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Estimating Health Impacts of Pesticides Use: New Evidence from Vegetable Farmers in Sri Lanka

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ABSTRACT

Pesticides are a significant and growing component of the modern agricultural practices. Farmers face acute and chronic health effects because of prolonged exposure to pesticides. This is because the existing pesticides pricing, regulatory structure and inadequate storage, unsafe handling practices, and improper maintenance create an environment with greater accessibility with raising health cost of using them. Poisoning due to occupational exposure is very common among Sri Lankan farmers, but less well documented. This study investigates the health impacts of pesticides use on vegetable farmers in Sri Lanka. Data covering 385 farmers who cultivate vegetable for commercial purposes are used for the analysis. The results reveal that approximately 48 % of the respondents have the experience of pesticide exposure related one or more illnesses during a typical cultivation season. While estimating the cost of illness, the study compares farmers Willingness to Pay (WTP) to avoid pesticides induced illnesses with cost of illness estimates. The study finds that the average monthly cost of illness per person was USD 5.7. However, mean WTP to avoid pesticides induced illnesses was USD 3.3 per person per month. Results clearly show that mean WTP estimates tends to underestimate real values of the cost of illness. The study also identifies the factors that determines the WTP and then discusses some of the key policy implications of the analysis.

Introduction

Agriculture is the most important sector of the economy in the world as it provides food and livelihood securities [1,2]. After Second World War with the industrialization of agriculture has favored the use of plenty of agrochemicals including fertilizer, pesticide, micronutrients and plant growth regulators [3]. Pesticides are an integral part of modern agriculture, employed in various agricultural practices to control pests, weeds and diseases in plants. It includes a wide range of herbicides, insecticides, fungicides, rodenticides, etc. From the economic point of view, the use of pesticides is based on three-legged supports of efficiency namely the increase in production of crops, the increase in quality of production and the reduction in agricultural labour and energy expenses [4]. In the world approximately 5.7 billion pounds of pesticides are utilized annually for agricultural purposes. Over the past 20 years' global pesticide use has grown to 3.5 billion-kilogram active ingredients per year, amounting to a global market worth $45 billion [4]. Globally herbicides accounts for 42%, insecticides 27%, fungicides 22%, and disinfectants and other agrochemicals 9% of global pesticides sale [5]. Some studies in this field [6-8] found that the health risk was reported to be the most important factor for consumer choice, but consumers are uncertain about their magnitude because they have limited information about pesticide concentrations, the cumulative toxicity of repeated exposure to trace quantities and the extent to which pesticides may be remove by washing, cooking and other treatment. There is visible parallel correlation between higher productivity and higher chemical input use which has resulted in number of environmental issues and health effects [3].

Pesticides have been used for agricultural practices in Sri Lanka since the 1950s. Due to the positive trends observed via the scope and use of pesticides their import has grown over the years. Despite many advantages, there are some potential hazards and risks associated with pesticide use. In many developing countries like ours, very often small farmers are not competent enough to use highly toxic pesticides safely while protecting their health and quality of the environment. Some studies show that pesticides residues are found in food, drinking water, surface water, breast milk and urine [8,9]. Non-optimal and non-judicious use of pesticides may lead to the development of resistance in pests to pesticides in the long run and certain externalities like environmental pollution and health hazards.

In Sri Lanka vegetable growers commonly depend on pesticides, typically used in heavy doses. However, its heavy use in agriculture is likely to contaminate soils, ground and surface water and mainly increase health risk of farmers and consumers because of exposure to the pesticides used in agriculture. In Sri Lanka, studies using the cost-of-illness approach [3-10] have estimated that a farmer on average incurs a cost of around US $ 97.58 annually in handling and spraying of pesticides. There are reports of health problems such a liver disorder, cancers often attributed to long-term exposing to pesticides as well as lung disorders and skin disorders associated with short term exposure, immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities recorded by local health clinics [11]. Pesticide application in agriculture has obvious short-term economic benefits. They may reduce the cost of production or reduce crop loss due to pest or disease infection. However, it also cost to society in terms of health or environmental cost indirectly. Accordingly, the economic evaluation of health cost of pesticides is required to design effective rural health policies to reduce pesticide poisoning cases among the farming population. There are only few studies that have analyzed farmers' willingness to pay for reducing the health effects of pesticides in developing countries. In this context, this paper presents health impacts of pesticide use on vegetable farmers in Sri Lanka, while estimating the cost of illness. The objective is to assess farmers' willingness to pay to avoid pesticides related health impacts. The results of this study will assist in the design of programs or policies to effectively reduce the negative effects of pesticides usage in Sri Lanka.

Research Method and Data

There is growing evidence to show that pesticide has negative effects on human health in crop production [3-7] In this context, some authors attempted valuing the risk of pesticides to human health and identified its short-run and long run effects. Meanwhile, other scholars [12-14] included the environmental component into cost analysis and found substantially higher environmental costs of pesticide risk than health costs. Exposure to pesticides can occur in many ways. Farmers and farm workers can be exposed to pesticides in agriculture through the treatment of crops, plants and grain stores. According to model available in the literature [15] an individual's well-being increases with aggregate consumption (C) and leisure (L) but is negatively affected by sick days (S).

$$U = U\left(C, L, S; X_n\right) \quad (1)$$

Where the utility is increasing in C and L while it is decreasing in S. X is a vector of individual characteristics capturing preferences for income, leisure and health [12]. The relationship between pesticides induced damage (D) and health outcomes (S) can be summarized into a dose-response function [8]. Assume that health outcomes is a function of pollution level (P) and averting expenditure (A).

$$S = S\left(D, A; X_s\right) \quad (2)$$

$\partial S / \partial A < 0$ and $\partial S / \partial D > 0$

It is expected that the number of sick days is negatively related with averting expenditure (A) while it is positively related with pesticides related damage level (D). Assume that the individual allocates his total time (T) between work (W) and leisure (L) and spend income on aggregate consumption, medical care and averting activities. Individuals choose the level of C, L and A to maximize utility subject to the following budget constraint [7].

$$Y + w\left[T - L - W\left(S\right)\right] = C + P_m M\left(S\right) + P_a A \quad (3)$$

Where Pm, Pa are price of medical care (M) and averting activities (A) respectively while w denotes wage rate [15] The price of a unit of the aggregate consumption good is normalized to one. This budget constraint assumes that individual allocate his time between work and leisure. According to the equation three, time allocation to work as well as medical care expenditure is expressed as a function of the number of sick days [12]. Using this simple utility maximization problem it is possible to identify the willingness to pay for a small change in pollution as follows:

$$WTP = \frac{dS}{dD}\left[w\frac{dW}{dS} + P_m\frac{dM}{dS} + Pa\frac{dA}{dS} - \frac{U_s}{\lambda}\right] \quad (4)$$

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According to Equation 4, WTP can be expressed as the product of the dose response function (dS/dD) times the marginal value of illness. The term in brackets is the marginal value of illness, broken down into its four main components [3]. Accordingly, marginal value of illness includes the values of marginal lost earnings (dW/dS) which represents the opportunity cost of labour, marginal cost of medical expenditures (dM/dS) and of the marginal cost of the averting activities (dA/dS). In addition, WTP includes the disutility of illness (US/λ), converted into money value through dividing by the marginal utility of income [12]. This study uses this basic theoretical model to assess the willingness to pay to avoid pesticides induced illness in the study area.

The study also estimates the WTP compensation and compare it with the costs of illness estimates for the study group. Furthermore, it is also important to identify factors influencing WTP compensation. For this purpose, we use OLS and Tobit methods. A vector of explanatory variables is used in the regression analysis. This study includes variables such as medical expenditure, lost of earning, averting expenditure, income, education, age, family size and main occupation.

General specifications of the OLS and Tobit models are as follows:

$$OLS - Y_i = X_i^{'}\delta + \varepsilon_i \quad (5)$$

$$Tobit - Y_i = X_i^{'}\beta + u_i \ \text{ if } RHS > 0 \quad (6)$$

$$= 0$$

The dependent variable Y indicating WTP compensation are a censored variable as some have said that there was no any harmful effects of pesticides uses to them. For example, the dependent variable is zero for household who have incurred zero costs. Xi denotes a vector of explanatory variables discussed above.

Data used in the study are primary data collected directly from farmers using structural questionnaires during the May and June in 2018. A total of 300 vegetable farmers in *Girandurukotte* in Badulla district were randomly selected for the survey. The survey covers information on input use, management practices, output level and other socio-economic information. The survey was carried out at household level including individual responses for health status, health expenditure, cultivation practices and education on pesticides induced illnesses in the area. In addition to that various socio-economic information and other details such as medical expenditure, averting activities… etc. were gathered at the same time. Village officers were discussed for the sake of validation of data acquired at household and individual level. Data were collected through face-to-face interview of the head of the house along with any helping hands.

However, around 15 questionnaires had to be dropped out from the analysis as erroneous answers and some outliers were found. The questionnaire used in the survey was validated in a pilot survey and through focus group discussions. The final questionnaire was adjusted following the pilot survey and focus group discussions. The gathering of data was conducted by a trained group of researchers under the close supervision of the research team. The interviews took place in the interviewee's home. The participants were informed about the purpose of the study and provided verbal consent to take part in the study. A field supervisor reviewed the quality of the data gathered and entered it into a database for analysis.

Results and Discussion

Main characteristics of individuals responding to survey are explained below. As the survey was carried out only on weekends, the response rate to every question was very high. Average age of the respondents is 45 years with a minimum of 24 and a maximum of 63 years. Majority of our sample was male respondents that accounts 83 per cent. The vegetable cultivation related employment is the main income source of the sample and 94 per cent is employed either their own vegetable farming or wage laborers in agriculture. Approximately 6 per cent of the respondents are engaged in various businesses or government sector jobs in the area. The mean monthly income of the respondents is Rs.29,300. No significant difference of income is found between vegetable farmers and other categories. This survey data reveals that 98 per cent of respondents cultivate vegetable for commercial purposes. However, of those approximately 92 per cent spray pesticides in their own farms while 8 per cent hires wage laborers for that purpose. It is evident that most respondents have obtained elementary and secondary education (27 per cent and 73 per cent respectively).

When considering the possible environmental issues of using pesticides for agricultural activities in these areas, approximately 53 per cent of respondents mentioned that the pesticides usage has severely caused to pollute the water in the area. Further, majority of respondents (76 per cent) agree that the usage of pesticides has resulted to disappear most of the environmentally friendly insects in the area. Most of the farmers (72 per cent) suggest that the Government must intervene to solve this problem through regulation while 20 per cent believe that people should get together and get it solved without third party intervention. However, around 8 per cent have mentioned that they do not have any idea about the solution. Further 84 per cent and 67 per cent of respondents are aware that the pesticides cause long term illness and even death respectively.

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Table 1 shows the summary statistics of the data used for the analysis. According to Table 1 average medical expenditure was USD 2.58 (month) per person and the average lost earning was USD 2.73 per person per month. Number of pesticides varieties used by the farmers varies from 3 to 9 while number of frequencies varies from 3 to 15 per month during a cultivation season. The general information about other variables such as averting expenditure, household income, family size, number of sick days and mitigating expenditure can be significant determinants of WTP to avoid health risk. Therefore, descriptive statistics of all those variables are given in Table 1.

Table 1: Descriptive statistics of the survey data.

Variables	Mean	Minimum	Maximum
Averting expenditure (monthly / USD)	0.38	0	1.75
Lost earning (monthly / USD)	2.73	0	16.22
Medical expenditure (monthly / USD)	2.58	0	8.27
Income (monthly / USD)	146.5	87.5	336
Pesticide quantity used per month(litters)	4.25	2.25	16
Number of pesticides varieties used	5	2	9
Number of frequencies (per month)	8	3	15
Direct exposure time (per day/ hours)	2.3	0.3	4.3
Number of self-reported symptoms	4	0	6
Family size	4	1	9
Education (years)	10	6	16
Age (years)	45	24	63
Experience in vegetable farming (years)	16	4	28
Sick days	3	0	6
Gender: dummy, 1 if male, otherwise 0	0.83	0	1
Main occupation: dummy, 1 if farming, otherwise 0	0.94	0	1
Usage of recommended quantity of pesticides: dummy, 1 if yes, otherwise 0	0.24	0	1
Using protective measures when spraying pesticides: dummy, 1 if yes, otherwise 0	0.18	0	1

Note: Farm income includes only direct income received by selling products and it does not include the value of home consumption. Average daily wage is USD 10 male and it is 7.5 for female worker.

Effects of exposure to pesticides generally fall into three main categories namely allergic, acute and delayed effects. Asthma, skin irritation and eye and nose irritation are called allergic that some workers develop a reaction after being exposed to a certain pesticide [8]. Acute effects may appear immediately after the exposure. Oral, inhalation, dermal and eye exposures are some of the acute effects are they can be cured if immediate attention is given [11-16]. Delayed effects also include developmental, reproductive and systemic effects for the human body. These are illnesses or injuries that persist over long periods and may not appear until several years after exposure to a pesticide. These includes production of tumors, cancer, kidney failure and changes in the genes or chromosomes [17].

Furthermore, the impacts of long-term exposure may affect to the reproductive system in men as well as women which results birth defects, miscarriage, infertility or sterility in men or women and impotence in men [18]. During the survey researchers explained about those three main categories and asked respondents to explain their experience about selected several illnesses such as asthma, skin irritation, eye and nose irritation, nausea or vomiting, diarrhoea, headache, loss of consciousness, and sore throat and/ or cough if they believe as a result of pesticides exposure. Figure 1 summarises those results.

The delayed effects may also result in making blood disorders such as anemia or an inability to coagulate, nerve or brain disorders such as paralysis, tremor, behavioral changes and brain damage, skin disorders such as rash, lung and respiratory disorders such as emphysema and asthma, and liver and kidney disorders such as jaundice and kidney failure [17-19]. Some of the long-term pesticide exposure that is linked to the development of depression and anxiety, hyperactivity disorder and cancer are possible. However, reliable data on those are not available in the country (Table 2).

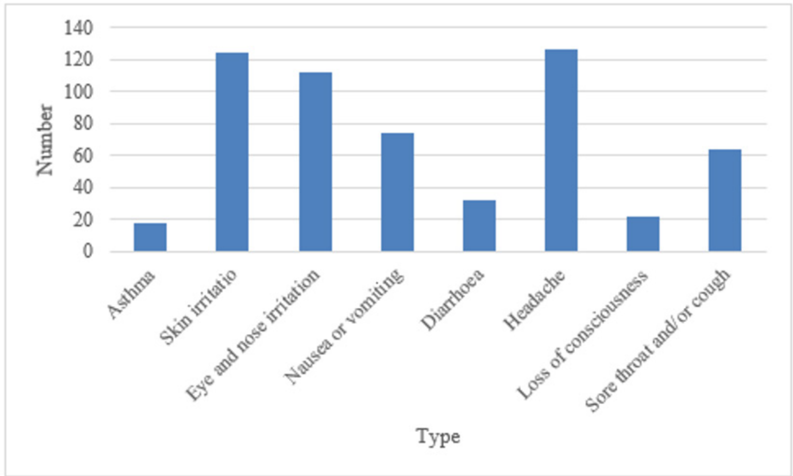

Figure 1: Different experience about the illness.

Table 2: Costs of illness estimates under different scenario (Rs/per month).

Scenario	Average medical costs (USD)	Number	Percentage
A, B and C	4.73	6	2.11
A and B	3.76	12	4.21
A and C	3.6	8	2.81
A	2.74	4	1.4
B and C	1.73	14	4.91
B	1.16	10	3.51
C	0.38	82	28.77
Average	2.58		0
Zero Cost		149	52.28
N		285	100

Note: Monthly (during a season) total costs for farmers who have different experiences are reported in this table. Zero costs mean the residents who did not have any experience of the above cases over the last 3 months.

As the first step of the analysis, we considered the variation of cost to farmers who have different experiences of illnesses due to direct exposure to pesticides. The average cost was calculated for farmers classified as serious (A- hospitalisation), moderate (B - a doctor is consulted, but no hospitalisation is required) and mild cases (C - no visits to the doctor, yet medication is taken). Only the private costs due to illnesses arising from pesticides induced illness were sought in this study. The results show that approximately 3 per cent of respondents have mentioned that they have been suffering from pesticides induced ill health and have been hospitalized over the last cultivation season. Another 9 per cent has mentioned that they have taken medicine from doctors due to pesticides related ill health. Approximately 29 per cent of respondents have taken some kind of treatment for pesticides induced health issues. However, as the issues are not serious, they have not meet doctors.

A vegetable farmer may have experienced one, any two or all three of the above. As can be seen, there is considerable variation in the costs incurred for different categories. Table 2 shows that on a typical spraying day approximately 2 per cent of the vegetable farmers interviewed mentioned that they have undergone all three experiences related to pesticides induced illnesses. Further approximately 10 percent had the experience of at least two scenarios mentioned above. These figures are consistent with some of the previous studies in this field [3-12]. Further approximately 28 per cent of the interviewed farmers said that they have suffered from some form of acute illness and incurred costs during the day of using pesticides over the last three years. However, 52 per cent of the interviewed vegetable farmers said that they have not suffered any form of illness and did not incur any form of expenditure due to exposure to pesticides during the previous cultivation season.

In addition to the medical expenditure, loss in earnings from being unable to work is a large cost to the farmers [3]. In this context, the lost earnings of the farmers with different experiences of the illness is estimated. The estimated lost earnings and mitigating expenditure for different experiences is shown in Table 3. It is clear that the high medical costs as well as lost earnings are a direct result of low levels of expenditure on averting activities. However, most of the farmers are not aware of the value of the labour costs since the market for labour does not function well in Sri Lanka. This is a problem encountered in markets that are not fully functioned (Table 4).

Table 3: Loss in earnings and mitigating expenditure (USD /per month).

	Scenario Lost earningsi	Averting expenditureii
A, B and C	5.86	0.12
A and B	4.3	0.18
A and C	3.13	0.26
A	2.34	0.36
B and C	1.56	0.4
B	1.17	0.39
C	0.78	0.99
Average	2.73	0.39
N	285	285

Note:

i. Daily wage varies between USD 7.5 and Rs. 12 in different areas (it varies between male and female as well). However, USD 8.75 was used as the average daily wage rate. Accordingly, average hourly wage rate is USD 1.09.

ii. mitigating expenditure mainly includes costs incurred on wwearing protective clothing, wearing marks, wearing gloves and wearing shoes.

Table 4: Comparison between WTP and cost of illness (USD/per month).

Scenario	Number	Total cost	WTP	WTP/Cost ratio
A, B and C	6	10.71	6.73	0.63
A and B	12	8.24	5.63	0.68
A and C	8	6.98	3.26	0.47
A	4	5.44	2.12	0.39
B and C	14	3.69	2.29	0.62
B	10	2.72	1.86	0.69
C	82	2.15	1.11	0.51
Average		5.7	3.28	0.57
N		285	100	

Note: Cost of illness estimates and WTP are calculated only farmers who have experience in any form of costs related to pesticides use. Last column gives the ratio between WTP and cost of illness.

The monthly labour cost of the farmers who have experiences of all three incidents are approximately 7.5 hours for farmers during the previous cultivation season. However, average monthly costs for the farmers due to loss of labour hours are USD 2.73 which is almost equal to the value of one day labour supply. Average labour lost for the entire sample is 3.5 hours and its cost equals Rs. 2.82. This means that during a typical cultivation season, every month farmers are losing approximately one third value of labour due to exposure to pesticides. In the sample area, spraying takes place every 2 to 7 days. However, it is evident that the extent of the precautions taken is low for all the farmers in the study area. One of the interesting observations of the data here is that the average monthly averting expenditure of the farmers who said that they had no cost or loss due to exposure to pesticides is more than double (USD 1 .96) the average of farmers who reported any form of expenditure. This show the value of using protective measures when spraying pesticides in their farms.

One of the main purposes of this study is to estimate the WTP compensation with costs of illness estimates. Therefore, total cost of the pesticides related illness which include medical cost, lost earning and averting expenditure is estimated. Then estimated WTP under different scenarios is compared with the total costs. Estimated average WTP values to avoid pesticides induced illnesses are given in Table 4. It is interesting to see that hospitalized group, the average willingness to pay is approximately USD 4.43 per month in a typical cultivation season. The average willingness to pay of farmers who have at least one or more experiences with pesticide induced illness, but no hospitalization experience is approximately USD 1.75. Also, the results show that the WTP values are underestimating the true cost of pesticides induced illnesses. For the entire group average WTP is USD 3.28 while cost of illness is USD 5.7. This finding clearly shows that the farmers' valuation of their own illnesses is very low which may be a common characteristic among poor farmers with low opportunity costs of their working time.

As the final step of the analysis, we attempted to identify the factors affecting WTP compensation. Estimation results of the Tobit and OLS regression model are shown in Table 5. Each slope coefficient in the OLS model is a partial slope coefficient and measures the changes in the estimated unit change in the value of the given regressor holding other regressor constant. The coefficients in the OLS model are interpreted as the marginal impact of the right-hand side variable on the dependent variable. Accordingly, this result reveals that all variables except age and family size in the WTP function have turned out to be significance. The coefficients of all the variables have expected signs in this equation. Among all variable's medical expenditure, loss of earning, number of sick days and income have positively related with WTP while averting expenditure, usage of recommended quantity and experience related variables have negative signs. Although it is not rational to compare the Tobit and OLS results, the signs on the coefficients and their significance levels can be comparable. In addition, the relative magnitudes of the coefficients across variables in the Tobit model are comparable to the relative magnitudes of the OLS model. It is evident that almost all variables in two models have taken the similar signs while showing the similarities in terms of their significance coefficients (Table 5).

Table 5: Results of OLD and Tobit models.

Variables	OLS: Coefficient	Tobit: Marginal effects
Intercept	-30.54(6.96) *	
Averting expenditure (AVE)	-0.43(0.21) **	-0.92(0.15) *
Lost in earning (LE)	0.09(0.05) **	0.03(0.01) **
Medical expenditure (ME)	0.08(0.01) *	0.09(0.04) *
Income (IN)	0.07(0.01) *	0.07(0.02) *
Family size (FS)	0.56(0.92)	6.58(7.59)
Experience (EX)	-0.05(0.01) *	-0.06(0.03) *
Sick days (SD)	228.44(18.96) *	235.69(29.32) *
Education (ED)	108.61(43.52) *	79.71(23.21) *
Age (years) (AGE)	0.40(0.73)	0.61(0.12)
Gender (G)	241.23(20.07) *	246.93(21.19) *
Self-reported symptoms (SR)	164.06(16.29) *	184.11(17.82) *
Main occupation (MO)	74.47(25.21) *	84.68(26.79) *
Usage of recommended quantity (UQ)	-48.411(25.82) **	-34.14(29.14)
R^2	0.66	
Adjusted R^2	0.64	
Pseudo R^2		0.16
N	285	285

Note:

i. Standard errors are shown in brackets. * and ** Denotes the significant variables under 5% and 10% level of significance respectively.

ii. A- OLS estimators are with robust standard errors.

iii. Marginal effects on the latent dependent variable are reported for the Tobit model.

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Among the significant variables under different significant level, medical expenditure and loss in earning have positive effects on the WTP while averting expenditure has negative effects on it. The negative sign of the averting expenditure variable confirms that the households who spend more on protective measures are less likely to pay as their probability of getting sick is less. Insignificant age suggests that willingness to accept for bearing existing health risks was independent from peoples' age. When analyzing the qualitative data on peoples' expectation about the future possible environmental risk that may be arisen from excessive usage of pesticides, it is found that majority of farmers (76%) are aware of them. Most farmers mentioned (67%) that environmental damage like water pollution and damage to environmentally friendly insects are possible due to extensive use of pesticides by farmers in the study area [20-22].

Conclusion and Policy Implication

This study calculates the amount of money which vegetable farmers are willing to pay for avoiding the prevailing level of health risk and compare the mean WTP with costs of illness estimates. Data were collected covering a sample of 285 vegetable farmers who are cultivating vegetable for mainly commercial purposes in *Giradurukotte* in Badulla district in Sri Lanka. In addition to estimate the WTP and costs of illness estimates, OLS and Tobit regression model estimates determinants of household willingness to pay for avoiding pesticides induced health risk. Results showed that the average monthly cost of illness which includes medical expenditure, loss earning and averting activities was USD 5.7 per person. However, we find that the monthly mean willingness to pay for avoiding existing health risk as USD 3.28 per person. It clearly shows that the, willingness to pay value underestimate the reality confirming the previous studies. However, peoples' understanding about the exogenous factors including future expectation as well as loss earning of them can have significant impact of making divergence between those two. As a result, policy-oriented research covering some of the excluded variables in our model in this field is needed to a better understanding of the problem. We also found that medical expenditure, lost earning, averting expenditure and income are some of the significant determinants of willingness to pay. This general result about the underestimation of WTP drawn from our study follows that of the results of many other contingent valuation studies reported in the literature.

It is evident that no previous study has done this type of analysis comparing the results of WTP and costs of illness for vegetable farmers in Sri Lanka. This study provides strong evidence that pesticide use in Sri Lanka results in a very high cumulative incidence rate of acute pesticide poisonings resulting in a huge social welfare loss every year. Unlike previous studies on acute pesticide poisoning incidence, this study dealt with a number of economics issues for the farming community. The findings by descriptive analysis of the data show that the reasons for the resulting adverse health effects are weak regulation, the low hazard awareness of users, inadequate use of personal protective equipment, lack of proper care during application and the use of highly toxic pesticides.

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