Farm Level Pesticide Use and Productivity in Smallholder Cotton Production in Zimbabwe: The Case of Gokwe Communal Area Farmers

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Abstract

This study uses an econometric approach to estimate the financial benefit that smallholder cotton farmers in Gokwe can derive from increased investment in pesticides. The stochastic production frontier model, which takes into consideration the damage abatement nature of pesticides is used to estimate the Marginal Value Product (MVP) of pesticides. The estimated value for the MVP was $2.03, suggesting potential benefits from increased pesticide use in the study area. This figure is however an overestimate if pesticide use externalities both to human beings and to the environment are taken into account. Multiple linear regression is used to indicate the determinants of pesticide use by Gokwe smallholder cotton producers. Knowledge of integrated pest management techniques and access to extension advice from NGOs have a negative effect on pesticide use while income, perceived crop loss from not using pesticides and advice from pesticide companies were found to encourage greater use of pesticides.

Introduction

Dependence on pesticides for pest control has been on an increase since the onset of the green revolution in horticulture and agriculture (Waibel and Fleischer, 1995). In Zimbabwe, it is estimated that the agricultural sector alone now uses chemicals worth 20 to 30 million US dollars every year (Chikanda, 1998). This was particularly enhanced by the move towards cash crop production especially by communal area farmers. These crops such as tobacco and cotton demand high use of pesticides to manage pests.

In communal areas, cotton is by far the most popular cash crop followed by sunflower (CSO, 2000). The major pest control method used by communal area farmers is the use of pesticides (Turner, 1995). Chikwenhere and Sithole (1995) found that most communal area farmers in Zimbabwe resort to chemical pest control because they lack knowledge about other pest control methods or they are discouraged from employing traditional crop protection strategies.

The use of pesticides in agriculture is however riddled with controversy and polarised viewpoints. While proponents claim high benefits and see pesticides as an indispensable input factor in modern agriculture, opponents point at perplexing potential and actual risks to humans and the environment and would like to see a “pesticide-free world” with organic farming as the dominant strategy to agricultural production.

In Zimbabwe, several studies regarding the occupational hazards of pesticide use and handling have been carried out. Studies carried out by Nhachi and Loewenson (1996) in Zimbabwe’s commercial farming sector show that about 50% of workers on the farms were exposed to organophosphates during spraying. Kasilo (1990) carried out studies on organophosphate poisoning in Zimbabwe’s urban areas over the period 1980 to 1989. The study showed an increase in poisoning cases that was attributed to an increase in pesticide use as a result of increased acreage under cultivation.

What becomes striking about the pesticide use debate in Zimbabwe as in many other African countries is that, despite all the controversy about pesticide productivity and heinousness, little empirical evidence has actually been gathered about the extend of farm level or aggregate national benefits of pesticides in agriculture. The theoretical problem is linked to the measurement of pesticide productivity, that is, how to treat pesticides in the framework of production theory. The nature of pesticides as a damage control agent makes them different from directly yield increasing factors of production (Chambers and Litchenberg, 1994).

The studies carried out by Turner (1995), Kasilo (1993) and Kiss et al (1993) and others focussed mainly on the technical aspects of pesticide use and Integrated Pest and Production Management. These studies were focussing on technically efficient pesticide use levels based on experimental data obtained from research stations and commercial farming areas. The recommendations from these studies were found not to suit the local conditions of smallholder farmers especially taking into consideration their poor resource base and other socio-economic factors (Mudimu, 1995).

Several researchers (Turner, 1995; Kasilo, 1990; Nhachi, 1993 for example) have asserted that there is more dependence on pesticides in Zimbabwe than is really necessary. However, little is known about the factors that have influenced this dependency especially from the socio-economic point of view. This suggests that it would be difficult to influence pesticide use patterns of farmers and to promote other alternative pest management strategies such as Integrated Pest and Production Management (IPPM).

In this paper, a stochastic production frontier model that takes into account the damage abatement nature of pesticides is used to estimate the farm level marginal productivity of pesticides in smallholder cotton production in Gokwe and a multiple regression model is used to find out the factors influencing farm level pesticide use levels by these farmers. The study attempts to answer the following specific questions:

- What are the farm level returns to increased farmer investment in pesticides in smallholder cotton production in Gokwe?
- What are the factors influencing pesticide use levels at farm level by smallholder cotton farmers in Gokwe?

Recommendations from this study would be important in giving public and private sector policy makers an insight into which variables they can manipulate so as to improve cotton pest management at least for Gokwe communal area farmers.

Methodology

Site Selection

Gokwe was selected as the research site. Gokwe is the largest district in Zimbabwe and lies in the northwestern parts of the country. The district is in the country's agro ecological zone 3, which receives 600 to 650mm of rainfall annually. Cotton production is the major agricultural income earner and following maize, cotton is the second most cultivated crop in the district. The most common land tenure system is communal followed by a few resettlement schemes.

The land tenure system, the agro-ecological conditions (rainfall, vegetation and soil type) and the socio-economic conditions in Gokwe are typical of those in most of Zimbabwe's communal areas where cotton is produced. This implies that the results obtained from this study can safely be generalized to represent the whole set-up in smallholder cotton production in the country.

In Gokwe, there are people of mixed tribal origins. This is because people migrated to the district to take advantage of the cotton production opportunities. This means that the socio-cultural set-up of Gokwe is representative of the different regions in the country.

Research Process

The first encounter with research participants was a reconnaissance visit that was carried out for general familiarization with the research area and the key players in cotton production and pest management in the area. The familiarization process was aided by the use of key informant interviews to elicit information on the general set-up on the ground.

Sampling was done during the reconnaissance visit. Multistage sampling procedures were used to randomly select three villages from the district and then a total of 120 farmers from the three villages (40 from each village).

A questionnaire was then drafted using some of the background knowledge from the reconnaissance visit and was administered to 110 farmers instead of the initial target of 120 since some sample elements could not be accessed (seven cases) and some questionnaires were spoilt (three cases). Each questionnaire was accompanied by a single paged farm input record sheet on which the farmer was to record general crop management data such as input quantities, prices, labour and the dates of carrying out specific operations.

Data Transformation and Analysis

Analytical models

Two main analytical models were used and these were based on the Special Package for Social Scientists (SPSS). The models are:

- The stochastic production frontier model
- Multiple linear regression

The Stochastic production frontier

The stochastic production function is a modification of the celebrated Cobb-Douglas production function which in its stochastic form can be expressed as follows:

$$Y_i = AZ^b e^u \quad \text{...} \quad (1)$$

Where:

Y_i = Output

Z = Vector of the inputs used

A = A constant

b = Elasticities of output with respect to inputs

u = Stochastic disturbance term

e = base of natural logarithm (Gujarati, 1995)

Using the Cobb-Douglas function framework, Headly (1968) estimated the marginal productivity of pesticide use in U.S.A agriculture for the period 1955 to 1963 to be US$4 and concluded that there were benefits from use of more pesticides in U.S.A agriculture.

However, according to Litchenberg and Zilberman (1986), applying a standard production function that ignores the damage abatement/ reduction characteristics of pesticides and treats them as yield increasing inputs overestimated their marginal productivity. They therefore incorporated pesticides in the production function in the form of a damage abatement function so that a modification of the Cobb-Douglas production function becomes:

$$Y_i = AZ^b g(X) e^u \quad \text{.........} \quad (2)$$

Where Y, A, and e^u are defined as in equation (1) but:

g(X) = damage abatement function

Various specifications can be used to represent the damage abatement function. Tauber and Moffit (1992) used three different specifications: the Weibull, the logistic and the exponential specifications and suggested that the exponential specification was more appropriate for pesticides.

This study uses the exponential specification of the damage abatement function so equation (2) is represented as:

$$Y_i = AZ^b e^{dX} e^u \quad \text{.........} \quad (3)$$

Where e^{dX} is the damage abatement function with X being pesticide and d being a coefficient.Taking natural logarithms on both sides of equation (3) gives:

$$Ln\, Y_i = Ln\, A + bLnZ + dX + u \quad \text{.........} \quad (4)$$

This paper uses the above model with the following variables:

Table 1: Description of variables in the stochastic production frontier model

Variable	**Description**	**Hypothesized Sign**
LnYield	The Natural logarithm of value of cotton produced per acre	Dependant
Lnseed	Natural logarithm of the value of seed used	Positive
LncpdD	Natural logarithm of the value of compound D used	Positive
LnAN	Natural logarithm of the value of ammonium nitrate used	Positive
Lnlabour	Natural logarithm of the value of labour used	Positive
Pesticide	Value of pesticide used	Positive
Lneduc	Natural logarithm of number of years of formal education	Positive
Extension	Dummy variable representing whether farmer has access to extension advice or not. 1 = yes and 0 = no	Positive
Sex	Dummy variable representing sex of household head. Takes value 1 if male headed and 0 otherwise	Positive
IPPM	Dummy variable representing whether farmer has undergone training on IPPM. 1 = yes and 0 = No	Positive

The Linear regression model

The Linear regression model is used to determine the farm level factors influencing current pesticide use levels by Gokwe smallholder cotton producers. The following is a description of the variables and the hypothesized signs of coefficients.

Table 2: Description of variables included in the multiple regression model

Variable	Description	Hypothesized Sign
Pesticide	The value of pesticide applied by the farmer	Dependant
Educ	Number of years of formal schooling	Negative
Exp	Number of years on cotton production	Positive
IPPM	Dummy variable representing whether farmer has undergone IPPM training or not. 1 = Yes and 0 = No	Negative
Age	Age of household head	Positive
Inc	Farmer's yearly total income	Positive
Lab	Number of household people available to work on cotton	Positive
Farm	Total area under cotton	Negative
Credit	Dummy variable representing whether farmer has access to credit or not. 1 = Yes and 0 = No.	Positive
Sprayer	Dummy variable representing whether farmer owns a sprayer or not. 1 = Yes and 0 = No.	Positive
AREX	Dummy variable representing whether farmer gets extension advice from AREX or not. 1 = Yes and 0 = No.	Positive
Pcompany	Dummy variable representing whether farmer gets extension advice from pesticide companies or not. 1 = Yes and 0 = N0	Positive
NGOs	Dummy variable representing whether farmer gets extension advice from NGOs or not. 1 = Yes and 0 = No.	Negative
Risk	A measure of the farmer's risk attitude – farmer's perceived crop loss if he/she does not use pesticide (%).	Positive

Results

General household characteristics

Table 3 shows the general household characteristics of the surveyed households. The majority (72%) are male headed and the man is the key decision maker in cotton production while the wife is involved in all other cotton production operations including spraying. Total land area available to households is high by communal area standards and so land cannot be labelled as a constraint to cotton production. The mean labour availability of around 4 people cannot be adequate for manual cotton production especially during peak labour requirements. The mean education level of grade 7 is hardly enough for reading and interpreting instructions on pesticide containers and let alone to follow proper scouting procedures. IPPM is still a new thing in the study area and only 23.1% of the respondents have gone through or are undergoing training. Roughly three quarters of the surveyed farmers own a sprayer.

Table 3: General household characteristics of surveyed households and description of variables included in the models

Male headed (%)	74
Mean age (years)	37.52
Mean farm size (acres)	10.10
Mean years of schooling	7.74
Mean labour availability	3.97
Ownership of a sprayer (%)	76
Mean yearly income ($)*	43 767.13
IPPM training (%)	23.1
Mean farming experience (years)	7.70
Access to credit (% of farmers)	68.3
Risk perception (mean % score)	72.1
Mean revenue per acre ($)*	327.52

* All costs and revenues are stated as at June 2000

Results of the stochastic production function model

Table 4 below shows results from the stochastic production function model in which pesticides entered as a damage control agent. The dependant variable is the natural logarithm of the value of pesticides used.

Table 4: Results of the stochastic production function model

Variable	Coefficient	Significance
Intercept*	0.919	0.012
Lnseed	0.856	0.084
LncpdD	0.601	0.105
LnAN*	0.813	0.039
Lnlabour	0.417	0.187
Pesticide*	0.015	0.019
Ftrain*	0.548	0.218
Extension*	0.219	0.016
IPPM*	-0.497	0.027

* Significant at 10% level of significance DW = 1.892 R^2 = 0.524

The results generally show that all the inputs have a positive contribution to the value of cotton output but only the value of ammonium nitrate used has got a significant contribution at the 10% significance level. The coefficient for the value of pesticide used is 0.015. If we use the exponential specification of the damage abatement function ($\mathbf{e^{dX}}$), the partial derivative of the damage abatement function with respect to the value of output per acre (**Y**) is $\mathbf{de^{dX}}$. Substituting **d** by the actual coefficient of the value of pesticide used (0.015) in the partial derivative gives us the change in the value of output that results from a dollar increase in expenditure on pesticides. This is the marginal value product of pesticide use and was calculated to be 2.03 meaning that a dollar increase in expenditure on pesticides will bring additional $2.03 to revenue from cotton.

Results of the Linear Multiple Regression – Determinants of pesticide use

Table 5 shows results of the multiple regression model that was run to find out the determinants of pesticide use in the study area.

Table 5: Determinants of pesticide use

Variable	Coefficient	Significance
Intercept	16.230	0.051
Educ	25.587	0.321
Exp	87.221	0.377
IPPM*	-0.613	0.048
Age	11.415	0.113
Inc*	2.004	0.020
Lab	42.507	0.205
Farm	112.041	0.139
Credit*	0.916	0.003
Sprayer	0.384	0.416
AREX	0.870	0.115
Pcompany*	0.346	0.044
NGOs*	-0.187	0.047
Risk*	6.232	0.003

R^2 = 0.416 DW = 2.104 * Significant at 10% level of significance

The main factors that were found to significantly encourage the use of pesticides in the study area were farmer's income, access to input credit (including pesticides), the farmer's perception of crop loss if pesticides are not used (risk), and advice obtained from pesticide companies (Pcompany). Training on integrated pest management (IPPM) and advice obtained from Non-Governmental Organizations (NGOs) have a discouraging effect on pesticide use levels. Many other factors stimulate pesticide use but their effects were found not to be significant at the 10% level of significance. The overall R^2 of 0.416 is good enough since the data used in the study was cross sectional.

Conclusions and Recommendations

The results presented in this paper show that pesticide use has a positive contribution to cotton revenue and that farmers can benefit financially by increasing investment on pesticides.

It is however very important to note that the study did not take into consideration the full costs of pesticides such as health costs to the farmer and the community and the potential damage to the ecosystem. Results from this study only give the financial benefits that a farmer may get from increasing pesticide use and does not show the full economic costs of pesticides. The results therefore overestimate the benefits of pesticides especially from the aggregate economic point of view. The study is intended to serve as a starting point to facilitate a detailed and more encompassing economic evaluation of pesticide use in smallholder cotton production.

Increased effort by NGOs to educate farmers on the externalities of pesticides through training on IPPM techniques can help reduce dependency on pesticides while at the same time maintaining or improving the profitability of cotton production because IPPM knowledge has a significant positive contribution to cotton revenue as shown in the stochastic production frontier model.

References

Angern, B. (1996). “Plant Protection Agents in Developing Country Agriculture: Empirical Evidence and Methodological Aspects of Productivity and User Safety”; a thesis submitted to the Swiss Federal Institute of Technology, Zurich, Switzerland.

Chikwenhere, G. and Sithole, S. (1993). “Integrated Pest Management in Zimbabwe”. IPPM workshop proceedings 7 – 11 March 1993, Harare, Zimbabwe.

Gujarati, D.N (1989) “Econometrics”. Basil Blackwell Company, Oxford, UK.

Jowa, P. and Rubvuta (1995), D. “IPM on Cotton in Zimbabwe”. IPM workshop proceedings 5 – 11 October, Harare, Zimbabwe.

Jungbluth, F. (1996) “Crop protection policy in Thailand: Economic and political factors affecting pesticide use”. Pesticide policy publication series number 5, University of Hanover, Hanover, Germany.

Kiss, A and Meerman, F. (1993) “Integrated Pest Management in African Agriculture”. World Bank working paper number142, The World Bank, Washington D.C, USA.

Mudimu, G. (1997) “Pesticide use and policies in Zimbabwe: current perspectives and emerging issues for research”. Pesticide policy project publication series number 2, Hanover, Germany

Nhachi, F and Lowenson, P (1993) “Toxicology of pesticides and the occupational hazards of pesticide use and handling”. UZP, Harare, Zimbabwe.

Rola (1997). “Farmer Field School IPM knowledge and farmer efficiency”. University of Philippines, Laguna, Philippines.

Turner, A. “Description of general pest management practices used by smallholder farmers in Zimbabwe”. CIIFAD/Crop Science department, University of Zimbabwe, Harare, Zimbabwe

Waibel, H. and Fleischer, G. “The Economic benefits of pesticides: A case from Germany”. Hanover University, Germany.