Exposure to pesticides, ill-health and averting behaviour:

Costs and determining the relationships

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Abstract:

Farmers' exposure to pesticides is high in developing countries. As a result they suffer from ill-health, both short and long term. Deaths are not uncommon. The paper examines the cause of this high exposure by estimating farmers' expenditure on precautions taken using the avertive behaviour approach. The data show that the expenditures on defensive behaviour are low. The paper then uses tobit regression analysis to determine factors that influence defensive behaviour. The results are useful, not only for Sri Lanka, but for many countries in South Asia, Africa and Latin America in reducing the current high levels of direct exposure to pesticides among farmers and farm workers using hand sprayers. Farmers' exposure to pesticides is a major occupational *health hazard in these countries.*

Keywords Exposure to pesticides, ill-health, defensive behaviour, influencing factors, developing countries

I. Introduction

Exposure to pesticides by farmers and farm workers in developing countries is common (Gupta, 2004; Sodavy *et al.*, 2000; Antle *et al.*, 1998). Frequent exposure to pesticides results in ill-health, both in the short and long term. Deaths are also not uncommon. In fact ill-health resulting from such exposure is a major health hazard in the agricultural sector in developing countries and the problem shows no signs of abatement (Maumbe and Swinton, 2003; Roberts *et al.*, 2003). Recent estimates cited by Food and Agriculture Organisation (2000) from Pesticide Action Network (PAN) show that approximately 3 million people are poisoned and 200 000 die from pesticide poisoning every year. The largest number of poisonings and deaths occur in developing countries. In finding a solution to minimise the incidence off ill-health it is important to determine whether farmers take adequate precautions and what factors influence the level of precautions taken.

Field observations and published work (e.g. Wilson, 1999) show that farmers' exposure to pesticides is high mainly because of the inadequacy of protective gear worn and 'other precautions' taken. Field survey data [1] are used to examine to what extent precautions are taken by farmers while spraying on their farms. For this purpose the expenditures incurred on defensive behaviour are estimated using the avertive behaviour approach. The estimates show that the costs incurred are very low. The paper then identifies the factors that are likely to influence precautions taken. Field survey data are used to identify these variables using tobit regression analysis.

The remainder of the paper is set out as follows. Section II describes the background to pesticide use and the resulting health effects while Section III describes the defensive behaviour approach and its usefulness for the study. Section IV discusses the extent to which money is spent on defensive behaviour and ill-health resulting from exposure to pesticides. The empirical evidence is discussed. Section V examines the factors influencing defensive behaviour among farmers and Section VI presents the to bit regression results. The final section summarises and concludes.

II. Background to pesticide use and resulting health effects

Since the introduction of the Green Revolution technology in the 1960s farmers mainly in South Asia have been using pesticides in increasing quantities. The Green Revolution technology involved using high yielding varieties (HYVs) of seeds, pesticides and fertilizers in addition to irrigation. These inputs were part and parcel of the Green Revolution technology (Farmer, 1977). This technology was used mainly to boost wheat and rice. Since then the commercial cultivation of vegetables dependent on the use of pesticides have also increased, especially during the off-season when rice and wheat are uncultivated. The increased cultivation of vegetables has been made possible partly because HYVs have shorter crop duration and are not suitable when irrigation is limited. Furthermore, the cultivation of these crops is more profitable if over production can be avoided.

The Green Revolution technology increased production and productivity of rice and wheat by many fold (Wilson, 2000). There has been a similar success with the growing of vegetables. As a result of increased food production South Asia has been able to avoid a Maltusian food crisis. However, there is a dark side to increased commercial food production and the introduction of new technology. Farmers have become increasingly dependent on chemical inputs such as pesticides and fertilizers to grow their crops. Pesticides are now used in increasing quantities to control the pests and diseases that easily attack HYVs of rice and wheat and vegetable crops. Today for example, almost all semi-subsistence farmers in Sri Lanka use pesticides (Wilson, 1999). [2] Pesticides were not an option for many of the farmers in the 1960s before the introduction of this new technology and growing vegetables for a commercial market. In fact, many farmers in Asia and elsewhere who are using this technology and are involved in commercial agriculture are dependent on the use of pesticides. Data available from the 1970s show that the amount of pesticides (insecticides, herbicides and fungicides) used in Sri Lanka have increased from 59 metric tones in 1970 to 6,742 metric tons in 1995 which is a percentage increase of 11, 327% (Wilson, 1999). Available FAO data also shows that the quantity of pesticides used in some countries is still increasing (FAO, 2005). Furthermore, field survey data collected in Sri Lanka (see Section 4 for details of survey) show that farmers use a variety of pesticide brands and the quantities used are also large (Wilson, 1999). This is shown in Table I.

<Take in Table I>

Table I shows that insecticides are the most frequently used pesticides. They are used for the control of insects and they are the most toxic of all pesticides used. Most of the insecticides used in the study area were organophosphates and carbamates and to a lesser extent organochlorins. These pesticides are known to be toxic to humans, wildlife and the environment (Wilson and Tisdell, 2001). Table II also shows the quantity of pesticides used by an average farmer in the study area. It is around 356 ounces per farmer per year. In other words, a farmer uses more than twenty two, sixteen ounce bottles of pesticides a year, most of which are insecticides. Similar high levels of pesticide use have been reported in other countries (e.g. Maumbe and Swinton, 2003; Antle *et al.*, 1998). In spraying these pesticides, farmers are often directly exposed to these chemicals and some for as long as 6 hours in Sri Lanka. Long hours of spraying have been reported in other countries as well. Due to the nature of farming (mainly small scale agriculture) in developing countries, pesticide spraying is undertaken manually using hand sprayers. Hence the level of direct exposure is very high which results in high levels of morbidity and even mortality among the farmers. A breakdown of the average handling and spraying hours is shown in Table II.

<Take in Table II>

Table II shows that an average farmer handles and sprays pesticides for more than half a working day on his farm on a typical spraying day. The frequency of use varies from one spraying day a month to as much as two spraying days a week during the peak of the cultivating season. The frequency of use can vary greatly from crop to crop and season to season. On average, a farmer handles and sprays pesticides for around 197 hours a year (Wilson, 1999).

In using these pesticides, farmers take some form of precaution to avoid direct exposure to pesticides. However, such measures are usually found to be inadequate (Maumbe and Swinton, 2003; Sodavy *et al.*, 2000; Wilson, 1999). A breakdown of precautions taken is shown in Table III for farmers in Sri Lanka.

<Take in Table III>

Table III shows that in the sample group, approximately 34% of the respondents said that they wear some form of protective clothing when spraying pesticides, 31% wear masks and 44% wear gloves. Very few farmers were found to wear shoes. A farmer at a given time can take one or many of the precautions shown in Table III. Farmers using special storage facilities were very low. Approximately twenty nine percent of the farmers incurred costs in taking 'other precautions' such as hiring labour in order to protect them from direct exposure. Often, this was done on grounds of medical advice or when having to spray for long hours. Seventy percent of the interviewed farmers were found to take at least one of the precautions mentioned above. Such precautions taken, however, do not mean that they were adequate. Similar conclusions have been reached by Sodavy *et al.* (2000). Furthermore, almost all the spraying is done manually (by hand) due to the use of hand sprays and hence the direct exposure levels are even greater.

Pesticides, although designed to control pests and diseases, have several drawbacks. Farmers using them, when exposed become sick (Keim and Alavanja, 2001). The illnesses can range from headaches, skin rashes, nausea, twitching of muscles to chest pains and a host of other illnesses. Farmers as a result end up in hospital, take treatment from doctors or simply take home made remedies. The other negative effects include damage done to the environment and increasing resistance to pesticides by pests (Wilson and Tisdell, 2001). Furthermore, there are other consequences of dependence on pesticides such as lock-in aspects which are discussed in Wilson and Tisdell (2001).

Many field studies and secondary data worldwide confirm illnesses and deaths resulting from exposure to pesticides (e.g. Maumbe and Swinton, 2003; Wilson, 1999; Antle, 1998). Secondary data in Sri Lanka show that at least 15,000 farmers take treatment from government hospitals every year (Sri Lanka Annual Health bulletins, 1975-2001). Field surveys also show that large numbers of farmers suffer from some form of sickness due to exposure to pesticides while handling and spraying (e.g. Wilson, 1999). Secondary data also show that deaths are not uncommon (e.g. Sri Lanka Annual Health Bulletins, 1975-2001). However, this data should be interpreted with caution. This is because not all hospital admissions and deaths are due to occupational poisoning (i.e.

handling and spraying on the farms); they also include cases of self-ingestion (suicides), accidental ingestion, and homicides (Roberts *et al.*, 2003).

When farmers suffer from ill-health due to exposure to pesticides they incur many private costs (in addition to public costs), both tangible and intangible. Some of the tangible costs are as a result of consulting private doctors when public hospital care is unavailable or not desired, purchasing drugs, due to loss of working days on their farms, time spent on seeking treatment, hiring labour when sick, loss of efficiency on farms, leisure time losses and long term costs.

In addition, farmers take precautions to avoid exposure to pesticides. In this case, too, farmers incur costs. They include purchasing protective clothing, masks, gloves, shoes, building special storage units and taking other preventative measures (e.g. hiring labour). It is important to estimate these costs for several reasons. One reason is to see whether farmers take adequate precautions. Costs incurred on purchasing protective gear and 'other precautions' is a reasonable indicator of preventative measures undertaken. It is well documented that there is a relationship between costs incurred on avertive behaviour and ill-health resulting from exposure to pesticides (Wilson, 2003). This is because if the defensive behaviour is high then it is expected that the exposure would be low and hence the ill-health resulting from such exposure. This can be shown as follows.

Consider the following contingent valuation (CV) willingness to pay equation (WTP) to avoid exposure to pesticides

$$WTP = w\frac{dS}{dP} + \frac{dM}{dP}Q_M + \frac{dD}{dP}Q_D - \frac{U_S}{\lambda}\frac{dS}{dP} \qquad (1)$$

The equation shows that the CV WTP can be written as the sum of the value of lost time w(dS/dP) plus the observed changes in mitigating (e.g. medical) expenditures, Q_M (dM/dP), plus defensive expenditures, Q_D (dD/dP), and the disutility resulting from illness ($\partial U/\partial S$) (dS/dP)/λ where $\lambda = 1/m$, the marginal utility of income, converts the disutility of illness $\partial U/\partial S$ into monetary values. This implies that when the defensive measures undertaken are inadequate then the first two terms and the fourth term on the RHS of the equation will exist. On the other hand, if defensive measures undertaken to prevent total exposure are sufficient, then there will mainly be defensive expenditures. If defensive expenditures undertaken are small (inadequate) then the first two terms and the last term will be large.

III. Brief introduction to the avertive behaviour approach and its usefulness for the study

This approach can be used to show whether farmers take adequate precautions or not and to what extent these precautions are taken. Many studies have shown that the precautions undertaken are inadequate (Maumbe and Swinton, 2003; Sodavy *et al.,* 2000). This technique can reliably estimate the extent to which precautions are undertaken by farmers when using pesticides on their farms. Furthermore, the rest of the data collected from the survey can be used to determine what factors influence defensive behaviour. This could explain, to some extent, the high levels of exposure by farmers. The use of the avertive behaviour approach was first discussed in a paper by Stevens (1966) in an article in Water Resources Research. Stevens (1966) considered the benefits of avoiding water pollution that would otherwise affect recreational fishing success. His main argument was that the quality of fishing was represented by the recreational fishing success per unit effort. Water pollution, it was argued, would affect recreational fishing success. He tried to show the benefits of water pollution control by estimating a demand function for the sport. Several studies have been conducted in the field of health economics because this is one of the most appropriate methods available for estimating costs related to precautions taken.

The avertive behaviour approach is based on the notion that any defensive expenditure incurred (including time) infers an individual's value for the subject in question. In other words, it can be interpreted as the willingness to pay to reduce or avoid ill-health. In using this technique all the direct and indirect costs associated with defensive behaviour are considered. For example, any visits to the doctor (e.g. checkups), any medication taken in anticipation of any risks (e.g. medical care), the time spent on such visits, any leisure foregone to devote time for defensive behaviour, any protective gear used (such as masks used when spraying pesticides) and labour costs, are considered.

In avertive behaviour studies, it is important to determine the exact effectiveness of the defensive behaviour being adopted. Only the costs of the defensive behaviour that have specifically benefited the individual should be estimated. In some cases taking account of the defensive behaviour accurately and adequately could be a problem. A good example cited by Cropper and Freeman (1991) is the use of an air conditioner to reduce the effects of air pollution. It was pointed out that the mere presence of an air conditioner in a home or a car is not an accurate measure of an individual's reduced exposure to air pollution because of the many joint benefits that an air conditioner can provide. Furthermore, in the case of spraying pesticides joint effects such as hiring people to spray pesticides, although reducing risks of exposure to pesticides can also give rise to more leisure and other benefits for the person hiring the workers. Therefore, it is important to take into account both joint products and substitutability of products. In other words, it is important to isolate the health benefits for which it was intended and thereby estimate only these costs.

IV. Money incurred on defensive behaviour, ill-health due to exposure to pesticides: some empirical evidence

The data collected from a sample of 203 farmers surveyed in Sri Lanka in the summer of 1996 are used. Five areas were sampled from the intermediate dry zones of Sri Lanka where intensive agriculture is widespread. The regions covered were Yatawatte, Kandalama, Beligamuwa, Ambana and Polonnaruwa in the Central and North Central provinces of Sri Lanka, within a 75-100 mile radius. Only farmers who were regular pesticide users and cultivate land not less than half an acre and not more than three acres were selected, because according to a census conducted in 1982 by the Department of Census and Statistics, Sri Lanka, the average farm size was 1.94 acres. Therefore, as the census statistics show, a large number of farmers cultivate a land area which is less than three acres and more than half an acre. The five regions selected specialise in growing various food crops. As a result, the level and intensity of pesticides used and the level of exposure to pesticides vary from region to region. Judgment sampling was employed to collect the necessary data for the study. Prior to the interviews, a pilot study was conducted to determine the viability of questions prepared to collect the necessary data. The questionnaire was modified, removing questions that proved difficult to administer. From the data collected the average defensive behaviour costs are estimated.

The survey revealed that 61% of farmers interviewed had incurred some form of expenditure on protective gear and 32% on other defensive behaviour. The survey also revealed that 70% of the interviewed farmers incurred costs in wearing protective gear as a well as taking ‘other precautions’. However, they were inadequate. Similar results have been observed in other studies (e.g. Sodavy *et al.*, 2000). The survey results are shown in Table IV.

<Take in Table IV>

Table IV also shows a breakdown of the extent of precautions taken by the interviewed farmers in the five study areas. As can be seen there is considerable regional variation in the costs incurred ranging from 97% (Ambana) to 47% (Yatawatte). It is interesting to note that Ambana is one of the areas with high pesticide use due to intensive vegetable cultivation. In this area spraying takes place every 2-3 days. However, the extent of ‘other precautions’ taken is low for all the study areas.

Since many studies (e.g. Maumbe and Swinton, 2003; Sodavy *et al.* 2000; Sivayoganathan *et al.* 1995) show that the amount of precautions taken is inadequate it is important to determine how much farmers spend on defensive behaviour. One way of ascertaining whether the precautions taken were adequate is to calculate the costs of the protective gear used and 'other precautions' taken. To estimate the costs the prevailing market prices were used. The amount of money spent on each protective item and 'other precautions' taken during a twelve month period are shown in Table V.

<Take in Table V>

Table V confirms that the average cost of precautions taken to reduce direct exposure in the five surveyed regions is low. It was only Rs 405 per year. This amounts to approximately 7 dollars [6] a year, yet constitutes around 12% of an average farmers monthly income in Sri Lanka. The income was approximately Rs 4,748 (US $ 86). There is considerable regional variation in per capita defensive expenditure ranging from Rs 46.45 (Polonnaruwa) to Rs 1,079 (Ambana). However, costs incurred are very low. This explains why farmers in Sri Lanka suffer from high levels of ill-health. Table VI shows some of the common illnesses affecting farmers when exposed to pesticides on a typical pesticide spraying day.

<Take in Table VI>

Table V shows that although farmers spend more than 10% a year of an average farmer's monthly income it is not adequate because they suffer from several acute symptoms on a typical pesticide spraying day (Table VI). The columns in Table VI show the percentage of respondents (farmers) affected. The numbers from 1 to 6 in boxes show how often the respondents were bothered by the illnesses shown in the left-hand side column of the table. A farmer can suffer from any one or more of these illnesses. The health effects range from feeling faint to blurring vision and tremors (Table VI). These are the usual acute symptoms which appear on spraying days. Similar symptoms appear on non-spraying days as well (Maumbe and Swinton, 2003); Wilson, 1999). Chronic, long-term health effects range from chest pains, blindness, loss of memory, ulcers, depression and various cancers (Maumbe and Swinton, 2003; Keim and Alavanja, 2001).[7]

The illness shown in Table VI is a cost to farmers. Table VII shows the percentage of farmers incurring costs as a result of these illnesses during a twelve month period.

<Take in Table VII>

Table VII shows that on a typical spraying day or soon afterwards (usually within four hours), 20% of the farmers interviewed had been admitted to hospital and incurred costs, 30% had taken treatment from a doctor and incurred costs and another 64%, although they were not hospitalized or did not require treatment from a physician took home made self-treatment and incurred other private costs. Furthermore, 42% of the respondents incurred costs on non-spraying days and 35% incurred costs due to long-term illnesses resulting from direct exposure to pesticides. Approximately 96% of the interviewed farmers said that they suffered from some form of acute illness and incurred costs during a twelve month period. The costs to farmers have been estimated to be between Rs 273 million and 1639 (Wilson, 2002). High levels of costs have also been reported by Maumbe and Swinton (2003). The high costs show that low levels of expenditure do not provide adequate protection. In other words it is a waste of farmers' limited financial resources when the precautions taken are inadequate (Equation 1).

Furthermore, although the defensive cost incurred by an average farmer is low, it runs into millions of rupees when aggregated among all the farmers who use pesticides. This is shown in Table VIII.

<Take in Table VIII>

No one in Sri Lanka is certain how many farmers use pesticides. Assuming 100,000 farmers use pesticides, the costs of defensive behaviour is approximately Rs 40 million a year. If it is 300,000 farmers it is more than Rs 121 million a year. Furthermore, low costs of defensive behaviour by farmers also mean higher levels of ill-health (Equation 1). Ill-health incurs large costs, both direct and indirect as shown by Maumbe and Swinton (2003) and Wilson (1999).

Hence, when farmers take low levels of precautions they incur costs due to ill-health as well as costs arising from purchasing protective gear and 'other precautions' taken. The costs run into millions of rupees every year. These are both private and public costs. These costs are large for developing countries such as Sri Lanka which they can ill afford. Long term costs arising from exposure to pesticides are another issue.

Since the farmers' levels of exposure and the costs are high it is important to reduce the current high levels to save farmers' lives as well as money for farmers and the country. In order to rectify this situation it is important to examine what factors influence defensive behaviour so that such knowledge can be used to increase the level of precautions taken. It is hoped that this can substantially reduce the high levels of casualties. Otherwise, farmers will continue to spend more than 10% of a month's income per year and yet have little impact on the incidence of ill-health resulting from exposure to pesticides.

V. Factors influencing defensive behaviour among farmers

It is possible to use the survey data to identify factors that influence defensive behaviour among farmers. For this purpose to bit regression analysis is used. Many factors have been cited as influencing defensive behaviour by researchers such as Maumbe and Swinton (2003); Keim and Alavanja (2001); Sodavy *et al.* (2000); Antle *et al* (1998) and Sivayoganathan *et al.* (1995). They include the level of education, availability and affordability of protective gear, availability of repair facilities, awareness of harmful effects of pesticides used, type of crops cultivated, methods of application, types of pesticides used, acreage sprayed, frequency of pesticide use, prevailing temperature during pesticide spraying, government support to purchase protective gear, extension services provided by government agencies and cultural and environmental factors.

Although all of the above factors could influence the extent of precautions taken by farmers when spraying pesticides it is not an easy task to collect all the relevant data. However, data collected for seven variables during the survey are used. The variables for which data are available are education, yearly income, crops cultivated, frequency of pesticide use, types of pesticides used, whether or not farmers have read ‘instructions and warnings’ on the bottle and acres sprayed for a year. The dependent variables in the regression analysis are the costs incurred on defensive behaviour. The costs are used as a proxy for defensive behaviour.

Costs incurred on defensive behaviour (DE) are taken to represent the level of precautions taken which is written as a function of education (EDU), yearly income (INC), amount of crops cultivated (CROP), frequency of pesticide use (FOPU), types of pesticides used (TPEST), farmers reading instructions and warnings on the pesticide bottle (RW) and acres sprayed in a year (ACRE). As the signs indicate (Equation 2), it is expected that the higher are the years of education, higher would be the level of precautions taken. Furthermore, it is hypothesized that higher is the level of income, better would be the precautions taken. It is also hypothesized that the larger are the number of crops cultivated [8], the higher would be the precautions taken. In addition the more frequently are pesticides used, the higher are the chances of using protective gear. Also when a larger number of pesticide types are used, the higher would be the level of expenditures on precautions taken. It is also assumed that the more a farmer reads warnings on the pesticide bottle, higher would be the use of protective gear. Finally, we hypothesize that the larger is the acreage sprayed, the better would be the precautions taken.

Guided by the data collected from the field survey and research work (for example, see Maumbe and Swinton, 2003; Sodavy *et al.*, 2000); Antle *et al.*, 1998; Sivayoganathan *et* *al.,* 1995; Antle and Pingali, 1994; Forget, 1991; Jeyaratnam, 1982) the following specification was developed for a to bit regression analysis. The data have been transformed into yearly figures and normalized into per capita terms.

$$DE = f\,(\underset{+}{EDU},\ \underset{+}{INC},\ \underset{+}{CROP},\ \underset{+}{FOPU},\ \underset{+}{TPEST},\ \underset{+}{RW},\ \underset{+}{ACRE}) \qquad (2)$$

The expected signs of the partial derivatives are shown beneath each argument in the function. The means and standard deviations for all the variables that were included in the regression analysis are shown in Table IX.

<Take in Table IX>

The mean precautionary costs are only Rs 405.14 per year which is wholly inadequate by any standard, especially when the intensity of pesticide spraying by these farmers is taken into account (Table I and II). Hence, it not surprising to see the high levels of morbidity and mortality rates among farmers and the high costs associated with ill-health as discussed in Section 4. The acreage sprayed per year by an average farmer is 45 which is more than half an acre per week. A large number of farmers had read warnings in the pesticide bottles about the dangers of handling and spraying pesticides and the mean was as high as 0.92. The mean frequency of pesticide use is 33 where approximately five (4.94) pesticides a year are used on almost three crops (2.7). The average level of income per year is Rs 56,978 with almost eight years of schooling.

Tests performed showed some degree of heteroscedesticity as can be expected in cross sectional data. Many solutions have been suggested to overcome this problem and they include using logs or semi logs, taking the square roots or reciprocals of the variables (Bryman and Cramer, 1997). Since there are a few respondents who have not suffered any illnesses and hence they have not incurred any costs, it was not possible to use semi logs. The alternative was to take the square root transformation of the dependent variable. This minimised the heteroscedesticity problem and also improved the goodness of fit. The 'tolerances and variable inflation factor and the co linearity diagnostics' for the variables showed that multicollinearity was also not a problem. A tobit analysis is used because it is the more theoretically appropriate method when the dependent variable contains zeros. This is because the dependent variables are limited in their range (Amemiya, 1984):

$$y_t^* = x_t^{'}\beta + u_t, \qquad \begin{array}{ll} y_t = y_t^*, & \text{if RHS>0} \\ y_t = 0, & \text{otherwise} \end{array} \qquad (3)$$

where y_t^* is a non-observable random variable.

VI. Regression results

The results of the tobit analysis of the 203 observations are presented in Table X. The goodness of fit is small, but is not uncommon for work of this nature (e.g. see Brien *et al.,* 1994); Row and Chestnut, 1986). One of the reasons for this is because the data used are cross-sectional. For this regression analysis the results are interpreted for a one tailed test. The null hypothesis is H_0:$\beta = 0$ and the alternative hypothesis is, H_1: $\beta < 0$ or H_1: $\beta >$ 0.

<Take in Table X>

Many of the results are consistent with what was expected and has the correct signs. The EDU, CROP, FOPU, TPEST are significant. This means that the higher is the level of education, then better would be the amount of precautions taken. Furthermore, the more crops are grown (which includes crops that need regular pesticide spraying), the better are the precautions taken. Furthermore, the higher is the frequency of pesticide use, higher would be the precautions taken and the higher are the types of pesticides used, then better would be the precautions taken. The income (INC), read warnings (RW) and the acreage sprayed (ACRE) variables are not significant. This is contrary to what would be normally expected (Equation 2). The negative signs reported for these three variables are not surprising for subsistence farmers. When a farmer sprayed a larger acreage, what the results show is that he would be taking less precautions. This result is not surprising because given the inadequacy of precautions taken, as shown by the low expenditures on defensive activity, when a larger acreage is sprayed, and then the precautions taken are less. Furthermore, a larger acreage sprayed means, larger is the wear and tear of the protective gear. It is also possible that when a larger acreage is sprayed per given day, the amount of precautions taken (such as gloves, masks, shoes worn) tend to be less because of the temperature prevailing in the region (which was more than 30+ degrees Celsius). There is considerable discomfort in wearing protective clothing for long periods of time, especially in the tropical heat. This has been observed in other studies as well (e.g. Sodavy *et al.*, 2000; Sivayoganathan et al., 1995).

Although the negative income variable is inconsistent with what will normally be the case, this result is not surprising either. In the case of subsistence farmers, a marginal change in income cannot be expected to have an impact on the precautions taken, simply due to the fact that the marginal change in income is still below an average farmers expected level of income that may cause him to devote more resources to defensive action. Hence, a marginal change in income among subsistence farmers cannot be expected to increase the precautions taken against direct exposure to pesticides. The negative sign of 'read warnings' (RW) variable may be because although farmers read warnings they do not often adhere to instructions and warnings due to many reasons such as not being able to understand the instructions, the prevailing humidity, inability to obtain adequate protective gear, cultural taboos, and many other factors as pointed out by Sodavy *et al.* (2000); Antle *et al.* (1998) and Sivayoganathan *et al.* (1995).

VII. Conclusions

The paper shows the extent to which precautions are taken by farmers when handling and spraying pesticides on their farms. The average cost per year was approximately 12% of an average farmer's monthly income. The costs are low by any standard. These costs and the costs arising from pesticide exposure related illnesses per year when combined are very large and exceed a farmer's monthly income. When the intangible costs (e.g. pain, suffering, stress and discomfort) are also considered then the costs are bound to be larger. These costs demonstrate that farmers using pesticides incur large costs due to pesticide exposure related illnesses and it is imperative that these costs are reduced.

The regression results show that among subsistence farmers, the frequency of pesticide use, education, number of crops cultivated and the types of pesticides used influence defensive behaviour. The results also show that income of the farmer is insignificant as well as the number of acres sprayed and the ‘read warnings’ (RW) variables. An outcome of these variables is that (although insignificant), when farmers spray a larger acreage, then the level of precautions taken tends to decrease. This may be due to wear and tear of protective gear, prevailing high temperatures, being uncomfortable to use protective gear for long periods of time, and the inability to purchase more expensive protective gear that minimises the discomfort.

The regression analysis examined only some of the variables that are believed to have an impact on the precautions taken. Some very important variables such as cultural taboos, prevailing temperatures on the day of spraying, availability of suitable protective gear and many other factors that Maumbe and Swinton (2003); Keim and Alavanja (2001); Sodavy *et al.* (2000); Antle *et al.* (1998); Sivayoganathan *et al.* (1995); Antle and Pingali (1994); Forget (1991) and Jeyaratnam (1982) have regarded as important variables influencing defensive behaviour were left out for lack of data. Inclusion of such variables to examine their effect on the level of defensive behaviour is necessary in future work. Finally the results of this study are useful for agricultural managers in South Asia, Africa and Latin America in their attempt to reduce the current high levels of direct exposure to pesticides among farmers.

Notes

1. Field survey data were collected by the author with the assistance of two trained

research assistants from five agricultural regions in Sri Lanka during the summer of 1996. Details of the survey are reported in Section 4 of the paper.

2. It is worth mentioning that semi subsistence farmers because of their land holding size use hand sprayers to spray pesticides as opposed to large scale farmers who spray pesticides from inside a tractor or by aircraft.

3. Details of the survey are reported in Section 4 of the paper.

4. Details of the survey are reported in Section 4 of the paper.

5. Details of the survey are reported in Section 4 of the paper.

6. The exchange rate prevailing during the study period (June-September, 1996) was US$1 = Rs 55 (approximately).

7. These observations were made by farmers based on their perceptions of ill-health using pesticides which were confirmed by physicians. In the USA many studies have established these links. For example, see Blair and Zahm (1993) and Potti and Sehgal (2005).

8. This is because to spray different crops, the precautions taken are different. For example, to spray a vine more head gear has to be worn to prevent pesticide mist falling on to the head and face. Hence, the more crops a farmer sprays, the more likely it is that he will have to incur large costs on defensive behaviour because of the different precautions that have to be taken.

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Table I.
Number of brands and quantity of pesticides used per year in five study areas of Sri Lanka

Pesticides	Number of brands	Average use of Pesticide brands
1. Insecticides	48	2.82
2. Herbicides	27	1.11
3. Fungicides	28	0.99
	Total use	**Average use**
Ounces	72,330	356.30

Source: Wilson (1999). [3]

Table II.
Handling and spraying exposure to pesticides on a typical pesticide spraying day in Sri Lanka

Direct exposure time	Average hours of a typical pesticide spraying day
Spraying hours per day	5.71
Handling and mixing hours per day	0.19
Total	5.91

Source: Wilson (1999). [4]

Table IV.
Percentage of respondents incurring costs on defensive behaviour to avoid exposure to pesticides in the study area

	Beligamuwa	**Ambana**	**Kandalama**	**Yatawatte**	**Polonnaruwa**	**Total**
Respondents	42	31	46	53	31	203
	%	**%**	**%**	**%**	**%**	**%**
Defensive costs						
PC	48%	97%	69%	47%	51%	61%
OC	10%	29%	46%	49%	10%	32%
All	52%	100%	69%	75%	55%	70%

Note: **PC:** Number of respondents incurring costs on some form of protective gear.
OC: Number of respondents incurring costs apart from costs on protective gear (for example, costs incurred on special storage and hiring labour).
ALL: Includes all respondents incurring costs on protective clothing and other defensive behaviour.

Table III.
Protective items and percentage of farmers taking precautions in Sri Lanka in the study areas

Protective item	Percentage
Wearing Protective Clothing	34.48
Wearing Masks	31.52
Wearing Gloves	44.33
Wearing Shoes	4.43
Building Special Storage Units	5.41
‘Other precautions’ Taken (e.g. hired labour)	28.57

Source: Wilson (1999). [5]

Table V.
Costs of precautions taken to reduce direct exposure to pesticides

	Protective Item	Total cost (Rs)	Average (Rs)
[1]	Wearing Protective Clothing	26,745	131.74
[2]	Wearing Masks	4,189	20. 63
[3]	Wearing Gloves	3,900	19. 21
[4]	Wearing Shoes	445	2.19
[5]	Building Special Storage Units	10,075	49. 63
[6]	'Other precautions' Taken (e.g. hired labour)	36,890	181.72
	Total	**82,244.5**	**405.14**

Table VI.
Frequency of illnesses affecting farmers on a typical pesticide spraying day

	1	2	3	4	5	6
Illnesses Recorded on a Spraying day	%	%	%	%	%	%
Faintish feeling	19	05	03	05	38	36
Headache	20	09	04	12	24	19
Dizziness	16	07	06	08	23	37
Nausea	13	07	03	04	23	51
Excessive Salivation	44	10	01	06	14	26
Eye irritation	09	07	02	04	10	66
Eye tearing	07	01	01	06	14	77
Vomiting	02	0.4	02	06	25	69
Weakness of muscles	12	03	02	03	11	67
Difficulty in breathing	06	04	02	03	13	70
Twitching of eye lids	05	03	00	04	06	91
Cramps	06	03	02	03	07	86
Diarrhea	00	0.4	00	01	01	12
Twitching of muscles in the face	08	05	01	04	04	75
Twitching of muscles in the body	20	05	02	03	12	55
Blurring Vision	08	04	02	03	07	74
Tremor	18	02	01	04	18	71

1 Every day
2 Almost every day
3 About half of the time
4 Now and then, but less than half of the time
5 Rarely
6 Not at all

Table VII.
Percentage of respondents incurring costs due to pesticide pollution in the study area

	Beligamuwa	Ambana	Kandalama	Yatawatte	Polonnarua	Total
Respondents	42	31	46	53	31	203
	%	**%**	**%**	**%**	**%**	**%**
Medical costs						
A	30%	19%	17%	15%	19%	20%
B	21%	13%	50%	41%	13%	30%
C	78%	97%	43%	47%	90%	64%
NSD	50%	45%	73%	26%	13%	42%
LTC	21%	22%	50%	47%	23%	35%
E P	100%	100%	100%	92%	87%	96%

A: Respondents admitted to hospital and incurring private costs (includes all costs associated with pesticide pollution).
B: Respondents consulting a doctor and incurring private costs (includes all costs associated with pesticide pollution).
C: Respondents not admitted to hospital or consulting a doctor, but seeking some form of treatment and incurring private costs (includes all costs associated with pesticide pollution).
NSD: All private costs incurred on non-spraying days due to exposure to pesticides (includes costs on medicine, consultation and other costs).
LTC: All long-term private costs incurred due to direct exposure to pesticides (includes costs on medicine, consultation and other costs).
EP: Number of respondents suffering from acute illnesses described in the interview on a typical pesticide spraying day (excludes non-spaying days and long-term illnesses) and incurring costs. There were eight respondents in the sample (n = 203) who did not incur any costs.

Note: It is possible that a farmer may experience any two or more of the above mentioned costs in a given year.

Table VIII.
Defensive cost scenarios to reduce direct exposure to pesticides by farmers in Sri Lanka

	Protective item	Cost scenarios A	B	C	D
[1]	Wearing Protective Clothing	6587000	13174000	19761000	39522000
[2]	Wearing Masks	1031500	2063000	3094500	6189000
[3]	Wearing Gloves	960500	1921000	2881500	5763000
[4]	Wearing Shoes	109500	219000	328500	657000
[5]	Building Special Storage Units	2481500	4963000	7444500	14889000
[6]	Others (e.g. hired labour)	9086000	18172000	27258000	54516000
	Total	**20,257000**	**40,514000**	**60,771000**	**121,542000**

Note: The average cost of defensive behaviour per protective item shown above (see Wilson, 1999) are multiplied by the number of farmers whom we believe are affected by direct exposure to pesticides. We believe between 50,000 to 300,000 farmers are affected. Accordingly, we prepare the scenarios as follows: Scenario A =50,000 farmers. Scenario B = 100,000 farmers. Scenario C = 150,000 farmers. Scenario D = 300,000 farmers.

Table IX.
Variables that influence defensive behaviour

Variable	Description	Mean	Standard deviation	Min	Max
PC	Precautionary Costs	405.14	815.00	0	5060
ACRE	Acreage Sprayed per Year	45.29	39.67	6	280
FOPU	Frequency of Pesticide Use per Year	33.29	17.98	6	92
INC	Yearly Income	56,978.1	53855.01	2,400	360,000
TPEST	Types of Pesticides Used	4.94	2.32	1	12
EDU	Years of Education	7.50	3.32	0	14
CROPS	Total number of crops grown	2.7	1.7	1	9
RW	Read Warnings	0.92	0.26	0	1

Table X.
Regression results showing factors influencing defensive behaviour to reduce direct exposure to pesticides

Variable	Coefficients	Standard error	z = b / s. e.
ACRE	-0.064	.032	-0.700
FOPU	0.191	.070	2.359****
INC	-0.077	.000	-1.291
TPEST	0.139	.460	1.625*
EDU	0.120	.305	1.820**
CROP	0.149	.609	1.603*
RW	-0.051	3.791	-0.834
(Constant)	-	5.287	-0.557

R Squared = 0.114 Adjusted R Square = .082 Standard Error = 14.07 F = 3.58
The asterisks *** *, ***, ** and * indicate 1, 2.5, 5 and 10% level of significance respectively for a one tailed test.
59 observations at zero
144 non-zero observations
n = 203

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