Fertilizer	0.072	0.036**	0.072	0.036	0.073	0.036**
Irrigation	0.139	0.045***	0.138	0.045	0.138	0.045***
Labor	–0.092	0.045**	–0.092	0.045	–0.092	0.045**
R.Y. Khan	0.073	0.028***	0.074	0.028***	0.073	0.028**
Mianwali	0.203	0.048***	0.201	0.048***	0.202	0.048***
Cropping season	–0.108	0.024***	–0.109	0.024***	–0.108	0.024**
Age	–0.003	0.001**	–0.003	0.001**	–0.003	0.001**
Farming experience	0.005	0.001***	0.006	0.001***	0.005	0.001***
Farm size	0.001	0.0005***	0.001	0.0005***	0.001	0.000***
Residual			–0.003	0.016		
Damage control						
γ_1					0.220	0.049***
γ_2					0.058	0.040
R^2	0.132		0.132			0.132

****, ** and * are level of significance at 1%, 5% and 10% respectively.

Second column of Table 2 shows Hausman test. The residual value from pesticide use function was included in the Cobb-Douglas production function. Its coefficient was insignificant, implying that there was not severe enough problem of pesticide endogeneity resulting biased estimates, so pesticide variable is used instead of instrumental variable in the production function.

Results of Cobb-Douglas (column 1 of Table 2) and modified exponential function form (column 3 of Table 2) show that all variables have expected signs in both production functions except labor variable. Labor coefficient is negative and statistically significant. It may be due to the use of Bt cotton seed, since Bt cotton seed reduces labor demand for pesticide application and such farmers may be applying labor more efficiently. Fertilizer and irrigation have positive coefficients and statistically different from zero. So, cotton yield would increase by increasing use of these farm inputs. After discussion with soil scientists, it was found that fertilizer use in Pakistan is already very low and imbalanced and farmers can fetch higher yield by increasing fertilizer use. Our result is in line with Ashfaq *et al.* (2012) who argue that fertilizer use in Bt cotton production is underutilized while examining resource use efficiencies in Pakistan.

Although statistically insignificant, pesticide coefficient is positive. It may be due to the fact of inefficient use of pesticide in cotton production and farmers may be applying pesticide less than optimal level. Crost *et al.* (2007) conclude that insignificant pesticide variable is due to inefficient utilization of pesticide against cotton insect and pests in India. Ashfaq *et al.* (2012) also find overutilization of pesticide use in Pakistan. The most important variable in the present study is Bt cotton seed. Its coefficient in both production functions is statistically significant. It implies that farmers are able to obtain 22 percent higher yield by using Bt cotton seed. However, magnitude of Bt cotton coefficient is larger in modified exponential form compared to production function (18 percent). This shows that traditional production function underestimate impact of Bt cotton. Comparing the finding of the present study with other studies, we find that the yield effect of Bt cotton in the present study is lower from the yield shown in the studies of Ali and Abdulai (2010), Crost *et al.* (2007), Kouser and Qaim (2013) and Nazli (2009).

Cropping season 2009 is taken as dummy variable and it indicates that farmers gain lower yield compared to cropping season 2008. Adverse weather conditions are possible reasons for low productivity during cropping season of 2009 as Pakistan experienced worst weather conditions for agriculture sector and overall agriculture performance remained below the targets (Government of Pakistan 2010). Considering regional differences on cotton productivity, we find that farmers from Rahim Yar Khan and Mianwali district have higher cotton productivity than farmers from Multan district. These results are as per our expectation because Bt cotton seed was firstly introduced in Rahim Yar Khan because it has boundaries with Sindh province where Bt cotton was firstly introduced by some private seed companies (Hayee, 2005). However, it came very late to Multan district. So farmers may be less aware of Bt cotton seed and limited access to quality seed as well. Availability of unimproved Bt cotton seed in the market highlights weak institutions and uncertainty in the seed market as rightly indicated by Spielman *et al.* (2015).

Considering socioeconomic characteristics of the respondents, age is negatively related with cotton productivity as its coefficient is negative and statistically significant. This implies that aged farmers take less risk in using new technology and mostly follow traditional practices. However, farming experience is statistically significant and positive, indicating increasing cotton productivity with higher farming experience. Similarly farm size is also positively related cotton yield.

IV. CONCLUSION

This study is different from other studies conducted in Pakistan by collecting data on two cropping seasons. It accounts for year-to-year variability in yield and helps to understand the change in input use and output while controlling many factors, such as farm and farmer related characteristics. Results of the study have proved that Bt cotton contributes significantly in cotton yield, however, statistically insignificant pesticide hints that cotton growers were not able to apply pesticide efficiently due to lack of awareness, financial constraints and timely availability of pesticide products. A 22 percent increase of cotton productivity by Bt cotton seed highlights that farmers rightly give due weight to Bt cotton seed as it improves their welfare through reducing pesticide use and improving crop productivity. Strengthening seed market and making institutions strong would ensure access to quality seed, resulting in further higher crop productivity.

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