COST AND POLICY IMPLICATIONS OF AGRICULTURAL POLLUTION, WITH SPECIAL REFERENCE TO PESTICIDES

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COST AND POLICY IMPLICATIONS OF AGRICULTURAL POLLUTION WITH SPECIAL REFERENCE TO PESTICIDES

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Abstract

Modern commercial agricultural practices involving chemical inputs such as fertilisers and pesticides have been associated with huge increases in food production never witnessed before, and in the case of cereal production (especially wheat) under Green Revolution technology, recorded spectacular growth. As statistics show, production and productivity have increased. However, the high chemical usage of fertilizers and pesticides used to bring about these increases in food production are not without problems. A visible parallel correlation between higher productivity, high artificial input use and environmental degradation and human health effects is evident in many countries where commercial agriculture is widespread. The high usage of these chemical inputs has caused numerous pollution problems impacting on human health, agricultural land, other production processes, wildlife and the environment in general. The private and external costs are very high. Such a production path is clearly unsustainable.

This Ph.D. study lays its focus on estimating the private costs of illnesses arising from direct exposure to pesticides during handling and spraying by farmers on their farms in Sri Lanka. For this purpose three valuation techniques are used. They are the contingent valuation, cost of illness and the avertive behaviour approaches. Multiple regression analyses are also carried out to establish several relationships involving pesticide handling/spraying and direct exposure to pesticides. Policy implications of the regression analyses are then discussed. A health production model showing the relationships between the three approaches used for estimating the private costs of ill health and thereby inferring the willingness to pay for pollution control is presented. The theoretical background to agricultural pollution, drawing examples mostly from Asia, is also dealt with in this thesis.

Data for this Ph.D. study were obtained from a field survey carried out in the summer of 1996. During this survey, 227 subsistence farmers handling and spraying pesticides on a regular basis were interviewed to gather the necessary data. For the analysis of data, only 203 samples are used.

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To my beautiful Shirley, with all my love

This work would not have been possible if not for the financial support provided by the Department of Economics, The Russell Trust, University of St Andrews, Scotland, U.K, Overseas Research Scholarship (ORS), and Lt Col. John B Smith. I am extremely grateful for this generosity.

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I also owe a special debt of gratitude to all those who helped me with my field work in Sri Lanka, especially in translating the questionnaire into the local language, making valuable suggestions and comments regarding the field work and questionnaire, introducing me to the relevant officers and farmers, and above all accompanying me on my field trips to conduct the interviews, very often at their own expense. I am extremely grateful to all of them, without whose help it would not have been possible to study 227 farmers within a 3-4 month period.

I would like to express my very sincere thanks to the Department of Economics, the Russell Trust, Overseas Research Scholarship (ORS) and Lt. Col John B Smith for all the financial support provided without which this work would not have been possible. I am extremely grateful for this generosity.

Also I would like to express my sincere thanks to my parents, brothers and sister for all the support they extended during my Ph.D. work. I thank Shirley for helping me to obtain a substantial amount of the literature on pesticide pollution in Sri Lanka and for her incessant encouragement to finish this work.

Finally, I have done my utmost best to make this thesis interesting to read. However, there are sections that appear dull. In such situations I am reminded of the immortal words of Sir Richard Steel (1672-1729): " It is to be noted that when any part of this paper appears dull there is a design in it".

Clevo Wilson

Contents

GLOSSARY

Maha	Agricultural Cropping Season from October to January
Yala	Agricultural Cropping Season from March to July
Poojas	Offerings made to Gods

ABBREVIATIONS USED

AB	Avertive Behaviour
BHC	Benezene Hexachloride
BPH	Brown Plant Hopper
COI	Cost of Illness
CVM	Contingent Valuation Method
DDT	Dichlorodiphenyltrichloroethane
F	Fungicides
HYVs	High Yielding Varieties
I	Insecticides
IAD	International Agricultural Development
IGR	Insect Growth Regulator
IRRI	International Rice Research Institute
IWRB	International Wetlands Research Bureau
NARESA	National Resources, Energy and Science Authority of Sri Lanka
NOAA	National Oceanographic and Atmospheric Administration
OLS	Ordinary Least Squares
Ops	Organophosperous Chemicals
RGM	Rice Gall Midge
WCED	World Commission on Environment and Development
W	Weedicides
WHO	World Health Organisation
WRI	World Resources Institute
WTP	Willingness To Pay
WTA	Willingness To Accept
WBPH	White Backed Plant Hopper

Note: At the time of the study (June-September, 1996) the exchange rate was 1 pound = 75 rupees. The current exchange rate is 1 pound = 105 rupees.

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CHAPTER 1

INTRODUCTION

Modern commercial agricultural[1] practices involving chemical inputs such as fertilizers and pesticides have been associated with huge increases in food production never witnessed before, and in the case of cereal production (especially wheat) under Green Revolution technology, recorded spectacular growth. As statistics show, production and productivity have increased. However, the high chemical usage of fertilisers and pesticides used to bring about these increases in food production are not without problems. A visible parallel correlation between higher productivity, high artificial input use and environmental degradation and human health effects is evident in many countries where commercial agriculture is widespread. The high usage of these chemical inputs has caused numerous pollution problems impacting on human health, agricultural land, other production processes, wildlife and the environment in general. Such a production path is clearly unsustainable and is diametrically opposed to the definition of sustainable development endorsed by the World Commission on Environment and Development (WCED) which defines the concept as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.43).

The fertilizers (mainly nitrogenous) used have polluted the surface and ground water in many countries/areas, with disruptive effects on the environment and on human health. Agricultural scientists have established a link between increases in nitrogenous fertilisers and the proliferation of pests of rice. Pesticides, too, have affected the environment, other production processes, human beings and caused numerous occupational health hazards including deaths[2]. This is the theme of this Ph.D. study. In addition, pesticides used to destroy pests have also destroyed natural predators of these pests which have led to increases in pest attacks. Pests have also developed increased resistance to pesticides thus creating a pesticide treadmill.

This Ph.D. study will lay its focus on estimating the private costs of illnesses or in other words the economic value of such costs arising from direct exposure to pesticides during handling and spraying by subsistence farmers on their farms in Sri Lanka. The private costs of illnesses arising from direct exposure to pesticides are not considered by farmers which, when aggregated run into millions of rupees each year and also affect farmer incomes. These costs, which arise from direct exposure to pesticides are not taken into account by farmers mainly because they are difficult to quantify and are considered as indirect costs arising from ill health. Furthermore, as Siyayoganathan et al. (1995) point out, intangible costs such as discomfort, pain and suffering are considered as 'normal part of their work' by subsistence farmers. All

[1] Modern commercial agriculture does not necessary mean large-scale agriculture. It could involve small-scale farming as well.

[2] 'Occupational' refers to farmers engaged in farming activities who handle and spray pesticides on their farms on a regular basis.

these illnesses not only incur private costs[3] which affect farmers' welfare but also leads to a gradual deterioration of the human body (termed as human capital) by Pearce and Atkinson (1993). Since all costs are not borne out by the affected individuals, the public hospital costs are also very high. All these costs are not reflected in the price of the product that is produced and hence is sufficient grounds for government intervention. For the estimation of these costs, three valuation techniques are used. The three techniques used are the contingent valuation, avertive behaviour and the cost of illness approaches. The contingent valuation approach is a direct approach while the latter two approaches are indirect. The techniques used in this study have been chosen after giving much consideration to the adaptability of such techniques in a developing country situation, especially when dealing with subsistence farmers in the rural countryside. Multiple regression analyses are also carried out to establish several relationships involving pesticide handling/spraying and direct exposure to pesticides. The policy implications of the regression analyses together with the outcome of the survey results are also discussed in the relevant chapters. We briefly discuss below the themes, aims and objectives of each of the ten chapters of this Ph.D. study.

Chapter two of this study is a theoretical and empirical examination of the external and private costs of agricultural pollution arising from agricultural production. This is a general chapter laying the background to the problem of agricultural pollution resulting from the high use of chemical inputs such as nitrogenous fertilizer and pesticides under the Green Revolution technology and commercial agriculture. In the rest of the thesis, the discussion is narrowed down to examine only the private costs of ill health arising from direct exposure to pesticides while handling and spraying them on the farms and the benefits of reducing/avoiding such health effects.

The third chapter will examine in detail the health effects of direct exposure to pesticides in Sri Lanka with sections covering the history of pesticide use, a discussion on the history of pesticide poisoning with a thorough up to date review of work done on pesticide poisoning in the country. The last section of this chapter also discusses the short-term health effects from direct exposure to pesticides. Hospital data and the results of field studies are also presented and discussed.

Chapter four discusses in detail the three health valuation techniques used for this study. The first section discusses in detail the valuing of reducing/avoiding morbidity impacts from direct exposure to pesticides where the three valuation techniques used are discussed. The concept of willingness to pay bids/values which the three valuation approaches purport to estimate are also discussed. One section also reviews some of the applications of the three valuation approaches to health. The final section of this chapter reviews several studies that have been conducted to compare the results of the three techniques used in this Ph.D. study.

The fifth chapter presents a health production model showing the relationships between the three approaches to willingness to pay used in this Ph.D. thesis for

[3] These illnesses also incur public costs because government hospital treatment is mostly free in Sri Lanka.

pollution control. The basic health production and consumption model of consumer behaviour was first demonstrated by Grossman (1972) to examine health decisions. Later this model has been modified by Cropper (1981) Gerking et al. (1983); Harrington and Portney (1987); Harrington et al. (1989) to examine the health effects of pollution. The model presented in this Ph.D. thesis to examine the health effects of pollution and to show the relationships among the three approaches used to value the willingness to pay in this thesis is taken from Cropper and Freeman III (1991) and has been combined with the Chestnut et al. (1988) model to take into consideration all time valued at the wage rate. Time is essential because those suffering from health effects, not only incur out-of-pocket costs and lost earnings from inability to work and loss of productivity but also suffer from loss of leisure time due to illness and travelling to and from hospital to seek medical treatment, etc. This model is useful because it can also be used to define specific components of an individual's willingness to pay for changes in his own health by analysing the ways that health can be expected to affect an individual's utility. The results of the analysis suggest ways to approach the estimation of willingness to pay and give criteria by which to make willingness to pay estimates more complete.

Chapter six deals with the methods and issues in questionnaire development and gathering of data. This chapter discusses in detail the issues involved in questionnaire design including problems faced in designing and conducting contingent valuation studies in developing countries, method of data collection in the field, sampling size and editing and the structuring of the questionnaire. The questionnaire is divided into nine sections and each of the nine sections is discussed in detail. The last section of this chapter discusses the characteristics of the sample group. The questionnaire used for the field study and the list of pesticides used by the respondents in the study area are presented in the appendix.

Chapters seven discusses the theoretical aspects of the contingent valuation approach together with their advantages and disadvantages. The contingent valuation approach has been designed to obtain willingness to pay bids to <u>avoid</u> direct exposure to pesticides and the resulting health effects. These willingness to pay bids to avoid direct exposure to pesticides are then used to estimate contingent valuation cost scenarios for the entire country. The last section of this chapter determines the factors that contribute towards contingent valuation willingness to pay bids to avoid direct exposure to pesticides when subsistence farmers are involved. The regression results are also a test of validity of the contingent valuation exercise.

Chapter eight deals with the cost of illness approach which is an indirect valuation approach in determining the willingness to pay bids/values to <u>reduce</u> direct exposure to pesticides and the resulting health effects. In this chapter we discuss the advantages and disadvantages of the cost of illness approach citing previous studies. The cost of illness estimates obtained from the field study are then used to estimate the cost of illness scenarios for the entire country. The last section of chapter eight attempts to determine the relationships between ill health and direct exposure to pesticides. Exposure to pesticides cause many acute and chronic symptoms among the users (farmers). As a result, farmers incur very large direct and indirect private costs due to these illnesses. Hence, if the users direct exposure to toxic pesticides can be minimised or altogether prevented, then most of the above mentioned costs can be avoided. Therefore, in order to take preventive action, we must determine what factors are responsible for the very high levels of direct exposure to pesticides by farmers who use them. With this regard the relevant factors are identified and regressed with respect to ill health in order to establish the factors that cause ill health resulting from direct exposure to pesticides during handling and spraying by farmers on their farms.

In chapter nine we discuss the avertive behaviour approach which like the cost of illness approach is an indirect approach in determining the willingness to pay to reduce direct exposure to pesticides and the resulting health effects. For this approach, too, we discuss the advantages and disadvantages of the averting behaviour approach citing previous studies. We then use the avertive behaviour estimates obtained from the field study to derive cost scenarios for the entire country. This is because farmers are known to be exposed to high levels of direct exposure to pesticides and thus suffer from different levels of severity of illnesses which have a significant impact on the welfare of the farmers in the form of costs. An investment in defensive behaviour (both money and time) can, therefore, reduce the costs of private and medical bills and other expenses, while also reducing the pain, suffering and discomfort and of course preventing the gradual deterioration and wastage of human health. In the last section of chapter nine we present the estimates derived from the field study for this Ph.D. thesis using the three valuation approaches which is also another test of validity of the contingent valuation study.

Chapter 10 (conclusion) sums up briefly the main results of this Ph.D. study. The appendices in the relevant chapters contain valuable data/information that could not be used in the main study for lack of space.

Data for this study were obtained from a field survey carried out in the summer of 1996. From the field survey, 203 samples are selected from interviewed subsistence farmers handling and spraying pesticides on a regular basis for this Ph.D. study.

CHAPTER 2

EXTERNAL AND PRIVATE COSTS OF AGRICULTURAL POLLUTION: THE THEORETICAL BACKGROUND

Introduction

Agricultural production generates positive externalities, as well as numerous negative externalities and private costs due to agricultural pollution. Some of the negative externalities and private costs resulting from agriculture are generated by the very inputs that are used to boost agricultural production. The externalities are in the form of health, affecting agricultural production and other production processes, wildlife and the environment in general. The private costs are the health related costs suffered by the producer (user of these inputs) and declining agricultural land productivity on the producers land. Almost all negative externalities and private costs arise from the use of inorganic or chemical inputs[1]. The negative externalities and private costs that are considered in this chapter arise from two of the most harmful agricultural pollutants, namely pesticides and fertilizers. Most of these pollutants break down very slowly in the environment and hence have the potential to accumulate overtime[2]. Hence, they have been called 'stock' or conservative pollutants. A good example that is cited is DDT. Because of the very nature of the pollution that is generated, these pollutants can also give rise to a domino effect, setting off a series of chain reactions. This domino effect will be highlighted in this chapter which Zilberman and Marra (1993, p.247) have described as dynamic in nature. An off shoot of externalities and private costs arising due to pollution is that, if these costs are not taken into account (as it often happens) resource allocation becomes inefficient. Therefore, a study of externalities and private costs is important, not only to show the impact of agricultural production on the agricultural system itself, other production processes, the environment, wildlife and health of the producer and third parties, but also because such a study can shed light on the private and external costs on the users and those around thus showing the need to curb such activities. In other words, we can determine the value and show the welfare benefits of an environment that is free of pollution. The damage caused by private and external costs, also helps to determine

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[1] However, there are exceptions to this rule. For example, water logging and salination also cause many externalities.

[2] The rate at which nitrates and pesticides accumulate as a stock pollutant depends on the rate of degradation in the environment. This depends on photodegradation, microbial degradation and chemical degradation. Factors that influence photodegradation include: the intensity of the sunlight, properties of the application site, the application method, and in the case of pesticides the properties of the pesticide. Microbial degradation is the breakdown of pesticides by fungi, bacteria, and other microorganisms that use chemicals such as pesticides as a food source. Most microbial degradation of pesticides occurs in the soil. Soil conditions such as moisture, temperature, aeration, pH, and the amount of organic matter affect the rate of microbial degradation because of their direct influence on microbial growth and activity. Chemical degradation is the breakdown of chemicals such as pesticides and nitrates by processes that do not involve living organisms. Temperature, moisture, pH, and adsorption, in addition to the chemical and physical properties of the pesticide, determine which chemical reactions take place and how quickly they occur.

the extent of environmental/agricultural sustainability of such production processes. The chapter examines an agricultural environment with an N number of small-scale producers in a developing country situation.

This chapter will discuss briefly the definition of externalities and private costs and some of the special characteristics of the two agricultural pollutants before moving into the agricultural production function and the generation of pollution. Some examples will be cited. The section that follows will demonstrate the various private costs and negative externalities that have arisen due to inorganic chemical input use. The section will start by showing how inorganic chemical input use on intensively cultivated land has contributed towards diminishing returns on agricultural land, citing examples, all resulting in higher private costs on farms. The process of diminishing returns is demonstrated by the use of diagrams. This section goes on to show the other private costs, negative externalities and the negative multiplier effects that have been recorded in the agricultural fields. Most of the examples are taken from the Asian region, but are not wholly restricted to this region, especially the section dealing with wildlife and health impacts. All the private and external costs are summarized graphically for easy reference.

The next section briefly deals with the definition of externalities and private costs under two separate headings, both arising from agricultural pollution. The distinction made is crucial for this thesis.

Definition of Externalities

The use of inputs in the cultivation of food crops by farmers generate negative externalities (for example, from nitrates and pesticides) that, in the aggregate adversely affects the health of those living on the farms and surrounding areas, other production processes, the consumers of food crops, wildlife and the environment. Such production also incurs private costs to the farmers in the form of health impacts and declining productivity on their own farms due to soil fertility decline. Private costs, which are discussed in detail in the next section are costs directly incurred by the person involved in the production processes, while externalities are those that affect a third party. According to the definition of externalities, they can be beneficial or cause adverse effects (Randall, 1987, p.182). However, this study examines only the external diseconomies or the negative externalities arising through the use of inorganic agricultural inputs. Randall (p.182, 1987) shows that an externality exists whenever

$$U_j = [\, X_{1j} ,\ X_{2j}\ \ldots\ldots\ldots\ldots\ldots, X_{nj} , f(X_{mk})\,], j \neq k$$

where X_i ($i = 1, 2, \ldots\ldots\ldots\ldots n, m$) refer to activities, and j and k refer to individuals. That is, an externality is said to exist, whenever, the welfare of some individual j is affected by those activities under his or her control and also by the effect, $f(X_{mk})$, of an activity, X_{mk}, that is under the control of somebody else, k.

In the case of an agricultural production externality, if the activity of one farmer or farmers directly affects the activities or causes harm to other people on the farm or those living in the surrounding neighbourhood or elsewhere, other production processes, wildlife, the environment, etc. then it is called an externality. Randall (1987, p.183) further uses the term externality to mean Pareto-relevant externality. A Pareto-relevant externalty exists, when it is possible to modify the activity, X_{mk} , in such a way so as to make the affected party, j, better off without making the acting party, k, worse off. When a Pareto-relevant externality exists, there is the unrealized potential for a Pareto-improvement. Thus Pareto-relevant externalities can exist, only when the economy is not Pareto-efficient (ibid.).

There are many Pareto relevant externalities arising out of agricultural production. As argued by many economists, these externalities are simply manifestations of inefficient pricing. Efficiency can be achieved when a Pareto-relevant externality exists, only if the correct price, or shadow price, negative for a diseconomy, is placed on the externality (Randall, 1986, p.185)[3]. Hence, we have seen that a Pareto-relevant external diseconomy, is an inefficient situation that can be remedied, if an efficient negative price is placed on the externality. As the Environment Policy Committee report (1994, p.6) points out "left alone, the market system under supplies environmental quality by producing an excess of external environmental costs, and too few external environmental benefits". This means that, in an unregulated economy, agricultural inputs and production cause too many negative externalities. Government intervention, therefore, maybe necessary to internalize the situation. This is distinct from any moral, political, or scientific motivation for intervention (ibid.).

Varian (1992, p.433) points out that, in general, market equilibrium will be inefficient in the presence of externalities. He also states that the first theorem[4] of welfare economics is violated in the presence of externalities. Clearly then, the welfare of the sufferers from the externalities is reduced or affected. The reason is that, there are things that people care about or which are needed for their sustenance that are not priced. Achieving an efficient allocation in the presence of externalities, essentially involves making sure that agents face the correct prices for their actions. This is where economic instruments become important.

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[3] Turner et al. (1994) point out that the economist's case is that regulatory control is inferior in efficiency terms to an approach based on charges/taxes. Baumol and Oates (1992) state that it is possible to design policies such as standards for the control of externalities that are reasonably efficient. Turner et al. (1994) quote evidence from a study carried out in USA by Luken and Clarke (1991) who examined whether regulation (standards) can be efficient. Luken and Clarke's (1991) study shows that ambient and benefits-based standards are more efficient than technology based standards, because the latter do not require any measure of actual environmental results. Turner et al. (1994) go on to point out that environmental regulations (standards) are often both inefficient in themselves and in relation to economic incentive instruments. However, they point out that in the context of uncertainty over possible pollution related environmental damage, or known hazardous waste risks and the aim is to totally prevent some discharge/emission, then regulatory standards offer the 'best' approach' and 'may well be more efficient' (p. 191).

[4] The first welfare theorem states that in a private ownership economy without externalities and public goods, a competitive market equilibrium is Pareto efficient.

Definition of Private Costs

In the last section, we noted that pollution generates negative externalities. According to the definition, it was shown that such impacts are on third parties. This section deals with costs incurred by the producer himself, as a result of the pollution that he himself generates. The costs arising to him from the pollution, which he himself generates are termed private costs. For example, a farmer using pesticides is affected by the pollution which he himself generates, in addition to affecting those around him, the wildlife, environment, other agricultural land, other production processes, etc. The private costs which he himself bears from the pollution which he generates is distinct from the definition of external costs. Therefore, any damage that a farmer does from the pollution which he generates, be it health or the land he cultivates, is termed as private costs. However, it should be mentioned here that some authors and institutions [for example, National Research Council, (1987); Carlson and Wetzstein (1993)] do not make a clear distinction between private costs and externalities and use the word 'externalities' interchangeably to describe private costs as well as externalities. In this thesis, however, a clear cut definition is made between these two different definitions and care is taken to distinguish the various costs arising from pollution into private and external costs respectively.

In the next section, we examine a number of concepts which are useful in describing the types of pollution, the manner in which agricultural pollution is generated and of course the distinction between private and external costs are made clearer before going on to discuss the various private and external costs that have arisen due to agricultural pollution. The next section begins by examining what is meant by point and non-point pollution and to show that unique differences exist between externalities generated by industrial and agricultural production.

Point and Non Point Source Pollution

It has been argued that the most important characteristic of agricultural pollution is that, it is, to varying extents, "non point" in nature (Environmental Policy Committee report 1994, p.11). A good example that has been cited is the farm nutrients that enter watercourses over a wide and diffuse area. As a result, no single physical point exists at which the amount of nutrients flowing from a water body can be measured.

As pointed out in the report this non-point, diffuse characteristic has two important consequences.

- actual emissions of agricultural source pollutants are very difficult to measure.

- controls cannot, therefore, be placed on actual effluents, but rather on estimated effluents, or on the production practices which give rise to the effluents. This means that policy makers must have some estimate of a pollution production function, which relates farm practices (such as fertilizer use, type of crop grown and method of cultivation). This pollution production function will contain some factors which are beyond the control of the farmer, such as soil types and rainfall. Because of variations in these factors, identical production activities on two different farms may produce very different impacts.

However, while this view is generally true, there exists many exceptions, where agricultural pollution (pesticides and nitrates) may also be a source of point pollution, and in addition to causing numerous externalities, also result in many private costs to the users.

Nitrate and pesticide pollution could also be a source of point source pollution due to the combined characteristics of the physical geography and the quantity of inputs used in the production process. With reference to physical geography, many factors have to be taken into consideration which can result in pollution being defined as point and non-point. Some of the characteristics that have to be considered are; soil types, wind patterns, rainfall, the terrain, availability and size of water sources, water flow, presence of aquifers, vegetation, etc. Some examples of agricultural point source pollution could be cited. In Sri Lanka, for instance, certain water wells surrounded by nearby agricultural land have been affected and not large water bodies such as reservoirs and rivers. In other words, the nitrogen effluents have not affected a wide and diffuse area. In this case, single physical points causing the pollution has been identified. In the case of pesticides, too, thousands of mortality and morbidity effects are reported each year from Asia due to direct exposure to pesticides. This is referred to as 'occupational deaths' where a clear source of pollution is identified, which cause, not only external costs, but also private costs.

Another important factor that determines whether pollution is point or non-point is the quantity and type of fertilizer and pesticide used. In developing countries, due to the presence of many small-scale farmers, they use agricultural inputs such as fertilizers and pesticides in small quantities. In this case, too, only the small agricultural wells surrounded by agricultural land have been affected and not large water bodies. This is because the assimilative capacity of the environment is greater than the level of pollution generated. Furthermore, physical characteristics such as rainfall, type of soil, terrain of agricultural land, etc. have to be considered. The terrain is also an important factor. For example, a farm located above a well causes pollution in the well but not a farm located below a well. Soil types and rainfall are also important factors. Hence, in devising/using instruments for pollution control, it is necessary to consider the physical factors involved as well. Otherwise, it could lead to biases where farmers who are not a cause for pollution can be penalized. For example, an equal tax on nitrate leaching on the farms above and below the well is unequal. This is because the pollution in the well is caused by farms above the well. Therefore, the marginal damage costs have to be considered before a pollution tax is implemented. However, in the presence of a very large number of small-scale farmers this is difficult.

The type of pesticide used is also important. Pesticides causing 'stock' pollution are more likely to cause non-point pollution than less harmful pesticides. This is because, pesticides that build up in the environment accumulate over a period of time and also enter watercourses etc. over a wide and diffuse area. These processes are exacerbated by the prevailing soil types, rainfall, presence of aquifers, vegetation, etc. On the other hand, in the case of pesticides that do not tend to build up in the environment, but breakdown in the environment rapidly, have a lesser chance of causing non-point pollution.

The next section makes a distinction between industrial and agricultural pollution and shows how these two different types of pollution can affect the production process in very different ways.

Industrial and Agricultural Pollution and its Impact on Production

An important feature that should be observed in the discussion of agricultural and industrial pollution is that, unlike in industrial pollution, agricultural pollution can affect its own production processes which is not a common feature in industrial production. In other words, the pollution generated does not affect the productivity of the firm. However, on the other hand, in agriculture, certain important inputs used in the production process (for e.g. fertilizers and pesticides) which cause pollution, not only affect the farmers themselves and those outside it, but also affects the productivity of the farm after a period of pollution 'stock' accumulation. In industrial production, what we experience is the loss of productivity of a neighbouring unit, rather than its own productivity. For example, an industrial plant which generates smoke may affect a laundry, buildings or human health (including the health of its workers), but does not itself get directly affected (i.e. its productivity) by the smoke. On the other hand, a farm that uses chemical inputs affects its own soil fertility, the health of the workers, etc., leading to declining productivity in successive rounds of production, while also generating many externalities. There are many instances where declining soil fertility (and hence productivity) has led to the total abandonment of cultivation of crops in certain areas in Sri Lanka. Hence in the case of agricultural production, we see that the very inputs used in the production process impact on its own production processes which on the other hand is not a significant feature in industrial production. The next section shows how agricultural production generates pollution and hence the resulting external and private costs.

Agricultural Production Function and the Generation of Pollution

A simple production function can be employed for agriculture to show the generation of pollution and the wider consequences resulting from it (such as externalities and private costs), apart from the production that is involved. The production function shows that output is a function of inputs which can be written as

$$Y = f(X) \qquad (2.1)$$

X consists of many inputs. In the case of agricultural production, in addition to capital (fixed inputs), labour and many variable inputs, there are also agrochemicals, such as pesticides and fertilizers which are used. These agrochemicals can have a profound effect on productivity. This is especially so with hybrid high yielding varieties (HYVs) which are highly dependent on these two factors for increased output and productivity. A good example are the HYVs introduced to Asia. The HYVs first introduced to the Asian agricultural fields (the so called Green Revolution[5]) in the 1960s, have been associated with increases in cereal production never witnessed before, and in the case of wheat, spectacular growth (Farmer, 1986, p.177; Conway and Barbier, 1990, p.20; Lipton and Longhurst, 1989, p.1). As statistics show, both production and productivity[6] have increased. Such increases have enabled the countries in the Asian region to reach self-sufficiency or near self-sufficiency in cereal production, reduce imports, meet the food needs of a rapidly expanding population and avoid a possible Malthusian crisis. However, the high yielding varieties (the seeds), are only one component of the Green Revolution package. If the full benefits of this 'miracle technology' are to be harnessed, it is essential to apply large quantities of chemical substances, such as chemical fertilizers and pesticides. Hence, the spectacular increases in cereal production have been accompanied, amongst other inputs, by huge increases in the use of fertilizer and pesticides. This is evident in every country/area that has adopted the Green Revolution technology (for a full discussion see, Wilson, 1994, pp. 7-10).

The experience during the last 30-35 years shows that the use of inorganic chemical inputs have been harmful to human health, the agricultural land, other production processes, wildlife and the environment in general. The chemical inputs have often caused serious soil and environmental problems and other side effects. The environmental and health consequences arising from the Green Revolution inputs are many and varied. A visible parallel correlation between high yields, high artificial input use and environmental degradation and pollution is evident in many countries/areas where the Green Revolution has been successful and where commercial agriculture is widespread. The pollution is not only affecting the environment and the health of humans, but also impacting on production and productivity, leading to falling or stagnating yields [IAD, May/June (1994, p.7); Conway and Barbier (1990, p.22); Dhanapala, per comm (1994); Wilson (1994)].

The fertilizers (mainly nitrogenous) used have polluted the surface and ground water in many areas, with disruptive effects on the environment, wildlife and the health of humans. Pesticides, too, have affected the environment, wildlife, human beings and caused many occupational[7] morbidity and mortality effects due to direct exposure to pesticides. These are some of the private and external costs that have arisen due to agricultural pollution, resulting from the large-scale use of inorganic chemical inputs. We show below, how this pollution is generated by agricultural production and accumulates in the environment over a period of time.

[5] According to John Harris (1987, p.229), this expression was deliberately coined with the phrase 'Red Revolution', and the notion that developing countries were to undergo far-reaching changes as a result of an agricultural revolution rather than because of radical political transformation.

[6] The impact of the Green Revolution on wheat and rice production is a function of both the area sown with the new wheat and rice varieties and the increase in yields per unit of land.

7 Occupational refers to farmers engaged in farming activities and pesticide handling and spraying.

In order to do this, the production function (1) can be expanded to show all inputs used in the production process.

$$Y = f(\bar{X}_1, X_2, X_3, X_4) \qquad (2.2)$$

$\bar{X}_1$ = Fixed inputs such as arable land (both in the short term and long term)
X_2 = All variable inputs excluding chemical inputs
X_3 = Chemical inputs (pesticides and fertilizers)
X_4 = Human effort

Although many of the inputs used in the production process can cause pollution related private costs and negative externalities, in this study, as mentioned in the introduction, only the private costs and negative externalities arising from pollution resulting from the use of agrochemical inputs such as fertilizers and pesticides, (X_3), are considered.

An off shoot of the agricultural production function is a pollution generation function (g). We assume that only X_3 cause pollution and affects agricultural productivity, other production processes, human health, the environment and wildlife. There are an N number of farmers in the area, N is large and all of them use the inputs, X_3. This is due to the Green/Agricultural Revolution technology and commercially grown vegetables and other cash crops that are grown, where large-scale use of chemical inputs such a fertilizers and pesticides are a common practice. Also, it is assumed that the farmers produce for a market. We can write the pollution generation function from a single producer at time t as;

$$Z_{it} = g(X3_{it}) \qquad \text{where } i = 1, \ldots\ldots, N \qquad (2.3)$$

Z_t is the quantity of pollution from farm i at time t.

where

$$\frac{\partial Z_{it}}{\partial X_{3it}} > 0 \qquad (2.4)$$

The second derivative is also positive. This is because pollution increase at an increasing rate as more and more of X_3 are used and also because of the existing level of stock pollution. In other words pollution is exponential.

The use of the inputs, X_3 cause negative externalities and private costs due to the nature of the inputs (which are agro-chemicals), where most of the pollution that is generated from these inputs, tend to accumulate overtime. As stated earlier, they breakdown very slowly and can stay in the environment for long periods of time. This we call as 'stock' or 'conservative' pollutants (in the case of the green revolution, for example, some of the agricultural pollution have been accumulating over the last 30-35 years). Hence, the private costs and the negative externalities (pollution related) stock accumulation function from X_3, from the N number of farmers at time t, can be written as;

$$S_{Nt} = S_{Nt-1} + \sum_{i=1}^{N} Z_{it} \qquad (2.5)$$

S_{Nt} is a stock of pollution[8], at time t, from the N number of farmers. It is assumed that input use, X_3, by the farmers is the source of the stock pollution.

The stock pollution (i.e. both current and past pollution) causes the negative externalities and private costs. Externalities impose costs outside the farm, while the private costs are picked up by the respective producers, as described in the respective definitions of the two concepts. We know that when private costs arising from ill health to the producer from pollution are not taken into account, and in the presence of externalities, resource allocation becomes inefficient. This is because, some of the costs arising from production are not taken into account. Private health costs arising from pollution are not taken into account by farmers due to many reasons. One main reason is that such costs are difficult to quantify and are regarded as indirect costs. Interestingly Sivayoganathan et al. (1995) point out that intangible costs such as discomfort, pain and suffering are considered as a 'normal part of their work' by farmers. This has to be remedied, for which the use of the price mechanism has been recommended. In such a situation, in order to show the necessary condition for efficient resource allocation, let P_t, Q_t and R_t denote output and input prices and the price of pollution[9] in the form of health effects to the producer, generated by his own production activities respectively at a particular time t and V denote a hypothetical shadow price of the externality at time t. Input use of the ith farmer, at time t, when resources are allocated efficiently is done according to

$$P_t\, \partial Y/\partial X3i_t = Q_t + R_t + V_t\, \partial Z/\partial X3i_t \qquad (2.6)$$

$$\text{where } \frac{\partial Y}{\partial X_{3it}} > 0 \qquad \text{And} \qquad \frac{\partial Z}{\partial X_{3it}} > 0$$

When resources are allocated efficiently, the value of marginal product of input use is equal to the sum of the input price, Q_t, plus the price paid for the private cost of pollution, R_t and the cost of marginal externality, by the input, X_3 ($V_t\, \partial Z/\partial X3_{it}$). In the case of externalities, it is important not to ignore the external costs, even though the costs may be picked up by future generations or non producers. The extent of externalities, also gives an indication of the extent of private costs arising from production related pollution.

8 There is natural degradation of the stock of pollution. However, it is assumed that the rate of pollution accumulation is greater than the natural rate of degradation. Hence, a build up of a stock of pollution. The factors that influence the break down of chemical pollution such as fertilizers and pesticides were discussed earlier in this chapter.

9 The prices can be both hypothetical shadow prices and/or existing market prices.

As Zilberman and Marra (1993, p.248/49) have correctly pointed out, ignoring the costs of externalities leads, not only to an overuse of the inputs[10], but also to an accelerated build-up of the stock of pollution. Thus, the growth of S_t can impact on the environment, wildlife, affect the production processes on other farms and other production activities, lead to a drop in agricultural output/productivity on the land, affect farmers health and also cause health problems to those living on the farms and outside. Zilberman and Marra, too, confirm that the excessive accumulation of externality in the early periods, tends to result in a substantial reduction in productivity in agricultural land in the long run, with output levels declining much below what is required by the efficient solution. The model presented above shows that pollution generated could build up as a stock resulting in many private and external costs. It is only when these costs are considered that production can be efficient. The model, however, implies that as the stock of pollution grows, it can affect future production as shown in Figure 2.1. Hence production becomes inefficient. Furthermore, it must be pointed out, that, it is imperative to take into account the private costs of pollution arising to the producer. This is usually not considered by the producers, as will be demonstrated in this thesis, and that, these costs are substantial. When these pollution related private costs are not considered, the market price does not reflect the true costs of production and hence resource allocation is inefficient. Therefore, inefficiencies can arise when externalities are not considered and also when pollution related private costs are not taken into account.

There are many examples of declining agricultural productivity as mentioned above. There are now signs that the growth rates for high yielding varieties developed in Asia in the so-called "green revolution" era, have begun to slow down or stagnate (Conway and Barbier, 1990, p.21; Dhanapala, per comm, 1994; IAD, May/June, 1994, p.7) and in the case of trial plots, a decline in yields has been observed (IAD, May/June, 1994, p.7). On test plots at the International Rice Research Institute (IRRI) at Los Banos in the Philippines, where the HYVs were developed, varieties which yielded 10 tons a hectare in 1966 are now yielding less than 7 tons per ha (ibid.). The stagnation in yields experienced in Sri Lanka, is attributed to soil fertility decline caused by prolonged intensive monocultures of high yielding cultivars, aided by high chemical inputs on the land (Dhanapala, 1994, per comm). Declining yields discussed here, are not related to the concept of diminishing returns, but rather are an end result of pollution. Such pollution which is generated by farmers activities cause private costs to the farmers themselves, as well as externalities to neighbours. When pollution exists, then the process of diminishing returns is accelerated. The next section discusses the concept of diminishing returns and pollution impacts on output (which are two different concepts) and show how the point of diminishing returns is accelerated.

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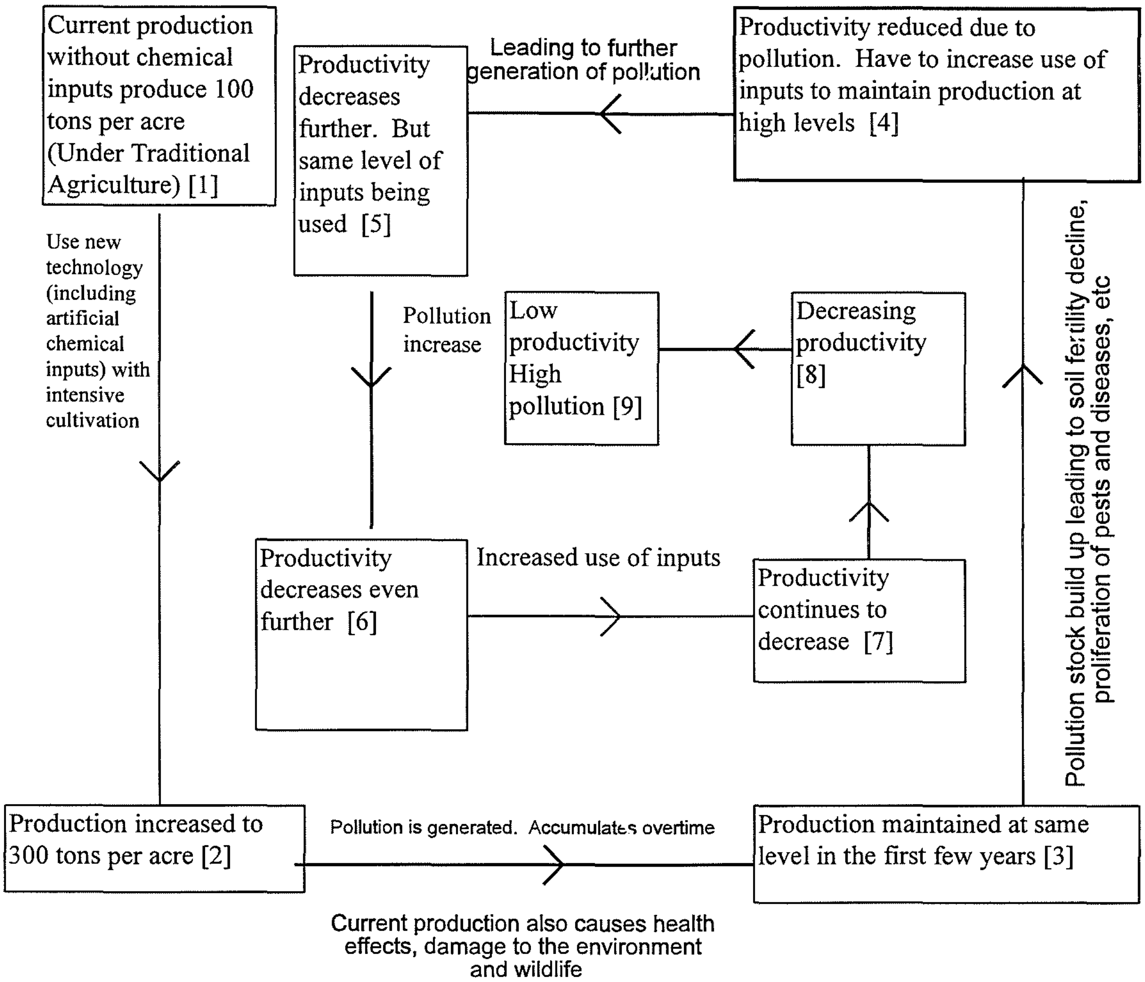
[10] Here the inputs are overused or increased, in order to increase the Total Product or output, which is increasing at a decreasing rate. In other words, Average Product and Marginal Product are decreasing. This is shown in Figure 2.2.

Input Use and Diminishing Returns

The law of diminishing returns shows that, as increasing amounts of a variable factor are applied to a fixed quantity of another factor, the output per unit of the variable factor will eventually decrease. In such a case it is assumed that the quality of the inputs do not deteriorate, but rather are producing at maximum levels. This is true for either industrial or agricultural production. The important point here is that, there is a fixed input and a variable input. Hence, when the variable input is increased, while the fixed input remains constant, at some point, diminishing returns begin to take place. With the existence of pollution, on the other hand, the process of diminishing returns is accelerated. For example, let us assume that we have a fixed input, say one acre of land. The variable input is nitrogenous fertilizer. In a situation without pollution, let us assume that the level of output where average productivity reaches a maximum is 10 tonnes per acre, with 50 kgs of fertilizer. On the other hand, when pollution exists, the production process is affected and the point of diminishing returns is lessened, for example, to 08 tons per acre for the same 50 kgs of fertilizer. This is because, the quality of the land has been affected by the pollution. The irony is that, the very inputs that are used to boost up production, in turn impact on production, that is caused by the pollution of these inputs. The efficient solution to this problem requires that input use and output decline overtime while the price of pollution and output price increases. Such a scenario can be shown in a simple diagram. Figure 2.1 shows how production and productivity can be increased from traditional levels of output to higher levels, by using chemical inputs, but however, these higher levels of production and productivity can be affected and reach low levels due to the accumulation of pollution on agricultural lands.

Figure: 2.1 Hypothetical Scenario of Decreasing Production Due to Agricultural Pollution



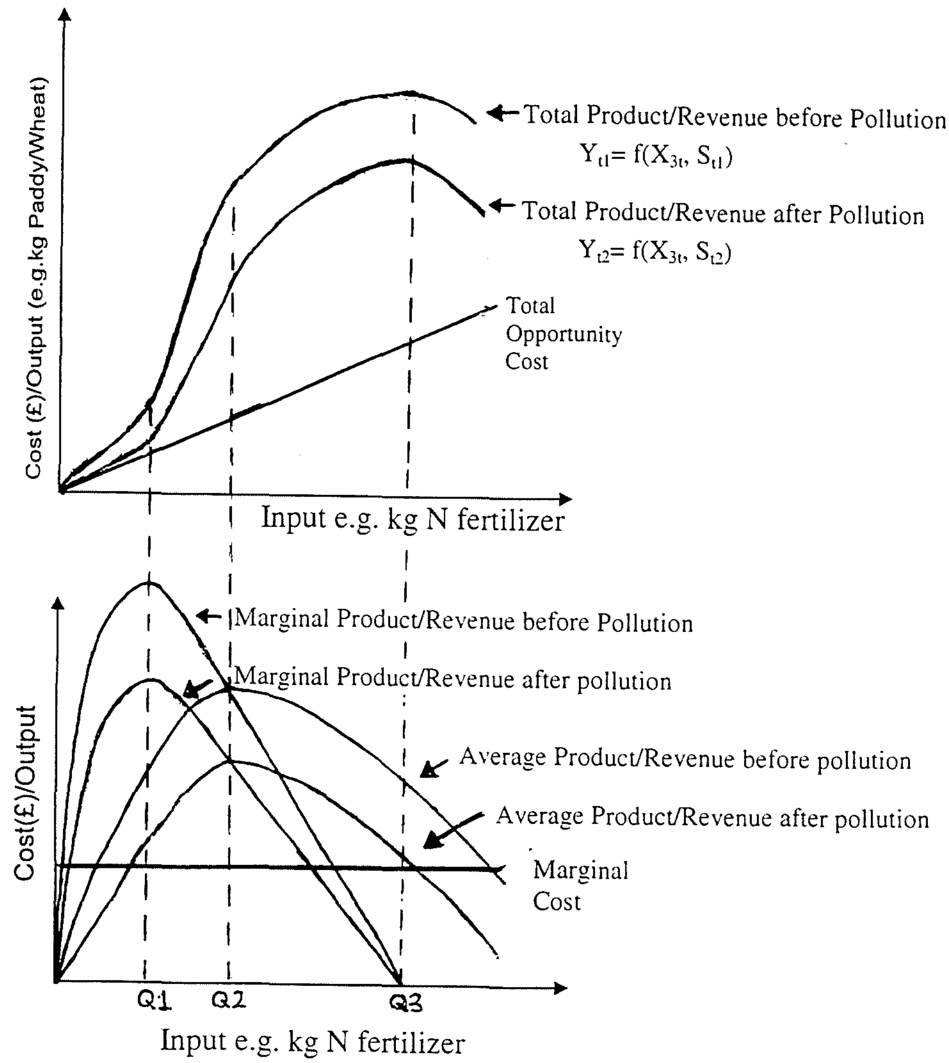
Fiure 2.1 shows how agricultural production and productivity can oscillate from normal production levels (under traditional agriculture) to very high levels of production (under modern agriculture) using high technology (artificial chemical inputs, intensive farming) and then due to pollution generated, oscillate towards low levels of production and productivity.

The processes described in Figure 2.1 are unique to agriculture. The production path shown in Figure 2.1 is clearly unsustainable and is diametrically opposed to the definition of sustainable development endorsed by the World Commission on Environment and Development (WCED) which defines the concept as "development that meets the need of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.43). The conventional yield-input use relationship can also be shown in diagrammatic form. Figure 2.2 shows, how the total output produced can be affected by the pollution that is generated by the very inputs used in the production process, and that after each production cycle, the 'point' of diminishing returns, decreases with the accumulation of pollution, and the decreases take place at an increasing rate due to a combination of stock pollution and multiplier effects taking place on agricultural land. Hence, the cost of pollution, is the reduction in productivity on the land. Therefore, in addition to the diminishing returns resulting from increased use of input(s), diminishing returns are also accelerated by high levels of pollution in agricultural fields.

Figure: 2.2 **Conventional Yield-Input Use Relationship**

2.2 (a)

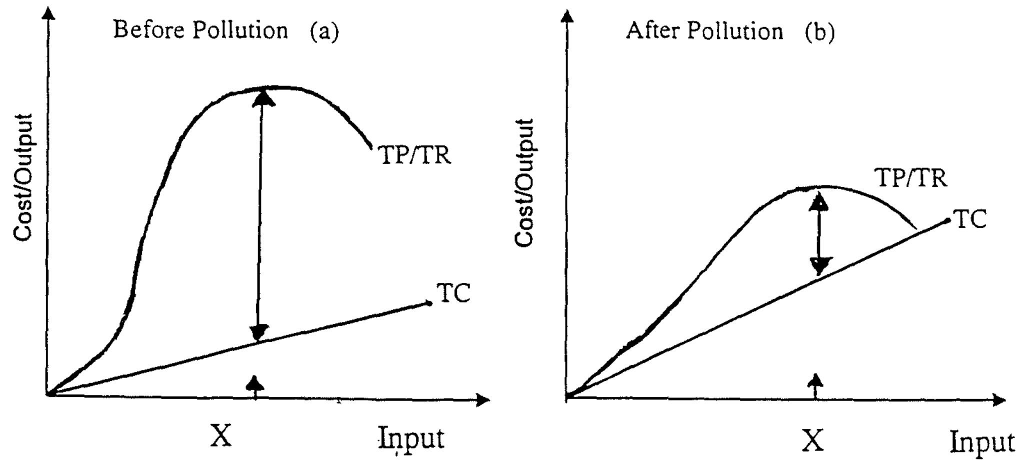
2.2 (b)



Note: As shown in figure 2.2 (b) marginal product increases in the early growth phase of the production curve to a maximum (q_1) and then falls away to (q_3) when total production is maximised. However, in the presence of pollution, as the total product decreases [shown in 2.2 (a)] the marginal and the average product, too, decreases as shown in 2.2 (b).

As shown in Figure 2.2, increasing the amount of input use, for e.g. fertilizer and pesticides, to a fixed amount of land, results in diminishing marginal and average returns. As inputs are added to the production function, they also generate pollution which tends to accumulate over the years, resulting in a pollution 'stock' accumulation function as shown in equation 2.5. The pollution caused by nitrates and pesticides, affects the soil and the agricultural environment in many ways, which in turn impacts on agricultural production and productivity. The losses are overtime and are a discounted term. The accumulation of the stock of pollution tends to result in a substantial reduction in productivity in the long-run with output levels declining below what is required by the efficient solution. Such a scenario is depicted in Figure 2.2(a) where the Total Product curve when pollution exists is less than the Total Product before pollution. Figure 2.2(b) shows the Marginal Product and Average Product curves before and after pollution. When such a situation exists, not only is the total revenue affected, but also the cost of production is increased. Such a scenario is demonstrated in Figure 2.3.

Figure: 2.3 Output/Cost Relationships Before and After Agricultural Pollution



Note: In the above diagram X indicates the level of inputs used to produce an output. The diagram shows how Total Product (TP) could decrease and Total Costs (TC) can increase after pollution. Figure (a) shows that before pollution output is large and TC is low. Figure (b) shows a situation after pollution where TP has moved rightwards while TC has moved leftwards. In other words, TC has increased. This is due to increased use of inputs such as fertilizers and pesticides and increasing costs of pollution.

Figure 2.3 (a) shows output before pollution where total product or yields are high while the total costs of production are low. This means that, the difference between TR - TC is large. However, as pollution increases, more and more inputs have to be used to boost production, as outputs are reduced due to pollution impacts. For example, IRRI scientists point out that farmers have to apply up to 40 percent more nitrogen fertilizer than they did 10 years ago to produce the same amount of rice (IAD, May/June, 1994, p.8). Furthermore, the private costs of pollution are also large. All these costs, shift the Total Cost curve leftwards as shown in Figure 2.3 (b). Furthermore, the output may not be as large as before pollution or even decreasing as shown in Figure 2.1. For example, it has been shown that on test plots at IRRI in the Philippines where HYV's were developed, varieties that yield 10 tons a hectare in 1966 are now yielding less than 7 tons per hectare [IAD, (1994, p.7); Conway and Barbier (1990, p.21)]. It is interesting to note that, in the initial years of the green revolution technology, output and productivity increased rapidly and reached a plateau stage and now there is increasing evidence to show that there is declining productivity due to pollution and soil fertility decline. Available data suggests such a trend. Hence, we see that the gap between TR - TC is smaller. This means that the total cost of production has increased and also the production levels are falling. Although total output can be increased by adding extra inputs, it only increases at a decreasing rate. In fact AP and MP are declining as shown in Figure 2.2 (b). Of course, using more of the inputs cause further problems, as the stock of pollution, S_t, accumulates. In such a case the pollution impacts are multiplied and the private and external costs keep increasing. In the next section, we discuss the pollution impacts resulting from agricultural activities which are both private and external in nature. Most of the examples cited below are taken from Asian countries and are mostly restricted to green revolution varieties, although similar examples can be derived for other crops as well. Many examples are cited, in order to show the seriousness of the problem and the numerous private and external costs that are involved.

Private and External Costs of Production

Agricultural Impacts

There are many impacts on the agricultural environment due to agricultural pollution, especially from nitrates and pesticides, which lead to declining productivity. Soil damage has occurred in many agricultural lands with heavy use of inorganic chemical fertilizers[11], pesticides resulting in a reduction of essential soil nutrients such as Zinc and Boron (IAD, July/August, 1983, P.17; Shiva, 1991, p.114). Figure 2.4 shows micro nutrient deficiencies in Punjab soils. Zinc is the most widespread of all micro nutrient deficiencies in Punjab, India. Such deficiency has reduced yields of rice, wheat and maize by up to 3.9 tonnes, 1.98 tones, 3.4 tonnes per hectare respectively (Shiva, 1989, p.77). Furthermore, with increased fertilizer application, acidification of soils have increased (IAD, November/December 1993, p.16-17). According to Baker, (in IAD, 1993, p.16) intensively grown monocultural systems with chemical fertilizers and water throughout the year can exhaust organic matter in soils. Furthermore, it has been pointed out that, there is a potential for pesticides to adversely affect paddy soils (Greaves, 1984, p.14).

Apart from decreasing yields resulting from fertilizer contamination of the soils, pesticides, too, affect yields indirectly. Increases in pesticide use to control the pests that easily attack high yielding varieties have led to an increase in the virulence of rice, wheat and other crops pests (IAD, March/April, 1990, p.6; Shiva 1991, p.88-89) due to the destruction of non-target species, which include natural predators of pests [Litsinger (1989, p.235); Bramble (1989, p.229); Teng (1990)]. The best examples that can be cited are the brown planthopper and rice gall midge. There are many more species that have proliferated with the destruction of natural predators which earlier were not serious (Litsinger, 1989, p.235; Kenmore et al, 1984; Way and Bowling, 1991; Sogawa, 1982). Hence a pesticide treadmill has been created. Severe outbreaks of the brown planthopper occurred on rice in the 1970s, 1980s and in the 1990s in Asia with losses running into millions of hectares of rice destroyed[12]. Figure 2.5 shows the distribution of the brown planthopper in the Australian-Asian region. Planthoppers are naturally controlled by wolf spiders and a variety of other natural predators and parasites which are destroyed by many of the pesticides commonly used on rice (Conway and Barbier, 1990, p.22; Conway and McCauley, 1983). According to Way and Bowling, (1991, p.237) "as the Green Revolution varieties became more

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[11] According to Nortcliff (in IAD, Nov/Dec, 1993, p.16-17) 'inorganic fertilizer is partly responsible for declining yields, but there may be other factors, such as decline in soil structure'. Baker (in IAD, Nov/Dec, 1993, p.17) states that when chemical fertilizers have been applied over long periods, yields have eventually declined.

[12] The best example of crop damage from brown planthopper can be taken from Indonesia. From 1977 to 1979, over two million hectares of rice were lost due to brown planthopper damage. Again from 1984 and 1986 BPH outbreaks reduced rice yields nation wide (Whalon et al. 1990, p.156).

widely accepted and grown, more insecticides were applied to protect high yielding crops requiring greater inputs. The increased use of insecticides decimated natural enemies and led to secondary pest outbreaks and the resurgence of planthoppers". This connection is also shown by Heinrichs (1979); Chelliah and Heinrichs (1980); Krishnaiah and Kalode (1987); Teng (1990). Numerous outbreaks have occurred during the last four decades. These outbreaks of pests are, however, not restricted to Green Revolution varieties, but also to all commercially grown crops. Figure 2.6 shows some of the natural predators of pests that have been decimated by continuous use of pesticides.

Insect resistant varieties (both Green Revolution varieties and non Green Revolution varieties) have not been able to prevent these outbreaks as the pests rapidly select new biotypes (Litsinger,1989, p.235). Outbreaks of BPH and tungo virus vectored by the green leafhopper have proliferated after their natural enemies were destroyed by insecticides (Litsinger, 1989, p.235; Kenmore et al. 1984; Way and Bowling (1991); Sogawa (1982). Furthermore, the white backed planthopper (WBPH) which was earlier considered a minor pest has now become a serious pest to rice production in several Asian countries including Pakistan, India, Bangladesh and Nepal. Serious outbreaks have been reported from Madhya Pradesh, Orissa, Tamil Nadu, Kerala, Andhra Pradesh and West Bengal (Chatterjee et al. 1976) Haryana (Kushwaha et al. 1982), Punjab (Sidhu, 1979), Uttar Pradesh (Verma et al. 1979) and Nepal (Pradhan et al. 1983). The damaged caused to grain yields by this species (i.e. WBPH) and its allied species, the brown planthopper is estimated between 10 and 100% in various states/areas (Kushwaha, et al. 1986, p.21).

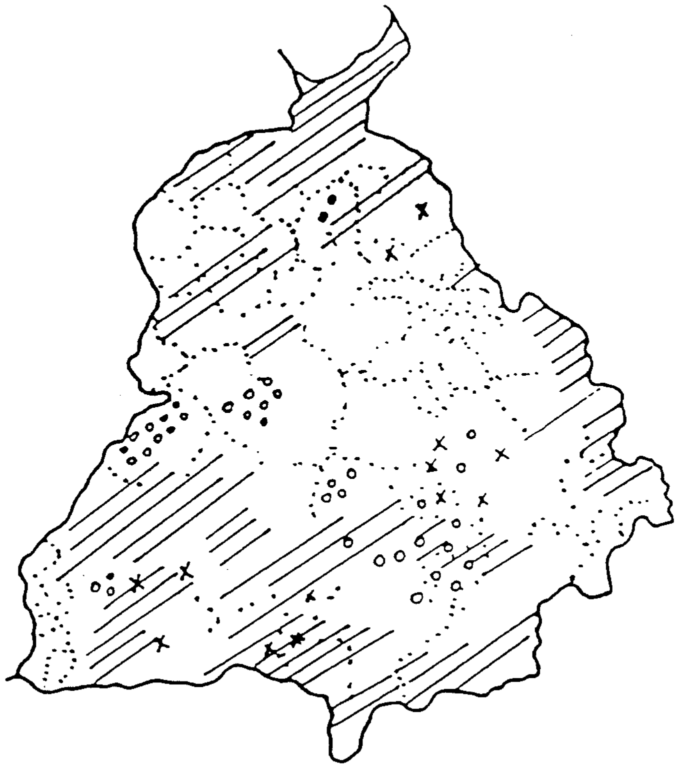
Furthermore, rice scientists have, in recent times, established a link between increases in nitrogenous fertiliser and proliferation of pests in rice. When fertilizer applications increased, the amount of pests and diseases in rice have also simultaneously increased (Chakraborty et al. 1990, p.167; Litsinger, 1989). It has also been shown that increased nitrogen is often associated with more leaf disease, because it provides a micro climate more conducive to fungal growth. Among the diseases that have increased in South Asia are; bacterial diseases, sheath brown rot, narrow brown leaf spot (Estrada et al. 1981) tungo, grassy stunt (Mew, 1991, p.187-227). Hence, through crop damage yields could decrease. These problems are also not restricted to the Green Revolution varieties but also to all commercially grown food crops requiring the use of chemical inputs. Soil pests, especially root nematodes, have also increased with agricultural intensification [Prot et al. (1992)]. Fischer, (1985, p.208) also states that pollution not only affects yields and the quality of crops but also the vegetation is made more susceptible to damage by insects and diseases.

Other Costs of Fertilizer and Pesticide Use

Eutrophication and Algal Blooms from Nitrate Pollution

In addition to fertilizer impacts on health, there are side effects on the environment too. Nitrates act as fertilizers for aquatic plants (Saull, 1990, p.2). Nitrates seeping out of soil into streams, rivers and lakes in excessive quantities can boost the growth of algae and other aquatic plants. This enrichment is called eutrophication. The increase in the growth of aquatic plants in certain areas has clogged up rivers and lakes (IAD, Nov./Dec., 1989, p.2) as well as killed fish due to deoxgenation. Waterways in Asia provide a valuable form of water transport and when rivers and lakes are clogged up, the impact on water transport can be considerable. Fertilizers have also increased weed growth in rice fields and provided breeding grounds for malaria. The increased weed growth has led to an increase in the use of herbicides. This can be attributed partly to the efficacy and the cheapness of herbicides over manual labour.

Figure: 2.4 Micronutient Deficiencies In Punjab Soils



Zn [single line represents 20% area deficient in a block]

Fe [single 'x' represents 10% area deficient in a block]

Mn [visual symptoms and response]

Probable areas of Fe, Mn and S deficiency

Source: Shiva.1991.p.115.Originally from Punjab Agricultural University.

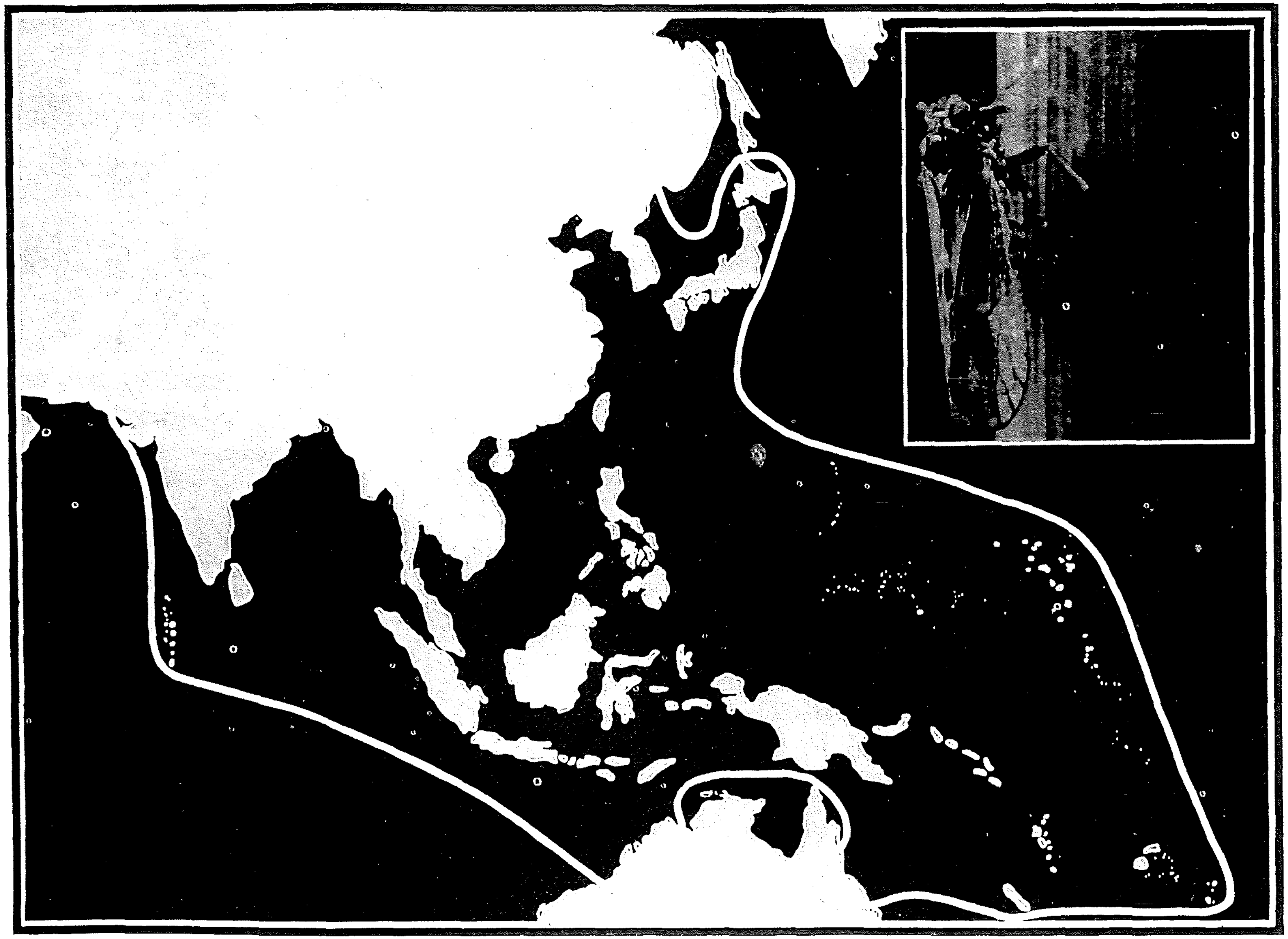


Figure: 2.5 Distribution of Brown Planthopper (Nilaparvata Ingens), 1982.
Inset; Brown Planthopper

Source: Bull,1982, p13. Originally from Centre for Overseas Pest Research.

Figure 2.5 shows the present range of the brown planthopper where it is a serious threat to the paddy plant. Prior to the decimation of its predators such as the wolf spider due to the use of pesticides, it was not capable of causing large-scale damage. The best example of damage caused after the decimation of its predators can be taken from Indonesia. For example, see Conway and MaCauley (1983); Joyce (1988); Cook and Perfect (1989); Teng (1990).

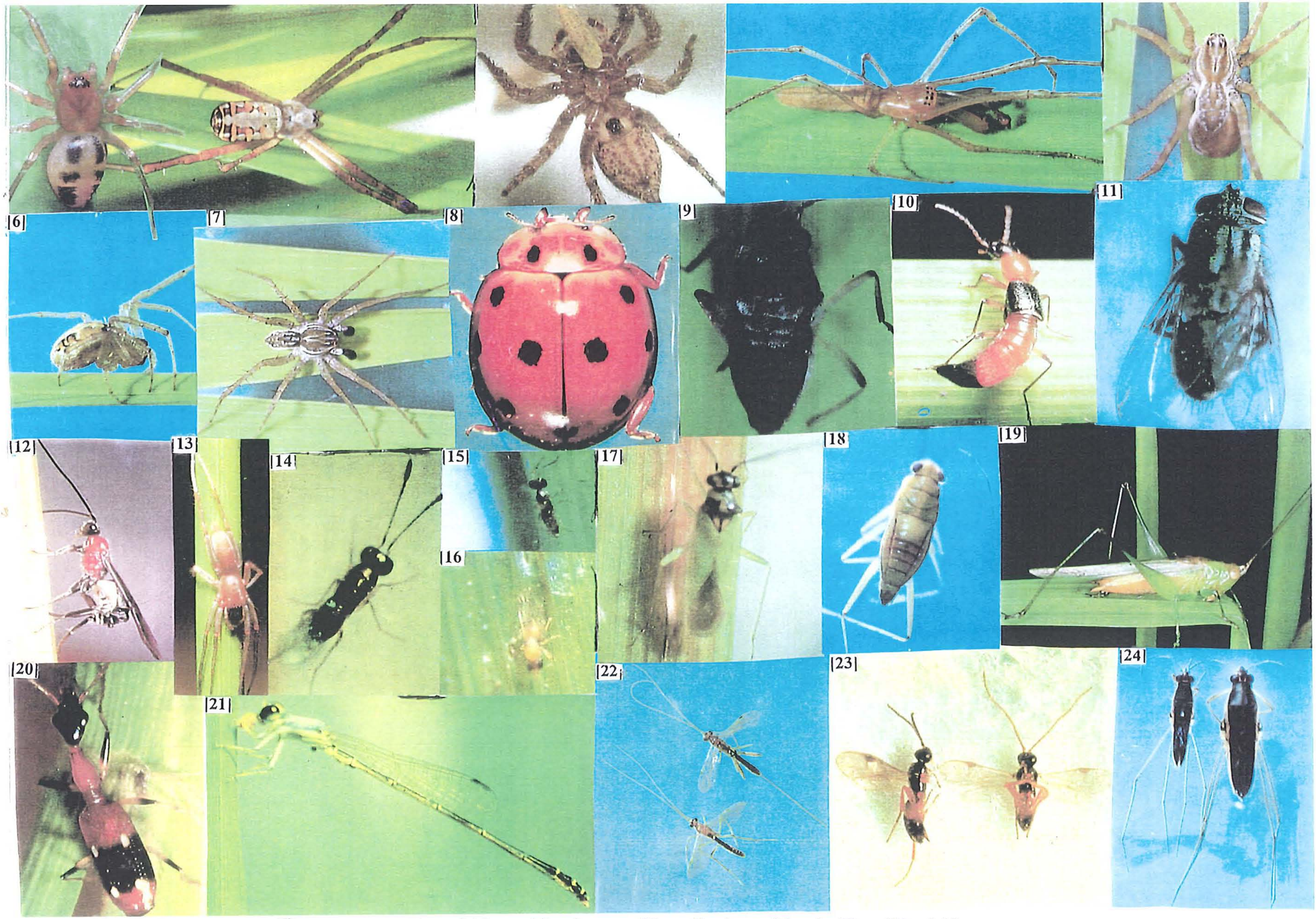


Figure: 2.6 Natural Predators of Pests Decimated by the Use of Pesticides

[1] Atypena (callitrichia) formosana (oi). [2] Argiope catenulata. [3] Salticid spiders. [4] Clubiona japonicola (Boesenberg). [5] Lycosa pseudoannulata (Boesenberg and Strand). [6] Araneus inustus (L koch). [7] Tetragnatha spp. [8] Sinharmonia octomaculatus (Fabricius). [9] Microvelia douglasi astrolineata Bergroth. [10] Paederus fascipes (curtis)-Staphylinidae). [11] Sturmiopsis inferens (Townsend). [12] Bracon chinesis (Szepligeti). [13] Clubiona japonicola (Boesenberg and Strand). [14] Gonatocerus spp. [15] Oligoista naias (Girault). [16 & 17] Anagrus Optabilis (Perkins). [18] Cyrtorhinus lividipennis Reuter. [19] Conocephalus longipennis (de Haan). [20] Ophionea nigrofasciata. [21] Agriocnemis spp. [22] Macrocentrus spp. [23] Apanteles spp. [24] Limnogonus spp.

Wildlife Impacts from Pesticide Use

No one knows for certain the extent of the damage done to wildlife from the use of pesticides. This is because, no detailed study has been carried out in Asia to determine the real damage to fauna. However, many species have been affected, especially animals[13] at the top of the food chain, and according to Bramble (1989, p.228) the natural balance of predators and prey has been disrupted, particularly in the insect world[14]. Birds, too, have been a casualty from pesticide poisoning[15]. According to Urfi (1994, p.35) cranes and storks have been affected due to green revolution agricultural toxins. It is believed that agricultural toxins have decimated water insects and invertebrates in the agricultural lands that constitute up to 75% of Uttar Pradesh. As a result, Sarus cranes, the world's largest flying bird, begun to disappear due to the disappearance of their specialized food. Storks, too, have been affected. The number of Black Necked Storks have shown a visible decline and among the many factors responsible, have been the thinning of the shells of their eggs due to pesticides (Urfi, 1994, P.35). A study conducted in Karnataka state of 338 wetlands by IWRB (1992, p.49) has shown that pesticide and fertilizer pollution threatened 17 of 338 wetlands.

There is a paucity of studies conducted to determine the welfare estimates of environmental effects of pesticides both in developed and developing countries despite the damage done to local flora and fauna being high. Antle et al. (1998) have conducted an analysis of economic, environmental and health tradeoffs in Ecuador but the welfare estimates of environmental damages are not presented. Pingali and Rosegrant (1994), too, discuss the environmental consequences of the green revolution in Asia but no welfare estimates of environmental damage are presented. In Britain, Marchant et al. (1990), Department of the Environment (1996), have estimated that nine species of British farmland birds have experienced a serious decline between 25%-60% during the 1980's and that pesticide usage has been a significant factor. Foster and Mourato (1997) have used this analysis to form the basis of their contingent ranking[16] methodology to value the various environmental consequences of pesticide use in bread production. In this study three product attributes are considered, namely the price of a standard loaf of bread, causes of human illness as a result of field exposure to pesticides during cultivation and a number of farmland bird species in a state of serious long-term decline as a result of pesticide use in arable farming. Tradeoffs between money, human morbidity and bird biodiversity are then examined. The willingness to pay valuation is expressed in terms of pence per loaf for a unit reduction of one case of ill health each year and one less bird species facing serious long-term decline. The willingness to pay results show that to protect a bird species is typically six times higher (at around six pence per loaf) than the willingness to pay to

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13 For pesticide poisoning of mammals in Britain and elsewhere, see Mason et al. (1986, pp. 656-66); Blackmore (1963, pp. 391-409).

14 For a discussion on the impact in bees see Shries (1983, pp. 118-20); Murray (1985, pp. 560-64).

15 For evidence of pesticide poisoning of birds in UK and North America, see Lundholm (1987, pp.1-22); Peakall et al. (1976, pp.392-4); Newton and Bogan (1978, pp. 105-116); Lincer (1975, pp.781-93).

16 Contingent ranking is a survey based technique which has been designed to isolate the value of industrial product characteristics (attributes) which are typically supplied in combination to one another [Foster and Mourato (1997)].

avoid a single case of human ill health (at around one pence per loaf). Higley and Wintersteen (1992), too, apply monetary weights to the different aspects of environmental degradation. Their contingent valuation survey was carried out among farmers in the USA. The results show that about 66% of the farmers were willing to pay to avoid environmental risks. The mean environmental cost estimates were $ 12.54 to avoid high risks, $8.76 to avoid moderate risks, $5.79 to avoid low risks (n= 1,114).

Impact on other Production Processes

In addition to the damage caused to the environment, wildlife and health from the pollution that is generated from pesticides and nitrogenous fertilizer, these pollutants, also impact directly on other production processes. One such process that has been directly affected is the fisheries sector. We discuss briefly the impact of pesticides on the fisheries sector in the next section.

Shrinking Fish Production

In addition to the effects on the environment, wildlife and health from pesticide and nitrogenous fertilizer, there are other negative externalities caused from these two inputs. One major side effect has been a decrease in fish production (Bull, 1982, pp. 63-65; Ministry of Finance, Bangladesh, 1992, p.32), both in paddy fields and fresh water lakes and rivers. Many of the pesticides used are highly toxic to fish at normal rate of application (Grist, 1986, P.318)[17]. There is increasing evidence for this from India as well as Bangladesh. In Kuttanad, the rice bowl of Kerala, since the 1980s, fishing has become practically extinct (IAD, March/April, 1990). In Bangladesh, fish production over the years has shown a noticeable decrease. Among the many factors that have been sighted as a cause for decline in fish production is the presence of pesticides in fresh water as well as crop fields (Ministry of Finance, 1992, P.32). In addition to fish, Prawns, Crayfish and Crabs are also known to suffer from pesticides but detailed studies of pesticide poisoning are not available. Greaves (1984, p.15) states that there is evidence that pesticides, particularly insecticides, can cause mortality in crabs and fish.

Health Impacts Due to Agricultural Chemical Pollution

Health Effects due to Nitrate Pollution

Apart from the impacts on agricultural productivity, there are many external impacts resulting from the use of inputs, which affect the health of third parties, wildlife and other production processes and the environment in general. One externality that is widely reported is water contamination in agricultural areas from fertilizers used in agriculture. High nitrate levels in drinking water in some Asian countries are known to occur. The pollution of ground water due to fertilizer (especially nitrogenous) is suspected to have caused diseases and in some rare cases deaths in humans. Diseases such as Cancers, the Blue Baby syndrome and Jaundice in children (although not

[17] In the Philippines and Malaysia farmers have linked declining fish yields in rice fields to pesticide poisoning (Dinham, 1993, p.69; Sudderuddin and Kim, 1979).

conclusively proved) have been linked to nitrate pollution in drinking water (Singh 1989, p.1). In some areas of South Asia, the level of nitrates[18] in the water has exceeded the World Health Organization limits (British Geological Survey, 1992; Conway and Pretty, 1991, p.195; NARESA, 1991, p.173; Gunasekeram, 1983).

According to various surveys in India, some 20-50% of wells contain nitrate levels greater than WHO limits and in some cases, as high as several hundred mg/l[19] (Pretty and Conway, 1988, P.4). Many diseases, including cancers, have been linked to nitrates in drinking water (Pretty and Conway, 1988, p.1). Theoretical models describing the chain of events from nitrate pollution to Cancer appear fairly complete. The carcinogens in this chain are N-nitroso compounds (ibid.). Many of these compounds tested have been found to cause Cancers in many species of animals, especially of the stomach, liver, oesophagus and bladder. Gastric, bladder, and oesophageal cancers have been suspected to be caused by high levels of N-nitroso compounds in water (Pretty and Conway, 1988, p.1). Some parts of India and Sri Lanka show increasing incidence of these Cancers, most of which come from agricultural areas.

Nitrogenous fertilizer has also been identified as one of the causes of methaemoglobinaemia, commonly referred to as the Blue-Baby syndrome in agricultural areas (Pretty and Conway, 1988, p.1). Many such deaths have been reported from agricultural regions in USA and Hungary and there are a few records of the Blue-Baby syndrome in tropical countries (ibid.). Furthermore, Jaundice has been reported in the Punjab due to ground water being contaminated with fertilizer effluents (Singh, 1989, p.32).

The next section shows the extent of mobidity and mortality effects resulting from pesticide pollution.

Morbidity and Mortality Due to Agricultural Pesticides

From the time traditional agriculture gave way to commercial agriculture with increased reliance on chemical inputs, such as fertilizers and pesticides (chemical pesticides have been used for the last 50 years and especially since the beginning of the green revolution in Asia) pesticide usage has been growing[20]. In India, for example, some 80 million hectares of India's cropland now receive treatment with chemical pesticides compared with just 6 million in 1960 (Gupta, 1986). In Ludiana district, for example, two thirds of the wheat area is now treated with herbicides (Sidhu and Byerlee, 1991, p. A-160). The pesticides are used on a wide variety of agricultural crops, including rice paddy and commonly grown vegetables. Similarly, other countries, too, use high levels of pesticides. In addition some pesticides banned in the western world are freely used in developing countries (Bull, 1982, p.93; Dinham, 1993, p.11; Postel, 1988, p.121; Forget, 1991). For example, DDT and Benezene

[18] However, not all nitrate pollution is caused by fertilizers. Domestic excreta leaching into ground water is a major source of ground water pollution (Conway and Pretty, 1991, p.195: Dissanayake, 1988, p.80).

[19] The WHO guideline for safe levels in drinking water is 45mg nitrate/litre.

[20] According to Dinham (1993, p.159) Green Revolution turned India into a major pesticide consumer.

hexachloride (BHC), both banned in USA and much of Europe, account for about three quarters of total pesticide use in India (Postel, 1988, p.12). The potency of insecticides used, especially those that are banned, can be very high. All this has increased the risk of pesticide use as will be shown in this thesis.

Very high levels of pesticide residues, too, have been detected in Indian food and high pesticide residues of persistent organochlorine found in the blood of Indians, including DDT and BHC residues in breast milk (Dinham, 1993, p.169). All collected human milk samples were found to contain very high levels of DDT and BHC. Out of 980 samples of milk tested in Andra Pradesh, 95% of them contained DDT, HCH in 90% and dieldrin in 1% (Dinham, 1993, p.169). One study points out to 53% DDT in all 1,651 samples of cereals and cereal produced in Punjab, Haryana, Uttar Pradesh and Andhra Pradesh (Dinham, 1993, p.169). The average level of DDT residues in wheat grain is 0.03/mg/kg in Punjab (Singh, 1989, p.37). Several hundred deaths have been recorded from India and the figures are increasing. Table 2.1 shows pesticide related deaths in India, state wise.

Table: 2.1 Reports of Pesticide-Related Deaths Notifiable Under The Insecticides Act 1968 (excluding Occupational Health Hazards and Illnesses Which are Not Recorded)

State	1987-88	1988-89	1989-90
Andhra Pradesh	Nil	n/a	34
Haryana	3 (animal)	6	10
Himachal Pradesh	n/a	n/a	n/a
Kerala	Nil	n/a	237
Madhya Pradesh	772 cases of poisonin including a number o deaths from 1986-88		n/a
Orissa	2	Nil	2
Punjab	126	n/a	149
Tamil Nadu	4 (animal)	n/a	1
Uttar Pradesh	54	78	100
Pondichery	Nil	108	131
Total reported deaths	182+	192+	664+

Source: Indian Government Answer to Parliamentary Question on 4.1.91 extracted from Dinham (1993, p.165).

It has been suggested that the increase in certain neoplasmic diseases (Cancer) in Asia is linked to carcinogens released from pesticides and nitrogenous fertilizer. In India, there is concern among doctors that Cancer is increasing among communities directly exposed to pesticides. For example, a study has tried to show the link between high pesticide use among farmers and frequent cases of cancer of lip, stomach, skin and brain, as well as Leukaemia, Lymphoma and Multiple Myeloma (Dinham, 1993, p.49).

A survey conducted in Tamil Nadu, India, among farmers who had been spraying pesticides for between five and 20 yrs to determine a link between cancer and pesticide use[21] has shown higher chromosomal aberrations and chromatid exchanges in the labourers which indicate increased carcinogenic risk. The study found that these measures were significantly higher in the study group, compared to the control group, indicating chromosomal anomalies, which increase significantly with duration of pesticide use (Dinham, 1993, p.49).

Deaths due to direct pesticide poisoning (including occupational) is also very high in Sri Lanka. Sri Lanka, in fact has one of the highest rates of pesticide poisoning in the world (Jeyaratnam et al. (1982a p.14); Jeyaratnam et al. (1987); Jeyaratnam (1990). The first case of pesticide poisoning was reported in 1954 (Sirimana, 1955). Since then the death rate from pesticides has been phenomenal. Although incidences of pesticide poisoning is high, the real morbidity and mortality effects are believed to be even higher considering the fact that a very large number of farmers use pesticides without adequate precautions and that most of these cases of pesticide poisoning go unreported. Even in the 1980s this was observed, which prompted Kotagoda (1983, p.13), a medical doctor, to note that " the indictment against the hazards of pesticides is even more heavy when consideration is given to the fact that the stated figures are unavoidably under-estimates". Since then even larger quantities of pesticides have been used and under recording have prevented the highlighting of the real gravity of the problem.

The only previous data showing a national morbidity rate as high as 76 cases/100,000 population were those published by Zegarski (1979) for Poland in 1968, although it is possible that in other predominantly agricultural countries of the third world, the figure will be equally high. Dinham (1993) and Jeyaratnam et al. (1987) show high figures for developing countries.

Jeyaratnam et al. (1982a) assuming that there are 472, 435[22] agricultural workers in Sri Lanka, states that, out of this figure at least five of every 1000 are hospitalized annually due to pesticide poisoning from an occupational nature. He believes that, these figures are an under-representation of the true state of affairs (ibid). The number of agricultural workers quoted by Jeyaratnam is an under-estimate, because of the fact that 60%-70% of the 17 million inhabitants are farmers of whom 55-60% are known to be using pesticides at different degrees of intensity. Hence pesticide poisoning levels due to direct exposure, are bound to be higher and the national statistics do not reflect the true picture of 'direct exposure to pesticides' problem in Sri Lanka.

Only deaths and hospital admissions were discussed. What is more alarming is the long-term health consequences resulting from poisonings. Already certain districts (all agricultural) are recording increases in diseases such as Cancers, which are suspected of been linked to pesticides and other agricultural pollutants (NARESA, 1991).

Mortality rates due to direct exposure to pesticides are also high in some other Asian countries such as Indonesia, Malaysia, Thailand and the Philippines [Turnbull et al. (1985); Jeyaratnam et al. (1987); Loevinsohn (1987); Rola and Pingali (1993); Kishi et al. (1995); Antle and Pinali (1994); Lum et al. (1993)]. Work that highlights the

21 Men spray from 4-20 acres for 8-10 hours a day to earn extra cash (Dinham, 1993, p.49, 167).

22 These are employment figures released in 1978.

pesticide poisoning problem in other countries, especially in Africa and Latin America include: Partanen et al. (1991); Mwanthi and Kimani (1993) and Condarco et al. (1993). The various illnesses and the deaths that arise from pesticide poisoning incur very large costs to the affected parties. All the costs described above and others are summarized and shown in Figure 2.7.

Figure 2.7 shows costs arising from agricultural production due to pollution that is generated from the use of chemical inputs such as fertilizers and pesticides.

Figure: 2.7 **Costs of Agricultural Pollution**

Agricultural production

$$[Y = f(\bar{X}_1, X_2, X_3, X_4)]$$

↓

(Pesticides and Nitrates, X_3 generate)

Private Costs

- Health effects on users (Short-Term and Long-Term Illnesses which are discussed in Chapter three)
- Pollution affecting users land (declining productivity)
- User deaths

Externalities

Positive → (High Productivity)

Negative → $[Z = g(X_{3t})]$ →

(i) From pesticides
(ii) From nitrates

(i) From Pesticides

↓

Short-Term and Long-Term effects on

- Humans

↓

- Users Family
- Neighbouring population
- Consumers

Short-Term

- Morbidity effects
- Accidental poisoning leading to deaths

Long-Term

- Morbidity effects
- Mortality due to Long-Term pesticide poisoning

- Other Effects (both Short and Long-Term)
  - Affects agricultural lands
  - Waterways, wells and reservoirs
  - Fauna and flora
  - Proliferation of pests and disease

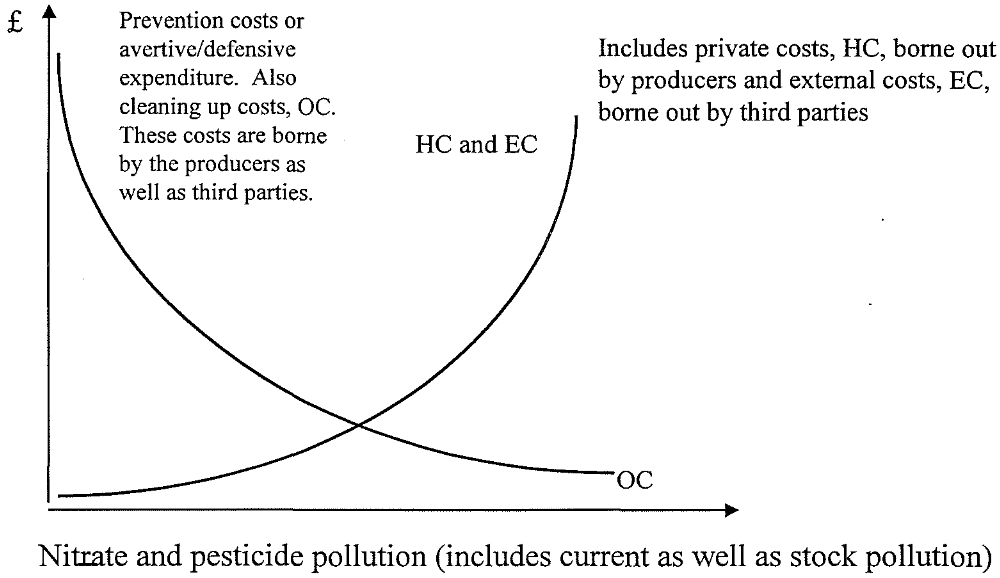
(ii) From Nitrates

Short-Term and Long-Term effects on

- Humans -(mainly Long-Term)
- Eutrophication/algal blooms
- Excessive weed growth
- Effects on water transportation (via clogging of waterways)
- Soil Acidification (leading to declining yields)
- Proliferation of insects (also Short-Term)

In addition to these costs, there are many other private costs that may have to be borne by the affected parties (including the producers). They include: prevention or avertive/defensive expenditures and cleaning up costs. These various costs are shown in Figure 2.8. The figure below shows how the private and external costs can be curtailed or even altogether prevented with protective/defensive expenditures and cleaning up the pollution.

Figure: 2.8 Other Costs Arising Due to Agricultural Pollution



As the above diagram shows, when the prevention and the cleaning up costs are large, then the private and external costs are small and vice versa. This goes on to show that precautionary measures and the cleaning up activities are an important feature in reducing costs. These vital relationships will be studied in this thesis.

The line sloping downwards shows prevention and cleaning up costs of pollution termed, OC. OC are those costs involved in averting behaviour such as; wearing protective clothing, wearing masks, wearing gloves, wearing shoes, building special storage units and other precautions taken (for example hiring of labour) during handling and use of pesticides. The cleaning up costs are also included in the OC. The upward sloping line shows all the private and external costs termed, HC and EC, respectively arising due to agricultural pollution in the short and long-term as shown in Figure 2.4. Short-term (acute)[23] private costs on humans include: medical costs, dietary expenses resulting from, for example, a pesticide related illness, travel costs associated with medical treatment, time spent on traveling/seeking treatment, loss of work days/hours on farm, loss of work efficiency, hired labour due to inability to work, leisure time losses (hours/days) and any other losses incurred due to illnesses, for example, from pesticide poisoning (e.g. crop damage due to inability to look after crops such as from theft and damage from wild animals). Long-term (chronic)[24] effects include; hospitalization/medical costs due to various cancers, blue baby syndrome, jaundice, tumours, loss of memory, chest pains, blindness, premature

[23] Acute poisoning is when toxic reactions follow shortly after direct exposure to pesticides.

[24] Chronic poisoning occurs when the reactions appear gradually after prolonged exposure (Goulding, R., quoted in Jeyaratnam et al. 1987, p.521).

retirement, etc. Loss of income to the family arising from deaths due to poisoning is also included in this category.

The downward sloping curve, OC, shows that when precautionary/defensive costs and cleaning up costs are high, then the level of pollution is low. This means that the private and external costs are also low. On the other hand, when the precautionary/defensive costs, OC, are low, then the level of pollution is high. Hence the level of private and the external costs are high.

Conclusion

This chapter showed how the use of chemical inputs, such as fertilizers and pesticides in the production process generate pollution, and in turn cause numerous costs, both private and external. Such a production path was shown to be clearly unsustainable. In the rest of this thesis, we concentrate only on the private costs arising from direct exposure to pesticides by farmers during handling and use on the farms. No other costs (such as hospital treatment or any external costs) are considered. Chapter three discusses the health effects to farmers arising from direct exposure to pesticides in Sri Lanka. This chapter also contains an introduction to the history of pesticide use and pesticide poisoning and a review of all work carried out on pesticide pollution in Sri Lanka.

CHAPTER 3

HEALTH EFFECTS OF PESTICIDE POLLUTION IN SRI LANKA

Introduction

Since the beginning of the use of pesticides it has been well known that pesticides are harmful to human health, wildlife and the environment in general. Rachel Carson's "Silent Spring" and Lewis Herber's "Our Synthetic Environment" showed how the use and careless disposal of products and by-products of modern technology were proving hazardous to human health and to the survival of many species. Among the many contaminants identified by Carson were pesticides which she alleged "have the power to kill every insect, to still the song of birds and the leaping of fish in the stream".

Since these books were written in the 1960s evidence of the harmful effects to man, wildlife and the environment have been mounting and have been well documented throughout the world. Pesticides have also been abused for suicides and homicides and numerous accidents have also been recorded, where thousands of deaths and hospitalized cases are recorded each year. In Sri Lanka this is a major problem. As a result, most of the work related to pesticide poisoning refer to these cases, while pesticide poisonings due to direct exposure affecting agricultural workers in the fields, have been given less attention, although such poisonings are also very high due to the large scale, carelessness and misuse by farmers.

Only passing reference is made to mortality and mobidity effects arising from direct exposure to pesticides during handling and use among farmers, although the problem is serious. Such reporting has given a distorted picture of the pesticide poisonings due to direct exposure among farmers during handling and spraying on their farms. As a result, the problem of pesticide pollution on farms has not been adequately highlighted. Hence, the reporting of pesticide pollution related morbidity and mortality effects in Sri Lanka has been under reported, misleading and inconsistent. As Dinham (1993, p.50) comments "where figures on pesticide poisonings exist, they frequently come from hospital poisons units, which tend to receive very acute cases of poisonings-predominantly, though not exclusively, cases of suicides or attempted suicides. These figures skew the overall statistics relating to pesticide poisoning and may give the impression that suicides are the most significant problem".

The focus of this chapter is to highlight the health effects due to direct exposure to pesticides among farmers during handling and spraying on their farms in Sri Lanka. Before this is attempted, a thorough review of work already done on pesticide pollution is reviewed with an introduction to the history of pesticide use in Sri Lanka.

History of Pesticide Use in Sri Lanka

Pesticides such as DDT[1] were first used in Sri Lanka[2] in the 1940s (Weeraratna, 1983). This was for the control of the Malaria mosquito. Pesticides such as DDT continued to be used in public health programmes to kill vectors of Malaria and Filariasis. However, during the period of late 1950s to the early 1970s witnessed a noticeable change in the application of pesticides. For the first time pesticides began to be used on a regular basis (though still on a small scale) on agricultural crops and as the decades passed larger and larger quantities were being used by a larger number of farmers. The main reason for this shift was the adoption of high yielding varieties especially in rice under the 'Green Revolution' technology and the high yielding and hybrid varieties of commercially grown vegetables and other cash crops. Since the introduction of the Green Revolution varieties (the so called 'miracle technology') to Sri Lanka in the early part of the 1960s[3], the use of pesticides in agriculture has grown rapidly (Abeysekera, 1988, p.21). They were first used mainly on the Green Revolution varieties such as rice but since then especially since the 1970s pesticides have been widely used on almost all commercially cultivated vegetables and other cash crops. Large acres of land were also brought under the cultivation of Green Revolution varieties. By 1982 the percentage of HYVs in rice was 94% (Abeygunawardena and Bessler, 1989). By 1990 the spread was almost complete. Similarly the acreage of paddy land and commercially grown vegetables have grown significantly over the years. A feature of these high yielding varieties was that they were highly dependent on the use of agro-chemicals, namely pesticides and fertilizers, because of poor resistance to pests and diseases and because they needed extra nutrients in the form of fertilizers to produce these large harvests. The shift to commercial agriculture with high yielding varieties and hybrids also meant intensive cultivation (usually both seasons) and involving monocultural crops. These factors too would have no doubt contributed significantly to the widespread increase in pests and diseases in agricultural fields. Furthermore, the importation of seed varieties, mainly vegetable with little resistance to local pests and diseases too have no doubt contributed to the increase and spread of pests and diseases. Another reason for the increase in pests

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1 The insecticidal property was first discovered by Mueller in 1939 for which he was awarded the Nobel Prize in 1948.

2 The first record of DDT use, an insecticide, was in 1947 (Jeyaratnam and Ponnambalam, 1980). There is no record to show when pesticides were first used on agricultural farms in Sri Lanka but it is likely they were used in the late 1940s or early 1950s but on a small scale. However, there is reference to the first use of pesticides on the tea plantations in Sri Lanka. Thirugnanasuntharan (1987) states that large scale experimentation of insecticides in the tea plantations was carried out in the 1950s. The first reference to any herbicide trial in Tea appears in the TRI Annual Report for the year 1949 (Somaratne, 1987) and fungicides were used to control the Blister Blight Leaf disease in 1946 (Arulpragasam, 1987).

3 Improving yields was not a new phenomenon in Sri Lanka as research was underway since the 1940s and 1950s. But what was new in the breakthrough with the breeding of varieties is that they were particularly responsive to chemical fertilizers, are short-strawed, resistant to lodging, adopted to carrying bigger ears and are relatively of a short duration, taking 3 to 31/2 months to mature (Farmer, 1977).

could be due to the decimation of natural predators of pests by chemical pesticides as was witnessed in Indonesia in the 1970s and 1980s[4].

Data available from 1970s show that the amount of pesticides (insecticides, herbicides and fungicides) used in Sri Lanka have increased from a few tons in 1970 to 6,742 metric tones in 1995. Table 3.1 shows the data of pesticide use from 1970-1995. As the data show, the amount of pesticides used has increased almost 110 times. Since the 1980s, the increase has been more than four fold. From 1987, the use of pesticides have doubled while data available on the extent of land cultivated do not show a significant increase[5]. Hence the quantity of pesticides used per acre of land has increased.

With these developments, the health hazards to users (mainly farmers), those around and consumers of food products and impacts on other production processes, wildlife and the environment, too, have increased significantly. Furthermore, the number of deaths resulting from suicides, accidents and homicides due to pesticides have shown a phenomenal increase over the last three decades as shown in the Appendix of 3.1. As a result, most of the work that has been carried out has been focused on such cases, while morbidity effects and mortalities resulting from direct exposure to pesticides during handling and use of pesticides among farmers have gone unnoticed and also have remained under documented. However, Jeyaratnam (1982b) in a study highlights the problem of occupational related acute pesticide poisoning for the first time in a detailed manner in Sri Lanka, although it has been known for a long time, that direct exposure pesticides has remained a health hazard to users. Vethanayagam (1962), perhaps, was the first to point out that from the late 1950s pesticides have been a health hazards to those handling and using them. Most of the initial work on pesticide poisoning, however, refer to suicides, accidents and homicidal cases. This is because such cases were more apparent although the morbidity effects on the users would have been significant judging from the very high use of pesticides and what is revealed from current studies. Fernando (1988, p.1), in his introduction to the "Management of acute pesticide poisoning" states that " poisoning by dermal absorption and inhalation is a common occupational hazard of pesticide sprayers". This is especially so when protective measures undertaken by farmers are minimal and inadequate. Furthermore, a large percentage of farmers seek treatment for direct pesticide poisoning during spraying as out-patients from hospitals or take self-treatment (home remedies) or Ayruvedic (native) treatment. Jeyaratnam et al. (1987) point out that a majority of cases of poisoning recorded by the users must have been very mild (but nevertheless having symptoms and important) with no treatment or self-treatment. None of these cases get recorded in hospitals. Patients who get admitted to hospitals are recorded merely as cases of pesticide poisoning, where in most cases, reference is not made to the nature of poisoning (i.e. whether the poisoning was due to the handling and use of pesticides on the farm, accidental, suicides or homicides). Farmers who fall ill after a few days of

[4] For a discussion on the damage done to rice by the brown planthopper, see for example, Conway and McCauley (1983), Cook and Perfect (1989); Teng (1990); Whalon, et al. (1990); Oka (1987).

[5] For data on the extent of land cultivated in Sri Lanka, see United Nations Statistical Year Books (1984, 1991).

pesticide use due to direct exposure to pesticides in many cases, are also not diagnosed or recorded as victims due to exposure to pesticides while handling and spraying on farms. The long- term illnesses arising from pesticides are also not identified more thoroughly. Forget (1991, p.13) has recognized this problem and states that " in most cases, however, only acute, obvious cases-those exhibiting a classic sympotomatology-are consigned to medical records". Furthermore, he states that "researchers are now increasingly aware of underreporting. For example, Loevinsohn (1987) found an association between occupational exposure to pesticides and an increased mortality from non-traumatic causes in the Central Luzon province of the Philippines. The increased mortality (27%) was correlated with conditions, such as strokes, that are likely to be confused with some of the symptoms of organochloride poisoning, and could easily be misdiagnosed in rural primary health-care facilities of the developing world. This is a clear warning that the actual incidence of pesticides-or toxic chemicals-related deaths may be grossly underestimated, not only for lack of proper records but possibly also because attending physicians and health-practitioners may fail to recognize the symptoms of pesticide poisoning". Also in some instances, the cases of pesticide poisonings of 'health and agricultural workers' are not distinguished. Hence, it is extremely difficult to obtain data from hospitals that reveal the true extent of the health effects to farmers due to direct exposure to pesticides. The next section undertakes a thorough review of all work undertaken in Sri Lanka on pesticide poisoning, which includes suicides, homicides, accidents and occupational (both health workers and farmers).

History of Pesticide Poisoning

The first ever case of pesticide poisoning was reported in Sri Lanka in 1954 when three cases were reported to be suffering from insecticide (DDT) poisoning (Sirimana, 1955). They were probably health workers who were involved with the anti Malaria work rather than those involved in agriculture. Since then the number of cases of pesticide poisonings reported to hospitals have gradually increased. According to Sirimana (1964) in the year ending 30th September, 1963, the active constituents of insecticides were identified in 226 cases of which 200 were fatal. In 1960 the number of cases identified with insecticide poisoning were 165 (Sirimana, 1961) as opposed to 68 in the previous year (Sirimana, 1960). These alarming figures prompted the government analyst to observe that "these preparations (insecticides) which are so essential for the improvement of the country's food production have become a menace" (Sirimana, 1963). Although the government analyst refers to the link between pesticides and country's food production, a very large or in fact all of the poisonings were not among those legitimately using them (Sirimana, 1963). What is meant by the reference to agriculture, is that, the free availability of pesticides meant for use on crops has led to it's abuse outside the farms such as for suicides, a few homicides and in many cases accidents have taken place involving pesticides. However, this does not preclude the fact that, there were no morbidity effects and some mortalities among farmers who were using them.

Table: 3.1 **Use of Pesticides in Sri Lanka (MT/KL)[6]**

Year	Insecticides	Herbicides	Fungicides	Total
•1970	59.05	-	-	59.05
•1972	45.27	-	1.57	46.84
•1974	34.44	-	-	34.44
•1976	855.31	3.44	28.54	888.29
•1978	762.79	10.82	93.50	868.11
*1980	655.00	695.00	315.00	1,665.00
*1981	824.00	958.00	371.00	2,153.00
*1982	941.00	1,028.00	458.00	2,427.00
1984	422.00	1,456.00	508.00	2,386.00
†1986	1,352.00	2,183.00	721.00	4,256.00
†1987	1,412.00	1,079.00	650.00	3,141.00
+1990	1,676.98	2,321.32	639.03	4,637.33
+1991	1,848.93	2,338.48	753.93	4,941.34
+1992	1,812.92	1,980.62	816.86	4,610.40
+1993	2,248.72	1,977.57	1,022.06	5,248.35
+1994	2,348.43	2,779.03	853.79	5,980.82
+1995	2,843.20	3,043.13	855.68	6,742.01

Sources: • Pesticides Imported to Sri Lanka-Weeratna (1983, p.11). Note: The amount of pesticides manufactured in Sri Lanka would have been negligible in the 1970s given the size of the total market.
* Domestic Supply Formulations, RENPAF Gazette, 1985.
Agricultural Economics and Projects/Department of Agriculture, Sri Lanka, 1988.
† Pesticide Registration Office, Peradeniya, Sri Lanka, 1988.
\+ Annual sale of pesticides-Pesticide Registration Office, Peradeniya, Sri Lanka, 1995.

Note: No single organization has consistent records of the amounts of pesticides used in Sri Lanka. As a result the data used in table 3.1 have been taken from various sources. However, the data shown in table 3.1 are consistent with the agricultural trends in the country (for example, increase in the adoption of high yielding varieties and commercial agricultural practices which require large chemical inputs such as pesticides and fertilizers).

[6] Herbicides and Fungicides have been exclusively used for agricultural purposes while some insecticides were used for health campaigns such as for the eradication of Malaria and Filaria. However, a large quantity of the insecticides used are for the eradication of pests in agriculture.

Most of the morbidity effects would have gone unnoticed and unrecorded in hospitals, as it still happens even today[7]. Hoek et al. (1997) in their work state that " many cases of intoxication due to occupational exposure may not require admission to a hospital are therefore not included in routine health statistics" (p.8). They go on to state that many minor poisoning cases due to occupational exposure are not seen at the government hospitals.

However, there are records available from the late 1950s to indicate that pesticides were a health hazard to users (both health workers and farmers). For example, although Sirimana (1963) states that no fatal cases of poisoning among those legitimately (referring to farmers using pesticides) using insecticides in the field[8] have been reported in Sri Lanka, he does not rule out the possibility of morbidity effects arising from pesticide pollution. Vethanayagam (1962) provides evidence to show that from the late 1950s pesticides have been identified as a health hazard to those using them. For example, he mentions 51 such cases being admitted to the General Hospital, Jaffna during the period 1st January, 1959 to 30th June, 1960. The poisonings stated by him were due to "eating, chewing and smoking with unwashed hands during, or after, spraying and also to inhalation of the substance during spraying". There is no reference to agricultural workers, but the pesticide in question, Folidol, is chiefly used as an insecticide against tobacco pests and hence, the high incidence of folidol poisoning in the tobacco growing areas of Sri Lanka, namely Northern and Eastern provinces (Vethanayagam, 1962).

However, a large number of the articles published on pesticide pollution in Sri Lanka, do not refer specifically to occupational health hazards arising while spraying or handling pesticides in agricultural activity but attribute mainly to deliberate ingestion and accidental poisoning. Only passing remarks are made to occupational health hazards. For example, Jayewardena and Sarvanabavananthan (1966) report only the accidental ingestion of pesticides, suicides and homicides in their work, while Fernando (1972) refers to deliberate ingestion and Attygalle and Fernando (1959) refer to accidental poisoning mistaking the pesticide for a drink. Senewiratne and Thambipillai (1974) refer to both self poisoning (suicides) and accidental poisoning. Fernando (1977) in addition to the above two types of poisoning, also refers to homicidal poisoning. Kottegoda and Bibile (1966) and Rajanayagam and Kathirgamathamby (1970) in addition to making

[7] It is interesting to note that farmers treated for pesticide poisoning (possibly for other illnesses too) as out-patients are not recorded in hospitals. Furthermore, occupational related cases are not properly recorded in the registers and simply categorized as organophosphates (OP's), agro chemical poisoning or pesticide poisoning. Hence, it is difficult to attribute the poisoning due to an occupation, suicides or accidents. Only in certain cases, that there is specific identification of the cause which attributes it to an occupational nature. This applies to fatal cases as well. On the other hand, suicide related cases are properly identified. Hence, there is a considerable amount of under reporting of both morbidity and mortality cases resulting from the use of pesticides by farmers in Sri Lanka. Furthermore, since there is a considerable level of 'private practice' by doctors in rural areas, patients treated for exposure to pesticides during use on farms are never reported and hence go unnoticed. Hence, the statistics available, are an under representation of the real dangers arising from direct exposure to pesticide pollution by farmers.

[8] Here, by referring to field, it could refer to both health workers as well as farmers spraying pesticides.

reference to suicides also refers to occupational (legitimate use either by health workers or farmers) poisoning cases from inhalation or skin absorption of pesticides. Fernando et al (1990) specifically refer to a case of fatal accidental poisoning. Fernando (1988) in his introduction to "Pesticides in Sri Lanka"[9], too, points out to the dangers arising from pesticides and gives statistics on deaths and admissions arising from pesticide pollution and refers to suicides and accidents. Weeraratna (1983) gives an overview of the problems caused to human health and refers in passing to occupational health hazard's. Ponambalam (1983), too, has a similar article. Most articles, however, refer to pesticide poisoning due to suicides, accidents or homicides and refer to their clinical symptoms and treatment. Some article titles are also misleading, often giving the idea that the poisoning occurred during spraying. For example, in the Alwis and Salgado (1980) article titled "Agrochemical Poisoning in Sri Lanka" the statistics refer to the overall hospital admissions recorded in the country, mainly referring to suicides, and accidents and only passing remarks are made with reference to direct exposure to pesticides by farmers handling and using them. They are not studies carried out specifically to highlight the problem of direct exposure to pesticides by farmers during handling and use. Herath and Rajendra (1984), give a profile of accidents and episodes involving toxic chemicals in the country. Ganeswaran et al. (1984); Berger (1988) and Silva et al. (1989) refer exclusively to the problem of pesticide related suicides in Sri Lanka.

Following the high level of suicides, accidents and a few cases of homicides, many studies have also been done on the diagnosis and treatment of pesticide poisoning cases. They are: Wijekoon, Sivaramakrishna and Nimalasuriya (1974); Sentheshanmuganathan and Rajaratnam (1975); Senanayake and Jeyaratnam (1981); Senanayake (1981); Senanayake and Johnson (1982); Senanayake and Jayatissa (1984); Senanayake (1985); Karalliedde et al. (1986); Fernando, De Silva et al. (1986); Karalliedde and Senanayake (1986); Senanayake (1986a); Senanayake and Karalliedde (1986a); Peiris, Fernando, De Abrew (1986); Senanayake (1986a); Senanayake and Karalliedde (1986b); Senanayake and Karalliedde (1986c); Senanayake and Karalliedde (1987); Senanayake (1990); De Silva et al. (1992); Senanayake and Karalliedde (1992); Senanayake et al. (1993); De Silva (1994); Senanayake and Sanmuganathan (1995); Sedgwick et al. (1997). Other articles that diagnose and describe pesticide poisoning at clinical level include: Fernando (1988); Senanayake and Karalliedde (1986); Senanayake and Karalliedde (1988); Senanayake and Karalliedde (1988); Markus et al. (1984); Family Health Bulletin (1984/85); Ganeshamoorthy (1985); Senanayake (1998). Fernando (1988) makes specific reference to the prevention of acute organophosperous poisoning deaths. Two books have also been published on the management and treatment of pesticide poisoning. Fernando (1988) devotes the entire book to the management of pesticide poisoning while Fernando (1991) has a substantial section devoted to the same subject. Similar work has also been carried out by Lionel (1979). Senanayake and Pieris (1995) also describe mortality due to pesticide poisoning where almost all the deaths are due to deliberate and accidental ingestion of pesticides.

[9] This work is a useful compilation of most of the articles published on pesticide poisoning in Sri Lanka up to 1988.

Apart from the work done to show the damage that is being caused from the abuse of pesticides and its treatment, the health effects of those living around, arising from accidents in factories that produce or store them have also been studied. They are: Mubarak et al. (1986); Wijesundere (1986); Jayatissa et al. (1986). The symptoms reported are, in many ways, similar to symptoms described by farmers, usually requiring many days of hospitalization, taking treatment from a doctor or self-treatment. The last section of this chapter refers specifically to short-term health effects arising from acute pesticide poisoning mainly from inhalation or skin contamination due to direct exposure to pesticides during handling and spraying on agricultural fields.

Despite the very high use of pesticides by small scale farmers (who use hand sprayers) and the apparent high levels of exposure and the resulting morbidity and mortality effects, not many surveys, till recent times, have been carried out to determine the real extent of farmer exposure to pesticides. To date, with one exception, no clinical examination of farmers using pesticides on a regular basis have been carried out to determine the short run and, more importantly, the long-term consequences of continuous direct exposure to pesticides by farmers, although exposure to pesticides during handling and spraying has been identified as a serious health hazard. Jeyaratnam et al. (1982b) attempts such a study with a small number of patients in a hospital. Needless to say, the effects of pesticide pollution on third parties, have not even been discussed. The studies (mainly field work) that have been carried out to show the ill effects of exposure to pesticides, fall into two categories, namely health workers and agricultural workers. The number of those surveyed in these studies number only a few hundred, chosen from a few areas where pesticides are widely being used.

Jeyaratnam and Ponnambalam (1980) have studied the exposure of health workers to pesticides. They point out that, many of the workers, indeed suffer from many morbidity effects ranging from serious to mild symptoms during and after spraying of pesticides. Many of the symptoms mentioned are very similar to those experienced by agricultural workers which are dealt later on in the chapter.

With respect to direct exposure to pesticides among farmers, there are general articles that refer to the problem of agricultural pesticide poisoning in Sri Lanka where all aspects of poisonings, such as self poisoning, accidental, homicidal and occupational poisoning are discussed. However, as mentioned earlier, only a handful of studies have been carried out specifically devoted to examining the problem of direct exposure to pesticides among farmers who are affected while handling and spraying them. In such cases, farmers have been interviewed to examine the impact of direct exposure to pesticides. The data available in hospitals on direct exposure to pesticides by farmers due to handling and spraying on the farms is incomplete and do not give a clear picture of the real problem of pesticide poisoning due to direct exposure to pesticides during handling and spraying. In most cases, all forms of poisonings have been simply recorded as pesticide poisonings. This could be due to self-ingestion (suicides), accidental ingestion, homicides and occupational exposure among health workers and farmers. As a result, the statistics are misleading. Since, as reported, almost 75%-80% of the poisonings are suicides, most of the work revolves around such cases, rather than arising from an agricultural occupation. Only passing remarks are made about poisonings from agricultural activity on the farm [For example, see Lionel (1979); De Alwis and Salgado (1988)]. Interestingly, all the articles point out that, most of the incidents of poisonings are reported from agricultural districts. This can be attributed to the free availability of pesticides in these areas.

Jeyaratnam (1982a), from a random study of clinical records of patients discharged during 1979 with a diagnosis of pesticide poisoning from the ten General hospitals and five of the 14 base hospitals in Sri Lanka shows that, in addition to the problem of pesticide poisoning due to suicides, accidents and homicides, users of pesticides on the farms are also at risk. They state "on the basis of the observation that 24.8% of cases in the sample surveyed were caused by occupational or accidental exposure to pesticides, it can be estimated that in 1979, 2,820 patients were admitted to hospital for this reason. Assuming that all the occupational and accidental poisonings occurred among the 472,435 agricultural workers in Sri Lanka[10], it would appear that 5/1000 of the agricultural workers are hospitalized annually for pesticide poisoning" and goes on to state that the figures are " an under-representation of the true state of affairs" due to incomplete data, etc. Articles that are similar in nature are: Jeyaratnam (1982); Weeraratne (1983); Sim (1985). In addition to agricultural workers, Sim (1985) also refers to workers in formulating factories and health workers who are affected. The article also refers to suicides and accidents, as is the case with the above mentioned authors. Perera (1988) in her work, has a brief section that discusses occupational (farmers and health workers) exposure to pesticides. Fernando and Fernando (1995) reviewing pesticide poisoning in Sri Lanka deal with national hospital data and a hospital based study, mostly referring to suicides and accidents, but also highlight the dangers of direct exposure to pesticides by farmers whilst handling and using them on their farms, by referring to several studies that have been carried out to show the health effects to farmers using pesticides. Fernando (1988) discusses the effects of pesticides on the human body and presents some national data, mostly referring to suicides and accidents and mention is made of pesticide poisoning by farmers during handling and spraying.

Perhaps the first detailed study making specific reference to the effect of pesticides on farmers showing their harmful effects is by Jeyaratnam et al. (1982b) in an article entitled 'Occupational Pesticide Poisoning'. This was a study carried out, based on hospital data. The study refers to 23 patients admitted to a government hospital in Sri Lanka with acute pesticide poisoning during the paddy cultivation season of May-July[11]. These patients were diagnosed as having clinical features of acute pesticide poisoning.

10 Employment Survey, 1978. Department of Labour, Government of Sri Lanka.

11 Pesticide spraying by paddy farmers is at its highest during the 'Yala' season because of increased attacks by pests during this period of the year. This phenomenon is thought to be due to the longer day length, resulting in increased photoperiodism and increased vegetative growth of the plants making them more susceptible to pest attack. During the season when these workers were poisoned, there was a major outbreak of 'Brown-Hopper' pest infestation resulting in the excessive use of pesticides [Jeyaratnam et al. (1982b)].

The chemical class of pesticides used were organochlorines, organophosphates or carbamates and this was ascertained by examination of the empty bottles of the pesticides provided by the patients or their relatives. Of the 23 patients who were treated in hospital, one patient died. The study found that, more than half of the patients developed symptoms either during spraying or within one hour of stopping work. All of the patients were aware of symptoms within four hours after cessation of spraying. When these patients were examined a year after they were hospitalized, many were found to be still suffering from symptoms associated with direct exposure to pesticides during handling and spraying on the farms. This goes on to show that many long-term illnesses can arise due to direct exposure to pesticides, which is an area that remains largely unexplored in Sri Lanka. Hettiarachchi and Kodithuwakku (1989) examining hospital data for a well defined geographical district (Gale District) note that a large majority of fatal as well as non-fatal poisoning was due to intentional self-poisoning. They conclude that the fatality rate due to intentional poisoning is higher than that for accidental poisoning. An interesting observation made by this study is that there is seasonal variation in poisoning. Siyayoganathan et al. (1995), too, observe seasonal effects. It is interesting to note that seasonal variation is also observed from the data collected from the hospitals in the field study area (please refer to appendix 3.2). Hoek et al. (1998) examining data from two hospitals from a predominantly agricultural area record that sixty eight percent of the 526 cases of poisoning recorded at Thambuttegamuwa hospital was self inflicted (suicides), 19% were due to spraying and 13% were caused by accidental ingestion. All deaths were due to suicides.

More specific studies followed such as by Chandrasekera et al. (1985)[12]. This was a field study [where as Jeyaratnam et al. (1982b) was based on hospital data] carried out among two hundred and eighty eight farmers from vegetable growing areas from four districts. It was found that in the four districts, namely Kandy, Matale, Nuwara Eliya and Badulla, 44%, 51%, 57% and 62% farmers respectively complained that they suffered from some illnesses such as faintness, dizziness, headache or vomiting after the application of pesticides to their crops. The study also gives figures, not only of farmers hospitalized due to pesticide spraying, but also give statistics of the number of farmers who die due to exposure to pesticides while spraying them in the field. Dissanayake (1986), too, has carried out a similar survey on pesticide use among vegetable growers in Sri Lanka.

Jeyaratnam (1985), in the editorial to the British Journal of Industrial Medicine highlights the health problems faced by farmers using pesticides in Sri Lanka. Jeyaratnam et al. (1987) have carried out a rather detailed study to investigate the extent of acute pesticide poisoning in selected agricultural communities in Sri Lanka, Indonesia, Malayasia and Thailand, by which time direct exposure to pesticides had been recognized as a major problem in developing countries[13]. The study confirmed the

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12 Perhaps this is the first field study undertaken to study the use of pesticides by farmers and the health effects, etc.

13 Studies that highlight the health problems of direct exposure to pesticides by farmers in the Asian region are: Loevinsohn (1987); Lum et al. (1993); Rola and Pingali (1993); Kishi et al. (1995); Antle and

existence of 'pesticide ill effects' among farmers due to direct exposure to pesticides during handling and spraying in all these countries.

More studies have been undertaken since then to show the health hazards arising from pesticide use during handling and spraying by farmers and also to investigate the protective measures taken to avoid symptoms among agro-pesticide applicators in Sri Lanka. They are: Gnanachandran and Siyayoganathan (1989); Jayathilake et al. (1989); Dharmawardena (1994); Hoek et al. (1997); Siyayoganathan et al. (1995). These are detailed studies that show the health hazards arising from direct exposure to pesticides by farmers during handling and spraying on farms and show the inadequacy of precautions taken by farmers using pesticides. The studies show that direct exposure to pesticides during handling and spraying (often due to inadequate precautions taken) on farms is a major health hazards faced by farmers. Abeysekera (1988) and Sivapalam (1988), too, highlight the problem of insufficient precautions taken by users of pesticides (mainly farmers) during handling and spraying of pesticides (also see, Forget, 1991) which cause ill health. Other studies include: Jeyaratnam (1982) and Gerard (1983).

Furthermore, work has also been carried out to facilitate the easy identification of pesticides involved in poisoning cases and in the diagnosis of patients poisoned by various pesticides and in their treatment. Lionel (1979) lists trade names and their chemical classes of pesticides used in Sri Lanka thus enabling the doctors treating pesticide poisoning cases easier. Fernando (1988, 1991), too, has detailed lists of pesticides used in Sri Lanka with their generic names, chemical classes, trade names and type of pesticides used in his work on the management and treatment of pesticide poisoning cases.

Despite the lack of studies done in the 1960s and 1970s on the dangers of pesticide use (mainly by farmers), legislation was passed in parliament in September, 1980 (see Control of Pesticides Parliament Act, No. 33 of 1980) to provide for the safe use of pesticides, to license pesticides used in Sri Lanka, to regulate the import, packing, labeling, storage, formulation, transport, sale, and for the appointment of a licensing authority for pesticides and for the establishment of a pesticide formulary committee and for matters connected with it. As a consequence to the Pesticides Act, 1980, a registrar of pesticides was appointed in 1983, with authority to set regulations and standards for pesticides in Sri Lanka. The Malathion Control Act was enacted in 1985. De Alwis (1988) discusses the regulation, formulation, sale and use of pesticides in the country. The statistics discussed in this paper cover the sale and use of pesticides. It is legally mandatory that the labels of the pesticides give, amongst other items, sufficient information on how to use (that is when and how much to use), the period of effectiveness of the pesticide, the pre-harvest interval during which time pesticides should not be used and precautions to be taken in spray preparations and during application. As regards to the sale, the standards are enforced by the pesticide registrar. Furthermore, agricultural extension workers, too, give regular advise on the handling and

Pinali (1994); Hirchhorn et al. (1995); Other work outside Asia include: Bonsall (1985); Xue (1987); Forget (1991); Partanen et al. (1991); Condarco et al. (1993); Mwanthi and Kimani (1993).

use of pesticides, protective measures to be undertaken, the correct dosage, etc. However, the problem faced by agricultural extension workers is the non-compliance of farmers in the correct use of pesticides. It is not mandatory for farmers to carry out instructions issued by agricultural extension workers of the Department of Agriculture. Jeyaratnam (1987) in a brief paper discusses pesticide legislation in developing countries, including Sri Lanka. Apart from legislation to minimize the harmful effects of pesticides, the medical profession have also felt the need for the establishment of a poisons information center from as early as the 1970s, when pesticides usage was still at a very low level (Fernando, 1987). As a consequence, a National Poisons Information Center was set up in 1988 to disseminate information on all aspects of poisoning especially pesticides. The problem of pesticide poisoning (affecting farmers and health workers using them, deliberate ingestion for suicides, accidents and homicides) in Sri Lanka has become so acute that the Presidential Task Force on formulating a National Health Policy has taken note of the dangers posed by pesticides and have recommended various measures to combat this problem (Sessional Paper,1993). Fernando (1995) also discusses pesticide poisoning in the Asia-Pacific region and the role of a regional information network to combat the problem of pesticide poisoning in the region. De Alwis (1989) analyses the nature of the market for agro-chemicals in Sri Lanka.

The next section discusses the acute symptoms arising from direct exposure to pesticides during handling and spraying on their farms. The common clinical symptoms diagnosed by physicians and those recorded by agricultural research workers and farmers are also described. For this purpose the work of Fernando (1988, 1991) is considered.

Short-Term Health Effects from Acute Pesticide Poisoning

The last section reviewed the work carried out showing the high rates of morbidity and mortality prevailing in the region due to pesticide poisoning. In this section, we look at the morbidity and mortality effects of 'pesticide poisoning' with reference to Sri Lanka. We provide hospital figures (both for national and study areas), as well as survey statistics of all 'pesticide poisoning' cases and try to isolate the morbidity and mortality data recorded due to direct exposure to pesticides. We begin with the morbidity effects and then go on to discuss the mortality figures. Apart from these high figures, various field studies carried out, too, have confirmed very high mobidity effects from direct exposure to pesticides ranging from minor symptoms such as headaches to the risk of serious illnesses. They are both short-term and long-term in nature. Studies carried out such as by Jeyaratnam (1982b); Chandrasekera et al. (1985); Dharmawardena (1994); Jeyaratnam (1987); Jeyaratnam et al. (1990); Sivayoganathan et al. (1995); Hoek et al. (1997) etc. confirm this.

Morbidity effects from pesticide poisoning are very high in Sri Lanka. The 'hospital recorded' morbidity data are due to:

(1) Ingestion of pesticides, such as due to suicides (self-ingestion), accidental ingestion and homicides. Most of the hospital data, as pointed earlier refer to such effects.

(2) Direct exposure to pesticides during handling and spraying by health workers and farmers. In this thesis, we are only interested in ill health resulting from direct exposure to pesticides by farmers. The data presented in this section, are from hospital sources, as well as from field studies. The hospital data record the number of admissions due to symptoms arising from direct exposure to pesticides, while field studies record both the symptoms and the number of farmers who complained of ill health due to direct exposure to pesticides during handling and spraying on the farms. Some of these symptoms are of a minor nature which does not require hospitalization, but nevertheless affects the patients well-being.

Figure 3.1 shows the national hospital admission figures for the period 1986-1996. As mentioned earlier, they are mainly due to self-ingestion (suicides), accidental ingestion or due to homicides. As the national figures show, the total number of hospital admissions has remained around 14,500 from 1986-1996 (for more details please see Appendix 3.1). The symptoms arising from self-ingestion, accidental ingestion and homicides are far greater and serious (and more life threatening), than those arising from direct exposure to pesticides. Fernando (1988, 1991), discusses in detail the symptoms that arise due to pesticide ingestion. Not all of the hospital admission cases shown in Figure 3.1 are, however, due to ingestion of pesticides, as discussed in the last section. Some of the admissions are also due to direct exposure to pesticides. According to Jeyaratnam et al. (1982a) at least 24.8% of all hospital admissions are due to an occupational nature. The hospital data for the study areas, too, show high admission figures (see Appendix 3.2). From the hospital data available from the study areas, we have been able to isolate to a very large extent, the self-ingestion, accidental ingestion and homicide cases from those arising due to direct exposure to pesticides.

Jeyaratnam (1982a), as far back as the early 1980s, showed that as many as five out of 1000 agricultural workers in Sri Lanka are hospitalized each year due to 'pesticide use' poisoning (which is around 24.8% of all hospitalized cases due to pesticide poisoning) and that occupational health effects from pesticide poisoning are numerous. Since then, not only have the incidences of all cases of pesticide poisoning increased, as many sources of data show, but the extent of pesticide poisoning due to direct exposure during handling and spraying have also remained inadequately documented. For example, many farmers take treatment from private physicians. Furthermore, the out-patient treatment of direct pesticide exposure cases has not been recorded nor studied. It is also known that a very large number of farmers take self-treatment (home made). Hence, the real extent of the problem is not highlighted; the seriousness of the health hazards remain undetected. Several field studies carried out, have demonstrated that farmers suffer numerous morbidity effects during handling and spraying of pesticides. These studies have also noted down the various symptoms that arise due to direct exposure to pesticides. Sivayoganathan et al. (1995, p.436) point out in a study carried out in Sri Lanka, that the majority of those interviewed (62%) had at least one morbidity effect arising from direct exposure to pesticides. The morbidity effects ranged from headaches, dizziness, nausea to blurring vision. The various morbidity effects, their frequency and percentages of the sample studied are shown in Table 3.2.

Most of symptoms shown in Table 3.2 were recorded during or after spraying (usually within four hours of spraying) on a typical pesticide spraying day. Chandrasekera et al. (1985), too, show from their field study in four districts in Sri Lanka, that more than 50% of those interviewed suffered from some form of the symptoms mentioned in Table 3.2 during or soon after the application of pesticides. A study carried out by Dharmawardena (1994), too, show that the incidence of direct pesticide poisoning is high among farmers in Sri Lanka and point out that the true incidence of pesticide poisoning is likely to be more than that shown by the hospital morbidity figures.

Figure: 3.1 Hospital Admissions Due To Pesticide Poisoning In Sri Lanka

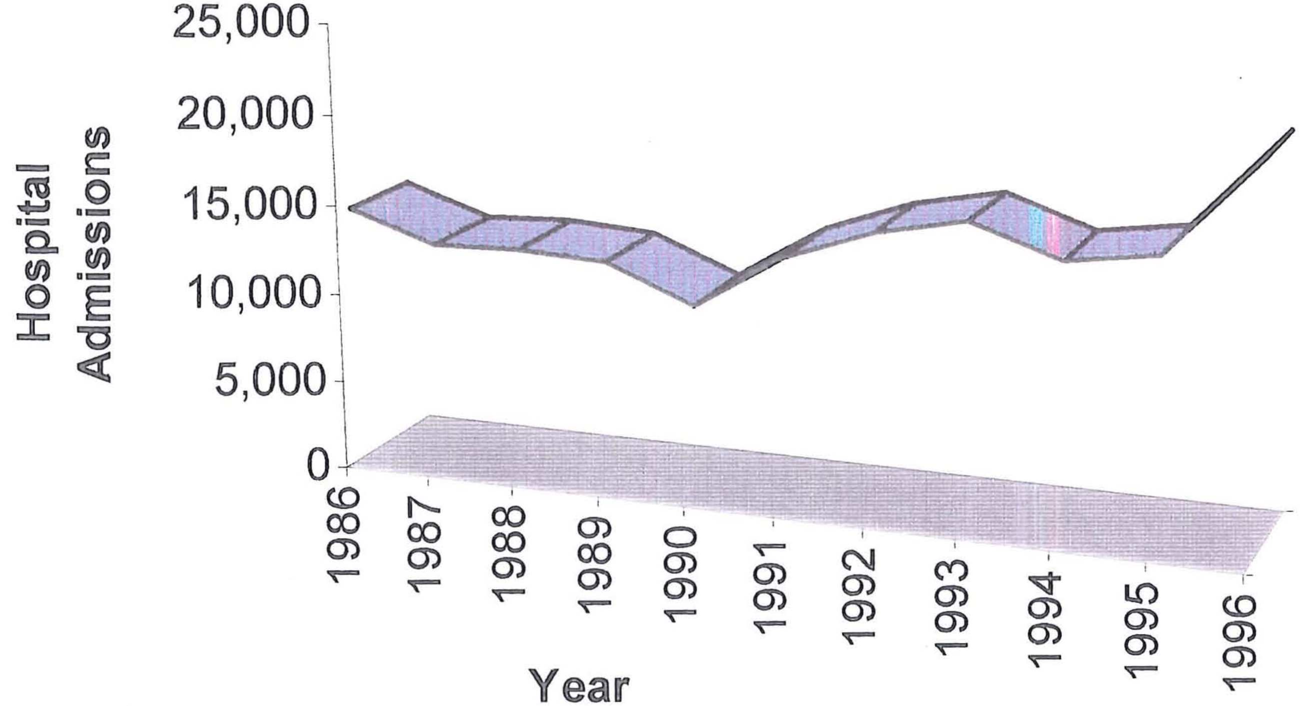


Figure 3.1 shows hospital admissions due to pesticide poisoning. They include self-poisoning, accidental ingestion, homicides and occupational (both health workers and farmers) cases. A breakdown of hospital admissions from direct exposure to pesticides is not available (Director, Pesticides Bureau, Per comm., 1998). However, it is presumed that hospital admissions from direct exposure to pesticides are significant. Free and easy accessibility of pesticides in the agricultural areas has been identified as the major cause for the very high levels of pesticide poisoning in Sri Lanka [Siyayoganathan et al. (1995); Hoyek et al. (1997)]. As noted in table 3.1 the use of pesticides has shown a phenomenal increase during the last 20 years while the agricultural cropping area has shown only a marginal increase (United Nations Statistical Year Books, 1984, 1991). From 1988-1990 the data show a downward trend in hospital admissions due to pesticide poisoning. This is due to the political unrest in the country during this period which made data recording difficult in hospitals (for example, due to non availability of staff, partial closure of hospitals, etc.) and also because the availability of pesticides was greatly reduced in agricultural areas. The dip at the end of 1993 is difficult to explain. This could be due to an error in the collection of data and/or non-recording of data owing to lack of staff in hospitals as a result of election canvassing. General and Presidential elections were held during this time.

Table: 3.2 Frequency and Percentages of Morbidity Effects of Pesticide Users

Symptoms	Frequency	Percent
Faintish Feeling	37	24.7
Headache	35	23.3
Dizziness	25	16.7
Nausea	09	6.0
Excessive Salivation	07	4.7
Eye Irritation	07	4.7
Eye Tearing	06	4.0
Vomiting	06	4.0
Weakness of Muscles	06	4.0
Difficulty in Breathing	03	2.0
Twitching of Muscles in Eyelids	03	2.0
Cramps	03	2.0
Diarrhea	02	1.3
Twitching of Muscles in the Face	02	1.3
Twitching of Muscles in the Body	02	1.3
Blurring Vision	02	1.3
Tremor	01	0.7

Source: Sivayoganathan et al. 1995, p.436

Other studies carried out, not only in Sri Lanka, but in other Asian countries, too, confirm that many morbidity effects take place during application of pesticides in agriculture [Jeyaratnam et al. (1987), Rola and Pingali (1993); Loevinsohn (1987); Kishi et al. (1995); Antle and Pinali (1994); Lum et al. (1993).]. Jeyaratnam et al. (1987) in this study asked the respondents if they thought they had ever suffered from acute pesticide poisoning during handling and spraying and whether this had occurred during the previous year. The questions were based on pesticide user's perception of a pesticide-related acute illness. The results of their study for the four countries are shown in Table 3.3. Table 3.3 shows the percentages of farmers poisoned during the past year while handling and spraying pesticides on their farms.

As Table 3.3 shows, in Sri Lanka and Malaysia the percentage of farmers suffering from symptoms due to direct exposure to pesticides were 7.1% and 7.3% respectively, compared with only 0.3% in Indonesia. There was no result for Thailand as this particular question had by mistake been omitted. As shown, the proportion of pesticide users ever poisoned was reasonably similar in the four countries (range, 11.9% to 19.4%). Most of those interviewed were aware that pesticides were a health hazard and that the common symptoms recorded were due to direct exposure to pesticides during handling and spraying on farms. The symptoms referred to were due to direct exposure during handling and spraying on the farms. Jeyaratnam et al. (1987) do not describe the symptoms as Sivayoganathan et al. (1995) and Chandrasekera et al. (1985) have recorded in their work. Gnanachandran and Sivayoganathan (1989), too, record a few symptoms in their study. However, Jeyaratnam et al. (1987) show the route of absorption. They record inhalation to be the most important route of poisoning, while dermal absorption is also mentioned. Akerblom et al. (1983) and Kolmodin-Hedman et al. (1983) in their studies, too, had recorded dermal absorption of pesticides. Jeyaratnam et al. (1982b) also mentions of accidental acute poisoning due to malfunctioning spray equipment resulting in contamination of workers' skin surface with pesticides. Jeyaratnam and Ponnambalam (1980), list a number of symptoms, similar to those recorded among farmers in their study of health workers engaged in anti malaria and anti-filaria work in Sri Lanka.

Table: 3.3 Percentage of Workers with Pesticide Poisoning Among Agricultural Workers Using Pesticides

	Percentage of agricultural workers Poisoned in		Percentage of pesticide users Poisoned in	
Country	Ever Poisoned	Previous Year	Ever Poisoned	Previous Year
Indonesia	4.1	0.08	13.8	0.3
Malaysia	13.3	6.7	14.5	7.3
Sri Lanka	4.6	2.7	11.9	7.1
Thailand	8.1	NA	19.4	NA

Source: Jeyaratnam et al. 1987, p.523

The above mentioned studies recorded the symptoms experienced by farmers either during handling and spraying or soon after (usually within four hours of completing pesticide application) spraying. Some of these symptoms could also appear a day, or days later, after showing mild symptoms on the day of spraying. Fernando (1988, 1991) also describes the clinical symptoms of inhalation and skin contact of pesticides, as often happens during handling and spraying by farmers, especially when adequate precautions are not taken by the users. The toxicity of the pesticides used, as shown by Fernando (1988, 1991) however, varies according to the chemical class of the pesticide. Hence, the toxicity can vary from pesticide to pesticide. For instance, it is shown that herbicides and fungicides belonging to the carbamate chemical class are of low toxicity (1988, 1991) while carbamate insecticides have a toxicity similar to that of organophosphates, which are very toxic to humans. Fernando (1991) lists the clinical features of inhalation and skin contact according to the chemical classes. This is shown in Table 3.4.

Table: 3.4 Short-Term Symptoms Due to Direct Exposure to Pesticides

	Some Short-Term Symptoms Due to Direct Exposure to Pesticides		
Chemical Class	**Toxicity**	**Inhalation**	**Skin Contact**
Carbamates			
Herbicides	Very low		
Fungicides	Very low		
Insecticides	High	Similar to organophosphates	-do-
Dithiocarbamates			
Fungicides	Low acute	Cough, hoarse voice and pneumonitis	dermatitis with redness and itching
Herbicides Low acute		-do-	-do-
Glyphosate			
Herbicide	Very High	Many clinical effects	-do-
Organic Mercury			
Fungicide	Low/medium	Redness, blisters,dermatitis	
Nitrophenols			
Herbicide	Very High	Headache, sweating, thirst, weakness, fever, tachycardia, dyspnoea, apprehension, restlessness and anxiety.	-do-
Organochlorines			
Insecticide	Very High	Irritation of eyes, nose and throat cough and plumonary oedema.	dermatitis
Organophosphates	Very High	Cough, difficulty in, breathing bronchiti, pneumonia	Eye Exposure: Irritation or pain, lachrymation, swelling, miosis, blurring of vision and photophobia
Paraquat			
Herbicide	Very High	-	Eye Exposure: Splashing can cause corneal and conjunctival inflammation and oedema leading to ulceration and secondary infection. Skin

Table 3.4 continued

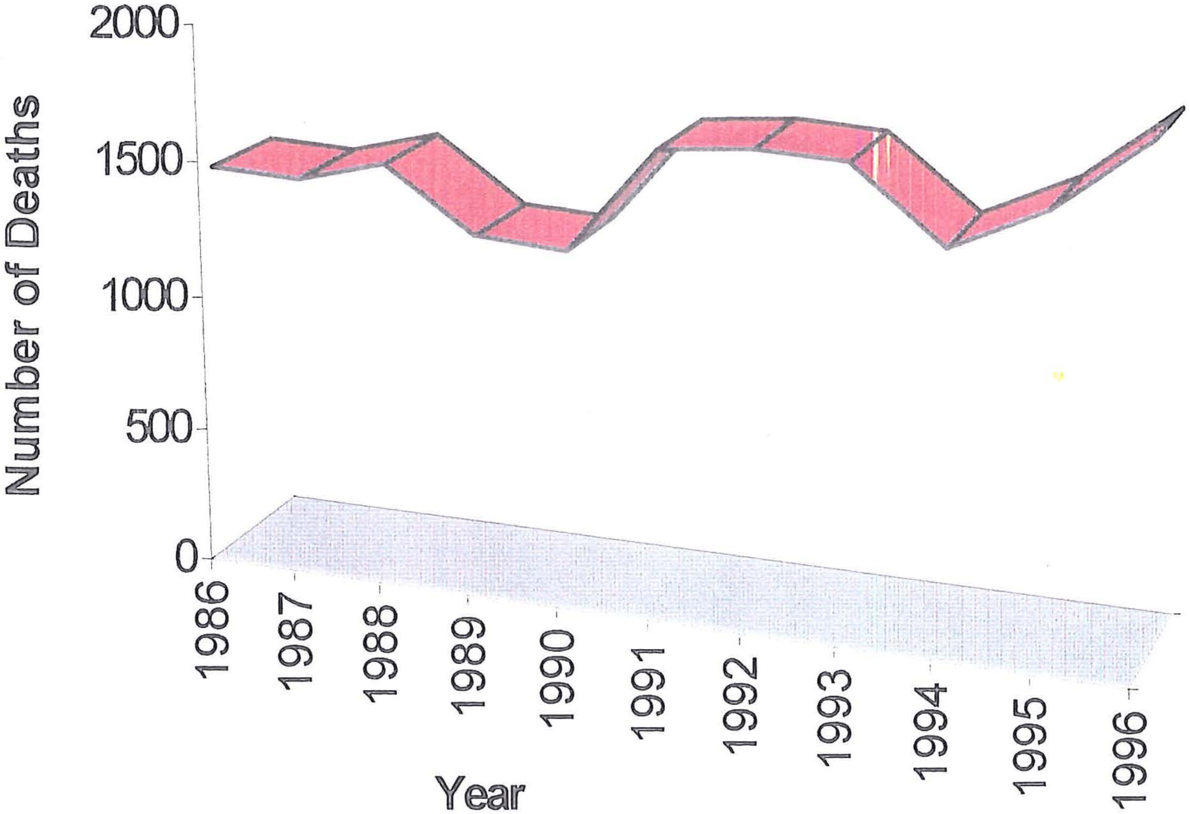
	Some Short-Term Symptoms Due to Direct Exposure to Pesticides		
Chemical Class	**Toxicity**	**Inhalation**	**Skin Contact**
	-	-	contact: Skin irritation cause blistering dermatitis and white spotting, Herbicide transverse cracking and loss of nails. Systematic toxicity can occur due to absorption from damaged skin.
Propanil Herbicide	Low	-	-
Pyrethrum Insecticide	High	Bronchospasm, wheeezing, swelling of oral and laryngeal mucosa and rarely, anaphylactic shock	Eye exposure: Causes lachrymation, photophobia oedema of the conjunctiva and eyelids. Skin Contact: Allergic dermatitis and paraesthesia
Thiocarbamates Herbicide	Medium/ High	Cough, irritation of throat and sneezing	-

Source: Fernando (1988, 1991). Various pages with few adjustments

In addition to the above mentioned symptoms, many other symptoms, have been recorded in field studies carried out [see for example, Jeyaratnam and Ponnambalam (1980); Chandrasekera et al. (1985); Gnanachandran and Siyayoganathan (1989); Dharmawardena (1994); Sivayoganathan et al. (1995)]. These recordings of symptoms were based on farmers perceptions of ill health caused by direct exposure to pesticides. These observations were confirmed by the field study of 1996, the results of which are discussed in chapter six.

The toxicity of pesticides used, as pointed out by Fernando and Fernando (1988, 1991), varies and the degree of toxicity of pesticides is difficult to determine (Perera, 1988, p.44). In general, the insecticides are the most potent (because of organoclorines and

Figure: 3.2 Deaths Due To Pesticide Poisoning In Sri Lanka



Note: The data from 1986-1996 do not show a clear trend. There are dips in certain years. From 1988-1990 the data show a downward trend in pesticide poisoning deaths. This is due to the political unrest in the country during this time which made data recording difficult in hospitals (for example, due to non availability of staff, partial closure of hospitals, etc.) and also because the availability of pesticides was greatly reduced in agricultural areas. The dip at the end of 1993 is difficult to explain. This could be due to an error in the collection of data and/or non-recording of data owing to lack of staff in hospitals as a result of election canvassing. General and Presidential elections were held during this time.

organophosphates), followed by herbicides and fungicides[14]. However, some herbicides as shown in Table 3.4 are extremely toxic. Toxicity to humans also varies according to the strength of the formulations used[15], frequency of use, health condition of the user, protective measures used, weather conditions and time of day sprayed, food taken before spraying and a host of other factors. Therefore, due to one or many of the factors mentioned above, a user can be affected. Hence, in such cases even a pesticide with low toxicity can cause ill health among the users.

Apart from these acute short-term ill effects recorded, many long-term illnesses, have been recorded. For example, long term illnesses such as, cancers, tumors, loss of memory, blindness, asthma, swellings in body, weight loss, numbness of fingers, were recorded during the field study of 1996. These observations were made by farmers, based on their perceptions of ill health using pesticides which were confirmed by physicians. Comas and Paralysis have also been recorded [Perera (1988, p.56)]. Numerous studies carried out in the United States have documented long-term illnesses [For example, see Hoar (1986); Nielson and Lee (1987); Davis et al. (1992); Blair and Zahm (1993); Balir et al. (1993); Boyle and Zardize (1993); Brown et al. (1993); Collins et al. (1993);]. Fernando (1991), too, describes some of the long-term illnesses, but the reference is made to patients who have deliberately ingested pesticides or through accidental ingestion involving pesticides.

In addition to the short-term and long-term illnesses described above, direct exposure to pesticides during handling and spraying on the farms also result in many deaths. Fernando (1991, p.98), for example, refers to cases of fatal poisoning due to skin contamination probably due to an accident during spraying on the farms. Chandrasekera et al. (1985) in their study show, that many deaths occur due to direct exposure to pesticides. Data collected from farmers during the field in 1996 for this Ph.D. study showed that deaths due to direct exposure to pesticides on the farms is not an uncommon feature. This was confirmed by hospital data in the study area (please see Appendix 3.3). Apart from these deaths, thousands die each year in Sri Lanka due to deliberate and accidental ingestion of pesticides. A small number also die due to homicides. Figure 3.2 shows the amount of deaths in Sri Lanka from 1986-1996. As shown, the amount of deaths from pesticide poisonings in Sri Lanka are around 1,500 a year[16]. Appendix 3.1 also shows the mortality figures, deaths per thousand and their rankings for the whole country during this period 1975-1996. These national figures include all deaths due to pesticide poisoning, which includes occupational deaths among farmers and health workers as well.

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14 However, deaths have also been recorded from the ingestion of certain pesticides classified as being of low toxicity such as carbamates and pyrethrums (De Alwis and Salgado, 1988).

15 Farmers in Sri Lanka have been found to be using pesticide dosages higher than the recommended levels for an instantaneous eradication of pests and diseases. They have also been found to be using a mixture of two or many pesticides to increase the efficacy of the pesticides used [Abeysekera (1988); Jayathilake and Bandara (1989); Chandrasekera et al. (1985)].

16 Hettiarachchi and Kodithuwakku (1989) from their study note a mortality rate of 22 per 100,000 population, all of which are from self poisoning (suicides).

Conclusion

This chapter concentrated on the health effects of pesticide pollution in Sri Lanka and showed that not only pesticide pollution in general is a serious problem in Sri Lanka, but also direct exposure to pesticides during handling and spraying is also a major health hazard, as many studies have demonstrated. In the next chapter, we examine the economic health valuation techniques developed, so as to value the costs from direct exposure to pesticides. In other words, the estimates obtained can be used to infer the value of ill health avoided if direct exposure to pesticides by farmers can be reduced or prevented altogether.

Appendix: 3.1

Hospital Admissions and Deaths Due to Pesticide Poisoning in Sri Lanka, 1975-1996

Year	Total Pesticide Deaths	Total Pesticide Admissions	Deaths Per100,000 Population	Rank Order*
1975	938	14,653	-	-
1976	964	13,778	-	-
1977	938	15,591	-	-
1978	1029	15,504	-	-
1979	1045	11,372	-	-
1980	1112	11,811	-	-
1981	1205	12,308	-	-
1982	1376	15,480	-	-
1983	1521	16,649	-	-
1984	1459	16,085	-	7th
1985	1439	14,423	-	4th
1986	1452	14,413	-	6th
1987	1435	12,841	8.8	6th
1988	1524	12,997	9.2	6th
1989	1296	12,763	7.7	6th
1990	1275	10,783	8.8	6th
1991	1667	13,837	11.3	4th
1992	1698	15,636	-	4th
1993	1682	16,692	9.5	5th
1994	1421	14,979	8.1	5th
1995	1581	15,740	9.5	6th
1996	1850	21,129	-	6th

Source: National Poisons Information Centre, General Hospital, Colombo, Sri Lanka, 1997.

* Rank order shows the leading causes of deaths in the country. As the rank order shows, pesticide poisoning is a major cause of death in Sri Lanka.

Appendix: 3.2

Hospital Data Showing Admissions Due to Pesticide Poisoning in the Study Area

Hospitalization Due to Pesticide Poisoning (Includes Suicidal, Accidental and Occupational)

	1992	1992	1992	1992	1993	1993	1993	1993	1994	1994	1994	1994	1995	1995	1995	1995	1996	1996
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd
Total	25	45	34	44	41	70	63	69	31	67	75	71	50	51	60	46	46	18
Male	11	29	21	33	29	45	44	45	19	37	49	55	37	32	40	30	34	11
Female	14	16	13	11	15	25	19	24	12	25	26	16	13	19	20	16	12	7

Source: Dambulla (Sri Lanka), Government Hospital Register (Various Years). Note: All

Hospitalisation Due to Pesticide Poisoning (Includes Suicidal, Accidental and Occupational)

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	1	1	2	3	3	0	5	3	0	1	2	3	2	1	1	0	0	2	2
Female	2	0	0	0	1	3	1	1	1	0	0	0	1	1	1	3	2	0	0

Source: Nalanda (Sri Lanka) Government Hospital Register. Note: All

Hospitalisation Due to Spray Poisoning

	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	1	0	1	1	2	0	4	0	0	1	1	1	2	0	1	0	0	0	1

Source: Nalanda (Sri Lanka) Government Hospital Register.
Note: Spray poisonings and one day pesticide poisonings which are thought to be spray poisonings.

Hospitalisation Due to Spray Poisoning

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	0	0	0	0	0	0	3	0	0	0	1	1	1						

Source: Nalanda (Sri Lanka) Government Hospital Register.
Note: Spray poisonings only.

Hospitalisation Due to Pesticide Poisoning (Includes Suicidal, Accidental and Occupational)

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	0	0	0	0	4	3	3	7	4	8	2	4	0	5	3	2	6	3	6
Female	0	1	0	2	1	2	6	0	1	1	3	3	1	4	4	1	0	0	5

Source: Galewela (Sri Lanka) Government Hospital Register. Note: ALL

Hospitalisation Due to Spray Poisoning

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	0	0	0	0	1	0	1	2	1	0	0	0	0	1	1	0	0	0	0
Female	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Source: Galewela (Sri Lanka) Government Hospital Register. Note: Spray poisonings only

Hospitalisation Due to Spray Poisoning

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male					1		1	2	1	1				2	1	0	2	0	0

Source: Galewela (Sri Lanka) Government Hospital Register.
Note: Spray poisonings and one day pesticide poisonings which are thought to be spray poisonings.

Hospitalisation Due to Pesticide Poisoning (Includes Suicidal, Accidental and Occupational)

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	15	15	18	11	0	16	25	19	9	15	8	12	13	10	22	15	16	11	19
Female	4	7	5	5	5	5	5	6	4	6	2	2	1	7	9	5	4	3	8

Source: Matale (Sri Lanka) Government Hospital Register. Note: ALL

Hospitalisation Due to Spray Poisoning

1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1996	1996	1996	1996	1996	1996	1996
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Male	0	0	0	0	0	0	1	2	0	0	0	1	3	1	0	0	2	1	2
Female	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: Matale (Sri Lanka) Government Hospital Register. Note: Spray poisonings only

Hospitalisation Due to Pesticide Poisoning (Includes Suicidal, Accidental and Occupational)

	1993 Nov	1994 Jan	1995 -	1996 May	1996 July
Male	1	0	0	1	1
Female	0	1	0	0	0

Source: Yatawatha (Sri Lanka) Government Hospital Register. Note: ALL

Hospitalisation Due to Spray Poisoning

	1993 Nov	1994 Jan	1995 -	1996 May	1996 July
Male	0	0	0	1	0
Female	0	0	0	0	0

Source: Yatawatha (Sri Lanka) Government Hospital Register.
Note: Spray poisonings only.

Hospitalisation Due to Pesticide Poisoning (Includes Suicidal, Accidental and Occupational)

	1989	1989	1989	1989	1990	1990	1990	1990	1991	1991	1991	1991	1992	1992	1992	1992	1993	1993	1993	1993	1994	1994	1994
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd
Male	5	10	4	2	0	3	5	2	3	4	4	3	7	4	5	3	4	7	4	1	2	2	5
Female	4	3	4	1	0	3	1	0	3	1	4	2	2	2	6	1	4	1	1	3	1	2	0
Total	9	13	8	3	0	6	6	2	6	5	8	5	9	6	11	4	8	8	5	4	3	4	5

Source: Kohongahawela (Sri Lanka) Government Hospital Register. Note: ALL

Appendix: 3.3

Hospital Data Showing Deaths Due to Pesticide Poisoning in the Study Area (Includes Suicidal, Accidental and Occupational Deaths)

Deaths Due to Pesticide Poisoning

	1992	1992	1992	1992	1993	1993	1993	1993	1994	1994	1994	1994	1995	1995	1995	1995	1996	1996
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd
Total	2	6	1	7	4	8	9	4	2	5	2	2	0	5	3	10	2	2

Source: Dambulla (Sri Lanka), Government Hospital Register (Various Years). Note: All

Deaths Due to Pesticide Poisoning

	1989	1989	1989	1989	1990	1990	1990	1990	1991	1991	1991	1991	1992	1992	1992	1992	1993	1993	1993	1993	1994	1994
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd
Male	0	1	1	0	2	1	0	2	3	0	2	2	3	1	0	0	0	4	2	0	0	0
Female	0	1	1	1	0	0	0	1	0	1	2	0	0	0	0	1	0	1	0	0	0	0
Total	0	2	2	1	2	1	0	3	3	1	4	2	3	1	0	1	0	5	2	0	0	0

Source: Kohongahawela (Sri Lanka) Government Hospital Register. Note: All

CHAPTER 4

BACKGROUND ON ECONOMIC HEALTH VALUATION

Indroduction

Agricultural pollution generated, for example, by pesticides, not only affects the quality of the environment, agricultural land/productivity and wildlife, but as was shown in detail in chapter three, also impacts on human health, leading to numerous morbidity and mortality effects. It was shown that the morbidity and mortality rates arising from direct exposure to pesticides as well as pesticide poisoning due to other effects were high in Sri Lanka. The long-term chronic effects from direct exposure to pesticides are less well described and difficult to quantify, but are assumed to be high judging by the very high mortality and morbidity rates that have been observed from hospital and field studies due to short-term direct exposure to pesticides. The aim of this chapter is to examine ways and means of determining the costs of ill health resulting from direct exposure to pesticides during handling and spraying on farms and thereby infer a value of reducing/avoiding ill health resulting from direct exposure to pesticides. In other words, the aim is to obtain willingness to pay bids/values from individuals to reduce/avoid ill health resulting from direct exposure to pesticides during handling and spraying on their farms. The ill health can be both short-term and long-term. There exists no known market from which we can derive these estimates. In order to overcome this problem, the creation of constructed markets, either real or hypothetical, has been suggested. Hence, the study will examine creating hypothetical markets to value the benefits of good health in the context of reducing/avoiding direct exposure to pesticides. In the discussion we refer to both reducing/avoiding direct exposure to pesticides and the resulting illnesses because two of the approaches discussed in this chapter and used in the thesis, namely the avertive and the cost of illness approaches estimate the value of reducing[1] direct exposure to pesticides while the third technique, namely the contingent valuation approach measures the value of avoiding direct exposure to pesticides. Where appropriate, we specifically refer to 'reduce' or 'avoid' exposure to pesticides, otherwise we refer to 'reduce/avoid' exposure to pesticides in the general discussion.

In the context of direct exposure to pesticide pollution, we hope to obtain the willingness to pay (WTP)[2] to reduce/avoid morbidity effects arising from direct exposure to pesticides from the affected individuals[3]. In this context we use two

[1] The avertive behaviour and the cost of illness approaches measure the value of reduced exposure to pesticides and the resulting illnesses rather than the value of avoided illnesses in this thesis because, although farmers do take precautions against direct exposure to pesticides, such measures are inadequate and hence farmers suffer from ill health. The precautionary measures taken by farmers only reduce direct exposure to pesticides but do not totally avoid exposure to pesticides. The cost of illness approach, although takes into consideration medical and time costs, does not consider intangible costs. Hence, such a measure also measures the value of reducing direct exposure to pesticides.

[2] Here, we hope to obtain/infer willingness to pay bids from three approaches as will be discussed later in this chapter.

[3] It is also possible to obtain willingness to accept compensation (WTAC) bids. However, this approach has been avoided because the 'willingness to pay' approach was selected. This is because in the case of contingent valuation studies as Kenkel et al. (1994) note, willingness to pay studies have yielded more realistic results than WTAC studies. NOAA report also recommends the use of a WTP approach instead of a compensation required approach because the former is the conservative choice.

approaches to obtain willingness to pay bids to reduce exposure to pesticides (cost of illness and the avertive behaviour approaches) while the third approach (contingent valuation approach) obtains willingness to pay bids to avoid direct exposure to pesticides. The willingness to pay bids/values obtained can then be interpreted as the value to reduce/avoid 'pesticide use/handling' health effects by the affected individuals. This implies that the higher is the willingness to pay, the higher is the demand to reduce or avoid morbidity effects and deaths. Several approaches have been suggested to obtain such values and one way of obtaining the willingness to pay bids/values is from a constructed market. This technique is known as the contingent valuation method (CVM). This technique is a direct approach. It has also been suggested (and demonstrated) that the cost of illness approach and the averting behaviour approach could also be used to determine the willingness to pay bids/values[4]. Three two techniques are indirect approaches. In addition to these three approaches, hedonic price approach is also popularly used to value benefits of improved health. For this Ph.D. study using this technique would have entailed gathering data on wage differentials between labourers spraying pesticides and those who do not spray pesticides. This was not possible because farmers who use pesticides are mainly self-employed. The hedonic approach can also be used by taking the price difference between toxic pesticides and less toxic pesticides. However, there were at least two main difficulties encountered in doing this. (a) There was no alternative choice of pesticides for farmers in the village shop. (b) A very large number of pesticide brands were being used by farmers in the study area (please see Appendix 6.2). For a study that has used the hedonic price to examine the price differentials in the context of user safety and water quality for a single herbicide, see Beach and Carlson (1993). Beach and Carlson in their study also state that three key assumptions have to be satisfied to apply the hedonic price model and one of the assumptions that has to be satisfied in the context of pesticides is that the firm selling pesticides must offer farmers a "wide variety of distinct packages of characteristics at various prices". Hence, because of the difficulties in gathering data for the hedonic approach, this technique is not used in this Ph.D. study. The three approaches considered in this thesis as mentioned earlier are the contingent valuation, cost of illness and the avertive behaviour approaches. The willingness to pay bids/values obtained from these techniques, apart from measuring the value of reducing/avoiding ill health arising from direct exposure to pesticides can also indirectly suggest the demand for environmental quality (because of damage done from pesticides) and determine the welfare effects of reducing/avoiding direct exposure to pesticides. In this chapter we discuss the concept of valuing reducing/avoiding morbidity effects arising from direct exposure to pesticides and the various costs that are involved with such exposure. We then go on to discuss the three techniques used in this thesis to value reducing/preventing morbidity effects arising from direct exposure to pesticides and the willingness to pay function. The last section contains a brief review of the studies that have been carried out using these three approaches. We also examine a few studies that have been carried out to compare the three techniques. In chapter five we discuss a model that shows the relationship between the three approaches.

Furthermore, all studies that have used the other two approaches that will be used in this thesis, namely the cost of illness and the avertive approaches have inferred willingness to pay bids/values from the estimates obtained from these two approaches rather than WTAC bids/ values.

[4] For example, see Cropper and Freeman III (1991, p.194) who consider theoretically these three approaches to valuing changes in morbidity effects in individuals suffering from air pollution. For an empirical study see Chestnut et al. (1996).

Chapter six discusses in detail the field questionnaire used to gather the required data using the three valuation techniques. Chapters seven, eight and nine discuss in detail, the contingent valuation, cost of illness and the avertive behaviour approaches respectively, highlighting the advantages and disadvantages of these techniques and also discuss the results of the field study.

Valuing the Demand to Reduce/Avoid Mortality and Morbidity Effects Arising from Pesticide Use

From the three approaches that were described in the introduction of this chapter, it is possible to estimate the value of reducing/avoiding mortality and morbidity effects arising due to direct exposure to pesticides. Although the value of reducing/avoiding mortality impacts from direct exposure to pesticides will be discussed briefly in this chapter, an empirical study will not be carried out. This is because it was not possible to obtain data from such an exercise. During the pilot study that was conducted to test the questionnaire, one of the questions was aimed at obtaining the farmers willingness to pay to avoid deaths from direct exposure to pesticides. Many farmers refused to give a value for this question. Many of the respondents said that it was impossible to say how much value they could place on avoiding mortality from direct exposure to pesticides. Hence, the second willingness to pay question was dropped from the original questionnaire. Only the value of reducing/avoiding reduced morbidity effects arising from direct exposure to pesticides will be estimated using the three techniques. The contingent valuation approach in this Ph.D. thesis, as mentioned in the introduction, is aimed at obtaining willingness to pay bids to avoid exposure to pesticides while the cost of illness and avertive behaviour approaches obtain values from which the willingness to pay to reduce exposure to pesticides would be inferred.

Farmers are aware of the risks of direct exposure to pesticides and hence the need for self-protection. For example, studies carried out by Gnanachandran and Sivayoganathan (1989); Siyayoganathan et al. (1995); show that the majority of farmers surveyed in their studies were aware of the risks of exposure to pesticides and the need to take precautionary measures [Jeayaratnam (1982); Siyayoganathan et al. (1995)]. However, farmers are constrained in taking adequate precautions due to their inability to afford adequate precautions (hence using cheap substitutes), discomfort to wear protective gear (for example, farmers difficulty to wear shoes and walk about in the fields) uncomfortable to wear during the heat of the day[5]), cultural taboos (such as not wearing shoes in the field which is regarded like a temple in some respects because it is the land that produces food, elderly farmers reluctance to wear trousers due to their lower socio-economic status, etc. [Sivayoganathan et al. (1995)]. As a result of the inability to take adequate precautions due to the above mentioned factors farmers are directly exposed to pesticides and hence suffer from ill health. Farmers continue to use pesticides despite the adverse health effects because the alternatives available to avoid the use of pesticides are limited or non-existent. For example, all seed varieties available are not resistant to pests and diseases and hence the need to spray pesticides. Safer pesticides are not available and employment opportunities outside farming is very limited. Shogren and Crocker (1989) show that the traditional

[5] For example, see Antle et al. (1998) who state that the use of protective clothing is minimal due to tropical humidity. Their pesticide study was carried in Ecuador. Also see Forget (1991); Antle and Pingali (1994).

argument that individuals who are exposed to greater risk and those with greater wealth would value a given risk reduction more highly does not follow. They also go on to point out that increased risk need not imply increased self-protection expenditures.

Valuing Reduced/Avoided Mortality Risks from Direct Exposure to Pesticides

Direct Exposure to pesticides, not only leads to morbidity effects but also gives rise to mortality effects as shown in chapter three. The type of pollution being discussed in this chapter is pesticide pollution arising from direct exposure to pesticides during handling and spraying on crops. Deaths arising from such exposure have been firmly established, as hospital data, field studies and interviews carried out have shown. Many methods of valuing reducing/avoiding the risks of mortality have been suggested, ranging from comprehensive models of individual behaviour (for example, hedonic price models[6] avertive behaviour approach[7]) to models that are based on measurements of the economic productivity of the individual whose life is at risk and the contingent valuation approach. While the contingent valuation approach is a direct approach, the former are indirect approaches to infer the willingness to pay bids/values to reduce/avoid risks to life. In order to measure the value of reducing or preventing the risks of mortality arising from direct exposure to pesticides, many of the techniques developed to value the demand for environmental quality can be applied. However, as mentioned in the introduction, due to the difficulty in obtaining the necessary data, this thesis only attempts to value the demand for reduced/avoided mobidity effects or ill effects arising from direct exposure to pesticides during handling and spraying on the farms.

Valuing Reduced/Avoided Mobidity Impacts from Direct Exposure to Pesticides

It has been argued that mobidity effects caused by pollution is more difficult to measure than valuation of direct mortality effects. While this is certainly true for the long-term morbidity effects, it is not always the case with short-term effects. This Ph.D. study concentrates only on the short-term morbidity effects arising during handling and spraying or soon after (within 4-5 hours) the use of pesticides, where a direct linkage between pesticide usage and morbidity effects described in tables 3.1 and 3.3 of chapter three has been established [for example, see the work of Jeyaratnam (1982a); Turnbull et al. (1985); Rola and Pingali (1993); Forget (1991); Antle and Capalbo (1994); Antle and Pingali (1994a); Pingali et al. (1995); Siyayoganathan et al. (1995); Hoyek et al. (1997); Antle et al. (1998); Crissman et al. (1998); Cole et al. (1998)]. The health effects arising on non-spraying days (such as the day after spraying) have also been considered, where it is possible to show a linkage between pesticide use and ill health. The long-term effects, though difficult to prove have also been considered, where such an illness is perceived or has been diagnosed to result from direct exposure to pesticides.

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[6] Hedonic price models that value the reductions in risks to life are compensating wage studies that infer the value of a statistical life from wages premia that workers receive to compensate for risks of accidental death and hedonic property value studies where property values may be lower in polluted areas to compensate home-workers for their incurred risks of death.

[7] The use of smoke detectors (Dardis, 1980) and seat belts (Blomquist, 1979) are both good examples of activities that will at a cost, reduce an individuals risk of death.

Any attempt to measure the value of reducing or avoiding direct exposure to pesticides should take into consideration the many beneficial effects people can experience from reduced incidence or prevalence of diseases. For example, a farmer who experiences no headaches or nausea because of reducing or altogether avoiding exposure to pesticide pollution. If the mobidity effects mentioned in chapter three which affect his working efficiency or keep him away from work (working days/hours lost), expenditure on medication and treatment incurred, travel costs associated with the illness, special foods, the need to hire extra labour, leisure time foregone, or suffer pain and discomfort suffered, etc. can be reduced or averted, then he clearly benefits from reducing/avoiding direct exposure to such pollution. Some of these costs can be calculated directly while others are more difficult to take into account. The cost of working days lost, cost of medication and treatment, traveling expenses, costs of special foods are easy to calculate, but other costs such as loss of efficiency, leisure hours lost, pain, discomfort and suffering, effects such as loss of memory, etc. are more difficult to quantify. This is where certain techniques developed to measure the value of reducing/avoiding morbidity such as the contingent valuation method becomes useful, because it tries to capture the costs that are more difficult or impossible to quantify directly.

In addition to those mentioned above, there are other costs involved, such as avertive or defensive costs in the presence of pollution. Cleaning up costs should also be taken into account as shown in Figure 2.5 of chapter two. As a result, it has been pointed out by (Cropper and Freeman III, 1991, p.193) that benefits of pollution control can also be realized independent of any observed change in the incidence of the disease. Here they refer to the avertive or defensive expenditures that are incurred by taking precautions/defensive measures, such as wearing protective clothing, gloves, masks, foot wear, etc. to reduce/avoid the morbidity effects or sometimes even death when handling and using pesticides on the farms. If for example, a farmer suffers fewer health effects after these new changes, then he obviously has benefited in the form of costs saved which were mentioned in the last paragraph by taking precautions against health impacts of pesticide pollution. Supposing the amount of direct exposure to pesticides can be reduced, then this also means that the defensive expenditures/averting behaviour costs, too, are reduced. This relationship was graphically shown in Figure 2.5 of chapter two. Therefore, in order to bring about a reduction or altogether avoid direct exposure to pesticides/pesticide pollution related impacts, it is necessary to assess the value of such reductions. It can be assumed that, the higher the costs arising from pesticide handling/direct exposure related health impacts, the higher the value for reducing or even avoiding such impacts.

As discussed above, it is possible to adopt many of the techniques used to measure morbidity effects of pollution to obtain values for a reduction/prevention of mortality among the users, due to direct exposure to pesticides. However, as mentioned earlier, willingness to pay bids are not obtained to measure benefits of reduced mortality in this thesis. In the case of obtaining willingness to pay bids to reduce/avoid morbidity effects arising from pesticide pollution, all three methods suggested in the introduction, namely the contingent valuation, cost of illness and the avertive behaviour approaches would be used. It should be mentioned here that it is possible to use these techniques, not only to value to reduce or prevent mortality and morbidity effects to humans arising from direct exposure to pesticides, but depending on what is being measured, at least one of these techniques could be used to determine the value of reducing or even avoiding impacts of pesticide pollution on agricultural land, other production processes, wildlife, and the environment in general. These are not taken into consideration when valuing the benefits of reducing/avoiding morbidity due to ill health resulting from direct exposure to pesticides. Only the private costs to the user are considered. The next section briefly discusses the costs of pesticide pollution, before discussing the three valuation techniques used in this thesis to measure the value of reducing/avoiding morbidity effects arising from direct exposure to pesticides.

Costs of Pesticide Pollution

The pesticides used in the agricultural fields affect farmers' health in a number of different ways, ranging from minor symptoms such as headaches to the risk of serious long-term illnesses or deaths. The effects considered in this chapter are on the users, directly resulting from its use, while handling and spraying the pesticide or soon after spraying, usually within four hours. The ill effects arising on non-spraying days and some of the long-term effects are also considered. Pesticide chemicals affecting human health can reduce the affected persons welfare in many different ways. Some of the pollutants can also persist in the environment for long periods of time causing harmful effects. The various negative externalities and the private costs arising from agricultural pollution such as pesticides were discussed in chapter two. We describe below the private costs of direct exposure to pesticides. The costs mentioned below arise on pesticide spraying days, non spraying days and due to long-term illnesses arising from direct exposure to pesticides, leading to hospitalization, consulting a doctor or simply taking home made self-treatment. The illnesses can be described as serious, moderate and mild respectively. They are both short-term and long-term in nature. The costs are as follows:

Tangible Costs

Direct:

- Medical expenses associated with direct exposure to pollution. For example, consultation fees, hospitalization fees (government or private), laboratory costs, emergency room visits, etc.

- Money spent on traveling to hospital for treatment (e.g. by coach, train or taxi - includes the cost of person accompanying).

- Hired labour due to inability to work on farm due to ill health

- Defensive or averting expenditures associated with attempts to prevent direct exposure to pesticides related illnesses

- Other losses incurred due to hospitalization from direct exposure to pesticides (for example, crop damage from animals due to inability to look after the crops)

Indirect:

- Foregone wages/incomes due to loss of work days/hours on farm
- Time spent on traveling/seeking treatment from government hospital/private clinic
- Lost opportunities for leisure activities
- Loss of work efficiency and premature retirement
- Changes in life expectancy or risk of premature death
- Effects on family members arising from deaths/illnesses

Intangible Costs:

- Pain, discomfort, stress and suffering. Other costs include: movement restriction, depression and mood swings.

These costs can arise from both direct exposure (affecting mainly the users, but non users are not wholly excluded) and because of the 'conservative' nature of these pollutants non-users are also vulnerable. Not only are the direct impacts of these pollutants high but the inter-and intra-generational costs could also be large as suggested in chapter two. In taking these costs into consideration, reducing/avoiding exposure to pesticides can clearly have considerable welfare benefits to the affected parties because it reduces/prevents these adverse effects. Hence, in principle to calculate the welfare benefits of reducing/avoiding pesticide pollution, all of the above mentioned costs should be measured. In the next section we examine briefly the three valuation techniques that would be used in this study to determine the value of reducing/avoiding direct exposure to pesticides. Chapters seven, eight and nine discuss these three approaches in detail.

Techniques for the Empirical Valuation of Reducing/Avoiding Mobidity Effects Arising from Direct Exposure to Pesticides

Valuation techniques developed to measure the demand for environmental quality/recreation can easily be adopted to determine the value of reducing/ preventing morbidity effects that can be brought about by reducing/avoiding direct exposure to pesticides. The techniques that have been developed can be broadly categorized as those that rely on direct and indirect market information, those based on stated preferences in the absence of markets and dose-response methods [Cropper and Freeman III (1991, p.166); Markandiya (1992, p.142, 154)]. From the survey techniques available for environmental valuation/recreation, there are at least three different valuation techniques that can be used to measure economic valuation of reducing/avoiding changes in health. The three techniques used in this thesis are aimed at measuring the value of reducing/avoiding the risks to health from direct exposure to pesticides.

The purpose of the three approaches is to obtain individual values or bids as expressed in terms of willingness to pay for an environmental improvement/reduced/avoided mortality and morbidity effects. The willingness to pay approach, in other words, show the amount of money foregone in order to obtain some form of safety measures. In this study, the concept of willingness to pay is applied to determine the value of reducing/avoiding ill health resulting from direct exposure to pesticides. In other words, we try to determine the value of reducing/avoiding direct exposure to pesticides during handling and spraying on the farms.

The first category includes all of those techniques that rely on demand and cost functions, market prices and observed behaviour and choices [Cropper and Freeman (1991, p.166); Markandiya (1992, p.142)]. The techniques that fall under this category include: hedonic pricing and the travel cost method. The avertive behaviour approach chosen to measure the value of reduced exposure to pesticide pollution by farmers in this chapter also falls into this category and is in many respects is similar to hedonic pricing. This latter approach depends on a relationship that exists between environmental quality and some commodity, for example, the price of a house or land. Hence, cleaner is the environment (e.g. air), the higher are the prices of houses and land. Other environmental factors such as a good view, availability of recreational facilities are also considered. The problem with this method is that of decomposing the value of the relevant factors, because factors such as proximity to work, etc., security of neighborhood and many other factors also influence the price of a house or land. On the other hand, the averting behaviour method yields inferences about values from observations of how people change their behaviour in response to environmental changes or health risks they face by taking into account all averting/defensive expenditures, mitigating and precautionary expenditures that are incurred as a result of sickness arising from pollution such as direct exposure to pesticides. This approach involves inferring willingness to pay from real life situations where individuals are choosing a trade-off between some benefit or cost that has a money value and some perceived or derived change in health. The avertive behaviour expenditures can consist of both private as well as public costs. According to this approach, defensive/avertive costs incurred, for example, on reducing/avoiding the harmful effects of pollution, the cost of these actions estimates part of the household's willingness to pay for environmental improvements (Laughland et al. 1996). Courant and Porter (1981) investigating the suitability of defensive expenditures alone as a measure of the benefits of environmental improvements show that defensive expenditures over or underestimate willingness to pay depending on the shape of the dose response function, although an underestimate would be the most likely outcome. Harrington and Portney (1987), too, show how defensive expenditures can be less or exceed contingent valuation willingness to pay values. Bartik (1988), too, shows that upper and lower bounds to benefits can be derived.

The second category includes asking people directly to state their willingness to pay or accept compensation for a postulated change, how their behaviour could change or how they would rank alternative situations involving different combinations of health, income and consumption. The technique involved here is the well known contingent valuation method, which measures willingness to pay in a direct way. The willingness to pay measure is defined as the change in income that would cause the same change in utility (well-being) for the individual as that caused by the health condition of interest. The contingent valuation approach involves asking subjects to respond to a hypothetical situation in which such a trade-off is required. It is argued that the contingent valuation approach is conceptually correct because it takes into account not only direct and indirect costs but also intangible costs.

The third approach, like the first, is based on an indirect valuation approach where data on medical expenditures, lost time (including work, loss of productivity, leisure) due to illness are used to infer a lower bound to willingness to pay for reduced pollution (Cropper and Freeman III, 1991). This technique is called the cost of illness approach. This is perhaps the most widely used approach to value reduced morbidity in health studies which has its origins in the 17th century. However, its modern approach was developed in the 1950s and 1960s by works such as Renolds (1956); Fein (1958); Weisbrod (1961); Rice (1966) and Cooper (1967). The approach involves estimating the medical expenditures, working days lost, productivity losses, leisure hours, travel costs, dietary expenses, etc. associated with a disease under study[8]. These estimates are then used to infer the value of reduced morbidity in the form of savings. The ill health related costs can be broken down into private and public/social costs. This is because there is a difference in who incurs the impact of the costs. For example, a person getting sick due to exposure to pollution may not pay for treatment if hospital treatment is free of charge. Hence, it is a public/social cost. The cost of illness approach infers a lower bound to willingness to pay for reduced morbidity because, such an approach cannot take into account intangible costs such as discomfort, inconvenience, and activity restrictions, that go beyond what is reflected in direct expenditures and lost time.

Although some studies only refer to the contingent valuation approach and 'avertive behaviour' or contingent valuation and the cost of illness approaches to discuss the concept of willingness to pay to value changes in health, all three approaches have been shown (Cropper and Freeman, 1991, p.194-195) can be used to obtain individual values or bids as expressed in terms of willingness to pay for an environmental improvement/reduced or avoiding mortality and morbidity effects or willingness to pay compensation for an environmental deterioration, etc.

The advantage of the contingent valuation approach is that with some additional questions included in the survey questionnaire, the cost of illness and the avertive behaviour approaches can also be calculated. Another advantage is that, they can be compared to determine the accuracy of the studies, although they have proved not to be the same [e.g. Berger et al. (1986); Dickie et al. (1983, 1986); Rowe and Chestnut (1984); Murdoch and Thayer (1990); Dickie and Gerking (1991); Chestnut et al. (1996). Furthermore, these two indirect approaches are based on observed behaviour, unlike in the case of contingent valuation approach where the estimates are based on hypothetical figures. However, it should be stated that the avertive behaviour and cost of illness methods require a considerable amount of data if all costs are to be duly covered, which in reality is a difficult task. For example, in the case of the averting behaviour approach in gathering data, the researcher should consider the health

[8] As is often the case with any ad hoc constructs like the cost of illness, not everyone uses the same definition. They vary considerably. Most studies of particular illness incidence, including pollution studies count only on medical care and cost wages [Harrington and Portney (1987, p.101)] but Hodgson and Meiners (1982) have included other non health costs such as transportation to and from medical providers, special diets, certain household expenditures, costs of relocating (such as moving expenses) and certain property losses and so forth. Kenkel (1994) also argues for the inclusion of lost leisure hours as well, to make COI estimates more complete.

outcome of interest, the amount of mitigating or averting behaviour undertaken and calculate its costs. In addition, the researcher should also determine, how effective the individual thought his avertive behaviour was, or how effective the behaviour actually was and assume the individual correctly perceived this. In the cost of illness approach, the costs are numerous and careful attention has to be paid in identifying each and every cost involved. It is both time consuming and expensive. In the case of contingent valuation approach, such problems are avoided by asking each individual to state their values for a change in environmental quality/symptom frequency. The main drawback is that of basing its valuations on answers to hypothetical questions, which may be unrealistic due to several reasons. The disadvantages of the contingent valuation approach is discussed in detail in chapter seven.

It is important to note that in this thesis, the three approaches take into account only the private costs for an individual and then inferring a willingness to pay to reduce/avoid ill health. Before each approach is used, the costs that are estimated will be discussed. There are many social costs (such as hospital costs), but are not considered in this thesis when inferring an individual's willingness to pay for pollution control. In the case of contingent valuation approach, too, when considering an individuals willingness to pay to avoid morbidity from direct exposure to pesticides, the respondent is asked only how much he is willingness to pay to avoid ill health affecting him due to direct exposure to pesticides and not to avoid ill health affecting his family and/or the entire farming community.

It has been suggested that contingent valuation method studies are more appropriate than cost of illness measure to examine the real costs resulting from pollution and the benefits of controlling such pollution. This is because contingent valuation experiments can be designed to directly estimate what an individual would be willing to pay for a certain change in morbidity, which takes into account all intangible costs as well[9]. Hence, contingent valuation bids/values are estimates of the conceptually correct benefit measures for benefit-cost analysis under certainty. However, it must be pointed out that, although theoretically, the contingent valuation approach is more desirable for benefit-cost analysis, such measures are more difficult to obtain than cost of illness estimates. Furthermore, the proper design of contingent valuation studies is difficult and controversial and some economists doubt the validity of actual values obtained from individuals in a contingent valuation experiment. On the other hand, it must be pointed out that, on a practical level, cost of illness values are often judged superior to contingent valuation bids/values, while on a conceptual level, contingent valuation bids/values are preferred. In general, contingent valuation measures are expected to exceed cost of illness measures for the same change in health, although there may be some exceptions, as shown in the last section of this chapter.

For the Ph.D. study, a questionnaire will be designed to obtain the required information for the cost of illness, avertive behaviour and the contingent valuation approaches to estimate the costs of direct exposure to pesticides and thereby infer the willingness to reduce/avoid ill health resulting from direct exposure to pesticides. The data collected from the field study will also be used for the three regression analyses that will be carried out to determine various relationships that are discussed in

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[9] It must be mentioned here that the avertive behaviour approach also takes into consideration all the costs including intangible costs when an individual engages in defensive behaviour.

chapters seven, eight and nine. Chapter six deals with the methods and issues in questionnaire development and the gathering of data.

The next section discusses the concept of willingness to pay (WTP) which uses the cost estimates of pollution to infer the willingness to pay by the affected individuals to pay for pollution control/or bring about health outcomes, etc.

The Willingness To Pay Approach

All of the three above mentioned valuation methods developed to measure/value the demand for environmental quality/recreation, benefits of reducing/avoiding ill health etc. are aimed at obtaining the willingness to pay or willingness to accept estimates for an environmental improvement/reducing/avoiding ill health or accept compensation for an environmental deterioration/ill health respectively. The willingness to pay or willingness to accept estimates obtained from the above mentioned approaches from the affected individuals can be used as a basis for making decisions concerning changes in their economic welfare, such as preventing the incidence of death, or being affected by the morbidity effects according to what an individual is willing to pay to reduce or prevent mortality and morbidity effects or willingness to accept compensation. The benefits of reducing/avoiding the risk of death or incidence of illness have been defined as the sum of what each of the affected individuals is willing to pay to reduce/avoid his own risk of death or illness plus the sum of what everyone in society is willing to pay over and above this amount to reduce/avoid the risk of death or illness for any of the exposed individuals (Cropper and Freeman III, 1991, p.208). Another component of willingness to pay can arise because of the existence of non-use/passive values or altruistic feelings (National Oceanic and Atmospheric Administration, 1993). In such a situation, although individuals may not directly bear the costs of pollution, they would be willing to pay a sum of money for the above mentioned reasons, for example, because members of society are forced to bear the costs of illness or premature death, due to concern for children, and other reasons. Hence, when the willingness to pay bids are obtained, an individual not only considers the direct and indirect costs to himself but also considers the non-use/passive values too. In the case of ill health resulting from direct exposure to pesticides, an individual will consider intangible costs such as pain, discomfort and suffering as well.

To assume that individuals have a willingness to pay to reduce/avoid risks or illness implies that individuals can perceive and are aware of changes in these determinants of their well-being. If the value of reduced/avoided risk or symptom days is known, policy-makers can then calculate the benefits if they can predict the magnitude of the reduced/avoided ill health brought about, for example, pollution control. It must be stated that, the knowledge of risks involved and all other factors etc. play important roles in the empirical estimation of willingness to pay. For example, if the willingness to pay for risk reductions/avoidance from pesticide use is to be calculated correctly, then it must be assumed that individuals know about the risks of such use. Also, if willingness to pay to reduce/avoid illness is to be inferred from an individual's averting or mitigating behaviour or cost of illness approach in response to changes in pollution, then it must be assumed that the individual knows that there exists a relationship between pollution and illness.

In this study, as mentioned earlier, only willingness to pay bids to reduce/avoid morbidity effects arising from the use of pesticides would be obtained. One of the three techniques that would be used is the contingent valuation approach, where in a hypothetical market, individuals will be asked how much they are willing to pay to avoid direct exposure to pesticides that result in numerous morbidity effects. This can be in the form of paying more to use less toxic (safer) pesticides or planting crops that need less pesticides or abandoning of pesticides altogether or hiring of labour to spray pesticides, etc. Hence, when the welfare that is lost can be measured in a market (for example, in a constructed hypothetical market), an affected party's willingness to pay is revealed by what he states. People state the amount of income or wealth they are willing to forego, in return for better health. Therefore, by making a pavement, it is assumed that it is possible to avoid some of the risks to health/life. This implies that higher is the willingness to pay, the higher are the risks to health avoided. However, higher willingness to pay could also be due to higher income to avoid a given risk. The other two approaches use direct cost estimates to infer a willingness to pay to reduce health impacts resulting from direct exposure to pesticides. They are indirect approaches and the cost of illness approach is a lower bound for a willingness to pay because it cannot capture the intangible costs. The contingent valuation which is a direct approach and the avertive behaviour approach are assumed to capture all costs, including intangible costs. However, the difficulties in gathering the data for avertive behaviour approach usually makes it a lower bound.

Despite criticisms of the willingness to pay (in this instance referring to the contingent valuation) approach, an argument put forward is that people appear to be willing to make ex ante trade-off's involving risks of death or illness. This is based on the assumption that people are rational and their preferences are taken to be the basis of values of economic measures.

Measures of willingness to pay bids are obtained not to measure the value of life but rather to find out what people are willing to pay to minimize/avoid risks to their health. Such values could be of enormous benefit to policy-makers. The whole purpose of this exercise is as Markandiya (1992) has correctly pointed out is that " what one is valuing in studies of mortality and morbidity is not a certain person's willingness to pay to avoid dying sooner, or suffering a longer period of illness, but an increase in the risk of this happening". In this regard some degree of confusion has resulted from the fact that economists frequently speak of the 'value of a statistical life'. The value of a small reduction in mortality risks is often summarized by the value of a statistical life, which shows the willingness to pay by a group of people to reduce mortality risks so that one life is expected to be saved, in a statistical sense. This is best illustrated with the help of an example taken from Markandiya (1992). Supposing we assume that the probability of death is reduced from say 0.0002 to 0.0001 (i.e. is by one in ten thousand) and the average willingness to pay for this result is \$10, then the average value of life for that group is defined as \$ $10/10^{-4}$ or \$ 100,000. This is not what any one individual is willing to pay to avoid death but rather it is a summary way of expressing in one number, a willingness to pay and a change in probability. McGurie et al. (1988) note that this approach was first suggested by Dreze (1962) and since then has been firmly established in the work of Schelling (1968), Mishan (1971) and Jones-Lee (1976). Many examples of the values emerging from this approach are shown in Jones Lee (1985). The estimates of the value of statistical life are from both revealed preference studies as well as from questionnaire studies. The former studies are based on the study of individual's behaviour when actually faced with mortality risk and the latter using a questionnaire approach to try to elicit how they would behave when faced with risk of death. Pearce et al. (1989, p.80) have pointed out that "it is not essential to be persuaded that the monetary valuations are accurate but rather that the implications of the valuation procedures are understood". This in fact is the essence of the valuation process. The next section discusses the estimation of a willingness to pay function briefly. In this case, not only the factors determining the willingness to pay to avoid or bring about a reduction in pollution or an improvement in environmental quality for the contingent valuation approach are taken into consideration but factors that affect the cost of illness and defensive expenditure which are used to infer willingness to pay bids are also discussed. In other words, the willingness to pay refers to all three approaches unless one particular approach has been specified.

Estimation of a Willingness to Pay Function

The willingness to pay to avoid or bring about a reduction of a health risk to a particular individual is influenced by many factors. For example, in estimating the willingness to pay bids of an affected individual, a farmer's willingness to pay to reduce/avoid risks of death and other mobidity effects from pesticide use depends on many factors. The importance of socio-economic variables on the demand for health have been highlighted in the work of Grossman (1972); Feldstein (1993). This is for a contingent valuation study. Some of the relevant socio-economic variables that should be considered are: income (or Wealth), age, education, sex, household size, levels of poverty, etc. Other variables apart from socio-economic variables that should be considered are: ambient pollution levels, frequency, duration and severity of pollution related symptoms, avoidance and mitigating costs, expected costs of illness, risk perceptions, previous experience of ill effects, health status of the individual, availability of substitutes for pesticides and their prices, the extent of pest damage, market price of the crops grown, concern for the environment, etc. Sivayoganathan et al. draws attention to environmental (temperatures levels and wind conditions), cultural and prevailing taboos as well in considering the factors that influence defensive behaviour. We discuss these factors in more detail when the relevant regression analyses are undertaken in the respective chapters. Taking into consideration the factors that affect an individual's willingness to pay, a function known as the willingness to pay function can be written as follows

$$WTP_{(qi)} = f\,(\text{socio-economic variables, severity of illness and related variables, pollution variables, etc.})$$

Willingness to pay is the dependent variable, while the rest are independent variables where q_i is the environmental/health amenity (the potency of pesticide on humans) being changed.

It has been argued (Hanley and Spash, 1993, p.56) that investigating the determinants of willingness to pay bids is useful in aggregating willingness to pay data obtained from a sample into a population total figure and also for assessing the validity of the contingent valuation exercise. The bid curve can be estimated using the willingness to pay amounts as the dependent variable and a range of independent variables like those mentioned above.

Some Applications of the Three Valuation Approaches to Health

In this section we briefly examine some studies that have been carried out to value health symptoms (some of which are pollution related) using the three approaches that could be useful for inferring the value of changes in ill health from direct exposure to pesticides in this thesis. These studies are, however, not directly comparable with this Ph.D. study. We start with the studies that have been carried out using the contingent valuation approach. The contingent valuation studies that are reviewed are Dickie et al. (1987); Rowe and Chestnut (1985, 1986); Liu (1992); Liu et al. (1996); Kartman et al. (1996) and Alberni et al. (1997). Three of the contingent valuation studies reviewed are from a developing country, namely Taiwan. Harrington et al's (1989) avertive and cost of illness approach study is also reviewed.

Dickie, et al. (1987) have carried out a telephone survey among 221 residents in Glendora and Burbank, California, to estimate contingent valuation willingness to pay bids for reductions of symptoms which are believed to be related to ozone exposure such as sinus, headaches, coughs, throat irritation, tight chest, etc. The survey design was such that the respondents were made to think carefully about the health symptoms to be valued. Besides a set of standard questions on socioeconomic measures, the respondents were asked about their experience with a list of symptoms. Respondents were then asked about the frequency, duration, and severity of symptoms, as well as averting actions taken in response to the symptoms of the most bothersome symptoms. Next they determine their willingness to pay for one day of relief. Respondents who have experienced a symptom or symptoms were asked to value up to three symptoms. One hundred and sixty-five respondents reported having had at least one symptom and so answered one or more contingent valuation questions. The number of respondents providing contingent valuation willingness to pay bids for the nine ozone symptoms varied from 11 for wheezing/whistling breath to 61 for headache.

Dickie et al. have considered the reliability of the contingent valuation method in detail which is reflected in the designing of the questionnaire and the analysis of the results. In the study, after the information was presented with the implied monthly bid for avoiding symptoms, respondents were given an opportunity to revise their bids. There were high bids and in two cases exceeded not only the respondents' monthly incomes but even their annual incomes by substantial margins. Given the opportunity to revise their bids, the highest monthly total was in the range \$501-\$600.

Dickie, et al. (1986, 1987) present initial and revised mean and median results of contingent valuation results for nine symptoms where the reported range of values is extremely wide and high. In fact some of the bids are unrealistically high. They also subject the results to trimming and consistency checks. All three methods used were to improve the reliability allowing respondents to revise bids, trimming the samples, and subjecting the bids to consistency checks which have resulted in substantially lower means, as very large bids are removed from the sample. The trimmed values are far lower than the value of initial bids, though it is claimed that it is an arbitrary procedure (Kenkel et al. 1994, p.84). For example, the mean value of initial bids for a day of relief is often above \$100 (except for throat irritation, short breath and wheezing/whistling breath) and the 'could not breathe deep' bid exceeding 1,000 dollars. However, after trimming the mean values, most of the mean values are below

$20. The highest mean value placed on a day of relief in the sample is subjected to consistency checks is $ 26.70. The highest mean value in the sample of revised bids is $4.67. It should also be noted that the sample includes a number of unrealistically low values. Dickie et al. have pointed out that for six of the nine symptoms, the modal bid for relief was zero. In the sample of the revised bids, in five cases the median bid was zero, implying that half of the sample bid zero for relief. In terms of contingent valuation surveys, zero bids mean that respondents place no value on symptom relief where as it is rational to argue that any symptoms that caused discomfort or averting actions suggest a nonzero value. However, it is also possible to interpret zero values as representing very low values that respondents have approximated as zero (Kenkel, 1994, p.85). Because of the problems encountered, it is argued that it is inappropriate to seek precise estimates for reductions in symptom relief. However, the trimmed means provide useful evidence on the lower bound which placed the value of symptom relief in the range of $2.00 to $5.00 a day.

In another study, Rowe and Chestnut (1985, 1986) have examined the benefit of reducing or preventing asthma symptoms among 90 asthmatics in California in 1983. The general questionnaire that included the contingent valuation question was completed by 64 adults and 18 parents of children under 16 years of age. Of this total sample of 82, there was only one refusal. However, only 65 bids have been taken into consideration for the final analysis after checking for protesters and consistency. The selection of only asthmatics is considered a strength, because it is thought that people with asthma are a group likely to be affected by pollution who may value the changes differently than the general population. However, it should be emphasized that the sample was not chosen so as to be representative of asthmatics in general. Information was obtained on defensive measures taken to avoid asthma, medical costs and what they would be willingness to pay to have their symptoms reduced. It was shown that on average the subjects ranked reductions in discomfort and activity restrictions as more important than reductions in medical expenses and income loss. This goes on to show that cost of illness measures underestimate the total value of reducing or avoiding asthma symptoms. In the Rowe and Chestnut analysis, they found that for 65% of respondents would pay a mean bid of $401 per year, with a standard deviation of $85 for a 50% reduction in bad asthma days. These average amounts paid are for a reduction of 19 bad days. Hence, it was calculated that on average a bad asthma day is worth about $21.

Liu (1992) uses the "closed-ended" contingent valuation method to analyze the benefits of reductions in environmental risks in Taiwan. The environmental risks considered are nuclear power plant and air pollution risks from automobiles and motorcycles. The welfare estimates based on the logit model and linear utility function indicate that a 20 percent reduction in nuclear power risks results in a benefit of NT$830 per month, and a 20 percent reduction in car emission risks has a welfare benefit of NT$597 per month.

Liu et al. (1996) use the contingent valuation method to elicit respondents' willingness to pay to avoid their most recent episode of illness. They then compare the amounts residents of urban areas are willing to pay with the amounts of people who live near large petrochemical complexes. The urban areas considered in the study include the cities of Taipei, Kaoshiung, and Hualien. The areas near petrochemical complexes are Linyuan and Daiser, both in Kaoshiung County. An illness episode is defined in the study by a complex of attributes, for instance, they use a measure of its severity, duration, and a set of symptoms. The willingness to pay is then specified as a function of the characteristics of the illness episode and the respondent's characteristics. In the study they show that the median willingness to pay to avoid a recurrence of an illness episode is estimated at NT$1596 for the urban areas and NT$4831 for the areas near the petrochemical complexes. Their study demonstrates that individuals are willing to pay more to avoid living in areas with potential health risks such as near petrochemical complexes.

Kartman et al. (1996) compare the costs of health care programs with the benefits in Sweden. Their study reports the results of a contingent valuation study measuring the willingness to pay for reductions in angina pectoris attacks. The study shows that the willingness to pay for a 50% reduction in angina pectoris attack rate for three months was estimated at SEK 2,500 ($345) with the binary approach, and about SEK 2,100 ($290) using the bidding-game technique. Regression analyses show that income, angina pectoris status, attack rate, and percentage reduction in attack rate are all related to willingness to pay bids confirming the authors' hypothesis.

Alberini et al. (1997) carry out a contingent valuation survey in Taiwan to elicit willingness to pay to avoid a recurrence of an acute respiratory illness most recently experienced by the respondent. They show that the median willingness to pay to avoid a recurrence of an average episode is NT$980 or U.S.$39.20. The results suggest that willingness to pay bids to avoid respondent-described illnesses are internally valid. The regression results show that the willingness to pay increased with the duration of illness, with the number of symptoms experienced and with education and income.

Harrington et al. (1989), too, use the avertive behaviour and cost of illness approaches to study the economic losses of a waterborne disease (giardiasis) outbreak. The respondents interviewed, are, however, not the same. In this study, Harrington et al. (1989) discuss two categories of losses. i.e. losses due to illnesses and losses (costs) due to actions taken by individuals to avoid drinking contaminated water. To obtain information on the actions taken by individuals in the out break area to avoid contaminated water, fifty telephone interviewers were made during September and October, 1984, with households chosen at random from the telephone directory. The survey showed that households in the affected area chose a wide variety of strategies to ensure a safe drinking water supply. About one-half of the households (46%) either hauled water or boiled water, but not both. Virtually no one (2%) in the affected area relied on bottled water alone. Mixed strategies were popular. The households that hauled water obtained the largest quantity per week. No household in the sample installed a filtration system. From the information obtained on avertive/defensive costs incurred, including time spent, Harrington et al. compute upper and lower bound estimates of the losses due to actions taken by the sample of 50 households to avoid drinking contaminated water and then average them to obtain a "best estimate". Time spent on avoidance activities figure prominently in the damage estimates. The " best estimate" of averting losses to the average household range from $485 to $1,540 or from $1.13 to $ 3.59 per person per day for the duration of the outbreak. From these estimates they estimate the total losses to individuals in the outbreak area. They present the total costs in the form of three scenario's which range from $4.2 to $19.4 million for the lower bound estimate to $20.0 to $ 57.6 million for the upper bound estimates. Their best estimate range from \$12.1 to \$38.5 million. A similar approach is adopted to estimate the costs of illnesses. For this study 176 respondents were sampled. In this estimate they estimate losses in nine categories: doctor visits, hospital visits, emergency room visits, laboratory tests, medication, time and travel losses associated with medical treatment, work loss, work productivity loss, and leisure time loss. The losses in many of these categories depend to a considerable extent on the value of time-mainly the time spent ill but also time spent seeking medical care. Harrington et al. present the estimates of the cost of illness in three scenarios. The highest costs scenario estimates the cost at an average of \$1,255 per person while the lowest cost scenario puts the cost at an average of \$858 per person. The in between cost is placed at \$1,022.

In the next section we undertake a brief review of studies that have been carried out to determine the relationship between the three valuation approaches used in this thesis.

The Relationships Between the Three Approaches

In this section we examine some studies that have been carried out to determine the relationship between the three approaches. We look at some of the empirical studies that have compared the relationship between these approaches from the late 1970s to the present date. A study carried out by Rowe and Chestnut (1984) on the value of Asthma can be used to make a direct comparison of the contingent valuation bids representing willingness to pay and the cost of illness estimates. As Kenkel et al. (1994) point out the cost of illness and the contingent valuation approaches are two methods that allow a monetary value to be placed on a change in morbidity or sickness. Rowe and Chestnut compare the respondents' rankings of the importance of the benefits they might receive from reduced asthma from the two approaches. They show that discomfort and effects on leisure and recreation activities, which are part of the willingness to pay, but not part of cost of illness, clearly ranked above medical costs and work lost, which are the only components of willingness to pay that a cost of illness value includes. Hence, from the rankings, it is shown that cost of illness estimates do not include the most important benefits of reduced morbidity. Therefore, it shows that contingent valuation estimates should exceed the cost of illness estimates. Another form of evidence they provide is the comparison of the total contingent valuation bid and a constructed cost of illness value. This method shows a ratio of contingent valuation/cost of illness of 1.6, supporting the hypothesis that contingent valuation bids/values are greater than cost of illness values. This study offers evidence to show that contingent valuation bids exceed cost of illness estimates. However, the study involves only a relatively small sample of individuals with a chronic condition (asthma), and may not be relevant for the general population. Berger et al. (1986) explore the relationship between willingness to pay bids obtained from the contingent valuation approach for mobidity improvements and the cost of illness approach. This is done via a contingent valuation survey which measures the consumer surplus associated with 'certainty of avoiding days of mild symptoms' and then generalize the results to the relationship between willingness to pay bids (from the contingent valuation approach) and the expected cost of illness. They show that the mean willingness to pay from a contingent valuation study always exceeds the mean cost of illness approach. In the case of individual symptoms, too, the mean willingness to pay from the contingent valuation approach exceeds the mean of cost of illness approach. Even after the inclusion of lost consumption (such as lost time from any activity, e.g., market, work, school, work at home, etc.) into the private cost of illness calculation, it showed that the estimates were lower than those obtained from contingent valuation studies. Their results are therefore consistent with the hypothesis that contingent valuation willingness to pay bids exceed private cost of illness estimates, whether or not the value of lost consumption time is included. However, Loehman et al. (1979) provide some weak evidence against the hypothesis that contingent valuation values exceed cost of illness values. Dickie and Gerking (1991) in a willingness to pay study for tropospheric ozone control show that an individual is willing to pay \$170 annually for an environment in which ozone concentrations never exceed 12 pphm. They show that these figures are two to four times larger than medical expense savings caused by the same ozone reductions.

Studies have also been carried out to compare the contingent valuation approach with the avertive behaviour approach for the same quantity. One such study is the work of Dickie et al. (1986, 1987). The contingent valuation bids obtained ranged from \$0.60 to avoid a day of shortness of breath to \$5.97 to avoid a day of pain on deep inhalation, while the avertive behaviour estimates ranged from \$0.97 (shortness of breath) to \$23.87 (tight chest). These figures show that mean avertive behaviour values were higher than the contingent values. However, it has been pointed out that these avertive behaviour estimates should be regarded as upper bound estimates, since the full costs of joint products (such as in the use of an air conditioner) have been taken into account. Ideally, only the cost of air conditioning that benefited the individual against air pollution should be calculated. Moreover, the results must be regarded as preliminary, due to the small sample sizes that were involved. Interestingly, Murdoch and Thayer (1990) compare defensive/precautionary expenditure estimates for reducing the predicted increases in the rates of nonmelanoma skin cancers for the next 60 years with the cost of illness estimates and show that the cost of illness estimates are more than double the estimates of the defensive/precautionary approach.

Chestnut et al. (1996) provide further evidence to show that contingent valuation willingness to pay approach is more comprehensive than the traditional cost of illness (COI) approach, but point out that they are sometimes difficult to obtain. They also go on to show that the average willingness to pay to avoid additional angina episodes revealed by the averting-behavior questions was comparable to the directly elicited willingness to pay approach, providing a test of validity of the contingent valuation approach.

Conclusion

This chapter discussed in detail the three health valuation techniques that will be used in this thesis to estimate the costs of ill health resulting from direct exposure to pesticides among farmers. The concept of willingness to pay bids/values which the three valuation approaches purport to estimate were also discussed. In chapter five, we present a health production model showing the relationships between the three valuation approaches used in this Ph.D. study.

Chapter 5

A Health Production Model Showing the Relationships Between the Three Approaches to Willingness to Pay for Pollution Control

In the last chapter it was shown that at least three valuation techniques could be used to measure changes in morbidity resulting from pollution. In this chapter we hope to discuss a model that shows the theoretical relationships among the three approaches using a model of health production and consumption. As mentioned in chapter four, the direct questioning (contingent valuation) approach involves asking people what they are willing to pay (WTP) to reduce/avoid[1] the number of symptom days or illnesses they experience as a result of exposure to pollution. The avertive/defensive behaviour approach, which is an indirect method, like the cost of illness (COI) approach infers people's willingness to pay to reduce or to avoid[2] exposure to pollution from the amounts of money they spend on precautionary/avertive action taken. The cost of illness approach on the other hand uses available data on medical expenditures and other costs (out-of-pocket expenses) as well as opportunity costs (foregone earnings being the most obvious example), to infer a lower bound to willingness to pay to reduce pollution[3]. One problem with the cost of illness approach is that it ignores disutility arising from illness or injury (Harrington and Portney, 1987).

The health production and consumption model used in this chapter, was first demonstrated by Grossman (1972) to examine health decisions. Later this model has been modified by Cropper (1981), Gerking et al. (1983), Gerking and Stanley (1986) and Harrington and Portney (1987), Chestnut et al. (1988), Harrington et al. (1989) to examine the health effects of pollution[4,5]. The model presented in this chapter to examine the health effects of pollution and to show the relationships among the three approaches used to value the willingness to pay in this thesis is taken from Cropper and Freeman III (1991, p.194-196) and has been combined with the Chestnut et al. (1988) model to take into consideration all time valued at the wage rate. Time is essential because those suffering from health effects, not only incur out-of-pocket costs and lost earnings from inability to work and loss of productivity but also suffer from loss of leisure time due to illness and travelling to and from hospital to seek medical treatment, etc. The pollution referred to in this chapter is direct exposure to pesticides by farmers during handling and spraying on the farms. Pesticides, like

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[1] The Ph.D. field study gathered contingent valuation bids to avoid exposure to pesticides.

[2] For the Ph.D. study we infer the willingness to pay to reduce exposure to pesticides from avertive/defensive behaviour data collected from the field study.

[3] For a discussion on COI approach being a lower bound to willingness to pay for a reduction in pollution see Kenkel (1994).

[4] Alberini et al. (1997), too, use a similar model to provide a framework for interpreting their WTP survey results for air pollution in a developing country (Taiwan).

[5] Harrington and Portney (1987) for simplicity refer to any broadly defined environmental threat which could take the form of air and water pollution [for an application of the model for water pollution see Harrington et al. (1989)], exposure to a harmful substance in the work place or in a food stuff or other consumer product, or other hazard as pollution. Hence, this model could be applied to examine the health effects of pollution for a wide range of environmental threats.

chemical fertilisers are an essential input in the cultivation of high yielding commercially grown crops as described in chapter two. They are essential because these crops are highly susceptible to pests and diseases. Hence, farmers are highly dependent on the use of pesticides without which they are unable to cultivate high yielding commercial crops successfully. It is interesting to note that by 1982 the percentage of the cultivation of high yielding varieties in rice alone in Sri Lanka was 94% (Abeygunawardena and Bessler, 1989). This shows the extent to which farmers are dependent on chemical inputs such as pesticides.

In this model, the health outcome of interest is the time spent sick, that an individual spends ill due to direct exposure to pesticides[6]. Avertive/defensive behaviour and the level of medical treatment are considered in this model and for ease of presentation only one of each is assumed at one time.

Defining the relevant variables in the model:

S = Time spent sick
E = Level of exposure to pollution
M = Level of medical treatment
D = Level of defensive or avertive activity
P = Level of pollution

The relationships in the model can be described as follows: The number of days/hours time spent sick, (S), are a function of exposure to pesticides (E), and medical treatment (M), which can be written as follows:

$$S = S(E, M) \tag{5-1}$$

Medical treatment are many including hospitalization, visits to a doctor or simply taking home made self-treatment, nevertheless incurring a monetary and time cost.

The level of exposure level (E) is a function of the level of avoidance through avertive/defensive behaviour (D), and the level of pollution, P

$$E = E\,(D, P) \tag{5-2}$$

The avertive/defensive activities could include: using protective clothing, wearing masks, gloves, shoes during spraying, hiring labour to spray pesticides, etc. Purchasing protective gear costs money as well as time spent purchasing and maintaining them.

Substituting for E in equation (5-1) gives the health production as:

$$S = S\,(D, P, M) \tag{5-3}$$

[6] Farmers are exposed to pesticides in small quantities on a typical pesticide spraying day but nevertheless suffer from many morbidity effects. For recorded morbidity effects among farmers please see chapter three.

An individual is assumed to choose D and M to maximize his utility (welfare)[7], which is a function of S and other variables such as non-sick leisure time, income, etc. From this maximization process one can measure the value of reduced/avoided exposure to pollution/disutility of sick days in terms of the amount of income an individual has spent on D and M to keep him as well off as before. The techniques used for this purpose, as explained earlier, are known as the avertive behaviour and the cost of illness approaches and are indirect methods in measuring the value of reduced/avoided exposure to pollution. The direct approach is known as the contingent valuation approach.

Any morbidity affects the individual's utility (welfare) by causing discomfort, pain, suffering and also affects the amount of time (and possibly money) available for the consumption of goods and leisure activities, X. The utility (welfare) function[8] is then written as:

$$U = U\ (X, S) \qquad (5\text{-}4)$$

or equivalently

$$U = U\ [X, S(D,P,M)] \qquad (5\text{-}5)$$

The time spent sick, also has an impact on the budget constraint by reducing the time spent at work and hence the amount of income earned. Time spent sick also affects leisure activities. Then, the individual faces the following budget and time constraints.

$$XP_X + DP_D + MP_M = wT_W + I \qquad (5\text{-}6)$$

$$XT_X + DT_D + MT_M + S + T_W = T \qquad (5\text{-}7)$$

P_K = Price per unit of K, for K = X, D, and M
T_K = Time per unit of K, for K = X, D and M
T_W = Time spent working[9]
w = The individual's wage rate
I = Non wage income
T= Total time available

Equations (5-6) and (5-7) can be combined into a "full income" constraint by assuming all time is valued at the wage rate[10], and defining a combined monetary value and time cost: $Q_K = P_K + wT_K$. Using w as the value for all time assumes that individuals choose to work to the point where the marginal benefits of working (the wage earned) just equal the marginal costs in terms of the value of time lost from

[7] Here we refer to utility as the well being (welfare) of the individual.
[8] In order to include risk aversion we need to use an expected utility function and thereby introduce uncertainty in our model. For a discussion and graphical exposition of risk aversion please see Johansson (1995).
[9] Here we should refer to earnings from work from the farm since farmers are self-employed. However, for ease of presentation we use wT_w.
[10] For example, see Kenkel (1994) who values all time at the wage rate.

other activities. In this simple model, only the private costs of defensive and medical care borne by the affected individual are considered. No subsidized goods (medical care or avertive behaviour) are taken into consideration. Hence, the full income constraint can be written as:

$$XQ_X + DQ_D + MQ_M + wS = wT + I \qquad (5\text{-}8)$$

The problem for the individual is to choose the averting and medical treatment activities, D and M, the expenditure on all other goods and leisure activities, X, that will maximize function (5-5) subject to (5-8).

It is now possible to show the relationships among the three approaches used to obtain the willingness to pay bids. As stated in Cropper and Freeman III (1991, p.195), an individuals willingness to pay for a small change in the level of pollution, P, is defined as the largest amount of money that can be taken away from him without reducing his utility. For this reason we consider the expenditure function. Formally, economists define the individuals expenditure function as the minimum value of expenditure minus the wage income necessary to keep his utility at a given level, U^0, or in equation form as:

$$E = \min[XQ_X + DQ_D + MQ_M + wS - wT + m\{U^0 - U\{X, S(D, P, M)]\} \qquad (5\text{-}9)$$

Where E[11] is expenditure and m is the Lagrangian multiplier. By applying the envelope theorem to (5-9) and substituting from the first-order conditions for expenditure minimisation, willingness to pay for a marginal change in P, $\partial E/\partial P$, is given by

$$WTP = -(\partial S / \partial P)Q_M / (\partial S / \partial M) = -Q_M(\partial M / \partial P) > 0 \qquad (5\text{-}10a)$$

$$WTP = -(\partial S / \partial P)Q_D / (\partial S / \partial D) = -Q_D(\partial D / \partial P) > 0 \qquad (5\text{-}10b)$$

$$WTP = (\partial S / \partial P)WTP_S \qquad (5\text{-}10c)$$

Note: Proof is shown in Appendix 5.1

Where $WTP_S = (\partial E/\partial S)$. As Cropper and Freeman III point out, it is possible to show from the above three equations that willingness to pay is given by the change in sick time associated with a change in the level of pollution, $\partial S/\partial P$, multiplied by the marginal cost of pollution. The marginal cost of pollution can be any medical expenditures and other costs associated with ill health (cost of illness expenditures), avertive behaviour (defensive expenses) or simply what an individual would be willing to pay to bring about a change in exposure to pollution and the resulting ill health (the direct contingent valuation approach). A reduction in the number of sick days can be brought about with increased medical expenditures and associated costs,

[11] Here we use the same notation to describe expenditure as used in Cropper and Freeman III (1991) model.

i.e. $\partial S/\partial M$, or alternatively by increased averting behaviour, i.e. $\partial S/\partial D$ or even by a combination of all these activities.

As shown in (5-10a) WTP can be estimated from the changes in the medical expenditures and associated costs brought about by changes in pesticide pollution, $\partial M/\partial P$, which are reflected in the costs of mitigating behaviour, Q_M. Hence WTP = $Q_M(\partial M/\partial P)$. Similarly for averting behaviour, as shown in (5-10b), the WTP can be estimated from costs incurred on defensive/averting activities, Q_D, as a result from a marginal change in defensive/averting behaviour brought about by a marginal change in pollution, $(\partial D/\partial P)$. Hence, the WTP = $Q_D(\partial D/\partial P)$. As equation (5-10c) shows, the WTP for a marginal change in exposure to pesticides equals the resulting change in sick time as a result of a change in sick time, $\partial S/\partial P$, times the value of a marginal change in sick time, WTP_S. To a rational person the latter must in theory be equal to the marginal cost of bringing about a change in sick time [Cropper and Freeman III (1991)]. Dickie et al (1986) as quoted in Cropper and Freeman III (1991) show that the results in (5-10) can be generalized to the case of many symptoms and various forms of averting and mitigating behaviour.

As Cropper and Freeman III (1991) point out, computing equations (5-10) requires an estimate of the production function for the health outcome of interest and an evaluation of the numerator and denominator of the equation at current levels of all inputs. However, in practice this is difficult to implement. Harrington and Portney (1987) point out that since individuals do take defensive/avertive measures to mitigate or even prevent the effects of pollution, what is observed in cross-sectional studies is the total rather than the partial effect of pollution on health. For these reasons as shown by Cropper and Freeman III (1991), an alternative expression for WTP should be considered. Following Harrington and Portney (1987), willingness to pay can be written as shown in equation (5-11) which shows that willingness to pay can be written as the sum of the value of lost time w(dS/dP) and the disutility of the changes in illness $(\partial U/\partial S)$ $(dS/dP)/\lambda$ plus the observed changes in averting and mitigating expenditures, $Q_M(dM/dP)$ and $Q_D(dD/dP)$.

$$WTP = w\,(dS/dP) + Q_M\,(dM/dP) + Q_D\,(dD/dP) - \frac{\partial U/\partial S}{\lambda}\,dS/dP \qquad (5\text{-}11)$$

Note: Proof is shown in Appendix 5.2.

where $\lambda = 1/m$, the marginal utility of income, converts the disutility of illness $\partial U/\partial S$ into monetary values. An important difference between (5-11) and equations (5-10) is that as Cropper and Freeman III (1991) show is that the WTP equation (5-11) consists of total derivatives while equations (5-10) consist of partial derivatives. Furthermore, in equations (5-10), the three approaches have been derived separately while in (5-11) all the three approaches are in one equation. In fact, (5-10c) is similar to (5-11) because, it too, shows the direct (contingent valuation) question approach. However, equation (5-11) goes further in showing the various components an individual would consider in deciding on his willingness to pay bid[12].

According to (5-11) the true willingness to pay (which is the direct contingent valuation approach) to avoid an increase in pollution, therefore, consists of the amount resulting from COI approach [the first two terms on the RHS] plus the amount resulting from avertive behaviour approach (third term) and the monetary value of the disutility of pollution induced illness (fourth term). An individual directly asked, using the contingent valuation approach for his willingness to pay to avoid direct exposure to pesticide pollution would consider all expenditures shown in (5-11) in revealing his willingness to pay bid.

Equation (5-11) also implies that only if the defensive measures undertaken is inadequate then the first two terms and the fourth term can exist. On the other hand, if defensive measures undertaken are sufficient, then there will only be defensive expenditure. Hence, depending on the adequacy of the defensive expenditures, the first two terms and the last term can be big or small. If defensive expenditure undertaken is small (inadequate) then the first two terms and the last term is large and vice versa. Hence, as shown by Chestnut et al. (1988) defensive expenditure is a good measure of the WTP when the defensive expenditures undertaken is sufficient to reduce/avoid all illnesses, including loss of utility.

As Harrington and Portney (1987) point out that if $dS/dP > 0$ then the marginal WTP in contingent valuation studies always exceeds the sum of changes in defensive expenditures and cost of illness. Only if this derivative is negative is the sum of the cost of illness and defensive expenditures an overestimate. Harrington and Portney (1987) compare their results with those obtained by Courant and Porter (1981) who investigated the suitability of defensive expenditures alone as a measure of the benefits of environmental improvements. They show that defensive expenditures over or underestimate WTP depending on the dose-response function, although an underestimate would be the most likely outcome. Harington and Portney (1987) agree on this point. The only way that defensive expenditures can exceed contingent valuation WTP is for dS/dP term to be negative [Harrington and Portney, 1987)]. In other words, individuals would have to respond to an increase in pollution by increasing defensive expenditures so that there are no health effects among those exposed to pollution. Likewise, the only way the cost of illness can overestimate the contingent valuation WTP is for dD/dP to be negative – (U_S/λ dS/dP), in fact [Harrington and Portney, 1987)]. They go to point out that "although nothing in the model prevents either of these outcomes, both would be extremely unlikely in practice".

For the Ph.D. thesis, a questionnaire was used to collect data on the private costs of illnesses (including all private medical expenditures and lost time), defensive expenditures and also a contingent valuation question was administered (the questionnaire used is discussed in detail in chapter six). It was found that in addition

[12] See Kenkel (1994, p.6) who also states that theoretical models suggest that WTP reflect these four components.

to taking defensive expenditures, farmers also incurred large medical and time costs as a result of illnesses arising from pollution. This implies that, although farmers took precautions to avoid ill health arising from exposure to pesticides, they were inadequate and hence suffered medical and time costs due to pesticide exposure related illnesses. In such a case, a farmer also suffers from pain and suffering. Therefore, a farmer in answering a contingent valuation question for WTP to avoid exposure to pesticides would take into account all these costs in stating his contingent valuation bid.

In this thesis it is hoped to estimate the cost of illness and defensive expenditures incurred due to direct exposure to pesticides and then discuss the results of the contingent valuation study and see whether the contingent valuation results exceed the cost of illness and the defensive expenditures. This is our hypothesis. This is also a test of validity of the contingent valuation study.

The next chapter discusses in detail the methods and issues in questionnaire development and gathering of data. The questionnaire used to gather data is also discussed.

Appendix 5.1

Let us consider the minimum expenditure function which is shown in (5-9):

$$E = \min [XQ_X + DQ_D + MQ_M + wS - wT + m \{U^0 - U \{ X, S (D, P, M)]\} \quad (1)$$

Applying the envelope theorem to (1) we get

$$\partial E/\partial P = w (\partial S/\partial P) - m (\partial U/\partial S) (\partial S/\partial P) = (\partial S/\partial P) [w - m (\partial U/\partial S)] \quad (2)$$

$$\partial E/\partial S = w - m (\partial U/\partial S) \quad (3)$$

Then taking the first order conditions for expenditure minimization we get:

$$\partial E/\partial D = Q_D + w (\partial S/\partial D) - m (\partial U/\partial S) (\partial S/\partial D) = (\partial S/\partial D) [w - m (\partial U/\partial S)] + Q_D = 0$$

From which you get

$$[w - m (\partial U/\partial S)] = - Q_D (\partial D/\partial S) \quad (a)$$

$$\partial E/\partial M = Q_M + w (\partial S/\partial M) - m (\partial U/\partial S) (\partial S/\partial M) = (\partial S/\partial M) [w - m (\partial U/\partial S)] + Q_M = 0$$

From which you get

$$[w - m (\partial U/\partial S)] = - Q_M (\partial M/\partial S) \quad (b)$$

Now substituting (a), (b) and (3) in (2) as shown below we get the results shown in (5-10)

Substituting (a) in (2) we get

$$\partial E/\partial P = - Q_D (\partial S/\partial P)/(\partial S/\partial D) = -Q_D (\partial D/\partial P) > 0 \quad (4)$$

Substituting (b) in (2) we get

$$\partial E/\partial P = - Q_M (\partial S/\partial P)/(\partial S/\partial M) = -Q_M (\partial M/\partial P) > 0 \quad (5)$$

Substituting (3) in (2) we get

$$\partial E/\partial P = (\partial S/\partial P) (\partial E/\partial S) = (\partial S/\partial P)WTP_S \quad (6)$$

Appendix 5.2

Let us consider the total differential of S, where S = S (D, P, M)

$$dS = (\partial S/\partial D)\ dD + (\partial S/\partial P)\ dP + (\partial S/\partial M)\ dM \qquad \text{(A)}$$

Then taking the total derivative of S with respect to P we have:

$$dS/dP = (\partial S/\partial M)\ (dM/dP) + (\partial S/\partial D)\ (dD/dP) + \partial S/\partial P \qquad \text{(B)}$$

We can deduce the partial derivative, $(\partial S/\partial P)$:

$$\partial S/\partial P = dS/dP - (\partial S/\partial M)\ (dM/dP) - (\partial S/\partial D)\ (dD/dP) \qquad \text{(C)}$$

Then from (5-10c) we know

$$WTP = \partial S/\partial P\ WTP_S$$

And from appendix 5.1 we know

$$WTP = \partial S/\partial P\ (w - m\ \partial U/\partial S) \qquad \text{(D)}$$

Substituting (C) in (D), we get:

$$WTP = [dS/dP - (\partial S/\partial M)\ (dM/dP) - (\partial S/\partial D)\ (dD/dP)]\ [(w - m\ \partial U/\partial S)] \qquad \text{(E)}$$

Rearranging we have

$$WTP = w\ dS/dP - [(\partial S/\partial M)\ (dM/dP)]\ [(w - m\ \partial U/\partial S)] - [(\partial S/\partial D)\ (dD/dP)]\ [(w - m\ \partial U/\partial S)] - m\ [(\partial U/\partial S)\ (dS/dP)] \qquad \text{(F)}$$

From the first order conditions in (5-9) we get

$$Q_M + w\ \partial S/\partial M - m\ \partial U/\partial S\ \partial S/\partial M = 0 \Leftrightarrow -Q_M = (w - m\ \partial U/\partial S)\ \partial S/\partial M \qquad \text{(G)}$$

$$Q_D + w\ \partial S/\partial D - m\ \partial U/\partial S\ \partial S/\partial D = 0 \Leftrightarrow -Q_D = (w - m\ \partial U/\partial S)\ \partial S/\partial D \qquad \text{(H)}$$

Then by substituting in (F) we get

$$WTP = w\ (dS/dP) + Q_M (dM/dP) + Q_D (dD/dP) - m\ \partial U/\partial S\ dS/dP \qquad \text{(I)}$$

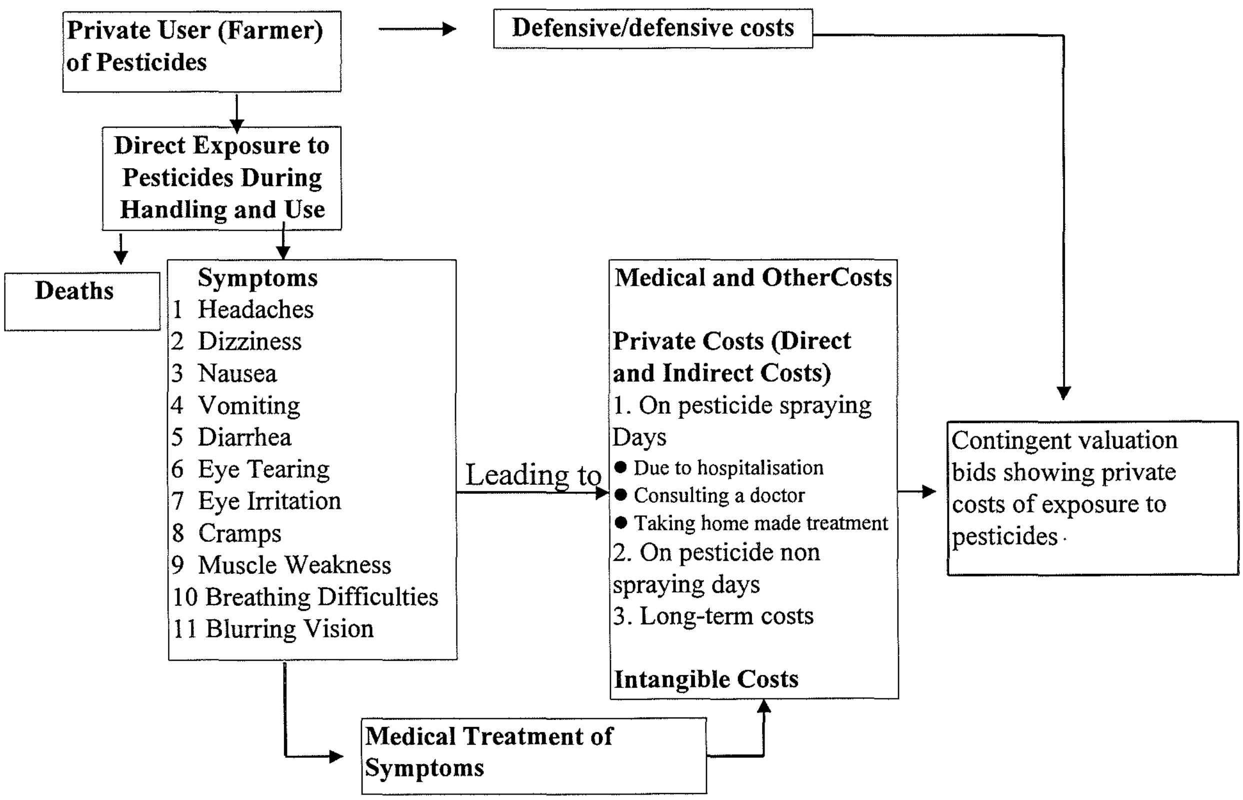
CHAPTER 6

METHODS AND ISSUES IN QUESTIONNAIRE DEVELOPMENT AND GATHERING OF DATA

Questionnaire Development

The main purpose of the field study was to gather the necessary data to estimate the costs of pesticide pollution using the three valuation techniques and thereby obtain willingness to pay bids/values for a reduction[1] in direct exposure to pesticides by farmers and to carry out econometric work. The work involved developing and testing a survey questionnaire for collecting the necessary information from farmers who use pesticides on a regular basis. The questionnaire was designed to collect information on all aspects of pesticide use, awareness on pesticide poisoning, health status of interviewee, short-term private costs resulting from pesticide use on pesticide spraying days, non spraying days, precautionary/defensive costs, long-term costs of pesticide pollution, the contingent valuation question and socio-economic data. Figure 6.1 shows a graphical illustration of the health behaviour model presented in chapter five as it is applied to farmers directly exposed to pesticides during handling and spraying on their farms.

Figure: 6.1 Linkage Between Exposure to Pesticide Pollution and Various Private Costs Including Contingent Valuation Bids



[1] In the contingent valuation approach the respondents were asked how much they were willing to pay to avoid direct exposure to pesticides while for the cost of illness and the avertive behaviour approaches, we infer the willingness to pay for a reduction in exposure to pesticides in the collected data.

The field survey study used three different valuation techniques shown in figure 6.1 and described in chapter four to estimate the costs of direct exposure to pesticides and thereby obtain willingness to pay bids/values to reduce/avoid direct exposure to pesticides by farmers during handling and spraying on farms. The techniques used were the costs of illness, the avertive/defensive behaviour approach and the contingent valuation approach[2].

The costs arising from illnesses due to direct exposure to pesticides are large. These costs can be broken down into private and public costs. The private costs are all costs borne out by the person exposed directly to pesticides during handling and spraying on the farms. These costs are direct, indirect and intangible. The public costs are all costs borne out by public expenditure. They include all government hospital costs (including hospitalization, free physician consultation, various laboratory tests, ambulance costs and other facilities offered). Other public costs include: subsidized transport, government insurance against crop losses, direct pest attacks or animal damage, etc. Since the estimation of all costs is too big a task for a Ph.D. study, the estimation of costs have been narrowed down to estimate only the private costs to the user arising due to direct exposure to pesticides. In the case of direct exposure to pesticides during handling and spraying, it is possible to isolate ill effects arising from exposure to pesticides [for example, see the work of Jeyaratnam (1982a); Turnbull et al.(1985); Rola and Pingali (1993); Forget (1991); Antle and Capalbo (1994); Antle and Pingali (1994a); Pingali and Roger (1995); Siyayoganathan et al.(1995); Hoyek et al.(1997); Antle et al. (1998); Crissman et al. (1998); Cole et al. (1998). This is useful, not only to estimate the costs, but also to make the contingent valuation question clear to the respondents.

In estimating the private costs via the cost of illness approach, the costs arising on pesticide spraying days, non-spraying days and long-term costs are considered. Furthermore, the costs arising on pesticide spraying days were subdivided into costs incurred due to hospitalization (Serious), consulting a doctor (moderate) and self-treatment (mild)[3]. All costs in each of the categories were subdivided into direct and indirect. We show below the various costs that were considered, both direct and indirect. The direct costs for a typical spraying day and non-spraying day were medical costs which includes: physician visits (i.e private consultation fees); private hospitalization costs; laboratory costs; emergency room visits; medication/drug costs. Other direct costs associated with pesticide related illnesses were: dietary expenses resulting from illnesses; travel costs associated with medical treatment; hired labour due to inability to work and any other losses incurred due to hospitalization from pesticide poisoning (for example, crop damage due to inability to look after crops and damage from animals). The indirect costs were: time spent on traveling/seeking treatment; loss of work days/hours on farm; loss of work efficiency on farm; leisure time losses; hired labour due to inability to work.

[2] The contingent valuation question, however, has been framed to obtain willingness to pay bids to avoid direct exposure to pesticides.

[3] The nature of treatment has been subdivided into three components so that the calculation of the costs incurred becomes more effective and detailed. This also enables the farmers to remember the various costs incurred more easily. It is possible that a farmer may have experienced any two or all of the three categories of treatment in a given year.

The private costs were collected for non spraying days as well, since many farmers complained that the after effects of direct exposure to pesticides appeared a day or a few days after spraying too, and hence incurred costs. In addition to the costs suffered due to acute symptoms (short-term), the costs due to chronic (long-term) illnesses which were diagnosed as arising due to direct exposure to pesticides were also calculated. Some of the long-term private costs calculated were due to: swellings in body; chest pains; loss of memory; numbness of fingers; blindness and other illnesses specified by the farmer.

It is clear from the wide array of data that had to be collected, not all private costs incurred would have been taken into account. This was due to time, financial and inherent difficulties involved in capturing such costs. Hence, the private costs estimated for cost of illness and avertive behaviour are lower bounds. This is made clear in the chapters on cost of illness and avertive behaviour approaches. All the costs considered were for a year (i.e June 1995-June 1996). For the calculation of long-term costs for a year, all the costs incurred during the period under consideration (i.e. June 1995-June 1996) diagnosed as arising from long-term illnesses were considered. In other words, the costs incurred for a single year due to a long-term illness were considered. It must be stated here that all the private costs estimated have been obtained from direct interviews rather than examining records (for example, receipts, insurance, etc.). Hence, this approach could result in some selection bias. However, it must be noted that in rural areas of developing countries receipts are rarely issued for purchased goods. Even when they are issued, no record is maintained by the people. Insurance to cover for costs of illnesses are almost non existent. Hence, it is not possible to examine such records either as is often done in developed countries to estimate the costs of ill health.

Although only some of the costs mentioned above are considered in this thesis, the estimated costs, however, are still useful. The public costs are not considered in this study. Hence the medical costs that are not borne by the individual would not be expected to be reflected in the estimates of willingness to pay derived from the individuals behaviour (cost of illness approach) or from the direct willingness to pay question (contingent valuation approach). Medical costs borne by hospitals are, however, a cost to society and should be considered in a comprehensive analysis of the effects of a policy that would result in changes in 'direct exposure to pesticides' health effects, both short and long-term[4]. Furthermore, medical care information is also important for the health production function. However, none of these costs are considered in this study due to the difficulty in obtaining such data. In addition to the various costs farmers have to incur due to illnesses arising from direct exposure to pesticides during handling and spraying, farmers also incur costs on precautions taken. One of the valuation techniques (avertive behaviour) is designed to capture these costs and thereby infer willingness to pay bids which can be used to value a reduction in direct exposure to pesticides. One section of the questionnaire was devoted to

[4] Information provision on the expected health effects and costs involved would highlight the seriousness of the problem of direct exposure to pesticides. This would influence users of pesticides to adopt a more careful approach to the handling and spraying of pesticides and would also influence the state to regulate and impose restrictions on the availability and handling and spraying of pesticides on the farms.

capturing these costs. Hence, data was collected on defensive/precautionary measures undertaken to reduce direct exposure to pesticides during storage, handling and spraying. The defensive costs that were calculated, as shown in the questionnaire (please see Appendix 6.1), were: wearing protective clothing; wearing masks; wearing gloves; wearing shoes; using the high quality sprayers; building special storage units; any other costs such as labour hired. The various amounts used and costs were recorded. Although these questions help the respondents with defensive expenditures to focus upon their own revealed willingness to pay to reduce direct exposure to pesticides, it was difficult to collect all defensive/precautionary costs such as time spent traveling and purchasing them, cleaning them and various other defensive measures undertaken such as poojas (offerings made to the Gods), switching to crops that do not need the application of pesticides, etc. It would have been useful for this study to have considered 'crop switching' to less profitable crops but need less pesticides to cultivate them. This was, in fact one of the original questions of the pilot study. However, during the pilot study it was found that it was extremely difficult to gather such data from the farmers. It was extremely time consuming and as a result affected the quality of the data gathered in the rest of the questionnaire. It was thought that a study of this nature should be conducted separately if the quality of the data collected are to be safeguarded.

The first two approaches, as mentioned in chapter four, are indirect ways of obtaining willingness to pay bids to reduce direct exposure to pesticides while the third technique used in this study, is a direct approach to measuring the value of avoiding direct exposure to pesticides. The first two approaches are lower bounds for eliciting the willingness to pay bids to reduce direct exposure to pesticides. The cost of illness approach takes into account only the direct and indirect costs, some of which are difficult to compute and hence are not recorded. Furthermore, this approach does not consider intangible costs such as pain, suffering and discomfort. In the case of precautionary/defensive cost approach, we consider only the direct costs. Difficulty in gathering data on certain defensive costs incurred, for example, for goods with multiple uses and benefits such as hand sprayers prevent us from estimating every cost incurred on defensive behaviour. Indirect costs such as time spent purchasing defensive gear, maintenance, etc. are also not included in this study due to the difficulty in gathering such data. On the other hand the third approach, the contingent valuation method, takes into consideration all these costs and hence conceptually, is a complete measure. The contingent valuation approach asks questions about the amounts respondents would be willing to pay to avoid direct exposure to pesticides. By the time the contingent valuation willingness to pay question was asked (which was almost at the end of the questionnaire), the respondents were well aware of the dangers and costs of direct exposure to pesticides. The questionnaire is carefully designed to capture costs in each of the approaches described. The questionnaire, as a result is divided into nine sections, together with an introduction.

Issues In Questionnaire Design

In designing the questionnaire, careful attention was given to the best and the optimum gathering of data which covered not only the relevant information on the use of pesticides, awareness of pesticide poisoning, the health effects of direct exposure to pesticides and gathering of socio-economic data, but also to gather the required information/data for the three valuation techniques used in the Ph.D. study. Great care was taken to avoid the many difficulties that arise in obtaining such information, especially with respect to the contingent valuation question. The various steps that were taken to avoid problems for the three techniques are discussed in this section. We first discuss the contingent valuation approach since gathering bids from this approach is a very complex and precise exercise.

As mentioned in chapter four, contingent valuation is a widely used tool (despite its many drawbacks) and have been widely discussed during the last decade suggesting ways and means of improving the technique [for example, see Cummings et al. (1986) and Mitchell and Carson (1989) Fabian and Tolley (1994); Journal of Economic Perspectives (1994); Carson (1998); Whittington (1988)]. Many issues have also emerged concerning the design and application of contingent valuation approach in developing countries that demand careful attention in order to obtain high quality results. These issues have been discussed and revised by various authors during the last few years. Wasikie (1996), for example, has reviewed the various issues that have been discussed in the literature and points out that several authors such as Tisdell (1986); Thomas et al. (1991); Boadu (1992); Krupnick et al. (1993); Munasinghe (1993); Paulsen (1993); Shyamsindar and Kramer (1993); Whittington and Swarna (1994); Swallow and Wouldyalow (1994) have noted potential problems in applying contingency valuation in developing countries. Some of the problems that have been discussed include: very low income levels, illiteracy, partial monetization of certain rural economies, unfamiliarity with hypothetical contingent valuation questions, translation of contingent valuation studies to suit the needs of a specific country, the effect of the presence of listeners, etc.

A major problem with contingent valuation in developing countries as Carson (personal com., June, 1998) points out is that of finding a plausible payment vehicle for the good in question. In developing countries, especially in the rural areas, it is difficult to suggest taxes or fees as the payment vehicle. This is partly because taxes are unfamiliar in rural areas. Furthermore, implementing a tax in the rural sector is also difficult. Hence, the tax as a payment vehicle may not be suitable and realistic to respondents. Therefore, as Carson points out, there is a great difficulty in finding a plausible and a realistic payment vehicle for the good in question.

Furthermore, certain rural economies are not fully monetized and such economies still prefer to barter commodities. Hence, a cash payment becomes inappropriate. Taking this problem into consideration Shyamsunder and Kramer (1993) have estimated the welfare losses resulting from land use restrictions associated with a newly established national park in Madagascar where researchers have denoted contingent valuation questions in baskets of rice. Another solution put forward to overcome the problem of measuring a commodity in cash has been to frame contingent valuation questions in terms of time rather than money. Swallow and Woudyalew (1994); Echessah, et al. (1997) have found that more respondents were willing to contribute labour than money. These two studies were conducted to evaluate the benefits of tsetse fly control in Ethiopia and Kenya respectively to reduce illness in humans. Dixon and Sherman (1990), too, point out that in remote villages or areas with migrating tribes, many things may be exchanged rather than bought and sold. One suggestion Dixon and Sherman (1990) put forward to overcome dependence on a monetary alternative is the costless-choice method. Here, it is suggested that people can be given the choice of a certain environmental and several alternative goods. For example, they point out that villages may be asked what they would be willing to accept in exchange for not hunting in a wildlife sanctuary. The choice they recommend could be in the form of cattle, rice, firewood, or even land which has a direct benefit on their daily lives.

Whittington et al. (1990) also discuss the problems concerning very poor and illiterate population in obtaining reasonable consistent answers. The level of literacy is a major issue since contingent valuation questions can be misinterpreted or misunderstood. Much time has to be spent in explaining the good that is about to be valued and the payment vehicle made realistic. Whittington et al. (1990), however, from their study point out " that it is possible to do a contingent valuation survey among a very poor, literate population and obtain reasonable, consistent answers". Whittington et al. go on to point out that there is no major problem with either starting point bias or hypothetical bias. They point out that the "evidence with regard to strategic bias is less conclusive, but neither the admittedly limited test for strategic bias nor the experience of the numerators indicated that it was a problem" [Whittington et al (1990)]. Whittington et al. (1992) also point out from a study carried out in Nigeria to evaluate rural households' willingness to pay for public taps and private connections to improve drinking water systems that the time given to respondents to think about their responses to value questions, too, affects the answers given by the respondents. As Whittington et al. (1992) point out, respondents may simply need more time to think about their decisions, and that discussing the matter with their neighbours is a good way of analysing the pros and cons of the proposed project.

Kwak and Russell (1994) also interestingly point out the problems encountered with respect to translating a contingent valuation study to meet the needs of a specific country. Their study involved translating a contingent valuation study to be applied in Korea. They point out that such a translation has to be 'country and culture' specific if the contingent valuation survey is to be applied successfully. Dixon and Sherman (1990) also point out that since contingent valuation questions rely on hypothetical situations, it is important that the situations are described clearly and completely. Also due to the prevalence of illiteracy and other factors in rural areas of developing countries, it is important to use visual aids and cite examples which are appropriate to various communities which can as Dixon and Sherman (1990) state "yield surprisingly robust results".

Whittington (1998) provides further new evidence on issues that have emerged on the design and implementation of contingent valuation surveys in developing countries. His discussion is focused on five main issues. They are: (a) explaining to enumerators what a contingent valuation study is all about; (b) interpreting responses to contingent valuation questions; (c) setting referendum prices; (d) constructing joint-private contingent valuation scenarios; and (e) ethical problems in conducting such surveys. All these issues are discussed in detail with examples from experiences had in the field being cited. We discuss below the main issues in brief.

With regard to (a) Whittington (1998) points out that one difficulty a contingent valuation researcher faces is explaining to government officials and interviewers what the study is about. Here he points out that the concepts of economic value and "maximum willingness to pay" are often difficult for the researcher to translate and for some non economists to grasp. With respect to (b) he points out the difficulties of understanding and interpreting respondent's answers to abstract (hypothetical) questions. He sates that such problems are well founded and careful questionnaire designing is needed to overcome these problems. In (c) he discusses at length the problems encountered in setting referendum prices. Whittington points out that if the amount the enumerator asks lacks credibility, the respondent is unlikely to answer the question on the basis of the price asked. Hence, there is difficulty in setting the right referendum prices and when an economy is semi monetized the problems become more complicated. Another problem encountered is the use of different prices in a referendum approach. Whittington states "Our use of a referendum approach with different prices may well have increased public uncertainty and confusion about the costs of improved water services in this town" (p.26). Also he points out that the goods and services described must be of value or relevance to the respondents. Another important problem that is pointed out is the tendency of the respondents to say "yes" to whatever question the interviewer asks which Whittington terms as "compliance bias". With regard to (e) Whittington points out that many of the contingent valuation studies conducted in developing countries have been concerned with estimating the demand for infrastructure services and points out that the scenarios required are much more complex than those used for surveys in environmental quality and hence it is often necessary to model jointly two households decisions namely into public and private components. He goes on to state that because these two decisions are conceptually linked to each other, it is necessary to present information to respondents about the terms and conditions of both parts of the deal. An outcome of this is that a large amount of information need to be conveyed to respondents. It is also pointed out that usually numerous questions are asked about the proposals and, therefore, it is very important that the interviewers are well trained at handling such situations and are also well informed. In (e) Whittington also discusses the ethical problems in conducting contingent valuation surveys and points out that contingent valuation research demands more than simply obtaining accurate and reliable results but also requires that "contingent valuation researchers confirm to accepted ethical standards of research with human subjects. Simply put, contingent valuation researchers must treat respondents in developing countries with more respect, as citizens rather than experimental subjects". (p.25).

In addition to these issues, several advantages, too, have been pointed out in carrying out contingent valuation studies in developing countries by Carson (per.com, June, 1998); Whittington (1998). One of the advantages that is pointed out by Whittington (1998) is that in less developed countries contingent valuation interviews are almost always conducted in person which appear to work out better. This is also a NOAA recommendation. Furthermore, both Carson (per.com, June, 1998) and Whittington (1998) point out that responses rates are high in developing countries and that respondents are often receptive to listening and considering the questions posed. They are also cheaper to conduct in developing countries than in industrialized counties as Carson and Whittington point out. This enables contingent valuation researchers to conduct large sample surveys and more elaborate experimental designs. Whittington (1998) states that it is easier to conduct contingent valuation surveys in developing countries than in industrialized countries.

These are some of the issues that have emerged from the design and implementation of contingent valuation surveys in developing countries. However, it must be pointed out that the various problems encountered in the developing world vary from country to country due to the diversity of different environments and conditions. Furthermore, even within a developing country, large differences exist between the cities and the rural areas. Therefore, as Kwak and Russell (1994) correctly point out that "each new country will turn up a new lesson". In this context, therefore, it is extremely important to carry out a pilot study to identify the endemic problems encountered in each country and thereby adjust the contingent valuation study. From such a study modifications and adjustments have to be made. Furthermore, it has also been pointed out that it is not only necessary to train interviewers but that they also have to be familiar with the surroundings of the study area and preferably be a resident of the study area who is fluent in the local language. Dixon and Sherman (1990, p.42) point out that in villages, people may be suspicious of outside interviewers and hence this could impact on the contingent valuation bids obtained.

A large number of contingent valuation studies have been carried out, especially in the last decade, in many developing countries, including Asia, Africa and Latin America[5]. Carson [personal com., (1998); Whittington (1998)] point out that many contingent valuation surveys in developing countries have focused on the provision of basic environmental services such as water and sewage. The contingent valuation studies that have been carried out concerning the demand for water services include: Whittington et al. (1989); Whittington et al. (1990); Whittington et al. (1990a); Whittington et al. (1990b); Briscoe et al. (1990); Whittington et al. (1991); Essenburg (1991); Whittington et al. (1992); Boadu (1992); Whittington et al. (1993a); Whittington et al. (1993b); Singh (1993); Altaf et al. (1993); Whittington and Swarna (1994); Kwak and Russell (1994); McPhail (1993); McPhail (1994); Griffin et al. (1995); Wasikie (1996)[6]; Hardner (1996). Gonzalez and Loomis (1997) apply the contingent valuation technique to estimate the willingness to pay for preserving in stream flows and for avoiding a dam in Puerto Rico. Whittington et al. (1993); Altaf (1994); Lauria et al. (1998) have used the contingent valuation approach to determine the demand for sanitation services in Ghana, Burkina Faso and the Philippines respectively, while Whittington et al. (1995) have carried out a contingent study for urban sewage in Indonesia. The contingent valuation approach has also been applied in developing countries to evaluate the quality of electricity services [Munasinghe (1990)] and housing services [Whittington et al. (1991a)].

[5] Whittington (1998) states that ten years ago only a few very rudimentary contingent valuation studies had been conducted in developing countries.

[6] Wasike (1996) has reviewed the above mentioned contingent valuation studies in detail for his Ph.D. dissertation. Essenburg (1991), too, has carried out a contingent valuation study of water services for his Ph.D. dissertation. Essenburg's study was carried out in the Philippines while Wasike's work was carried out in Kenya.

In addition to these studies, many contingent valuation studies have also been conducted on outdoor recreation (referring to surface water quality), for example, by Choe et al. (1996) to determine the recreational valve of wildlife viewing [Brown (1989); Mungatana and Navrud (1993); Navrud and Mungatana (1994); Shultz and Pinazzo (1997)], to determine the value of rainforests [Peters et al. (1989); Kramer et al. (1995), forests (Adger et al. 1994)], forest reserve value of indigenous peoples [Adamowicz (1998)], conservation of national parks and forests, biodiversity and natural resources and wildlife utilization management [Grandstaff and Dixon (1986); McConnell and Ducci (1988); Thomas et al. (1991); Shyamsundar and Kramer (1993); Shyamsundar and Kramer (1996); Menkhaus (1994); Moran (1994); Siachoono et al. (1995); Echeverria (1995); Marter and Gorden (1996); Shyamsundar and Kramer (1993); Hadker et al. (1997)]. Smith et al. (1997) carry out a study to determine the willingness to pay for environmental services among slash and burn farmers in the Peruvian Amazon.

Furthermore, a few health studies have also been conducted using the contingent valuation in less developed countries. Swallow and Wouldyalew (1994); Echessah et al. (1997) have conducted studies to evaluate the benefits of tsetse fly control to reduce illnesses in humans. Contingent valuation studies have also been carried out to determine the willingness to pay to avoid air pollution [Krupnick et al. (1993); Alberni et al. (1997) and nuclear power plant risks, motor cycles [Liu (1992)] and hazardous chemicals [Liu et al. (1996)]. Whittington et al. (1996) carry out a contingent value survey to determine the economic benefits of malaria control in Mozambique. Other health studies include: Jimenez (1987); Birdstall (1987). Interestingly contingent valuation studies have also been carried out to determine the willingness to pay for health insurance in developing countries [Asensoohyere (1997); Mathiyazhagan (1998)]. Contingent valuation studies that have been carried out with respect to financing education include: Thobani (1983); Tan et al. (1984) and Jimenez (1987). The contingent valuation technique has become so popular in developing countries that it has even been applied to evaluate the benefits of slum improvements [Abelson (1996)], to determine the value of child survival [Weaver (1996)] and to value the time saved by taking high speed trains [Fu et al. (1995)].

Whittington (1998) predicts an increase in the number of contingent valuation studies in the years to come. He states " in light of the controversy over the use of contingent valuation method (CVM) in the United States, a large fraction of future applications of the CVM are likely to be in the developing countries" (p.21). He further points out that bilateral donor agencies and the international development banks are "increasingly putting contingent valuation techniques to use in project and policy appraisal as an art of their everyday operations work" (p.21).

Following the progress made on theoretical and practical issues, attention has been paid to three methodological areas which are the essentials in carrying out a technically correct contingent valuation study. The areas identified are: the information and preference context of contingent valuation which frames the problem for respondents and helps them research their preferences; the structure of the contingent market, which defines the good to be valued in a clear, concise, and quantitative manner; and the bidding-game process, which assists respondents in arriving at carefully thought-out, unbiased values. We discuss these three areas below.

Fabian and Tolley (1994), discussing the issues in the information and preference context, point out that the quality of answers is affected by the fact that information that respondents posses is imperfect and that thinking requires effort. In such circumstances it is recommended that contingent valuation questions be asked only after much explanation about the subject. Otherwise, many random answers could be expected. It is very important to provide as much information and background information on the subject matter, for example, about past experiences, quoting previous studies and hospital data, various ill effects, health costs and disutilities they have borne, such as loss of work days and productivity, leisure time losses, pain and discomfort. By investing time on information, the respondents are helped to invest in thought about the considerations that go into a reasoned answer. It is also very important to take note of the tedium of the respondent, lest he/she might get too bored and the whole exercise could otherwise be counterproductive. Hence, limiting the questionnaire to manageable lengths is essential. Therefore, it is extremely important to focus on the most important issues first in view of the limited time available and to avoid the various biases such as over stressing certain effects/facts and understating others. It is extremely important to introduce all issues in commonsense terms.

The next major issue is the structuring of the contingent valuation market. It is important to present the good that is being valued in a natural, believable and realistic way so that the respondents can reach a valid judgment. This is especially so when rural folk like farmers are being interviewed. Furthermore, it is essential to define the good in such a way that it can be quantified and understood by the respondents. As correctly pointed out by Fabian and Tolley (1994) such practices need much experimentation. The questionnaire for the Ph.D. study was translated into the local language and all symptoms and other terminology were well explained in a manner that was well understood by the respondents. The questions should be asked in very simple terms and several examples given before the real contingent valuation question is asked to obtain the willingness to pay bids. Because the majority or in fact all of the respondents in this Ph.D. study have had first hand experience with symptoms related to direct exposure to pesticides, it was easy to explain the contingent valuation question and extract bids that were realistic. Experience with the problem being discussed is an important issue in contingent valuation studies. On the other hand, as pointed out by Fabian and Tolley, when respondents have less experience of what is being discussed, then a special effort is needed to help the respondents imagine what it would be like to live with extreme and recurrent pain, for example, in the case of severe angina or recurrent pain of less intensity in the case of mild angina.

Once the contingent market has been discussed, it is essential also to devise a vehicle for delivery of the good to the respondent and a vehicle of payment which has been discussed widely in the literature. The delivery vehicle, too, has to be realistic, especially when rural folk are involved. Fabian and Tolley (1994) discuss some of the objections that were raised with the delivery vehicle in their angina study. They state that similar problems can arise with the payment vehicle as well. As was the case with the vehicle for delivery of the good, they recommend an abstract payment vehicle that simply asks " How much would you be willing to pay for this good?"

Despite dichotomous choice (referendum) contingent valuation questions gaining popularity over the past several years and is the choice recommended by the NOAA panel, it was not used in this study for several reasons. One major reason was that the farmers before they were asked about the contingent valuation question had already stated the costs arising from illnesses and the defensive behaviour due to direct exposure to pesticides. Hence, the respondents were already aware of the costs incurred. In such a case it was better for the farmer to give a value than for the interviewer to suggest a payment. The farmer in this case, because he himself had incurred the costs and had already mentioned most of it in previous sections of the questionnaire was the best person to give a value. As mentioned previously, Whittington (1998) points out that if the amount the enumerator asks lacks credibility, the respondent is unlikely to answer the question on the basis of the prices asked. Hence there is difficulty in setting the right referendum prices. One of the reasons why the NOAA panel recommend a dichotomous choice approach is that 'the scenario at hand lacks realism'. But in this study it was not the case since farmers had actually incurred costs. The second reason why NOAA favour a dichotomous choice format is that open ended questions invite strategic overstatement. However, for this Ph.D. study this could not be the case since, as mentioned earlier, the respondent has been answering questions on costs before the willingness to pay question was asked and hence it was easy to detect if the respondent had understood the question well and whether the bids given were overstated or not. Interestingly, Lunander (1998) in a laboratory experiment carried out for a jointly consumed private good shows that when an individual had an incentive to overstate his true willingness to pay, the dichotomous choice format yielded higher estimates of willingness to pay than open ended format questions. Lunander further goes on to state that when an individual is subjected to opposite incentives, the tests suggest no behavioral differences between the two formats. Luander (1988) goes on to suggest that the NOAA panel's conclusion that the dichotomous choice format is less inviting to strategic overstatement than open ended format is not valid when simple majority rule is substituted for a provision and payment rule introducing incentives to overstate willingness to pay.

A particular concern is that the interviewer does not suggest answers being sought. This is very important, since respondents can easily be influenced by such suggestions. There is, as pointed out by Fabian and Tolley (1994); Whittington (1998), a tendency for the respondents to please the interviewer with the answers and/or to demonstrate their wisdom by giving answers which they believe the interviewer is looking for. This is especially so if monetary payments are made to conduct an interview. Other important issues that should be borne in mind are: "Anchoring", i.e. people seize upon a convenient, easy bid amount and stick to it across bids because they have little information-based incentive to do otherwise. Starting point bias, often seen as a weakness of iterative bidding, is probably more fundamentally a problem of limited investment in information and adequate researching of preferences on the part of the bidder. Furthermore, as more and more bids questions are asked about similar contingent market goods, it become increasingly difficult for the respondents to recognize meaningful variations in value. What is meant here is that a questionnaire should not include many contingent valuation questions, and more so if the questions pertain to measuring the willingness to pay to reduce or avoid each of the illnesses studied. In such a case, the first bid given to reduce or avoid an illness (symptom) may influence the next contingent valuation question asked to reduce or avoid another illness or symptom. In other words, the respondents may find it difficult to recognize the variations in the value of two illnesses (symptoms) and thereby result in the two bids being almost similar in value. Hence, it is always better to ask fewer valuation questions in a given questionnaire at a given time, especially if other questions pertaining to other approaches are being asked. These issues are, however, not relevant for this Ph.D. study since only one contingent valuation question was asked. However, for a more thorough discussion see Fabian and Tolley (1994). They also draw attention to the problems caused by extremely high bids and extremely low bids that are given without considering budget constraints in the former and lack of attention given in the latter case which are important issues that are encountered when obtaining bids. Fabian and Tolley (1994) discuss all these issues in detail.

As we saw in the last section, a certain well rehearsed and tested procedure had to be followed when a hypothetical question is involved in obtaining a verbal contingent valuation bid. In addition to this, the problems encountered in carrying out contingent valuation questions in developing countries, as discussed earlier, have also to be borne in mind when carrying out such studies in these countries. Though similar difficulties do not arise in the cost of illness and the avertive behaviour approaches, these two approaches require a considerable volume of data, both direct and indirect. The data are both private and public. We make a distinction between private and public costs because government hospital treatment is free of charge in Sri Lanka. Hence, the patient does not incur many costs on treatment[7]. When the costs have been recorded, then the whole issue becomes a straight forward affair. But usually this is not the case. For the public costs, usually the items used may be available (for example, in a hospital) in various records. For these items, we have to give a market value. In the case of private costs, if no records of costs are available, then we have to rely on the respondents answers. For indirect costs, too, we have to rely on the respondents answers and then impute market values. We discuss below some of the issues involved in obtaining data with respect to the cost of illness approach.

Although the cost of illness approach has undergone several refinements and improvements since the 1950s and 1960s, including the gathering of necessary data, several issues have to be borne in mind. The costs of illness arising from either pollution or any other illness are very large, both to the individual and the society at large. Hence, it is important to distinguish between private and public costs in such a study and decide whether to undertake a study to estimate all the costs or any particular costs according to resources, time and availability of data. Also a time period must be decided and usually it is the yearly costs that are estimated. Usually, public costs are written costs available in hospital records while private costs in most

[7] Although medical examination and treatment is free in Sri Lanka certain prescriptions may have to be purchased from a pharmacy and laboratory tests may have to be conducted in a private clinic. Furthermore, some farmers also seek treatment from private clinics.

cases, especially among rural farmers are unwritten. It is important to breakdown the various costs involved. For example, into private and public costs; direct and indirect costs and in the case of pesticide pollution, the costs arising from the severity of the illness, such as serious (requiring hospitalization), moderate (consulting a doctor), and mild (home made self-treatment). When symptoms become a regular occurrence as, for example, due to pesticide spraying, it is then important to list the costs of various items under each of these categories (see questionnaire, sections four and five in Appendix 6.1). Furthermore, costs from direct exposure to pesticides can arise on pesticide spraying days, non spraying days (for example, the following day) or long-term costs. It is important to break down the various direct and indirect costs that arise separately. These are private costs. The public (hospital) costs should be calculated separately.

Usually, the affected person is able to give estimates of the direct costs he has suffered directly. For example, traveling expenses to hospital, physician consultation fees (if privately treated), drugs purchased, special food taken, labour hired due to illnesses, damage done to crops due to inability to look after them, etc. These costs can be calculated in the form of weekly, monthly or yearly costs according to the frequency of illness (please see questionnaire, four and five). The indirect costs are even more difficult to measure. First, the number of days and hours lost, loss of efficiency etc., have to be calculated and then imputed with a market value. A similar procedure is adopted for other costs such as loss of leisure, time spent traveling for treatment, etc. The costs again are calculated on a weekly, monthly or yearly basis (please see questionnaire in Appendix 6.1).

For the estimation of public costs, the records have to be checked and usually the bed head ticket of the patient is a good guide to the amount of treatment he has had. From these records, it is possible to find out the number of days spent in hospital, doctor hours, meals provided by the hospital, treatment (drugs) and other services provided. Once these data are documented, the hospital audit office usually provides the costs for the relevant items. However, for this Ph.D. this study was not essential, since only the private costs are estimated in this study

It was important to make it known to the respondents that the visit to interview them was not from an institution aimed at paying compensation for the costs incurred due to illness. Otherwise, the costs for which no receipts are available could be exaggerated. To avoid these problems, it is better for the interviewer to first aquatint themselves with the respondents before the interview begins. It is even better, if it is possible to live in the study area, presumably with the respondents. Most of the interviewers for this study lived among the farmers and hence gathering of more accurate data became possible. Because of the unavailability of documents relating to cost accounts, the respondents calculation of some of the costs mentioned above are as tricky as the contingent valuation questions.

The estimation of costs using the avertive behaviour approach, too, involves similar problems as mentioned above. Most of the issues mentioned in the cost of illness approach also apply to the averting behaviour approach as well. In addition, the avertive behaviour approach confronts other unique problems. One such issue is the problem of decomposing joint benefits that arise from avertive behaviour. For example, hiring of labour to spray pesticides. Although the person who hires labour incurs a cost, but at the same time he may involve himself in some other activity such as irrigating the crops in another part of the farm. The benefits then have to be deducted from the costs. Only two such items are estimated in this study, namely the hiring of labour to spray pesticides in order to reduce direct exposure to pesticides and the other involves building storage facilities. In this study, it is assumed that the storage facilities are meant only for the exclusive storage of pesticides and for no other use. With respect to hiring of labour, the joint benefits are not decomposed. This is a shortcoming in this study. Furthermore, because of the difficulty of calculating the costs which have multiple uses, some costs have been deliberately avoided, for example, the cost of growing traditional varieties (which need little or no pesticides) over high yielding varieties, giving up agriculture altogether, time spent purchasing protective gear, time spent cleaning the protective gear and reading the instructions, any time spent disposing the used items, the various pooja costs (religious functions and donations made to the temple hoping the Gods will protect the farmers health), etc. Any free government or pesticide company sponsored protective gear are also not taken into account.

Method of Data Collection

Sampling Procedures

A field trip to Sri Lanka was undertaken in June, 1996 to collect the necessary data mentioned in the last few sections. The basic objective of the sample design was to obtain a representative cross section of farmers to base inferences about pesticide use and the numerous health effects arising from such use. The period from June 1995 to June 1996 was considered. Five areas were sampled from the intermediate and dry zones of Sri Lanka, where intensive agriculture is widespread. The regions covered were Yatawatte, Kandalama, Beligamuwa, Ambana and Polononaruwa in the Central and North Central provinces of Sri Lanka, within a 75-100 mile radius. Only farmers who are regular pesticide users and cultivate land not less than half and not more than three acres were selected. Large-scale cultivators of land were not considered. Farmers cultivating more than half an acre and less than three acres were selected because according to a census carried out in 1982 by the Department of Census and Statistics, the average size of land cultivated in the country 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 also specialize in growing certain food crops. As a result, the level and intensity of pesticides used and the level of direct exposure to pesticides vary from region to region. Also due to the type of crops they cultivate, often high yielding varieties, these farmers use pesticides for at least two cultivating seasons. Hence the level of hospital admission or consultation of a doctor can also vary. It was found that rice farmers used fewer pesticides than their vegetable growing counterparts. Furthermore, the frequency of pesticide use varies from season to season. In the mostly rice growing season (known as Maha), the frequency of pesticide use is less than in the more drier vegetable growing season (known as Yala). Farmers who use pesticides once, or twice a week (usually vegetable growers) were more vulnerable to suffer from acute pesticide poisoning than those farmers who used pesticides once a month or 3-5 times for the entire cropping season (usually rice growers) and get admitted to hospital or take treatment from a hospital. This is evident in the data collected.

Judgment sampling (which is a non-probability sampling technique) was employed to collect the data necessary for the study. This was owing to the impossibility of carrying out a simple random sampling study for the entire country due to financial and time constraints. Instead, judgment sampling was resorted to, according to the information and advice given by officials of the Department of Agriculture. Another reason that influenced judgment sampling was that the agriculture officials who were contacted were of the view that the region they recommended were one of the best for the Ph.D. study, which were representative of the farming community who used pesticides on a regular basis and were affected by direct exposure to pesticides[8]. Furthermore, a previous study [Sivayoganathan et al. (1995)] had been carried out, almost in the same areas covered by this study. The Sivayoganathan et al. (1995) study revealed health problems resulting from direct exposure to pesticides. The five areas from the intermediate and dry zones, covering two provinces represented a large and diverse group of farmers growing a large variety of crops (hence the quantity and variety of pesticides used) so that the sample taken would represent a cross section of farmers using pesticides in the country[9]. Although lists of farmers in the study area were available, they were found to be unreliable in selecting farmers who use pesticides on a regular basis. It was found that either the farmers were absent on the land, cultivated a small plot of land, didn't use pesticides on a regular basis or were not present on the farm the days they were visited. Hence, as a result of the problems involved, it was not possible to resort to simple random sampling techniques in collecting the data. Once again, non-probability sampling procedures had to be adopted. Convenience sampling was resorted to obtain the required samples, which was the best option available, given the problems mentioned earlier. Hence, the interviewer selected the samples from the areas under study. This was done as follows: after visiting a village in the study area the interviewer walked into a farm randomly and the farmer was asked whether they cultivated a land area which was not less than half and not more than three acres. If they did, they were asked whether they could be interviewed. Otherwise, another farm was chosen. Once an interview was completed (which was the only one conducted for the whole morning), another farm was selected from the same village (usually within one or two miles) for the

[8] With the inclusion of the other two regions that were recommended by the officials of the Department of Agriculture, a cluster sampling (a probability/random sampling technique) approach could have been used in the selection of the region/areas for the study. However, the region selected for the study was selected due its close proximity (2-3 hours journey by bus) to the interviewers home town. The climate and above all, some of the agricultural officials were known to the interviewers. The close proximity to the study area reduced the costs of the study significantly.

[9] It must be mentioned here that it would have been very useful to interview farmers who do not currently use pesticides. This would have been useful to compare the differences in the willingness to pay bids between those who use pesticides and those who do not. For example, Liu et al. (1996) compare the WTP amounts residents of urban areas are willing to pay to avoid a recent episode of an illness with WTP bids given by residents who live near large petrochemical complexes. They show that the WTP to avoid an illness recurrence of the most recent episode is three times larger for those living in areas near the petrochemical complexes than in urban areas. However, for this study this was not possible because of the difficulty in locating farmers who were not using pesticides. Furthermore, financial and time constraints prevented undertaking such a study.

afternoon, which too, fulfilled the requirements of the field study specified earlier. Very rarely were the interviewers able to conduct three interviews on a given day. On each day, a different part of the village was chosen. Once a village was sufficiently covered, another village was visited and the same procedure was applied. During the entire study period, a large number of the villages in the study areas were covered.

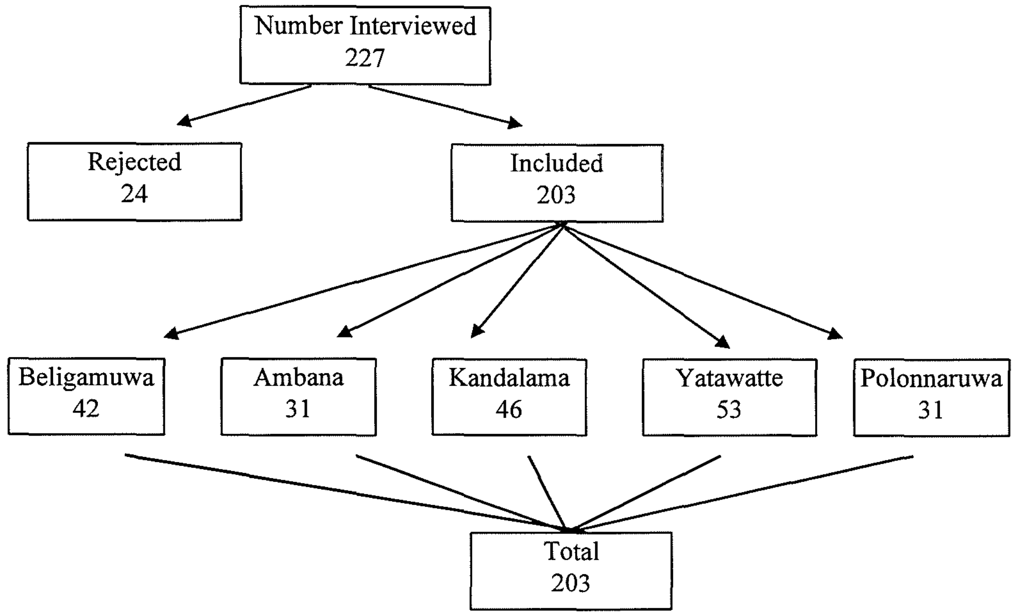
Non probability sampling techniques (as compared to probability/random sampling techniques) are not without their drawbacks and disadvantages. However, given the above mentioned problems and weaknesses encountered in not adopting a probability/random sampling approach, the best and the most feasible way of obtaining the required samples for the study was the non probability sampling techniques. For a discussion on the problems and drawbacks of using non-probability sampling techniques, please see Groebner and Shannon (1993, pp. 325-327).
The areas were visited during a three month period, July, August and September, 1996. Four local interviewers with experience in conducting interviews, were used in the study, each read dialogue and questions from the interviewer version questionnaire. The interview time ranged from 50 to 90 minutes. Immediately after concluding the interview, some additional time was spent checking out the answers for completeness of questionnaire information and review and edit interviewer notations.

Prior to the interviews a pilot study was also carried out in June and early July, 1996. A total of 27 such interviews were conducted, which made it possible to check out the viability of questions prepared to collect the necessary data. As a result, the questionnaire had to be modified greatly, removing questions that proved difficult to administer. In addition, the pilot study also enabled the interviewers to familiarize themselves with the questions and how to ask them, especially the contingent valuation question. The contingent valuation willingness to pay question was no doubt tricky, especially when it was asked from rural people who were not familiar with such questions. It had to be explained carefully in order for them to understand it. This question was also greatly modified in order to make it understandable to the farmers. Even the choice of words from the local language had to be chosen carefully so that the subjects understood the meaning of the question in it's proper sense.

Sample Size and Editing

Two hundred and twenty seven interviews were conducted in the field from all the five regions. All but two of the respondents were male. From each region a minimum of 31 farmers and a maximum of 53 farmers were interviewed. The breakdown showing subject selection and disposition are shown in Figure 6.2.

Figure: 6.2 'Direct Exposure to Pesticides' Subject Selection and Disposition



The results of the pilot study were not included among the 203 responses. In the process of collecting the data, valuable information on various types and toxicity of pesticides were recorded and many examples of externalities arising from pesticide pollution were revealed. Other information relating to pesticide use and pollution were documented and the relevant officials were also contacted during the period of study.

A few incomplete and inconsistent responses were found at the time of data tabulation. One respondent refused to give a bid value and two respondents gave zero bids. One of the respondents who gave a zero bid was found to be the father of the owner of the pesticide shop in the village. It was believed that he had an interest in the sons business. This was because he suffered from mild symptoms from pesticide spraying but yet gave a zero bid to avoid exposure to pesticides. There was another zero bid although this respondent too had suffered from ill health due to exposure to pesticides. Because of the lack of consistency of these two bidders, they were removed from the sample. The protest bid was also removed from the sample as recommended [Hanley and Spash (1994, p.55); Fabian and Tolley (1994, p.170)]. Twenty one questionnaires had also not recorded either household incomes, age, education, household size and acres sprayed. They too were removed from the sample.

The calculation of costs incurred on non-spraying days was rather difficult. This is because symptoms would appear during or soon after spraying and hence continue for a few days. The 'non spraying days' costs tried to capture any costs of illnesses that arise on any non spraying day rather than those illnesses that arise on the day of spraying. It was also difficult to calculate the long-term costs arising from direct exposure to pesticides. The costs are much larger than those captured in the study. In the next section, we discuss the structure of the questionnaire used to gather the necessary information.

Structure of the Questionnaire

The questionnaire designed for the Ph.D. study is a largely modified, Brien et al. (1994) questionnaire. As mentioned in the previous sections, it is extremely important to take into account the issues that were raised in questionnaire design and also the problems that are encountered in gathering information that is useful and worthwhile. It is important to carry out a pilot study to ascertain the feasibility of collecting such information. The questions should be asked in the respondents own language giving sufficient time for the respondent to think and answer each question. Simple language should be asked and private questions should be avoided as far as possible. We discuss below the structure of the questionnaire used to gather the necessary data for the Ph.D. study. The questionnaire is divided into nine sections with an introduction. The sections covered in the questionnaire are: the introduction, information on pesticides, awareness on pesticide poisoning, short-term private costs resulting from pesticide use, private costs on non spraying days, long-term costs on pesticide pollution, precautionary and defensive costs, the contingent valuation question and socio-economic data.

The first part of the questionnaire introduces the interviewer, briefly explains the purpose of the visit, and seeks an eligible respondent, who should have been using pesticides during the past year. The head of the household is preferred. The sex of the respondent was irrelevant[10]. After introducing the interviewer to the respondent, the purpose of the visit is explained, and the respondent is politely asked whether he would be willing to volunteer to answer a set of questions (not personal) relating to his farming activities, use of pesticides, the health effects arising from such use, their costs and a few socio-economic questions which would last approximately between 50 to 90 minutes. The respondents were not forced to volunteer nor was any monetary payment promised. Their consent was voluntary. Once their consent was sought, a comfortable place was chosen, either inside the cottage or under a shady tree on the farm. Very often other members of the household were present which became very useful in obtaining information for certain types of information, such as when the respondent was asked to show the bottles of pesticides used (they volunteered in delivering the used bottles which helped to save a considerable amount of time). It was also possible to verify certain answers given by the respondent from them and also reminded the respondent of certain illnesses and costs which the respondent failed to recall, especially due to hospitalization or taking treatment from a physician due to direct exposure to pesticides. They were also able to help with the dates of illnesses, etc.

The questionnaire was sub divided into nine sections and a section introducing the purpose of the study. Before each set of questions in the respective sections was asked, the purpose of the questions in each section was well explained to the respondents. After a broad introduction about pesticide pollution in the country in

[10] It is interesting to note that women, too, use pesticides on a regular basis in Sri Lanka.

general, the health hazards faced by farmers using pesticides on small-scale farms were explained. Previous studies carried out on the harmful effects of direct exposure to pesticides were quoted. At this point, almost all of the respondents showed their awareness to the problems of direct exposure to pesticides, because they had often suffered from such exposure or seen their kin and neighbours suffer from direct exposure to pesticides during handling and spraying. After the introduction, the first part of the questionnaire was designed to obtain information on all aspects of pesticides, including the type of crops on which pesticides are used, the cultivation season in which pesticides are used often (listing seasons and months according to intensity of use), how often they were used, name of pesticides used, acres sprayed and quantities of pesticides used, time of spraying, types of pests and diseases on which pesticides were used, etc.

The second section of the questionnaire obtained information on the farmers awareness on pesticide poisoning asking questions which ranged from their awareness to the harmful effects of pesticide use, deaths due to pesticide use on farms and whether they were aware of suicides in the area due to pesticide poisoning. Health status of the interviewee during handling and use of pesticides on the farm, was the theme of the next set of questions (section three). In the introduction they were specifically asked whether they have suffered or are suffering from any illnesses that can be attributed to pesticide spraying and handling. It must be noted here that there is a direct link between exposure to pesticides and ill health. The symptoms are very clear and farmers are able to identify whether the ill health is due to exposure to pesticides or not. Furthermore, the questionnaire recorded illnesses which have been well established by other studies [for example, Jeyaratnam (1982a); Turnbull et al. (1985); Rola and Pingali (1993); Antle and Capalbo (1994); Antle and Pingali (1994a); Siyayoganathan et al. (1995); Hoyek et al. (1997); Antle et al. (1998); Crissman et al. (1998); Cole et al. (1998)] and are the classic symptoms of direct exposure to pesticides. Most of the illnesses considered for this study were those that were recorded in the Siyayoganathan et al. (1995) study which included examination of the respondents by a physician. The data collected, therefore, only relate to those suffered due to direct exposure to pesticides and not from any other illness. The interesting point about direct exposure to pesticides is that the symptoms/illnesses arising from exposure to pesticides are unique and can easily be identified [for example, see Fernando (1989, 1991)]. The respondents were specifically told that in this section, we were interested only in the short-term health effects (usually during spraying or within four hours of spraying) arising from such handling and spraying. The usual short-term health problems arising from spraying and handling of pesticides were listed in the questionnaire and are taken from the Sivayoganathan et al. (1995) study of illnesses recorded during their field survey in 1990. Respondents were also asked if they suffered any other illness during spraying which were not covered in the questionnaire which were then recorded. They came up with some illnesses that were not mentioned in the questionnaire. The respondents were asked whether they were affected by any of the illnesses shown in the questionnaire (section three) and then asked how often they were bothered by any of the illnesses, bodily disorders, aches or pains during any normal pesticide spraying day.

The respondents were asked to describe the frequency of their illnesses and rank them as follows:

Every day	1
Almost every day	2
About half of the time	3
Now and then, but less than half of the time	4
Rarely	5
None of the time	6

The respondents were told to take into consideration the illnesses described in section three of the questionnaire and any other illnesses they suffered and then to tick in the appropriate boxes from 1-6 which would describe best the frequency of the illnesses arising on an average pesticide handling and spraying day (please refer to questionnaire in Appendix 6.1 for better clarification). It must be mentioned that this section and the next three sections and the contingent valuation question were the most extensive and time consuming sections of the questionnaire.

After these questions were asked, the various costs were recorded as shown in sections 4-6 of the questionnaire. They were the private short-term costs arising on spraying days, non-spraying days and the long-term costs. Section four takes into account all private costs arising due to illnesses from pesticide handling and spraying which were described in section three. In order to get an accurate recall of the severity of the illnesses and the accompanying costs over the last year, the severity of the illnesses is grouped into three categories namely severe, moderate and mild. An illness is described as serious where the respondent was hospitalized, a moderate illness is where the respondent took treatment from a physician but was not hospitalized and the mild case is where a respondent was neither hospitalized nor sought treatment but took home made self-treatment. In all of these categories, respondents suffered direct, indirect and intangible costs. The direct and indirect costs were subdivided into: medical costs which included doctor visits, hospitalization costs, laboratory costs, emergency room visits and medication/drug costs. These were categorized as direct costs. Other direct costs were: dietary expenses resulting from illnesses, travel costs associated with medical treatment, hired labour due to inability to work and any other direct costs incurred due to inability to stay on the farm due to direct exposure to pesticides such as crop damage, due to inability to look after the crops from animals, theft, etc. The indirect costs taken into account were: loss of work days on farm, loss of efficiency on farm, time spent on traveling/seeking treatment, and leisure time losses.

In the previous section (four) we asked about the costs that arise from illnesses due to direct exposure to pesticides on a typical pesticide spraying day. Section five of the questionnaire takes into account all costs arising from direct exposure to pesticides on non-spraying days. This is because a farmer can use pesticides on a typical pesticide spraying day but suffer from the after effects the following day or a few days later which can be directly attributed to direct exposure to pesticides. The respondents were asked to name the illnesses and were asked how often they occurred during a week, month or for the whole year. Then the various costs both direct and indirect were recorded. These costs were the same as those recorded in section four.

Until now we looked at the short-term costs arising from illnesses due to direct exposure to pesticides on a pesticide spraying day and a non-spraying day. Apart from these effects, it is well known that pesticide pollution can also cause serious long-term health hazards. Section six of the questionnaire examines these illnesses and their costs. The respondents were given a list of long-term illnesses and were asked whether they had suffered from any of these illnesses or any other which was not recorded on the questionnaire. If they were found to be suffering from any of these long-term illnesses arising from pesticide use, then they were asked to state some of the costs to the best of their ability as a monthly or an yearly figure. The respondents were also asked whether they were aware of any family members suffering from such long-term illnesses which can be attributed to exposure to pesticides.

In addition to the short-term costs arising on pesticide spraying days and non-spraying days and the long-term costs, the farmers also incur many defensive/precautionary costs because of the various precautions taken to reduce direct exposure to pesticides. Money spent on equipment and even effort and time spent to reduce the risk of health problems is an important part of what some people are willing to pay, for example, to reduce direct exposure to pesticides and the resulting illnesses. Some of the precautions taken by farmers include: wearing masks, gloves, special clothing, shoes, storage facilities, hiring of labour, etc. We calculate these costs as well, in order to use the precautionary behaviour approach to infer willingness to pay bids/values to reduce ill health, though it is widely presumed to be a lower bound. Section seven of the questionnaire examines the various precautionary behaviour measures undertaken by asking them whether they had practiced any of the standard precautions listed or any other precautions not listed and then the amounts and costs incurred per year are recorded. These precautions refer to defensive action taken to reduce mainly direct exposure to pesticides, though storage costs are also accounted for.

Sections four to seven gathered information pertaining to cost of illnesses and the precautionary costs that can then be used to infer willingness to pay bids/values to reduce ill health arising from direct exposure to pesticides. These are two of the valuation techniques that are used in this Ph.D. study. Another technique that is being used in this study, as mentioned in chapter four, is the conceptually more correct, but yet controversial approach, namely the contingent valuation technique. This question is covered in section eight of the questionnaire. By the time the interviewer got to this section of the questionnaire, the respondents were well aware of the objectives of the study and were very familiar with the health hazards posed due to direct exposure to pesticides. Hence the respondents were well prepared to answer a contingent valuation question. Only one contingent valuation question was asked because of the problems that arise by asking too many of them which were discussed in an earlier section of this chapter. In addition to the information gathered in the questionnaire and the refreshing of memory of the respondent, a detailed introduction was given to the nature of the contingent valuation question being asked (please see section eight of the questionnaire). Prior to the interview, an introduction was given about the dangers of pesticide pollution sighting hospital data and research work. The preceding questions before the willingness to pay questions prepared the respondent better to answer the willingness to pay questions and prompted the subject to think how valuable it would be to avoid direct exposure to pesticide pollution and hence the illnesses that affect him. Furthermore, a detailed explanation was given about the willingness to pay question that is stated below as explained to the subjects in the questionnaire.

Interviewer: In the next question, I am going to ask you how much it would be worth to you to avoid the symptoms and costs we have been talking about. The answers you give in this part are for yourself alone and not for any other members of your household.

When you pay for relief of symptoms and illnesses, the money will have to come out of your monthly income from your farm and/or some other source. Let's think about ways we normally deal with health problems such as arising from the use of pesticides. One way is to go to the doctor, another way is to buy medicine at the drugstore. Oftentimes, we don't do anything at all-we just suffer through the problem until it goes away, especially in the case of mild cases (category C) which we dealt with earlier. We also adopt or take precautionary or defensive action as we saw in the previous set of questions such as wearing protective clothing, gloves, masks, etc. These incur additional costs. These costs and costs like the price of a bottle of medicine, doctor consultation fees, hospitalization costs, loss of earnings due to sickness, etc. may be regarded as measures of a value of a cure. But if we stop to think about it, the cure might be worth much more to us than that - i.e. if we really had to pay for intangibles as well (for example, remember we did not estimate the costs of pain, discomfort and suffering - similarly there are many other such costs which we haven't considered).

The question below is strictly hypothetical. The aim of this question is to measure how much people are willing to pay to avoid direct exposure to pesticides and hence the resulting costs arising from ill health. Now assume that it is possible to avoid direct exposure to pesticides and hence short-term and long-term illnesses using one or a combination of the following: using safer, but more expensive pesticides, adopting integrated pest management strategies, not using pesticides at all, growing crops that use less pesticides, hiring labour to spray the pesticide, abandoning farming altogether, or even growing traditional crops and varieties which do not require the use of pesticides (however, in such crops the yields are low and the market demand is also low).

An advantage in this type of question (contingent valuation) is that it captures some of the costs which we could not estimate from the costs of illness and precautionary costs approaches which we just tried to estimate in the previous set of questions. For example, we could not calculate costs such as pain, suffering and discomfort. Therefore, in the question we are going to ask (contingent valuation question) it is possible to even capture some of these costs as well. In such a context we might ask ourselves "How much would I be willing to pay to get rid of this problem (associated with direct exposure to pesticides) right now, even if I don't want to take medicine, visit a doctor or take precautions or defensive action"? In other words, what is the value to me of avoiding direct exposure to pesticides"? With these thoughts in mind, please try to give the largest money value a prevention or avoiding of the short-term and long-term health effects arising from the use of pesticides would be worth to you when answering the next question. Please take your yearly income into consideration when answering this question.

The willingness to pay question that was asked was about how much an individual would be willing to pay to avoid direct exposure to pesticide pollution and the associated illnesses. No question on willingness to pay to avoid mortality was asked, although many respondents were aware of deaths due to direct exposure to pesticides. Only open-ended questions were asked where the subjects were asked to give a rupee value estimate of the maximum amount they would be willingness to pay to avoid direct exposure to pesticides taking into consideration their yearly incomes. The question was formulated as follows:

In view of the large short-term, long-term and precautionary costs which we saw in the preceding sections, what is the yearly value to you of avoiding direct exposure to pesticides and the resulting illnesses. In other words, what would you be willing to pay (WTP) for a year to avoid the costs arising from mobidity effects?

Although some studies have included close-ended questions in addition to open-ended questions [for example, Chestnut et al. (1996)] such questions were deliberately avoided because of the difficulty in setting referendum prices. For example, the costs arising from ill health varies from farmer to farmer and hence his willingness to pay bid to avoid such exposure. Furthermore, any rupee amounts suggested in the close-ended questions were thought would influence responses in the open-ended questions. Whittington (1998) points out that if the amount the enumerator asks lacks credibility, the respondent is unlikely to answer the question on the basis of the price suggested. There is also the danger of 'anchoring'[11] when a close-ended and an open-ended question are included in the same questionnaire. This is because during the pilot study it was noted that when a payment was suggested, some respondents wanted to please the interviewer with answers and/or demonstrate their wisdom by giving answers which they believed the interviewers were looking for rather than stating his own willingness to pay. Here the rural customs and behaviour have to be taken into consideration when questions are asked. Because by nature rural folk are subservient, there is a danger of influencing responses when payments are suggested. Whittington (1998) points out that if there is a tendency for respondents to say 'yes' to whatever question the interviewer asks, then 'compliance' bias can result. Hence, only the open-ended format was chosen. Another reason for choosing an open-ended format

[11] What is meant by 'anchoring' here is that if a referendum price is suggested, the respondents could stick to this price when answering the open-ended question.

was because as pointed out earlier, by the time the contingent valuation question was asked about the costs incurred on illnesses arising from direct exposure to pesticides and averting behaviour, the respondents had already been answering questions on costs before the contingent valuation willingness to pay question was asked and hence easy to detect if the respondent had understood the question well and whether the bids given were overestimated or not. Therefore, in a situation such as this it would have been difficult for the interviewer to suggest a referendum price to avoid direct exposure to pesticides because the costs of illness arising from direct exposure to pesticides vary from farmer to farmer and such costs are unknown to the enumerator. Interestingly, Langford et al. (1997) point out that their decision to use an open-ended format was "influenced by the lack of previous valuation estimates to support the definition of a dichotomous choice bid vector" (p.6). Interviews also recorded comments offered by the subjects while responding to these questions. With these thoughts in mind they were asked to state the highest money value in rupees for a year, taking into consideration, the budget constraints of the respondent.

Section nine of the questionnaire was devoted to gathering socio-economic data, which together with the information collected on health endowment data in the previous sections are very useful for the regression analyses that are carried out in the Ph.D. study. The socio-economic questions asked were: monthly income which was sub divided into farm and other sources, number of households, age, education which was sub divided again into secondary and /or any other form of education, number of hours worked on farm, the size of land cultivated and whether the respondents worked on weekends or not. At the end of the questionnaire, the interviewer recorded all comments made by the respondents that may be useful for the study. Some of the comments recorded were the pain, discomfort and suffering that the respondents had to suffer due to illnesses arising from direct exposure to pesticides. Stress and loss of confidence were also included in the comments. Because of the existence of such intangible costs, the decision to include the contingent valuation question as an estimation tool of willingness to pay for a reduction in ill health was well justified.

Data Analysis

Data gathered from the questionnaires were first recorded into data sheets and were then coded. They were then entered into a PC using Excel software. Accuracy of the coding and data entry was verified by double checking the sheets and the questionnaires completed. Specific statistical analyses are described where the data and the results are discussed.

Characteristics of the Sample

From the data obtained from the questionnaires we were able to gather a large volume of information about the respondents who were studied in the five areas using pesticides on a regular basis on their farms. We discuss some of the characteristics of the sample group below.

Table 6.1 provides descriptive statistics for the 203 respondents in the sample that were used in the analysis of estimating the costs arising from direct exposure to pesticides. As expected, the large majority of the farmers were male and the largest group of farmers belonged to the 34-40 age category. The mean age was 40 ranging from 20 to 70 years. The average monthly income is 4,748 Rs[12] with a maximum of 30,000 Rs and a minimum of 200 Rs. The income varies according to acreage cultivated, the crop grown, prices prevalent in the area, marketing facilities and many other factors. Farmers who use pesticides suffer from direct exposure to pesticides on spraying days, non-spraying days and from long-term illnesses. A farmer being affected on a spraying day can either be hospitalized, take treatment from a hospital but not get admitted to hospital or simply take self-treatment at home. In all these instances, a farmer incurs private costs. The direct private costs taken into account are: any privately purchased drugs, laboratory and other investigation costs done privately, costs of transport and costs involved with special diets. The indirect private costs are: loss of working days, loss of productivity/efficiency, loss of efficiency, the time a patient spends visiting hospitals or a doctor. As can be seen, in the table under economic effects, a farmer on average lost about 82 hours of work, 43 hours of 'efficiency loss[13] on the farms, and 18.55 hours traveling to hospital and seeking treatment.

[12] The exchange rate prevalent during the study period (June-September, 1996) was 1£ = 75 Rs. The current exchange rate is 1£ = 106 Rs.

[13] Loss of efficiency was defined as the lessening of one's productivity while working. In the questionnaire, we asked the respondents to give the number of hours 'effectively lost' working on the farms due to 'pesticide exposure' related illnesses.

Table: 6.1 Descriptive Statistics for Survey of Pesticide Pollution in Sri Lanka

Survey Data		
Number surveyed		227
Number used in the analysis		203
Sample Description		
Percentage Male		99.10
Percentage Female		00.90
Minimum Age		20
Maximum Age		70
Age distribution	**Number**	**%**
20-26	17	08.37
27-33	43	21.18
34-40	57	28.07
41-47	33	16.25
48-54	23	11.33
55-61	21	10.34
62-68	08	03.94
69>	01	00.49
Income Status		
Average Personal Income (Rs per year)		4,748.17
Maximum income in sample		30,000
Lowest income in Sample		200
Economic effects	**Total**	**Average**
Work hours lost	16,646.5	82.00
Loss of Efficiency	8,784.5	43.27
Time spent traveling to hospital/seeking treatment	3,779	18.61
Leisure time losses	9408.75	46.34

Survey Period: July to September, 1996

The low leisure hours lost (48 hours), we believe is an underestimate of the real loss of leisure hours (however, it is interesting to note that in Harrington et al's (1989) study, too, the lost leisure hours are small). The number of hours lost under all these categories can be considered high considering the number of spraying days a year. As reported in the next section, the number of 'handling and spraying pesticide' hours by an average farmer per year is around 197 hours.

The Use and Problems Associated with Pesticide Pollution in Sri Lanka

In Sri Lanka due to the nature of farming (mainly small scale agriculture) pesticide spraying is carried out using hand sprayers. Hence the level of direct exposure is very high resulting in high levels of morbidity and even mortality among the users (farmers) as shown in chapter three. A wide range of pesticides are also used in agriculture. They are insecticides, herbicides and fungicides. The most potent of these are insecticides followed by herbicides and fungicides.

It is also a known fact that Sri Lankan farmers use pesticides far more than the recommended levels [(Chandrasekera, et al. 1985); Sivayoganathan et al. (1995)] and use a wide variety of them too. In other words, farmers use pesticides more than is privately efficient. They do it in the mistaken belief that more toxic it is, the better results it will give. Jayathilake and Bandara (1989) show from their study that 'absolutely clean crop' attitude and 'quick kill' belief among the farmers have resulted in nearly 77% of farmers using stronger concentrations of pesticides than recommended in vegetable cultivation. They are also known to mix several pesticides together [Chandrasekera et al. (1985)]. These practices are not only costly but also increases the health hazards to farmers using pesticides. Archer and Shogren (1994) show that, for herbicides, farmers switch herbicides (in this case for less persistent herbicides) and also decrease the quantities of pesticides used when there is a risk of application and effectiveness failure[14]. Archer and Shogren (1996) also show that if self protection[15] and self insurance[16] are stochastic substitutes, non point source pollution policies targeted to reduce herbicide loadings can increase the use of more persistent herbicides. They point out that by reducing the total mass may result in substituting herbicides which can be more damaging or more likely to be transported to sensitive areas. Extension work is often carried out to educate the farmers on the dangers of pesticide use and the pesticide bottles carry out clear instructions to use them in a safe manner. However, much of the instructions are ignored[17]. The best method to measure the strength of the pesticide used is to take into account the ounces of pesticides used and compare it with the area sprayed. Another method is to compare the frequency of pesticide spraying with the quantity of pesticides used for a given period of time. Furthermore, the strength of formulation used can be measured by comparing the quantity of water mixed per ounce of pesticide used. The strength of the pesticide used, however, depends on the type of pesticide used where the chemical class to which the pesticide belongs determines the toxicity of the pesticide. Pesticides in Sri Lanka are available freely and in certain villages the only shop is the pesticide sales outlet. Pesticides are marketed by different companies and is widely advertised on television and radio. Some of the pesticides currently being used in Sri Lanka belong to the first generation of pesticides which are very toxic (for example, organochlorines). They are all banned in Western countries.

Pesticides are widely used on commercially grown food crops and the quantity and the frequency of usage varies from crop to crop. Usually for rice less pesticides are used, around once every month (during severe outbreaks of Brown Planthopper pests more pesticides are used) while for certain vegetable crops (such as capsicum) the

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[14] Application failure occurs when weather conditions prevent the producer from applying a herbicide, for example, when fields are too wet during the critical application times. Effectiveness failure occurs when weather conditions render an applied herbicide completely ineffective.

[15] Refers to 'which herbicide' to apply (Archer and Shogren (1996, p.44).

[16] Refers to the 'amount of herbicide' to apply (Archer and Shogren (1996, p.44).

[17] Farmers read warnings and instructions on pesticide bottles but they are mostly ignored due to social, economic, cultural and environmental reasons. These aspects are discussed in chapter nine.

frequency increases to about two sprays a week during the peak cultivating season. During the study, it was found that 103 different brands of pesticides (of which 48 were insecticides, 28 were fungicides and 27 were herbicides) were being used in the study areas (please see appendix 6.2 for complete list of types and brand names of pesticides used in the study area). Out of the 103 pesticides which were being used by farmers in the study area, nine pesticides had been de-registered in Sri Lanka from use since July, 1995. All pesticides sold for use in Sri Lanka have to be registered with the pesticide registrar. Only approved pesticides are registered and permitted to be sold [personal communication with pesticide registrar (1997)]. The breakdown of pesticides used is shown in Table 6.2.

Table: 6.2 Number of Brands and Quantity of Pesticides Used in the Study Area

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

Survey Period: July to September, 1996

As can be seen from Table 6.2 insecticides are the most frequently used pesticides. They are used for the control of insects and are the most toxic of all pesticides used. Most of the insecticides used in the study area were organophosphates and carbamates[18] and to a lesser extent organochlorines. Table 6.2 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. In spraying these

18 Most of the insecticides used in the 1960s were organochlorines such as DDT. However, there was increased scientific evidence on the link between the use of organochlorides and environmental degradation such as the thinning of eggshells of birds (Lincer,1975, Lundholm, 1987, Newton and Bogan, 1978, Peakall et al. 1976, Urfi, 1994, p.35), effect on other fauna (Blackmore, 1963, Mason et al. 1986) and the build-up of the long-lasting chlorine compounds in food chains. The external costs of organochlorine use loomed even higher when laboratory tests on animals at higher dosages showed that some of the compounds were carcinogenic to mammals. Hence starting from 1972, these chemicals were banned or tightly restricted (Carlson, 1977, 1989). Organochlorines were then replaced by organophosphate and carbamate insecticides. These pesticides were less persistent, but were more harmful to farmers and field workers. However, the toxicity and the development of resistance by insects to these chemicals then brought about another class of insecticides in the 1970s known as pyrethroids. The lower rates and relatively low acute toxicity made them safer to users, wildlife and food consumers. However, insect resistance to these chemicals developed in the 1980s. Furthermore, the residuals of these compounds, together with other soil insecticides are known to be readily taken up by crop roots, have been found in food produced, ground water, or surface water (Carlson, 1977, 1987) which are no doubt harmful to humans, fauna and the environment. There is evidence now that pyrethroid insecticides have affected non targeted insects such as bees (Murray, 1985).

pesticides, farmers are often directly exposed to these chemicals and some for as long as 6 hours. Due to the nature of farming (mainly small scale agriculture), pesticide spraying is carried out manually using hand sprayers[19]. Hence the level of direct exposure is very high which results in high levels of morbidity and even mortality among the users (farmers). A break down of the average handling and spraying hours is shown in Table 6.3.

Table: 6.3 Handling and Spraying Exposure to Pesticides on a Typical Pesticide Spraying Day

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

Survey Period: July to September, 1996

As can be seen from Table 6.3, an average farmer handles and sprays pesticides for more than half a working day on his farm. The frequency of use vary 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.

In using these pesticides, farmers take some form of precautions to avoid direct exposure to pesticides. However, such measures are usually found to be inadequate. A breakdown of precautions taken is shown in Table 6.4.

[19] However, it must be noted here that even on large farms in Sri Lanka pesticide spraying is done manually. The only difference is that it is hired labour that is involved rather than owners spraying it as is the case with subsistence farmers. In Sri Lanka, pesticides are not sprayed by protected 'spraying vehicles and airplanes'.

Table: 6.4 Number and Percentage of Farmers Taking Precautions

Protective Item	Number	Percentage
Wearing Protective Clothing	70	34.48
Wearing Masks	64	31.52
Wearing Gloves	90	44.33
Wearing Shoes	09	4.43
Building Special Storage Units	11	5.41
Other Precautions Taken (e.g. hired labour)	58	28.57

Survey Period: July to September, 1996

What Table 6.4 shows is that in the sample group, 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 6.4. Sixty nine percent of the farmers took some form of precautions in the form of either protective clothing, wearing masks, gloves, shoes or a combination of any one of the precautions mentioned above. Farmers using special storage facilities were very low. Twenty two percent of the farmers incurred costs on taking other precautions such as hiring labour, in order to spare them from direct exposure to pesticides. Often, this was done on grounds of medical advice or when having to spray for long hours. In all (farmers using protective gear and taking other precautions), 70% of the farmers were found to take some of the precautions mentioned above. Such precautions taken, however, do not mean that they were adequate.

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. The time of spraying, the wind direction, food taken before spraying and the physical well being of the user are some of the other factors that increase the risk of illness among the farmers. The common acute symptoms that appear on a typical pesticide spraying day and their frequency are shown in Table 6.5. The columns show the number of respondents (farmers) affected and the percentages. The numbers from 1 to 6 shown in boxes show how often the respondents were bothered by any of the illnesses shown in the left-hand side column of the table on a typical pesticide spraying day.

Table: 6.5 Frequency of Illnesses Affecting Farmers on a Typical Pesticide Spraying Day

	1		2		3		4		5		6	
Illnesses Recorded on a Spraying day	No	%	No	%	No	%	No	%	No	%	No	%
Faintish feeling	39	19	11	05	7	03	12	05	77	38	58	36
Headache	61	20	19	09	08	04	24	12	47	24	40	19
Dizziness	32	16	15	07	14	06	16	08	51	23	76	37
Nausea	26	13	14	07	06	03	09	04	47	23	104	51
Excessive Salivation	89	44	20	10	02	01	12	06	28	14	52	26
Eye irritation	18	09	14	07	04	02	09	04	21	10	136	66
Eye tearing	14	07	03	01	03	01	13	06	29	14	158	77
Vomiting	04	02	01	0.4	05	02	13	06	51	25	142	69
Weakness of muscles	24	12	07	03	04	02	07	03	23	11	138	67
Difficulty in breathing	13	06	10	04	04	02	07	03	26	13	143	70
Twitching of eye lids	11	05	07	03	00	00	08	04	12	06	165	91
Cramps	14	06	06	03	04	02	06	03	15	07	175	86
Diarrhea	00	00	01	0.4	00	00	03	01	03	01	25	12
Twitching of muscles in the face	17	08	11	05	03	01	08	04	10	04	154	75
Twitching of muscles in the body	41	20	12	05	05	02	07	03	26	12	112	55
Blurring Vision	16	08	08	04	05	02	06	03	15	07	152	74
Tremor	04	18	04	02	02	01	09	04	36	18	146	71

Survey Period: July to September, 1996

$\boxed{1}$ Every Day, $\boxed{2}$ Almost Every Day, $\boxed{3}$ About Half of the Time, $\boxed{4}$ Now and then, but less than half of the time, $\boxed{5}$ Rarely, $\boxed{6}$ None of the time.

A farmer can suffer from any one or more of these illnesses. The health effects range from faintish feeling to blurring vision and tremors. These are the usual acute symptoms which appear on spraying days. Similar symptoms appear on non-spraying days as well. Chronic, long-term health effects range from chest pains, blindness, loss of memory, ulcers, depression, various cancers, etc[20]. Due to these morbidity effects, some farmers need hospitalization while some farmers take treatment from a hospital or a physician (but are not admitted to hospital) while others take home made self-treatment. The pesticide related medical expenditures and other costs such as loss of efficiency and loss of leisure time are also large, as will be shown in chapter eight. Furthermore, many working days and hours are also lost due to various illnesses as shown in Table 6.5. The discomfort, pain and suffering is enormous, which is best captured in a contingent valuation study, which is discussed in chapter seven.

The private short-run costs to the users are very large and the long-term costs are even larger, although difficult to measure. The private costs to the consumers of food crops produced by using pesticides are unknown, although it is expected to be large. The public costs (hospital costs) are also large. The damage done to the environment should also be high. No study has been conducted to assess the extent of the damage done to fauna, especially birds, fish and insects, but it is quite evident that these fauna, that were once numerous, have decreased in numbers in areas where pesticides are widely used. The various costs incurred by the respondents (farmers) are also

[20] 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 [Hoar (1986); Nielson and Lee (1987); Blair and Zahm (1993); Balir et al. (1993); Boyle and Zardize (1993); Brown et al. (1993); Collins et al. (1993); Davis et al. (1992)].

included in Table 6.6. A breakdown of the costs incurred due to direct exposure to pesticides for the five regions is shown in Table 6.6. Apart from the costs arising from direct exposure to pesticides, farmers also incur costs on defensive or precautionary behaviour. A breakdown of the number of respondents (farmers) incurring such costs is also shown in Table 6.6.

In the present study, 96% of the respondents had suffered some form of after-effect on a typical pesticide spraying day (excludes effects on non-spraying days or long-term effects) during the past year, but not necessarily leading to hospitalization or taking treatment from a physician, but however, incurring costs such as due to self-treatment, loss of working days, efficiency at work, loss of leisure time, etc. 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 were not hospitalized or did not require treatment from a physician, but nevertheless 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 pollution. Table 6.6 shows the extent of the costs arising from direct exposure to pesticides and precautionary measures taken. Chapter eight and nine discuss these costs separately in detail.

Table: 6.6 Number of Respondents Incurring Costs Due to Pesticide Pollution in the Study Area

	Beligamuwa		Ambana		Kandalama		Yatawatte		Polonnaruwa		Total	
Respondents	42		31		46		53		31		203	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Medical And Other Costs												
A	13	30%	06	19%	08	17%	08	15%	06	19%	41	20%
B	09	21%	04	13%	23	50%	22	41%	4	13%	62	30%
C	33	78%	30	97%	20	43%	25	47%	28	90%	136	64%
NSD	21	50%	14	45%	34	73%	14	26%	04	13%	87	42%
LTC	09	21%	07	22%	23	50%	25	47%	07	23%	71	35%
Defensive Costs												
PC	20	48%	31	97%	32	69%	25	47%	16	51%	123	61%
OC	04	10%	09	29%	21	46%	26	49%	03	10%	66	32%
All	22	52%	31	100%	32	69%	40	75%	17	55%	142	70%
E P	42	100%	31	100%	46	100%	49	92%	27	87%	195	96%

Survey Period: July to September, 1996

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).
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.
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.

As Table 6.6 shows there is considerable variation in the number of respondents incurring costs across regions. Furthermore, there is considerable variation in precautionary costs as well. From the table we can see that in areas where precautionary costs are high, then, in general, the number of those admitted to hospitals (serious illnesses) and taking treatment from physicians (moderate illnesses) is low. There are, however, exceptions, to this rule. In the case of Polonnaruwa, the amount of precautions taken is low and also the number of respondents needing hospitalization and treatment from a physician is also low. This is because Polonnaruwa is mainly a paddy growing area and the frequency of pesticide use is low (on average, one pesticide spray a month). Table 6.6 suggests that when protective measures are undertaken, they could to some extent minimize the extent of serious and moderate illnesses, but, however, many pesticide users could yet suffer from mild symptoms. This is because the precautions taken are inadequate to prevent mild symptoms. For example, take Ambana, where the precautionary costs are high and, therefore, serious and moderate illnesses are low while the mild symptoms are high. On the other hand, when the precautionary costs are low, as for, example, in Beligamuwa and Yatawatte, then the serious and moderate illnesses tend to increase. These figures, however, should be treated with caution since only a small sample of farmers have been surveyed.

Conclusion

This chapter dealt with the methods and the issues involved in the questionnaire development to gather the necessary data to estimate the willingness to pay bids/values using the three approaches to reduce/avoid direct exposure to pesticides and the resulting illnesses. The next three chapters deal with each of these chapters in detail and present the results of the Ph.D. field study.

Appendix: 6.1

QUESTIONNAIRE

Introduction:

Hello, I am a Ph.D. student from the University of St. Andrews, Scotland, U.K carrying out a study/interview for my Ph.D. thesis. I intend to study the health risks arising from the use of pesticides during the cultivation of crops. We have selected a sample of households to represent your area and your household has been chosen as part of the sample.

Could you please tell us whether you are a regular user of pesticides? (If not, ask to speak to the person who actually uses the pesticides in the family farm).

Your responses/opinions are very important and we hope you will help us. Please be assured that this is purely a research project (Ph.D. work) and we do not represent any business or product or a government institution. No sales call or any government action will be involved as a result of your participation in this study. The information you provide us will remain confidential. For this reason we do not hope to take down your name or address if you don't wish to and will avoid asking personal questions. We would appreciate very much if you could spend sometime with us and answer some questions to the best of your ability and memory.

Note: The interviewer will then give a broad introduction about pollution in the country in general and will then narrow down his attention to the problems faced by farmers and others in the area under study due to pesticide pollution. Previous studies carried out on the harmful effects of direct exposure to pesticides will be quoted. Furthermore, it should be noted that farmers are already aware of the numerous hazards arising from pesticide use.

(1) INFORMATION ON PESTICIDES[21]

Interviewer: In answering the questions below please specify the crops grown.

	Crop	Variety
1.	Rice	....
2.	Vegetables	....
3.	Cash Crops	....
4.	Others	....

[21] This study considered the area (acreage) sprayed and the size of farm. The pilot study tried to obtain the area cultivated for each crop but proved difficult to obtain. This is because farmers cultivated many different crops on their land for two seasons. Hence, only the area (acreage) sprayed with pesticides per week/month and the size of farm were taken into account in the questionnaire.

During which cultivation season are pesticides (includes all chemicals such as weedicides, insecticides and fungicides) used most in your farm? Please list the seasons and months according to intensity of use.

Season	Time period
....	.... to ....
....	.... to ....
....	.... to ....

How often do you use these pesticides during a particular season?

Season .... days per week .... or month ....
Season .... days per week .... or month ....
Season .... days per week .... or month ....

Please can you name the pesticides

(1) Herbicides : ....
(2) Insecticides : ....
(3) Fungicides : ....

In what quantities are they used? Please specify quantities

	Weekly or Monthly	Acreage
(1) Litres :	....	....
(2) Gallons:	....	....
(3) Kilos :	....	....

Can you tell us how these pesticides are applied. An example would be the use of hand sprayers. Can you please name them.

(1) .... (2) .... (3) ....

Also could you tell us for how long you are engaged in handling and spraying of pesticides on an average spraying day? (Transportation and storage of pesticides are not considered).

	Hours
Spraying hours per day	....
Handling and mixing hours per day	....

At what time of the day are pesticides used?

	Time
Morning	....
Afternoon	....
Evening	....

Do you read the instructions and warnings in the bottle?[22] Yes/No

For what pests and diseases are pesticides used?

Names of Insects	Names of Diseases
....	....
....	....
....	....
....	....

Note: For the above questions, it is very important to help the farmers to answer the questions (for example, to identify the pesticide used, quantities used, frequency of use, season and time of spraying, etc.).

(2) AWARENESS ON PESTICIDE POISONING

Interviewer: Please circle where appropriate and fill in the blanks. Are you aware of harmful effects (here referring to sicknesses only) of pesticide use.

Yes No

Note: This includes farmers in the neighborhood and other members of the family only (this does not include the interviewee).

Interviewer: We know that pesticides are harmful to human health. Hospital data also show that many deaths take place as a result of direct exposure to pesticides (here referring to only deaths arising from the use of pesticides in farming (spray poisoning). Suicide related deaths are not included here.

In such a context are you aware of any person who has died from such direct exposure to pesticides poisoning in your area, which can be attributed to handling and the use of pesticides on the farms.

Yes No

	Family	Neighbours
Numbers:	....	....

It is also known that many people use pesticides as a medium to commit suicide? Please, could you tell us whether you are aware of such deaths?

Numbers: Male ....
Female ....

[22] This question is really useful as an indicator of the degree of care taken.

(3) HEALTH STATUS OF INTERVIEWEE

Interviewer: Now we are going to ask you whether you have suffered or is suffering from any illnesses that can be attributed to direct exposure to pesticide handling and spraying. In this section, we are interested in only the short-term health effects arising from such use and handling. The usual short-term health problems arising from handling and spraying of pesticides are listed below. Also the questions that immediately follow are related to short-term effects.

Note: Most people have difficulty remembering how many times they have experienced these problems, but it is important that you try to remember whether you experienced these illnesses soon after the use of pesticides.

Some of the short-term health effects that have been identified as a result of pesticide usage and handling on a typical spraying day are listed below.

Taking into consideration the health effects (illnesses) shown below, how often have you been bothered by any of the illnesses, bodily disorders, aches or pains during any normal pesticide spraying day?

Every day	1
Almost every day	2
About half of the time	3
Now and then, but less than half of the time	4
Rarely	5
None of the time	6

Now looking at the illnesses described below, could you please specify which of the illnesses that you suffer on an average pesticide handling and spraying day (please tick in the appropriate boxes given below).

	1	2	3	4	5	6
(5.b.1) Faintish feeling	☐	☐	☐	☐	☐	☐
(5.b.2) Headache	☐	☐	☐	☐	☐	☐
(5.b.3) Dizziness	☐	☐	☐	☐	☐	☐
(5.b.4) Nausea	☐	☐	☐	☐	☐	☐
(5.b.5) Excessive Salivation	☐	☐	☐	☐	☐	☐
(5.b.6) Eye irritation	☐	☐	☐	☐	☐	☐
(5.b.7) Eye tearing	☐	☐	☐	☐	☐	☐
(5.b.8) Vomiting	☐	☐	☐	☐	☐	☐

(5.b.9) Weakness of muscles	☐	☐	☐	☐	☐	☐
(5.b.10) Difficulty in breathing	☐	☐	☐	☐	☐	☐
(5.b.11) Twitching of muscles in eyelids	☐	☐	☐	☐	☐	☐
(5.b.12) Cramps	☐	☐	☐	☐	☐	☐
(5.b.13) Diarrhea	☐	☐	☐	☐	☐	☐
(5.b.14) Twitching of muscles in the face	☐	☐	☐	☐	☐	☐
(5.b.15) Twitching of muscles in the body	☐	☐	☐	☐	☐	☐
(5.b.16) Blurring vision	☐	☐	☐	☐	☐	☐
(5.b.17) Tremor	☐	☐	☐	☐	☐	☐
(5.b.18) Any Other effects	☐	☐	☐	☐	☐	☐

(4) SHORT-TERM PRIVATE COSTS RESULTING FROM PESTICIDE USE

In this section, we hope to ask you about the private costs due to illnesses arising from direct exposure to pesticides handling and spraying. Once again only the costs of short-term illnesses described earlier are considered. In this section, the long-term costs are not considered. Furthermore, in this section the costs of illnesses arising from an average spraying day are considered and not the costs that arise on non-spraying days. In this study the medical costs arising from both traditional and western medicines are considered. Please state only the private costs. This includes treatment taken from private clinics, consultation fees, drugs purchased, laboratory costs, etc.

Note: From the pre-tested samples, it was found out that almost all the farmers sought western medicines (from government hospitals and private clinics) than traditional medicines.

Question: How would you describe the illnesses that arise on an average spraying day or days?

(A) Serious (i.e. hospitalized cases)

Number of days in hospital

Days per week .... or days per month .... or days per year ....

(B) Moderate (i.e. doctor is consulted but no hospitalization is required)

Number of days in hospital

Days per week	or	days per month	or	days per year
....		....		....

(C) Mild (i.e. no visits to the doctor, yet medication is taken)

Number of days in hospital

Days per week	or	days per month	or	days per year
....		....		....

Note: It is possible that a farmer may have experienced any two or all three of the above.

If (A), then please state all costs associated with direct exposure to pesticides related illnesses, however minor they are. For example, even a tablet such as a disprin or an asprin taken should be taken into account.

(A)

	Costs in RS Weekly/Monthly/Yearly Rs	Cts
(6.e) Medical costs[23]:		
(6.e.1) Doctor visits (consultation fees)	------	------
(6.e.2) Hospitalisation costs (Govt or Private)	------	------
(6.e.2) Laboratory costs	------	------
(6.e.3) Emergency room visits	------	------
(6.e.4) Medication/drugs	------	------
Other costs associated with the illness:		
(6.f.5) Dietary expenses resulting from illness	------	------
(6.f.6) Travel costs associated with medical treatment	------	------
(6.f.7) Time spent on traveling/seeking treatment: Hours/visit	------	------
(6.f.8) Loss of work days/hours on farm[24]: Hours ------ Days ------	------	------
(6.f.9) Loss of work efficiency on farm: Hours ------ Days ------	------	-----
(6.f.10) Leisure time losses[25]: Hours/day ------	------	------

[23] Refers to private costs incurred by farmers due to direct exposure to pesticides. This is because, farmers in addition to taking treatment from government hospitals also take treatment from private clinics.

[24] 'Work time' was identified as anytime spent working on the farm, purchasing inputs or selling the cultivated crops, etc.

(6.f.11) Hired labour due to inability to work	------	------
(6.f.11) Any other losses incurred due to hospitalization from direct exposure to pesticides (for e.g. crop damage due to inability to look after crops and damage from animals)	------	------

(B)

If (B) then: (please specify the costs below).

	Costs in RS Weekly/Monthly/Yearly	
	Rs	Cts
(6.e) Medical costs:		
(6.e.1) Doctor visits (consultation fees)	------	------
(6.e.2) Laboratory costs	------	------
(6.e.3) Medication/drugs	------	------
Other costs associated with the illness:	------	------
(6.f.4) Travel costs associated with medical treatment	------	------
(6.f.5) Time spent on traveling/seeking treatment: Hours/visit ------	------	------
(6.f.6) Loss of work days/hours on farm: Hours ------ Days ----	------	------
(6.f.7) Loss of efficiency. Hours per day-------	------	------
(6.f.8) Dietary expenses resulting from illness	------	------
(6.f.9) Leisure time losses: Hours/day ------	------	------
(6.f.10) Hired labour due to inability to work	------	------

(C)

If (C) then: (please specify costs)

	Costs in RS Weekly/Monthly/Yearly	
	Rs	Cts
Medical costs:		
Medication/drugs		
1. Panadol/Disprin	------	------
2. Vicks	------	------
3. Other	------	------
Other costs associated with mild illnesses:		
Loss of work days/hours in farm; Hours ------ Days ------	------	------
Work efficiency loses: Hours lost per day ------	------	------
Leisure time losses: Hours lost per day	------	------
Dietary expenses resulting from illness ------	------	------

Any other incomes foregone:-

(A) ....

(B) ....

[25] Leisure hours were taken to be any time spent at home after work such as reading a newspaper, watching television, listening to the radio, playing a game or time spent with the family. Sleeping hours were not included nor was the time spent attending to domestic chores included.

(5) PRIVATE COSTS ON NON-SPRAYING DAYS

Interviewer: In the previous questions we asked about the costs that arise from illnesses due to direct exposure to pesticides on a normal spraying day or days. However, in the next few questions, we are going to ask you whether you suffer from any illnesses on non-spraying days which can be attributed to direct exposure to pesticides from the previous day. Once again, only the short-term illnesses are considered here.

Are the morbidity effects mentioned earlier recorded even on non-spraying days/weeks. If so, what are the symptoms and state the number of days/weeks/months that they last (only the short-term costs please!).

Time

Symptoms	Days per week	Days per month	Days per year
1.	....	....	....
2.	....	....	....
3.	....	....	....

Please specify the costs below

	Costs in RS Weekly/Monthly/Yearly Rs	Cts
(6.e) Medical costs:		
(6.e.1) Doctor visits (consultation fees)	------	------
(6.e.2) Hospitalization costs (Govt. or Private)	------	------
(6.e.2) Laboratory costs	------	------
(6.e.3) Emergency room visits	------	------
(6.e.4) Medication/drugs	------	------
Other costs associated with the illness:		
(6.f.6) Travel costs associated with medical treatment	------	------
(6.f.6) Time spent on traveling/seeking treatment: Hours/visit	------	------
(6.f.8) Loss of work days/hours on farm: Hours ------ Days ------	------	------
(6.f..) Loss of efficiency at work -hours per day	------	------
(6.f.10) Leisure time losses: Hours/day ------	------	------
(6.f.5) Dietary expenses resulting from illness	------	------

(6.f.11) Any other losses incurred due to hospitalization from pesticide poisoning (for e.g. hiring of labourers due to inability to work, crop damage due to inability to look after crops and damage from animals) ------ ------

(6) LONG-TERM COSTS OF PESTICIDE POLLUTION

Interviewer: So far we considered only the short-term effects and their costs arising from direct exposure to pesticides. Apart from these effects, it is well known that direct exposure to pesticides can also cause serious long-term health hazards. Therefore, the questions below refer to long-term health problems and costs only.

Question: Do you suffer from long-term health effects which can be attributed[26] to direct exposure to pesticides? If so what are they? Please circle.

Swellings in body
Chest pains
Loss of memory
Numbness of fingers
Blindness
Other illnesses (please specify) ....

If you are suffering from any long-term effects arising from pesticide use can you state some of the costs to the best of your ability?

Monthly .... or Yearly ....

Are you aware of family members suffering from such long-term effects arising from the use of pesticides?

Yes/No

(7) PRECAUTIONARY AND DEFENSIVE COSTS

Interviewer: In addition to the above mentioned costs arising from direct pesticide exposure related illnesses, it is known that many people (including farmers) incur defensive/avertive costs in order to minimize the harmful effects of pesticide use. For example, farmers wear masks, gloves special clothing, shoes etc. to protect themselves from toxic chemicals while they are being used.

In such a context, can you please tell us what form of precautions that you have adopted in order to minimize the adverse effects of pesticide use. Where possible please also state the costs. This question refers to avoiding direct exposure to pesticides arising from spraying and non-spraying days.

	Amount	Rs	Cts
Wearing protective clothing	....	....	....
Wearing masks	....	....	....
Wearing gloves	....	....	....
Wearing shoes	....	....	....
Using the high quality sprayers	....	....	....
Building special storage units	....	....	....
Any other costs	....	....	....

[26] Only the long-term illnesses diagnosed by physicians as arising from direct exposure to pesticides have been considered.

(8) CONTINGENT VALUATION QUESTION

Interviewer: In the next question, I am going to ask you how much it would be worth to you to avoid the symptoms and costs we're been talking about. The answers you give in this part are for yourself alone and not for any other members of your household.

When you pay to avoid symptoms and illnesses, the money will have to come out of your monthly income from your farm and/or some other source. Lets' think about ways we normally deal with health problems such as arising from the use of pesticides. One way is to go to the doctor, another way is to buy medicine at the drugstore. Oftentimes, we don't do anything at all-we just suffer through the problem until it goes away, especially in the case of mild cases (category C) which we dealt with earlier. We also adopt or take precautionary or defensive action as we saw in the previous set of questions such as wearing protective clothing, gloves, masks, etc. These incur additional costs. These costs and costs like the price of a bottle of medicine, doctor consultation fees, hospitalization costs, loss of earnings due to sickness, etc. may be regarded as measures of a value of a cure. But if we stop to think about it, the cure might be worth much more to us than that - i.e. if we really had to pay for intangibles as well (for example, remember we did not estimate the costs of pain, discomfort and suffering - similarly there are many other such costs which we haven't considered).

The question below is strictly hypothetical. The aim of this question is to measure how much people value a pesticide pollution free environment where one's health is not affected or in other words to measure how much people are willing to pay to avert illnesses arise from direct exposure to pesticides. Now assume that it is possible to avoid both short-term and long-term illnesses arising from direct exposure to pesticides by using one or a combination of the following: using safer but more expensive pesticides, adopting integrated pest management strategies, not using pesticides at all, growing crops that use less pesticides, hiring labour to spray the pesticide, abandoning farming altogether, or even growing traditional crops and varieties which do not require the use of pesticides (however, in such crops the yields are low and the market demand is also low).

An advantage in this type of question (contingent valuation) is that it captures some of the costs which we could not estimate from the costs of illness and precautionary cost approaches which we just tried to estimate in the previous set of questions. For example, we could not calculate costs such as pain, suffering and discomfort. Therefore, in the question we are going to ask (contingent valuation question) it is possible to even capture some of these costs as well. In such a context, we might ask ourselves "How much would I be willing to pay to get rid of this problem (associated with direct exposure to pesticides) right now, even if I don't want to take medicine, visit a doctor or take precautions or defensive action"? In other words, what is the value to me of avoiding direct exposure to pesticides"?

With these thoughts in mind, please try to give the largest money value a prevention or avoiding of the short-term and long-term health effects arising from the use of pesticides would be worth to you when answering the next question. Please take your yearly income into consideration when answering this question.

Question: In view of the large short-term and long-term and precautionary costs which we saw in the preceding sections, what is the yearly value to you of avoiding direct exposure to pesticides and the resulting illnesses. In other words what would you be willing to pay (WTP) for a year to avoid the costs arising from mobidity effects?

Please state the highest money value in Rs ....

Interviewer: The next set of questions refer to socio-economic data.

(9) SOCIO ECONOMIC DATA

Monthly Income: RS
From Farm : ....
From other sources: ....

Number of households: ....

Age: ....

Education: Years of secondary schooling
Time: .... Year: ....
....
....

Any other education: ....
Time: .... Year: ....
....

Number of hours worked on farm:

Season:- Maha season : .... average hours per day
Yala season : .... average hours per day
Any other season : .... average hours per day

Do you work on weekends? i.e. Saturday and Sunday? Yes/No

Size of farm: ....

Note: It was assumed that all farmers who use pesticides were male. However, during the survey it was found that women were also spraying pesticides on the farms. Two female subjects were interviewed for this study.

COMMENTS:

Appendix: 6.2

List of Pesticides Used by the Respondents in the Study Area

Pesticides Index of the Study Area

Trade Name	Generic Name	Use	Chemical Class	
Actellic	Pirimiphos Methyl	I	Organophosphate	
Admire S.L.200	Imidacloprid	I	Nitrogranidines	
Alachlor	Alachlor	H	Chloroacetanilide (acetamide)	
Anglo Paraquat	Paraquat	H	Bipyridyl	
Anglosulfan 35% EC	Endosulfan	I	Organochlorine	
Antracol WP 70%	Propineb	F	Carbamate	
Anthio 33	Formothion	I	Organophosphate	
Asuntol	Coumaphos	I	Organophosphate	
Atabron	Chlorfluazuron	I (IGR)	Urea Derivative (trifluoromethyl)	
Bassa 50% EC	BPMC	I	Carbamate	
Basudin 50 EC	Diazinon	I	Organophosphate (pyrimidine)	
Baur's Glyphosate	Glyphosate	H	Glycene Derivative	
Baur's MCPA M40	MCPA	H	Chlorophenoxy	
Baur's M 60	MCPA	H	Chlorophenoxy	
Baursate	Glyphosate	H	Glycene derivative	
Bayrusil EC 25%	Quinalphos	I	Organophosphate	
Benlate 50% WP	Benomyl	F	Carbamate (benzimidazole) MBC	
Bavistin	Carbendazim	F	Carbamate (benzimidazole) MBC	
Barkosan	Oxadixyl	F	Oxazolidine	
Baycarb EC 50%	BPMC	I	Carbamate	
Blitox	Mancozeb	F	Dithiocarbamate	
B.P.M.C 50 EC	BPMC	I	Carbamate	
Captan 50%	Captan	F	Phthalimide	
Carbofuran 3 G	Carbofuran	I	Carbamate	
Ceyphos	Chlorpyrifos	I	Organophosphate	
Champion	Cupric Hydroxide	F	Copper Cpd	
Cobox	Copper Oxychloride	F	Copper Cpd	inorganics
Copper Sandoz	Cuprous Oxide	F	Copper Cpd	
Counter	Glyphosate	H	Glycene Derivative (phosphnicAcid)	
Curaterr 3%	Carbofuran	I	Carbamate	
Demro	Dimethoate	I	Organophosphate	
Dimethoate	Dimethoate	I	Organophosphate	
Dithane M 45	Mancozeb	F	Dithiocarbamate	
Ekalux 25	Quinalphos	I	Organophosphate	
Elsan 50%EC	Phenthoate	I	Organophosphate	
Endomack	Endosulfan	I	Organochlorine	
Furadan 3G	Carbofuran	I	Carbamate	
Gammexane	Lindane	I	Organochlorine	
Goal 2 E	Oxyfluorfen	H	Diphenyl ether (trifluoromethyl)	
Gramoxone	Paraquat	H	Bipyridyl	
Harcozeb	Mancozeb	F	Dithiocarbamate	
Harcron	Chlorpyrifos	I	Organophosphate	
Harcros Glycel	Glyphosate	H	Glycene derivative (phosphinic acid)	
Hedonal M 40	MCPA	H	Chlorophenoxy	
Kasumin2 E	Kasugamycin	F	Antibiotic	
Kumulus, DF	Sulphur	F	Sulphur - inorganics	
Lankem 3/4 D.P.A	Propanil	H	Anilide	
Lankem M 50	MCPA	H	Chlorophenoxy	

Trade Name	Generic Name	Use	Chemical Class
Lannate L	Methomyl	I	Carbamate
Larvin	Thiodicarb	I	Carbamate
Lasso 48 EC	Alachlor	H	Chloroacetanilide (acetamide)
Lebaycid EC 50%	Fenthion	I	Organophosphate
Loochlor	Alachlor	H	Chloroacetanilide (acetamide)
Lorsban 40 EC	Chlorpyrifos	I	Organophosphate
Mackarb (BPMC)	BPMC	I	Carbamate
Mackdazin	Carbendazim	F	Benzimidazole (MBC)
Machete 60% EC	Butachlor	H	Chloro acetanilide
Malathion	Malathion	I	Organophosphate
Mackzeb	Mancozeb	F	Dithiocarbamate
Macksul	Sulphur	F	Sulphur - inorganics
Makuna	Chlordane	I	Organochlorine
Mancozeb	Mancozeb	F	Dithiocarbamate
Manex 4 L	Maneb Zinc added	F	Dithiocarbamate
Manzate 200 WP	Mancozeb	F	Dithiocarbamate
Marshal 20 EC	Carbosulfan	I	Carbamate
Marunil	Propanil	H	Anilide
M.C.P.A 40%	MCPA	H	Chlorophenoxy
*Methamidophos 60 W SC	Methamidophos	I	Organophosphate
*Monitor	Methamidophos	I	Organophosphate
*Monocron	Monocrotophos	I	Organophosphate
*Monocrotophos	Monocrotophos	I	Organophosphate
Morisal WP	Sulphur	F	Inorganic Sulphur
Nuvan 100SC	Dichlorvos	I	Organophosphate
*Nuvacron 600 SCW	Monocrotophos	I	Organophosphate
Thiodan	Endosulfan	I	Organochlorine
*Parathion 50	Parathion	I	Organophosphate
Perenox	Copper Oxide	F	Copper Cpd-inorganics
Polyram M WP	Maneb	F	Dithiocarbamate
Promasol Forte WP 80%	Thiram	F	Dithiocarbamate
Pyrinex 40% EC	Chlorpyrifos	I	Organophosphate
Pyrinex 20% EC	Chlorpyrifos	I	Organophosphate
Recop	Copper Oxychloride	F	Copper Cpd - inorganics
Red Star Alachlor	Alachlor	H	Chloroacetanilide (acetamide)
Red Star Aloran	Methamidophos	I	Organophosphate
Red Star Anglo Asian Sulpher 80%	Sulphur	F	Sulphur
Red Star Veedem 600	MCPA	H	Chlorophenoxy
Red Star Veedem 400	MCPA	H	Chlorophenoxy
Red Star Weedex 36%	Propanil	H	Anilide
*Riselect	Propanil	H	Anilide
Rogor 40 EC	Dimethoate	I	Organophosphate
Round Up	Glyphosate	H	Glycine derivative (phosphinic acid)
Selecron 50 EC	Profenophos	I	Organophosphate
Sevin 85WP	Carbaryl	I	Carbamate
Servin XLR	Carbaryl	I	Carbamate
Sulphur	Sulphur	F	Sulphur - inorganics
Sumicidin super 25% EC	Esfenvalarate	I	Pyrethroid
Surcopur 36%	Propanil	H	Anilide
*Tamaron EC 60%	Methamidophos	I	Organophosphate
Tribunil WP 70%	Methabenzthiazuron	H	Urea derivative (benzothiazole)
Thiovit W P	Sulphur	F	Sulphur (inorganic)
*Three Star	d-Allethrin	I	Pyrethroid
Topsin M 70	Thiophanate methyl	F	Benzimidazole Carbamate (MBC)

Trade Name	Generic Name	Use	Chemical Class
Whipsuper	Fenoxa prop-p-ethyl.	H	Benzoxazole (phenoxy)

The Abbreviations used are as follows:

F - Fungicides
H - Herbicides
I - Insecticides
IGR - Insect Growth Regulator

Note: The pesticides marked with an asterisk have been de-registered by the pesticide registrar since July, 1995. However, these pesticides were still being used by farmers in the study area a year after the de-registration took effect. The field study was conducted from July-September, 1996 (both months inclusive). Although legislation has been effective since July, 1995, no decision has been taken to withdraw the existing or already imported chemicals. Hence, consignments imported before July, 1995 could be expected in the market till July, 1997 (this is considering the latest stocks that were imported and the permissible two year shelf life period of the pesticide products)-Assistant Pesticide Registrar (personal communication, 09/09/97)

As can be seen from the chemical class of pesticides, very toxic chemicals are being used. As can be seen organochlorines which are first generation chemicals are also being used. The second generation of pesticides such as organophosphates and carbamates which are less persistent are, however, more toxic to users. Pyrethroids on the other hand are less toxic compared to the above mentioned chemical classes. However, as can be seen from the chemical list, not many pyrethoids are being used. Not only are toxic chemicals being used by farmers, but two or three chemicals are often mixed to get quick results [Abeysekera, (1988); Jayathilake and Bandara (1989) and Chadrasekera (1985)]. Farmers also use more than the recommended dosages [Chandrasekera (1985); Siyayoganathan et al. (1995)]. Hence, it is extremely difficult to categorize pesticides according to the toxicity for regression analyses. Furthermore, in a given year, on average, a farmer uses several types of pesticides, most of which are extremely toxic and hence creating variables according to toxicity for the regression analyses is difficult.

CHAPTER 7

ESTIMATING THE COSTS OF DIRECT EXPOSURE TO PESTICIDES USING THE CONTINGENT VALUATION APPROACH

Introduction

This chapter discusses in detail the concept of the contingent valuation approach, its various uses and the applications and the advantages and disadvantages. The chapter also deals with the criticisms of the method before going on to present the results of the contingent valuation approach which was conducted for this Ph.D. thesis in 1996 to obtain willingness to pay bids to avoid direct exposure to pesticides. A contingent valuation approach cost scenario is also presented for Sri Lanka. The last section of this chapter determines the factors that influence the contingent valuation willingness to pay bids to avoid direct exposure to pesticides and the resulting illnesses among subsistence farmers. As stated in chapter four, the contingent valuation approach is a direct approach available to value non-market goods and to infer willingness to pay for such goods. Because of its ability to consider costs that are usually invisible such as intangible costs (e.g. pain, discomfort, stress and suffering), this approach is considered as a more conceptually correct approach than the other two approaches (discussed in chapters eight and nine) which are indirect. Because this approach considers all the costs, it is more superior to the other two approaches because the estimates derived by them are lower bounds. However, it should be stated that the problems and issues involved in gathering contingent valuation bids are far more complicated and difficult than the problems confronting the other two issues as was discussed in the last chapter. The costs considered in the contingent valuation approach are only the private direct, indirect and intangible costs arising to the user from ill health due to direct exposure to pesticides.

The Concept of the Contingent Valuation Approach

The contingent valuation method (CVM) has been designed to value a non market good where individuals are asked directly what they would like to pay for a good, hypothetically assuming that there could be a market for the good in question. This technique has been applied for the valuation of a very large number of non-market goods such as the environment, the value of recreation and pollution and non pollution related health effects. Whittington (1998. p. 29) points out that the contingent valuation method can be applied to obtain values of pure public goods, goods with both private and public characteristics and private goods. Contingent valuation in the 1990s is a very well established and widely practiced technique for valuing non market goods and is supplemented by other direct techniques of measuring non market goods. The contingent valuation is a direct approach in valuing a non-market good while the other two approaches used in this thesis and discussed in detail in chapters eight and nine are all indirect.

Since the contingent valuation technique was proposed by Davis (1963), it has been widely used during the last thirty five years or so to estimate economic values for a wide range of commodities for which there is no market[1]. In the last decade, however, there has been a dramatic increase in the number of academic papers and presentations related to the contingent valuation technique including many studies conducted in developing countries. These works have dealt with the methodological issues concerning the contingent valuation method and debated on the advantages and disadvantages of each approach. Very comprehensive literature and in-depth discussions and critical assessments of the method have been carried out by Cummings, Brookshire and Schulze (1986); Mitchell and Carson (1989); Carson (1991); Carson et al. (1993); Harrison et al. (1992); Navrud (1992); Desvousages et al. (1992); Hausman (1993); Milgrom (1993); Arrow et al. (1993); Hoevenagel (1994); and the 1994 (fall) issue of the Journal of Economic Perspectives; Jacobsson and Dragun (1996) and Whittington (1998).

The contingent valuation method, the most frequently used of the constructed market techniques, is now a standard technique employed in the United States to settle environmental disputes in courts in environmental law suits, especially in estimating lost passive-use values (a good example, is the Ohio State vs. Department of the Interior court case of damage assessments), by many government agencies of many countries such as Australia, Canada and Norway. International organizations such as the World Bank have also used this technique in their work, especially in developing countries. The National Oceanic and Atmospheric Administration (NOAA) in the United States also uses this technique for the natural resource damage assessments under the oil pollution act of 1990. The evaluation of the contingent valuation technique by Arrow et al. have induced the NOAA (1993) to issue guidelines for the design of contingent valuation studies of large oil spills. This followed attempts to use the contingent valuation approach to evaluate the Exxon Valdez oil spill off the coast of Alaska in 1987. Such wide use and acceptance has given added impetus to the use of the contingent valuation technique and is now a widely used technique even in developing countries of Asia, Africa and Latin America.

The contingent valuation panel which was appointed by NOAA to evaluate the use of the contingent valuation approach in determining non use values have laid down a comprehensive set of guidelines which would be met by the best contingent valuation surveys for damage assessment. These guidelines assume reliability and usefulness of the information that is obtained. We state below the broad areas of the guidelines of the report in this section and summarize seven of the most important areas of the guidelines. The NOAA guidelines are set in three main headings: General guidelines; guidelines for value elicitation surveys and goals for value elicitation surveys. The general guidelines include: sample type and size, the need to minimize non responses, personal interviews, pre-testing for interviewer effects, reporting every aspect of the contingent valuation survey and careful pre-testing of the contingent valuation questionnaire. The section on guidelines for value elicitation surveys lay emphasis on the conservative design of the survey, elicitation format, referendum format, accurate

[1] For example, Carson (personal comm. 1998) states that more than 2,500 studies have been carried out in more than 50 countries using this method.

description of the program or policy, pre-testing of photographs, giving adequate time lapse from the accident, temporal averaging, 'no answer' options, yes/no follow ups, checks on understanding and acceptance of the contingent valuation questions. As mentioned above we reproduce below seven of the most important areas of the guidelines as summarized by Portney (1994).

First, applications of the contingent valuation method should rely upon personal interviews rather than telephone surveys where possible, and telephone surveys are preferable to mail surveys.

Second, applications of the contingent valuation method should elicit willingness to pay to prevent a future incident rather than minimum compensation required for an incident that has already occurred. (Note that the latter would be the theoretically correct measure of damages for an accident that has already taken place).

Third, applications of the contingent valuation method should utilize the referendum format; that is, the respondents be asked how they would vote if faced with a program that would produce some kind of environmental benefit in exchange for higher taxes or product prices. The panel reasoned that because individuals are often asked to make such choices in the real world, their answers would be more likely to reflect actual valuations than if confronted with, say, open-ended questions eliciting maximum willingness to pay for the programme.

Fourth, applications of the contingent valuation method must begin with a scenario that accurately and understandably describes the expected effects of the programme under consideration.

Fifth, applications of the contingent valuation method must contain reminders to respondents that a willingness to pay for the programme or policy in question would reduce the amount they would have to spend on other things.

Sixth, applications of the contingent valuation method must include reminders to respondents of substitutes for the "commodity" in question. For example, if respondents are being asked how they would vote on a measure to protect a wilderness area, they should be reminded of the other areas that already exist or are being created independent of the one in question.

Seventh, applications of the contingent valuation method should include one or more follow-up questions to ensure that respondents understood the choice they were being asked to make and to discover the reasons for their answer.

These are very detailed guidelines which cover every aspect of a contingent valuation survey aimed at measuring non use/passive values. It is a study especially aimed at obtaining information/values arising from adverse environmental events such as oil spills, chemical accidents and the like. Of course, these guidelines, with certain modifications (where appropriate) can also be applied to measure benefits of environmental conservation, recreation, etc. Although, the guidelines laid for environmental damage assessment is appropriate for such assessments, some of the recommendations need to be modified when applied to other areas such as health studies and also when applying the contingent valuation technique in developing countries as pointed out in chapter six in the section dealing with the design and application of contingent valuation approach. For example, probability sampling is recommended in the NOAA guidelines but as shown in chapter six of this Ph.D. study, this was not possible. Another recommendation of the NOAA report is that of using a referendum format. As Whittington (1998) points out there are drawbacks in using a referendum format. For example, if the amount the enumerator asks lacks credibility, the respondent is unlikely to answer the question on the basis of the price asked. However, for any contingent valuation study it is important to take into consideration these comprehensive guidelines and then where appropriate to make the necessary changes based on prevailing conditions in developing countries.

The appeal of the contingent valuation method is that, in principle, it can elicit willingness to pay bids/values from a broad segment of the population, and can value environmental goods and causes of death and illnesses that are specific to environmental hazards or a specific disease category. This method has been recommended especially for the estimation of costs that are difficult to estimate such as non-use values (passive values/existence values) and intangible costs (pain, discomfort and suffering) where there are no direct market transactions taking place to obtain and to estimate economic values. This technique tries to cover such a void. For example, to ask farmers what their value would be to keep them free of health risks arising from direct exposure to pesticides during handling and spraying pesticides. Because of these attributes, the contingent valuation approach has become a unique technique which provides a conceptually correct and a more complete approach to measure willingness to pay bids/values than any other technique that values non market goods such as the environment and/or the cost of ill health. Therefore, in valuing the environment, this technique can provide useful information about the economic significance of lost passive-use values and/or information costs in addition to capturing the direct and indirect costs of any damage done. A good example that can be cited is the NOAA report that discusses these issues in relation to oil discharges that damage marine resources.

Although initially this technique was developed to measure the value of non market goods such as the value of recreation, environment, etc., it has been adopted by economists to measure the value of risk reductions, too, and in recent years, a number of studies have been carried out by health economists to asses the value of health care and the cost of illnesses [for example, see Easthaugh (1991); Johannesson et al.(1991); Johannesson (1992); Lipscomb et al. (1998)]. The first attempt to use the contingent valuation approach to value risk reductions was probably that of Acton (1973) who investigated the willingness to pay for mobile coronary care units which would decrease the risk of dying after a heart attack. Jones-Lee (1976) carried out an early study of the value of airline safety. Some of the later studies that were carried out to value current changes in risk of accidental death are: Jones-Lee, Hammerton and Phillips (1985) and Gerking, De Haan and Schulze (1988) while Viscusi, Magat, and Huber (1991) and Krupnick and Cropper (1992) have estimated the value of reductions in the risk of chronic bronchitis. Contingent valuation studies that attempted to valve risk of death in an environmental context are Mitchell and Carson's

(1986) study of willingness to pay to reduce trihalomethane levels, Smith and Desvousges's (1987) study of willingness to pay to reduce exposure to hazardous waste and Loomis and duVair (1993) study of willingness to pay for reductions in risk of premature death from hazardous wastes. Contingent valuation approach has also been used most extensively to value changes in health resulting from pollution such as poor air and water quality. For example, Brookshire et al. (1979); Loehman et al. (1981); Schulze et al. (1983) Tolley and Fabian (1988), Alberini et al. (1997) have conducted studies to value changes in air quality and Smith and Desvousges (1986); Harrington et al. (1989) have conducted a study to value changes in water quality. Many contingent valuation studies have also been carried out to determine the value of symptoms associated with environmental pollution. Some studies carried out to value mobidity effects (such as headaches, eye irritation, sinus congestion, wheezing, nausea, etc.), both minor and acute, associated with air pollution include: Loehman et al. (1979), Rowe and Chestnut (1985), Tolley et al. (1986), Dickie et al. (1987) and Chestnut et al. (1988). Health Economists, too, now widely use this technique within the health care field. For example, contingent valuation studies have been carried out to determine the willingness to pay for anti-hypertensive drug therapy, willingness to pay and willingness to give up time to seek medical help to reduce high cholesterol levels and heart patients' willingness to pay for changes in angina symptoms (Chestnut et al. 1996). For a complete review of studies carried out in the heath care field up to the mid 1990s please see Donaldson (1993) and Johansson (1995).

The contingent valuation approach elicits these values from individuals through the use of carefully designed and administered sample surveys. The main strength of this technique in the field of environmental economics is in its potential to form a damage assessment in an area (lost passive-use values) where there appears to be no behavioural trails to be followed and in the field of health economics to capture intangible and invisible costs such as pain, discomfort, stress and suffering.

The first step involved in a contingent valuation method study is the setting up of a hypothetical market where respondents will be provided with information about a hypothetical program (government or non-governmental) that would reduce the likelihood of future adverse environmental pollution damage. In the case of the theme of this work, it would be the reduction of direct exposure to pesticides, which otherwise, would cause numerous morbidity effects and even deaths among farmers each year. The contingent valuation program could be directed at preventing a chemical accident, stop or reduce air or water pollution, etc. Respondents are usually given some specific information about the exact nature of the damages that the program in question would prevent, how they would be brought about. Respondents are also confronted in the study with a question or questions that provide information about the economic sacrifice they would have to make to support the environmental program. In the case of direct exposure to pesticides, it would be the prevention of the numerous morbidity effects arising from direct exposure to pesticides that are expensive. This can be brought about by using more protective gear, using safer pesticides, adopting Integrated Pest Management methods, or organic farming, hiring labour to spray pesticides, growing food crops that do not require pesticides or giving up pesticides altogether. This may take the form of open-ended questions, asking what is the maximum amount they would be willing to pay for the program in question. The willingness to pay bids can also be obtained by a series of questions confronting them with different prices for the program depending on their previous answers or it can take the form of a dichotomous choice or close ended question format where respondents are told how much each would have to pay if the measure passed and are then asked to cast a simple "yes" or "no" vote. This dichotomous choice contingent valuation question format has gained popularity over the last few years. This is due primarily to their purported advantages in avoiding many of the biases known to be inherent in other formats used in the contingent valuation method. The NOAA panel advocate a dichotomous choice contingent valuation question over open-ended questions. The NOAA panel are of the view that open-ended questions are unlikely to provide the most reliable valuation and give two main reasons for this. The first argument against an open-ended format that is mentioned is that an open-ended format lacks realism since respondents are rarely asked or required in the course of their everyday lives to place a value on a particular good. The responses to such questions are, therefore, likely to be unduly sensitive to trivial characteristics of the scenario presented. It has also been argued that an open-ended request for willingness to pay or willingness to accept compensation invites strategic overstatement. The NOAA report goes on to state that "the more seriously the respondent takes the question, the more likely it is that he or she will see that reporting a large response is a costless way to make a point". On the other hand the NOAA panel argue that the close-ended format has many advantages. The NOAA report points out that realistic referenda on the provision of public goods are not uncommon in real life. They point out that when a referenda on the provision of public goods is carried out "there is no strategic reason for the respondent to do other than answer truthfully, although a tendency to overestimate often appears even in connection with surveys concerning routine market goods" but the report believes that it "is not an insuperable obstacle"

However, despite these advantages, drawbacks of the close-ended format, too, have been pointed out from several studies. Lunander (1998) in an experiment carried out for a jointly consumed private good using the two elicitation methods shows that when an individual had an incentive to overstate his true willingness to pay, the dichotomous choice format yielded higher estimates of willingness to pay than the open-ended format. When an individual is subjected to opposite incentives, the tests suggests no behavioural differences between the two formats. Lunander (1998) points out that the results suggests that the NOAA panel's conclusion that the dichotomous choice format is less inviting to strategic overstatement than the open-ended format is not valid when the simple majority rule is substituted for a provision and payment rule introducing incentives to overstate willingness to pay. Boyle et al. (1996) analyze differences between the open-ended and close-ended formats in three different applications by comparing the first and second moments of the estimated distributions. They also conduct a non-parametric test of the equivalence of the distributions. Their findings are mixed. Based on their results, Boyle et al. suggest that the two formats do not lead to behaviorally different valuation but they affect the distribution of the value estimates. Cameron and Quiggin (1994) while pointing out that several varieties of bias may be minimized by dichotomous choice valuation questions point out that this elicitation method can be highly statistically inefficient in that vastly larger numbers of observations are required to identify the underlying distribution of resource values with any given degree of accuracy. Whittington (1998), too, points out to the problems arising in developing countries using close-ended formats. He notes that if what the numerator asks lacks credibility then the respondent is unlikely to answer the question on the basis of the price asked.

In this study reference will be made to the fact that current high levels of direct exposure to pesticides has a high probability of causing deaths or many of the side effects, as described in chapter three. Individual farmers will be asked an open-ended question as to how much they would be willing to pay in order to avoid direct exposure to pesticides and the resulting mobidity effects. It will be explained to the farmers that risks of ill health increases with high levels of direct exposure i.e. due to larger hours of spraying, acreage sprayed and potency of the pesticides used, the level of precautions taken, etc. All other relevant information regarding the threats from the use of pesticides will also be provided. Previous studies carried out to show the harmful effects of direct exposure to pesticides will be quoted.

Once the hypothetical market has been set up, the necessary bids could be obtained. For this purpose several methods have been suggested. They include: face-to-face interviewing, telephone interviewing or by obtaining responses by mail. The advantages and disadvantages of these methods have been discussed [for example, by Mitchell and Carson (1989); Tolley et al. (1994)] but in the case of assessing the value of a reduction in 'direct exposure to pesticides' related ill health in this thesis, direct interviewing would be undertaken. Once the necessary bids have been obtained, the average willingness to pay could be calculated for the sample under study and this data could be interpreted for the entire population under study. From the responses, it is also possible to estimate a bid curve. Hanley and Spash (1994, p.55-57) discuss in detail the methods involved in obtaining the mean values, aggregating them for the entire population and obtaining the bid curve. A bid curve is also useful in assessing the validity of the contingent valuation exercise (ibid.).

The contingent valuation bids give the maximum (once and for all) amount of money that can be taken from the individual while leaving her/him just as well off as s/he was before an improvement in environment or health. In other words, a contingent valuation bid is the willingness to pay for an improvement in the environment, avoid an environmental disaster and in the case of health, reducing/avoiding the health effects and in the case of pesticides to avoid direct exposure to pesticides and thus the resulting illnesses. On the other hand, if the health quality deteriorates, contingent valuation is the minimum amount of money that must be given to the individual to compensate him or her for the loss of health quality. Contingent valuation in such a case measures the willingness to accept compensation for a deterioration in health.

The contingent valuation survey technique, because of its ability to consider non use/passive values/intangibles and many other advantages over other techniques, is thus widely used for the estimation of environmental and health benefits as mentioned earlier. However, the technique is not without its pitfalls. We discuss below some of the disadvantages and criticisms of this technique which are real and cannot be ignored if the contingent valuation method is to be considered as a reliable tool. One of the major criticisms that has been pointed out is about the accuracy and reliability of the value of bids obtained. The various biases[2] that can arise is the major criticism of this technique. The criticisms, as well as other problems and drawbacks associated with this approach are discussed briefly in the next section. For full details, the relevant studies are cited.

Accuracy of the Contingent Valuation Techniques

The contingent valuation technique is no doubt a controversial technique despite the unique advantages it offers as discussed in the last section. It is argued that respondents give answers that are inconsistent with the tenants of rational choice, that respondents do not understand what they are being asked to value (and that the stated values reflect more than that which they are being asked to value) and that respondents fail to take contingent valuation questions seriously because the results of the surveys are not binding. These problems mainly arise because of the very nature of this technique and the biases that can arise in obtaining willingness to pay values from respondents. There are various biases that arise that were mentioned in the footnote of the previous page and are discussed separately in the next section after the general criticisms have been discussed in this section. Some of the criticisms discussed in this section, it must be pointed out, may arise due to the very biases that can arise from using this technique. One major drawback of the contingent valuation method is the difficulty of verifying the results obtained. A common question that is often asked is that in spite of a properly designed contingent valuation study, how accurate are the values reported? As Kenkel et al. (1994) correctly points out, the question is unanswerable since the true values are unobservable.

NOAA (1993) report, too, point out that one of the major criticisms of the contingent valuation approach arises from the 'near' impossibility of validating externally the results of contingent valuation studies and that contingent valuation studies can result in overestimates. However, several methods have been suggested to test the validity of contingent valuation studies. Hanemann (1994) notes that there are at least three ways of validating contingent valuation results. They are replication, comparison with estimates from other sources and comparing with actual behaviour where possible. Replication of a study as pointed out by Hanemann is useful even on a small scale and is the single best way for a researcher to determine whether somebody's survey instrument works as claimed. Hanemann also points out that more than 80 studies have been conducted comparing contingent valuation estimates with indirect methods[3] and state that the results are 'fairly close' referring to Carson et al. (1994) who state that the overall contingent valuation studies are slightly lower than revealed preference estimates and highly correlated with them. Carson et al. (1996) point out that although in some instances large divergences exist between estimates based on

[2] A bias is where some factor can influence the decision made by a respondent. Hanley and Spash (1994) state " biases exists in CVM responses if they systematically underestimate or overestimate true values" (p. 58). They point out that biases may result from a number of causes. Many types of biases have been mentioned in the literature. For example, see Mitchell and Carson (1989); NOAA (1993); Hanley and Spash (1994) and Kenkel (1994). Whittington (1998) also talks of 'compliance bias' in developing countries. Some of these biases are discussed in this chapter.

[3] The first test of comparison (comparing contingent valuation and the travel demand estimates) of willingness to pay was carried out by Knetsch and Davis (1966) for recreation in the Maine woods, USA.

actual and contingent valuation surveys, they are concentrated in situations using voluntary payment mechanisms where there is an incentive to free ride with respect to actual behaviour and to over-pledge in the contingent valuation surveys. The third approach which Hanemann calls the 'ideal' approach to test the contingent valuation approach is to construct experiments so that the results of a contingent valuation study which estimate willingness to pay bids can be compared with the 'real' results when the opportunity is made available to the same sample. There are at least 15[4] such tests in the literature[5]. In such a test Seip and Strand (1992) used contingent valuation to estimate the willingness to pay for membership in a Norwegian organization devoted to environmental affairs, and compared this estimate with actual responses when a number of the same respondents were presented with an opportunity to actually contribute. The findings showed that the self-reported willingness to pay was much higher than 'actual' willingness to pay. Duffield and Patterson (1991), too, show significantly higher bids when the payment is hypothetical than when an actual cash payment has to be made. Other studies that show significant differences between hypothetical and actual values are: Kealy et al. (1988); Boyle et al. (1989); Harrison and Rutstrom (1993); Neill et al. (1994). These studies suggest that the contingent valuation technique is likely to overstate "real" willingness to pay. Duffield and Patterson (1991), however, state that the differences are small and predictable enough so that contingent valuation estimates would be discounted for possible overstatement and then used as a conservative estimate of willingness to pay. Hanemann (1994) points out the various drawbacks of the above mentioned studies and notes that the differences that exist between hypothetical and real payments could be attributed to such drawbacks in these studies. He states "many studies do not incorporate the refinements in contingent valuation method described earlier that emphasize realism and commitment" (p.31). Loomis et al. (1996) in their study to test differences between hypothetical and actual willingness to pay for an art print elicited using an open-ended willingness to pay format reject the equality of hypothetical and actual willingness to pay bids but show that the differences are smaller than in other experiments, with hypothetical willingness to pay bids being two times larger than actual willingness to pay. Bishop and Heberlein (1990) have conducted a series of experiments with hunters who applied for a deer-hunting permit in a favoured game reserve show that the estimated willingness to pay was $31 in the real sale versus $35 in the hypothetical sale which is a statistically insignificant difference. Sinden (1988) who conducted a series of 17 parallel experiments soliciting actual and hypothetical monetary donations to a fund for assisting soil conservation or controlling eucalypt dieback shows no statistical difference between actual and hypothetical willingness to pay. Other studies that prove that there is no difference between hypothetical and actual bidding are: Carson et al. (1986); Dickie et al. (1987); Cumming et al. (1993); Cummings (1994). Thus, there is some substantial evidence for the validity of contingent valuation survey responses, although more studies are needed to solve the

[4] Hanemann (1994) mentions 10 such tests. Hanemann (1994) points out that Diamond and Hausman (1992) mention only five of these. The ones that are not mentioned provide results that are quite favourable to contingent valuation. Carson et al. (1994); Carson et al. (1996) have analysed 616 comparisons of contingent valuation to revealed preference estimates for 83 separate studies conducted over a 30 year period.

[5] Bohm (1972) was the first to conduct a test that compared contingent valuation predictions against actual behaviour.

controversy between hypothetical and actual bids. Furthermore, as pointed out by Tolley and Fabian (1988), several studies have also shown that contingent valuation values are heavily dependent on socio-economic variables such as income, age, education, availability of substitutes and other variables suggested by economic theory [for instance, see Grossman (1972)]. Based on this evidence, it is implied that the contingent market in many respects is similar to an actual market and that the values reported are not random but are within the realms of economic analysis.

Some of the other criticisms that have been pointed out are that the contingent valuation approach can produce results that appear to be inconsistent with assumptions of rational choices. One of the arguments in this issue is that usually, it is reasonable to assume that something which is good, is better, so long as an individual is not satiated. When translated into a contingent valuation context, it means that the willingness to pay somewhat higher for more of a good, as judged by an individual. Also, as pointed out by NOAA (1993), if marginal or incremental willingness to pay for additional amounts of a good does not decrease with the amount already available, then it is usually not reasonable to assume that willingness to pay declines very abruptly. However, some empirical studies have suggested that willingness to pay does not increase with the good. NOAA (1993) sighting Kahenemans (1986) study shows that willingness to pay for the cleanup of all lakes in Ontario was only slightly more than the willingness to pay for cleaning up lakes in just one region violating the tenants of rational decision making. Similar works are sighted by the NOAA (1993) report [for example, see Kahneman and Knetch (1992), Desvourages et al. (1992) and Diamond et al. (1992)] to prove this point [Boyle et al. (1994)[6]]. However, Carson (1997) refutes this claim after reviewing the existing literature and shows that direct tests of the hypothesis based on split sample comparisons overwhelmingly reject the null hypothesis that valuation estimates do not vary in the expected manner. Carson (1998) notes that over 30 different studies provide a clear rejection of the hypothesis and only four uniformly accept the scope insensitivity hypothesis. Carson (1997) further goes on to show why some studies have found that willingness to pay estimates do not vary with the scope being valued. Carson points out that these instances are probably due to the use of particular survey design features and methods of survey administration. For example, Carson and Mitchell (1995) discuss several contingent valuation survey designs which are likely to mimic an apparent insensitivity to the scope of the good being valued and many problems are identified [for a detailed discussion showing that contingent valuation is sensitive to scope see, Hanemann (1994); Carson and Mitchell (1995); Carson (1997); Carson (1998) and Carson et al. (forthcoming)].

NOAA (1993) report also discusses the problems that can arise as a result of an absence of a meaningful budget constraint, information provision and acceptance, extent of the market and the 'warm glow' effects. These issues are discussed very briefly below. For a detailed examination of the issues discussed, see NOAA (1993, p.4608).

[6] Boyle et al. (1994) and Kahneman and Knetsch (1992) claim that scope insensitivity is endemic in contingent valuation studies. For a critique of Boyle et al. (1994) study see Hanemann (1995) quoted in Carson et al. (forthcoming).

For example, it is pointed out that even if respondents in contingent valuation surveys take seriously the hypothetical referendum (or the other format types) questions being asked, then subjects may yet respond without thinking carefully about how much disposable income is available before answering the question. This concern is genuine and is a real problem encountered in contingent valuation studies.

With respect to information provision and acceptance it has been pointed out that if contingent valuation surveys are to elicit useful information about willingness to pay then respondents must understand exactly what they are being asked to value (or vote upon) and must accept their scenarios in formulating their responses. It is pointed out that frequently insufficient information is provided to respondents in contingent valuation surveys. This is an obvious shortcoming that can easily arise if adequate time is not provided during interviewing. It is extremely useful to provide as much information as possible on the relevant issue and 'educate' the respondent(s) before willingness to pay values are elicited. On the issue of the extent of the market, it is pointed out that there are problems in determining the size of the market in conducting a contingent valuation survey. NOAA (1993) report also discusses the 'warm glow' effects, in that, subjects may give nothing to certain causes while they contribute to some others which they support. Hence, it is argued that such people not only support the organization in question, but are also made to feel the "warm glow" that attends donating to worthy causes.

In addition to some of the general criticisms of the contingent valuation approach pointed out by NOAA (1993) report also discusses some of the problems and biases that can arise from the improper designing of contingent valuation instruments. For example, emphasis is laid on the proper wording of the questionnaire to obtain information about the reasons for choices made, the types of questions asked (carefully and in context), making the contingent valuation bid questions as real as possible rather than being too hypothetical and abstract (the need to motivate the respondents to take the study seriously is highlighted). Furthermore, the need to take measures to detect the presence of these sources of biases and also the need to devote time to explaining and eliciting values from respondents and the drawbacks involved in such measures are also discussed. In the next section we discuss some of the biases that can arise in a contingent valuation study.

Biases and the Contingent Valuation Approach

It has been argued by many economists that contingent valuation results may be inaccurate because of the possibility that responses may be biased from the unobservable true maximum willingness to pay (or accept). Kenkel et al. (1994) examine some of the common biases that arise such as hypothetical bias, strategic bias, starting point bias, vehicle bias, and information bias. They also mention that these categories can overlap. Mitchell and Carson (1989), too, describe many of the principal biases that can appear in a contingent valuation study (for example, see pages 236-7). The entire work is devoted to an examination of the contingent valuation approach. Arrow et al. (1993) in their consultancy report to NOAA also discuss the biases in detail and show how they can arise.

Kenkel et al. (1994), for example, point out that the hypothetical bias and strategic bias can be understood as a dilemma for contingent valuation. On the one hand, if respondents believe the questions to be entirely hypothetical, they have little incentive to give accurate information concerning their maximum willingness to pay as mentioned earlier. On the other hand, if they see the exercise as playing an important role in future policy making, and not hypothetical, respondents may have incentives to strategically misrepresent their values. Such biases are natural.

Other biases can stem from the structure of the contingent valuation questionnaire. If a bidding process is used that begins by asking whether the respondent is willing to pay a certain amount, respondents may view this figure as appropriate and so bids would be biased towards the starting point. This is especially so if all relevant information is not available. In order to overcome this form of biases, an alternative questionnaire structure, the dichotomous choice contingent valuation which avoids the starting point bias has been recommended. In a dichotomous choice questionnaire, respondents are presented with a policy and a randomly chosen policy price and asked to respond yes or no to a close-ended value elicitation questionnaire (Hoehn and Randall, 1987). Another alternative that has been recommended to remedy this form of biases is to employ open-ended questions, but this can result in unusually high bids or low bids or refusals. Another common problem is the choice of vehicle by which the contingent payment is made. If it is suggested that the payment will occur through a definite vehicle scheme such as an increase in taxes, respondents who dislike taxes may underreport their values or protest the exercise by giving zero bids. Whittington (1998) points out to 'compliance bias'referring to his work experiences in developing countries. He points out that that if there is a tendency for respondents to say " yes" to whatever question the interviewer asks (here the subservient nature of rural folk have to be considered), then such an attitude results in what he terms as 'compliance bias'.

Finally, the values reported by respondents in a contingent valuation experiment may be sensitive to the information provided to the subjects during the questioning, and it has been pointed out that even the order of questions asked may be important in obtaining near accurate replies. Ajzen et al. (1996) conducting a laboratory experiment to examine potential information bias in contingent valuation provide empirical evidence to support the hypothesis that contingent valuation measures are sensitive to information provided to respondents. This is consistent with the results of previous research [for example, see Bergstrom et al. (1990)]. Loomis and Duvair (1993) have conducted a dichotomous choice experiment using two commonly used graphical risk communication devices[7] to examine whether alternative risk communication devices yield different results and whether willingness to pay responses change with risk levels. Two different versions of a contingent valuation questionnaire that differ only in the device used to communicate risks from hazardous wastes were tried. Both risk communication devices provided willingness to pay functions which vary in a statistically significant fashion with absolute risk reduction. However, the empirical results also demonstrated that different risk communication

[7] The two graphical risk communication devices used to communicate risks were the risks ladder and risk circles/pie charts devices.

devices produce statistically different logit equations and hence estimates of willingness to pay for reductions in hazardous wastes. Loomis and Duvair (1993), therefore, point out that given the empirical evidence presented in their work, either device seems adequate for communicating risk reductions in the elicitation process of a contingent valuation survey but caution that before these conclusions can be generalized it is desirable to replicate for a wide variety of risk levels.

In the last few sections we discussed the advantages and disadvantages of the contingent valuation approach. In the next section, we present the results of the contingent valuation approach that was carried out for this Ph.D. study. The field study was carried out in the summer of 1996. The questionnaire design for this study was discussed in chapter six. We first present the results of the entire sample group and then give a breakdown for the respective study areas. The section that follows, discusses the cost scenarios.

Contingent Valuation Bids to Avoid Direct Exposure to Pesticides

In the questionnaire designed to gather data on direct exposure to pesticides, an entire section was devoted to gathering contingent valuation bids for a reduction in direct exposure to pesticides or in other words to avoid ill health resulting from direct exposure to pesticides.

Initially, 227 farmers were interviewed, out of whom, three gave zero bids. Another 21 questionnaires had missing data. The three questionnaires containing the three zero bids and the 21 questionnaire with missing data were excluded from this study as discussed in chapter six. For the entire study, the contingent valuation bids varied a great deal from bids as low as Rs 300 to as high bids as Rs 70,000 (please see Table 7.1). The amounts bid varied across individuals according to the severity of the illness suffered or according to the extent of direct exposure to pesticides, income, and a host of other factors. On average, farmers who were often exposed to pesticides and who suffered a great deal paid larger bids, while those with less exposure and who suffered fewer health effects paid less. Furthermore, farmers with higher incomes paid higher bids. The average contingent valuation bid for the sample group was Rs 11,471.18 which is more than two and a half months income of an average farmer in Sri Lanka. By any standard this is a very large cost. The contingent valuation bids for the respective areas were also high and exceeded more than a months income of an average farmer except one area (Yatawatte) which was close to two months salary. The payment was in the form of higher prices/costs which the respondents had to pay to avoid direct exposure to pesticides. They were very specifically told about the range of options they had to avoid direct exposure to pesticides [for example, using safer but more expensive pesticides, adopting Integrated pest management (IPM) strategies, hiring labour to spray pesticides] which, however, could cost more to use/adopt them (please see questionnaire). It was very important to make the payment vehicle as realistic as possible. Taxes were deliberately avoided because during the pre-testing of the questionnaire (pilot study) it was found that respondents disliked the idea of taxes[8] and thought that this Ph.D. study was being conducted to compile a register for the implementation of taxes in the future. Therefore, because of the difficulties mentioned, higher prices/costs were preferred to taxes[9]. Interestingly, Carson (per com. (1998) points out that a major problem with contingent valuation surveys in developing countries is that of finding a plausible payment vehicle for the good in question. All the respondents in the study areas were provided with the same information including the payment vehicles suggested. Table 7.1 presents the contingent valuation bids for the entire sample and the respective areas.

Table: 7.1 Contingent Valuation Bids for the Study Areas

Sample Group	Sample Size	Lowest Bid	Highest Bid	Average Bid
Study Sample	203	300	70,000	11,471.18
Ambana	31	300	38,000	12,829.03
Kandalama	46	500	50,000	12,834.78
Polonaruwa	31	1000	65,000	15,370.97
Yatawatte	53	300	70,000	7,548.11
Beligamuwa	42	600	50,000	11,047.62

Survey Period: July to September, 1996

As can be seen the individual sample bids vary a great deal (column 3 and 4). However, the average bids except in one area are more or less of the study sample average. The variations in individual bids as mentioned earlier can be attributed to income, awareness of pesticide poisoning, severity of illness due to direct exposure to pesticides and a host of other factors. Factors that influence the willingness to pay to avoid direct exposure to pesticides among subsistence farmers is the theme of the last section of this chapter. This is one way of assessing the validity of the contingent valuation exercise [Hanley and Spash (1991)]. We can now use the willingness to pay bids/values shown in Table 7.1 to estimate the contingent valuation cost scenarios for the entire country. We believe that the true figure lies in between this range. We have to resort to scenarios because no government agency in Sri Lanka, including the Department of Agriculture and the Department of Health or the Pesticide Poisons Bureau know the number of farmers affected by direct exposure to pesticides during handling and spraying on the farms. For the scenarios in this study we use 1978 employment survey data compiled by the Department of Labour which puts the number of agricultural workers in Sri Lanka at 472,435. A census carried out in 1982

[8] Loomis and Duvair (1993) point out that " the payment of higher taxes is not an emotionally netural subject for many people and that such a payment vehicle may increase the number of protest bids" (p.288).

[9] For a contingent valuation study that uses the wording 'higher prices' to describe the payment, see, Ready et al. (1996). Also see Kenkel et al. (1994).

puts the number of 'agricultural operators' at 1,803,99. An agricultural operator has been defined as any person responsible for operating an agricultural land or one who looks after livestock or poultry. The agricultural land defined includes all plantation crops such as Tea, Rubber and Coconut and cash crops where pesticide use is minimal. This also includes home gardens and land not cultivated on a regular basis. The owner of any of these lands or a person engaged in livestock or poultry farming is classified as an 'agricultural operator'. Since this definition of agricultural operators is wide, we prefer to use the employment survey data of 1978 for this Ph.D. study[10]. Since these two surveys were carried out, no survey has so far been conducted to determine the number of agricultural workers in the country. This is due to the continuing civil war in the North and East of the country which started in 1983. Of the 472,435 agricultural workers in Sri Lanka (according to the 1978 employment survey), not all use pesticides since some of them are plantation workers. In this Ph.D. study we assume that a minimum of 50,000 and a maximum of 300,000 agricultural workers are affected each year due to direct exposure to pesticides in Sri Lanka.

Table 7.2 shows such cost scenarios for the entire country. The lowest contingent valuation bid/value estimate shows that the value to farmers in Sri Lanka of avoiding

Table: 7.2 Contingent Valuation Cost Scenarios for Sri Lanka

Sample Group	A	B	C	D
Study Sample	573,559000	1147,118000	1720,677000	3441,354000
Ambana	641451500	1282903000	1924354500	3848709000
Kandalama	641739000	1283478000	1925217000	3850434000
Polonnaruwa	768548500	1537097000	2305645500	4611291000
Yatawatte	377405500	754811000	1132216500	2264433000
Beligamuwa	552381000	1104762000	1657143000	3314286000

Survey Period: July to September, 1996

Note: The average contingent valuation bids 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.

direct exposure to pesticides or in other words the cost of direct exposure to pesticides is more than 573 million Rs (scenario A) while the high value/cost scenario (scenario D) shows that farmers incur a cost of more than 3,441 million Rs in the form of contingent valuation costs due to direct exposure to pesticides. These costs include

[10] Jeyaratnam et al. (1982a), too, uses this data for his study.

not only the direct and indirect costs of direct exposure to pesticides but also includes intangible costs as well.

The contingent valuation approach conformed to all but one of the appropriate and applicable guidelines for this Ph.D. study laid down by the NOAA panel including the main guidelines as identified by Portney (1994) which were summarized at the beginning of this chapter. The contingent valuation study, however, could not adopt a referendum format due to the nature of the study and due to the problems encountered during the pilot study as discussed in an earlier section of this chapter and in chapter six.

There are several ways through which the validity of the contingent valuation exercise can be gauged. As Hanemann (1994) points out one method is to replicate the contingent valuation study. For this Ph.D. study this was not possible. A second approach is to compare the contingent valuation results with actual behaviour. This was not possible either for this Ph.D. study. A third approach is to compare the contingent valuation approach with indirect methods. For this Ph.D. study the results of the contingent valuation approach are compared with the results of two indirect methods used in this study, namely the cost of illness and the avertive behaviour approaches. The comparison shows (shown in the last section of chapter nine) that the contingent valuation bids obtained are valid. This is because, as hypothesized in chapter five, contingent valuation studies exceed the sum of changes in defensive expenditures and costs of illnesses. Unfortunately, there are no other studies of willingness to pay that have been carried out to avoid direct exposure to pesticides by farmers that can be compared with the results of this Ph.D. study. Furthermore, as regards 'content or face validity' the survey instrument was carefully designed and pre-tested as described in chapter six in order to make sure it adequately covered the domain of the goods it intended to measure. Another test of validity is the estimation of the bid curve that is shown in the next section. The results show that the subsistence farmers willingness to pay to avoid direct exposure to pesticides increase with farmers income, size of household, poor health resulting from direct exposure to pesticides and the length of time a farmer is involved in handling and spraying pesticides on the farm for a given year. We discuss the econometric work in more detail in the next section.

Factors Influencing Willingness to Pay to Avoid Direct Exposure to Pesticides and the Resulting Illnesses Among Subsistence Farmers

In this section we examine the relationship between contingent valuation willingness to pay bids/values to avoid direct exposure to pesticides affecting the users (farmers) health and the various socioeconomic, health and time variables. The aim is to determine how much of the variation in the contingent valuation willingness to pay bids could be explained by differences in the observed characteristics. The results of the econometric analysis are relevant, not only for economic models explaining the factors affecting the demand for environmental quality and/or to avoid direct exposure to pesticides[11], but also for policy decision making.

The first section examines the hypotheses determining the contingent valuation bids/values to avoid direct exposure to pesticides. The variables considered are socio-economic characteristics of the respondent, the health impacts of the farmer using pesticides and the length of time pesticides are used on the farms. We then go on to describe the regression analysis, showing first the summary statistics and then, the results are presented. The results are discussed and we then discuss the policy conclusions arising from the regression results. The section concludes with a brief summary of the results of the analysis and the policy implications stemming from determining the variables that affect the willingness to pay bids/values to avoid direct exposure to pesticides and/or pollution control.

Two statistical techniques commonly used in contingent valuation namely OLS estimation and Tobit analyses are used and the results are compared. It is because Tobit analysis is the more theoretically correct method for willingness to pay data sets (Halstead et al. (1991).

Hypotheses about the Determinants of the Valuation Bids

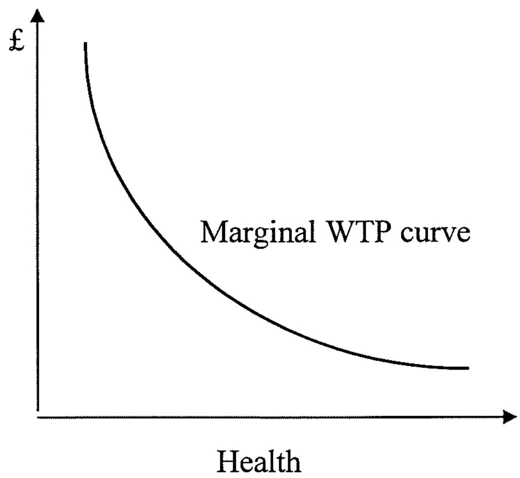
For the econometric analysis the standard socio-economic measures such as income, education, household size and age are used. The selection of socio-economic measures used as explanatory variables are similar to those that have been used by Brien et al. (1994) who examined the relationship between contingent valuation willingness to pay bids/values and socio-economic variables for various illnesses (not pollution related) and influenced by the theoretical work carried out by Grossman (1972) and Feldstein (1993) on demand for health and medical care. It is the perceived view that differences in demand for health and medical care can be influenced according to education, age, income and other socio-economic factors. Hence, in this section, it is hypothesized that the better educated individuals are expected to bid more to avoid direct exposure to pesticides and the resulting illnesses; individuals with higher incomes are willing to pay more to avoid direct exposure to pesticides and the resulting illnesses. It is also hypothesized that older individuals are expected to bid less than the young. This is because as older people come to the end of their working life their spending abilities are affected due to the need to save for retirement years. For farmers in Sri Lanka, no pension scheme exists. Furthermore, as a farmer gets older, his ability to work on the farm diminishes, especially when the work involved is labour intensive.

It is also hypothesized that individuals in bad health are expected to bid higher amounts for improvements in their health, reflecting increasing marginal disutility of bad health [Brien et al. (1994, p.169)]. This follows Grossman's (1972) standard

[11] The contingent valuation question was framed to obtain WTP bids to avoid direct exposure to pesticides only and not to obtain WTP bids for environmental quality or environmental protection. However, in the discussion, the WTP bids to avoid direct exposure to pesticides are taken to represent environmental quality/protection as well. This is an assumption made to make the interpretation of the regression results for policy implications much wider and easier.

assumption of diminishing marginal utility of good health, where, the more healthy days an individual experiences, the less she/he is willing to pay to obtain an additional good day. This can be shown by a marginal willingness to pay curve for improved health. As shown in Figure 7.1, the curve slopes downwards due to the individual by assumption, is willing to pay less for a marginal increase in health if his or her health is good than if his or her health is bad. A dummy variable is used to describe the health status of the respondents. The dummy variable indicates whether a respondent has suffered ill health from exposure to pesticides or not. We use 1 to indicate ill health and 0 to indicate 'no ill health' from exposure to pesticides resulting from handling and spraying pesticides on the farms.

Figure: 7.1 Expected Relationship Between Ill Health and Marginal Willingness to Pay for Improved Health



Source: Johansson, 1995 (p.12)

Another important variable used is the length of time pesticides are used on the farm for a given year. It is hypothesized that more months a farmer is engaged in handling and spraying pesticides, the more likely that she/he is to suffer health risks. Therefore, such an individual would bid more to avoid exposure to pesticides and hence the resulting illnesses that accompany such exposure.

Regression Analysis

Using the primary data collected during the field survey of 1996, OLS and Tobit regressions are performed. In the regression, farmers monthly income (INC), age (AGE), education (EDU), number of households (NOI), whether a farmer has suffered ill health or not from exposure to pesticides (SICK) and length of time pesticides are handled and sprayed shown by the months of pesticide use (TIME) are used as explanatory variables. The dependent variable is the contingent valuation willingness to pay bids to avoid exposure to pesticides. The following specification was developed for the regression analysis.

$$CV = f(\underset{+}{INC}, \underset{-}{AGE}, \underset{+}{EDU}, \underset{+}{NOI}, \underset{+}{SIC}, \underset{+}{TIME})$$

The variables in the above function are identified in Table 7.3 showing the summary statistics. The expected signs of the partial derivatives are indicated beneath each argument in the above function. As the signs indicate, the higher is the income of a farmer, then higher would be his contingent valuation willingness to pay bid to avoid direct exposure to pesticides. As a farmer gets older, he is expected to pay less to avoid ill health resulting from direct exposure to pesticides. This is because as older people come to the end of their working life their spending abilities are affected due to the need to save for retirement years. There exists no pension scheme for farmers in Sri Lanka. Furthermore, old age also reduces a farmers ability to work on the farm effectively especially when the work involved is labour intensive. The more educated a farmer is, the higher would be his contingent valuation willingness to pay bid to avoid direct exposure to pesticides; the higher is the number of households, then out of concern for his family a farmer would be willing to pay a higher bid. Furthermore, the higher the marginal disutility of ill health from exposure to pesticides, then higher would be his willingness to pay to avoid direct exposure to pesticides and longer an individual is engaged in spraying pesticides, then higher would be his willingness to pay to avoid exposure to pesticides.

Summary Statistics

Reported in Table 7.3 are the means and standard deviations for all variables that were included in the regression analysis.

The mean contingent valuation bid is Rs 11,471 for a year which is around two and a half times the average monthly income. The yearly average income is Rs 56,978. The mean age is 40 years and the household size is around five per family. The average level of education is 7.5 years. A large number of farmers suffered from morbidity effects due to exposure to pesticides and the mean is as high as 0.96 handling and spraying pesticides for around nine months of the year.

Regression Results

The results of the OLS and Tobit estimates are presented in Table 7.4. For the Tobit analysis only the t-raios are reported. Tests carried out showed evidence of violations of assumptions such as linearity, equality of variance and normality of the distribution of the residuals. This was minimized by taking the logs of the dependent variables in the regression analysis. The log transformation of the dependent variable also improved the goodness of fit. Appendix 7.1 shows the results of the various tests performed before and after the logarithmic transformation of data. The 'tolerances and variable inflation factor and the collinearity diagnostics' for the variables showed that multicollinearity was also not a problem among the independent variables. For this regression analysis we interpret the results 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: $\beta > 0$.

Table: 7.3 Means and Standard Deviations for a Reduction in Direct Exposure to Pesticides

Variable Label	Description	Mean	Standard Deviation
CVM	Contingent Valuation Bid	11,471.20 Rs	12684.43
INC	Yearly Income	56,978.10 Rs	53855.00
AGE	Age	40.00 Yrs	11.20
EDU	Education	7.57 Yrs	3.27
NOI	Household Size	4.92	3.20
SIC	Sickness	0.96	2.10
TIME	Months of Pesticide Use	8.99	2.10

Discussion of Results

The OLS and Tobit analyses show that there are no significant variations in the two analyses that affect the significance of the results. This may be due to the absence of non-zero values in the contingent valuation bids. The results show that income of the respondent is a significant factor influencing willingness to pay to avoid direct exposure to pesticides. The household size variable, too, is a significant factor influencing willingness to pay at the 10% level of significance for a one tailed test.

Education coefficient, however, is small and is insignificant. These results confirm the Brien et al. (1994) studies contradicting the theoretical belief that higher the level of education, the higher is the contingent valuation willingness to pay bids. However, this result is not surprising because in most schools environmental subjects, including harmful effects of pesticides, are not taught. Hence, the level of awareness is limited. The age coefficient has the correct negative sign but is insignificant.

On the other hand, there is ample evidence to show a strong relationship between the respondents' ill health resulting from exposure to pesticides and the amounts bids reflecting increasing marginal disutility of illness. This variable is highly significant. The length of time a farmer is engaged in handling and spraying pesticides for a given year is also significant.

Table: 7.4 Regression Results of the Contingent Valuation Willingness to Pay bids to Avoid Direct Exposure to Pesticides

	OLS				Tobit
Variable	Untandardized Coefficients B	Standardized Coefficients Beta	Standard Error	t-Ratio	z = b / s. e.
INC	3.4E-06	0.166	0.000	2.402****	2.444****
AGE	-6.8E-03	-0.068	0.007	-0.874	-0.890
EDU	2.0E-03	0.006	0.026	0.074	0.075
NOI	3.6E-02	0.103	0.023	1.518*	1.545*
TIM	8.2E-02	0.154	0.037	2.162***	2.201***
SIC	1.076	0.210	0.359	2.990****	3.043****
(Constant)	6.933	-	0.582	11.903	12.114

R Squared = 0.10 Adjusted R Square = 0.08 Standard Error = 1.06 F = 3.58
The asterisks *** *, ***, ** and * indicate 1, 2.5, 5 and 10% level of significance respectively for a one tailed test.
No non-zero observations
n = 203

Note: We interpret the beta coefficients in the regression results rather than the B coefficients. This is because the units of measurement of the variables are not the same. Hence, the coefficients are not directly comparable. Therefore, when variables differ substantially in units of measurement, the sheer magnitude of their coefficients does not reveal anything about their relative importance. Hence, in order to make the regression coefficients somewhat more comparable, the coefficients have been standardized to take into account the differences in the various units of measurement of the variables. Therefore, the beta coefficients are the standardized coefficients while B coefficients are the unstandardized coefficients. The standardized beta coefficients can be calculated directly from the regression coefficients using the following formula: B_1 (S_x/S_y) where B_1 is the regression coefficient and S_x is the standard deviation of the independent variable and S_y is the standard deviation of the dependent variable (SPSS, 6.0, 1993, p.314, 342).

Policy Implications

The conclusions of the regression results are useful for policy decision making. The results show that income of the farmer play a significant part in the determination of the willingness to pay bids in avoiding direct exposure to pesticides and/or pollution control or environmental protection. This is consistent with general economic theory including for a 'low income' developing country. The size of household is also significant at 10% level of significance. The results also show that education and age do not play a significant part in the determination of the willingness to pay bids while the effects of pesticide exposure on the health of the user and the length of time pesticides are sprayed for a year play a significant role in the determination of the willingness to pay bids to avoid exposure to pesticides. The education variable being insignificant in the determination of the willingness to pay to avoid direct exposure to pesticides has many implications. We know (as shown in chapter three) that exposure to pesticides cause many long-term illnesses, in addition to short-term health effects, most of which are incurable. The level of education here does not play a role in preventing such short-term and long-term illnesses. The problem is even more serious, especially because pesticide pollution that is released into the environment can also be non point in nature and is also very potent. The sum effect of all the pesticide pollution generated by a very large number of users is even more lethal and is made more dangerous because of the stock build up in the environment. Furthermore, another implication that arises out of the results is that, individuals begin to take note of the need to avoid direct exposure to pesticides only after they have suffered from ill health due to direct exposure to pesticides, until which time they may use pesticides. Hence, the damage done from exposure to pesticides not only to human health but to the native fauna and the environment in general is very large. By the time the victims of direct exposure to pesticides begin to pay to avoid such direct exposure because of the adverse effects (ill health), the damage done would be irreversible. Also in such a situation, the results imply that even governments would begin to act only once the damage to human health and the environment has begun to take effect and the damage done is visible. Foresight in avoiding the dangers and the health effects arising from direct exposure to pesticides and/or environmental pollution does not play a role.

The long-term consequences are even more frightening. We know that studies in the United States have shown a probable connection between pesticide poisoning and long-term effects such as various cancers, loss of memory, tumors, etc. (Hoar, 1986; Nielson and Lee, 1987). In such a case, even if a respondent realizes that a chronic illness is due to direct exposure to pesticides and is willing to pay to reduce such exposure, it would be too late since most of these illnesses are not completely curable.

Such a trend is very dangerous. As we have seen, not only are the health of users affected, but the fauna and the environment in general are also affected due to pesticide handling and spraying. Furthermore, the effect on those living around must also be considerable since water sources and the entire environment are affected. The entire food chain can be affected as a result. The damage done to consumers of cultivated food crops, though unknown must also be high. It has been shown that pesticides can be taken up by crop roots and end up in the food produced. Furthermore, the residues of pesticides sprayed on crops can end up in the food harvested. Hence, the long-term effects on consumers must be considerable. The cost of other negative externalities (discussed in chapter two) must also be high. Several interesting negative externalities arising from pesticides were noted during the study. Herbicides used on onion plots to destroy weeds when spread to neighbouring farms due to strong winds destroyed other crops which were not resistant to the herbicides used[12]. The damage done was very large since it affected the crop of an entire season. There were several externalities of this nature. The damage done to fish production is

[12] It is interesting to note that the Pea plant in recent years has been genetically engineered for the purpose of making it completely immune to herbicides such as Roundup. This enables farmers to blitz the entire farm with Roundup which virtually kills all plants and weeds (and also other microorganisms and insects) except the cultivated Pea crop.

unknown, although, in Malasiya, Philippines and Bangladesh declining fish yields have been linked to pesticide pollution (Dinham, 1993, p.69; Sudderuddin and Kim, 1970; Ministry of Finance, Bangladesh, 1992; IAD, March/April, 1990).

Conclusion

In this chapter the contingent valuation approach was considered and the contingent valuation bids to avoid direct exposure to pesticides and the resulting adverse health effects was obtained. The approach considered all costs incurred by farmers, including the intangible costs such as pain, discomfort, stress and suffering. The cost scenarios show that the total costs incurred by farmers in Sri Lanka are very large. It was also shown that on average, a farmer incurs a cost of around two and a half months income per year due to illnesses resulting from direct exposure to pesticides during handling and spraying on their farms. The costs by any standard are very large.

The regression results showed that a farmers income and size of household do play a role in the determination of the willingness to pay bids to avoid direct exposure to pesticides even in a low income developing country while the level of education and age do not influence a farmers willingness to pay to avoid direct exposure to pesticides. The results also show a strong relationship between poor health resulting from direct exposure to pesticides and the amounts bid reflecting increasing marginal disutility of illness. The length of time a farmer is involved in handling and spraying pesticides for a given year is also a significant variable in explaining the determination of the willingness to pay to avoid direct exposure to pesticides. These have important policy implications as discussed and also show that the contingent valuation willingness to pay responses to avoid direct exposure to pesticides are internally valid.

In the next two chapters we examine two indirect approaches, namely the cost of illness and the avertive behaviour approaches to examine the costs of direct exposure to pesticides and thereby to infer willingness to pay bids/values to bring about a reduction in direct exposure to pesticides and the health hazards arising from such exposure.

Appendix: 7.1

Tests for Violations of Assumptions

A diagrammatic (scatter plot) search was conducted on residuals to look for evidence that the necessary assumptions are violated. The studentized residuals which is the residual divided by an estimate of its standard deviation which varies from point to point, depending on the distance of X_i from the mean of X are used. The studentized residuals are used because it is believed that Studentized residuals reflect more precisely the differences in the true error variances from point to point.

A convenient method to check if the assumptions of linearity and homogenity of variance are met is to plot the residuals against the predicted values. If the assumptions of linearity and homogenity are met, there should be no relationship between the predicted and the residual values. Furthermore, the same plots can be used to check for violations of the equality-of-variance assumption. If the spread of the residuals increase or decrease with values of the independent variables or with predicted values, the assumption of constant variance of Y for all values of X should be in doubt.

Figure 7.1 shows a plot of the studentized residuals against the predicted values. As can be seen the spread of the residuals increases with the magnitude of the predicted values suggesting that the equality-of-variance assumption appears to be violated. It is also important to examine whether the distribution of residuals are normal or not. The distribution of the residuals may not appear to be normal for reasons other than actual non-normality such as mis-specification of the model, non constant variance, a small number of residuals actually available for analysis, etc. Hence, as is recommended, several lines of investigation should be pursued and one of the simplest and easiest to perform is a histogram of the residuals.

A normal distribution is superimposed on a histogram of observed frequencies (indicated by the bars). It is unreasonable to expect the observed residuals to be exactly normal. Some deviation is expected because of the sampling variation. Even if the errors are normally distributed in the population, sample residuals are only approximately normal. In the histogram shown in Figure 7.2, the distribution does not seem normal since there is an exaggerated clustering of residuals toward the centre and a straggling tail toward large positive values. Thus, the normality assumption may be violated. Another way to compare the observed distribution of residuals to the expected distribution under the assumption of normality is to plot the two cumulative distributions against each other for a series of points. If the two distributions are identical, a straight line results. By observing how points scatter about the expected straight line, it is possible to compare the two distributions.

Figure 7.3 is a cumulative probability plot of the residuals. Initially, the observed residuals are above the "normal" line, since there is a smaller number of large negative residuals than expected. Once the greatest concentration of residuals is reached, the observed points are below the line, since the observed cumulative proportion exceeds the expected. As shown in the three figures there is evidence of violations of assumptions. In order to correct for violations of assumptions many remedies have been recommended. One strategy is to reformulate the model by using weighted least squares. Another solution recommended is to transform the variables so that the current model will be more adequate. This can be done, for example, by taking logs, square roots, or reciprocals which can stabilise the variance, achieve normality, or linearize a relationship. Here we transform the dependent variable into logarithmic form.

With the transformation of data, the scatter plots show a marked improvement in the behaviour of the residuals shown in Figure 7.4. The spread no longer shows a tendency to increase. Furthermore, Figure 7.5 shows a near normal distribution. Figure 7.6 also shows an improvement over Figure 7.3. The observed residuals are closer to the straight line in Figure 7.6 than before the data transformation. The transformed data has also resulted in a slight increase in multiple R and the outlier plot has also improved. Thus, the transformation appears to have resulted in a better model.

Scatter Plots Before the Semi Log Transformation of the Dependent Variable.

Figure:7.1

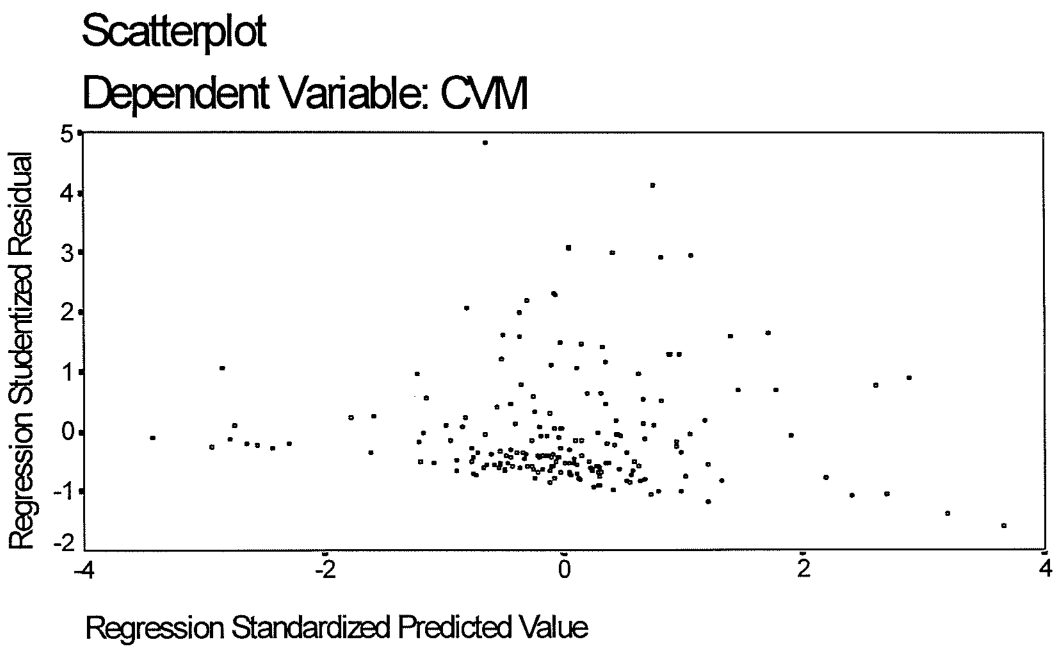


Figure:7.2

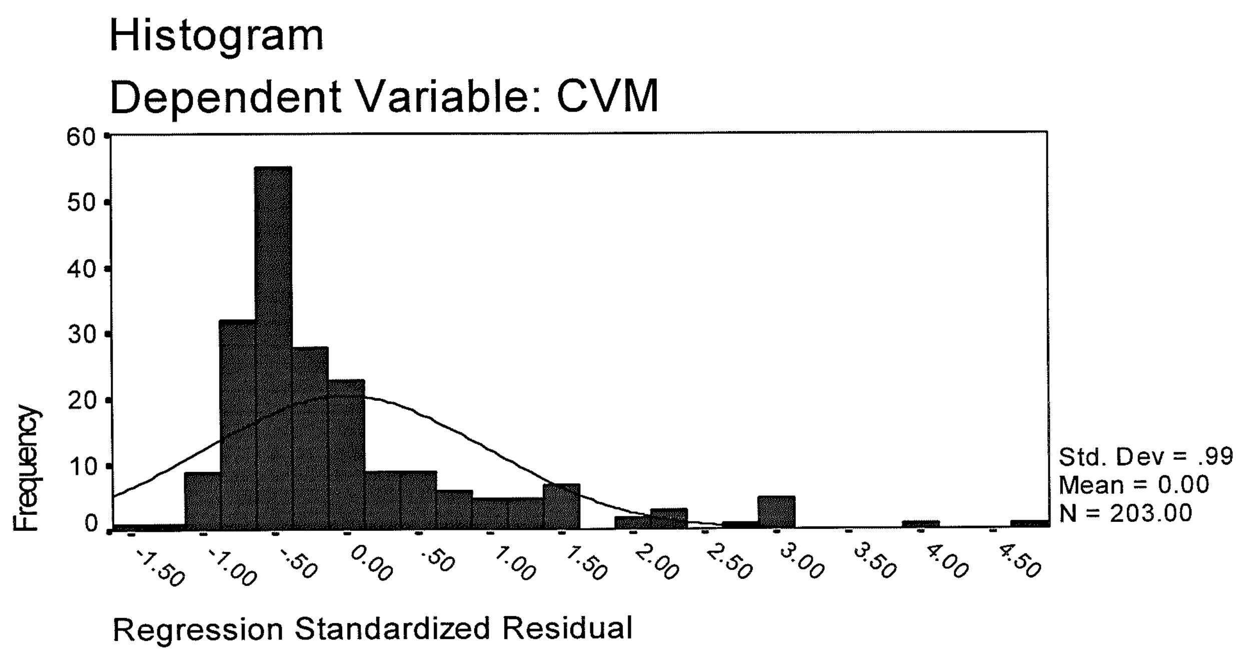
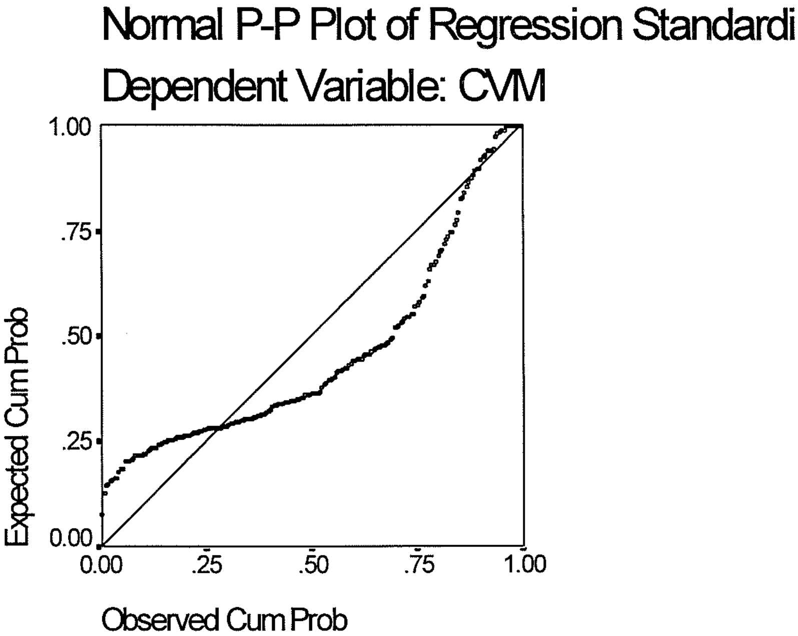


Figure:7.3


Normal P-P Plot of Regression Standardi
Dependent Variable: CVM
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Expected Cum Prob
Observed Cum Prob

Scatter Plots after the Semi Log Transformation of the Dependent Variable.

Figure:7.4

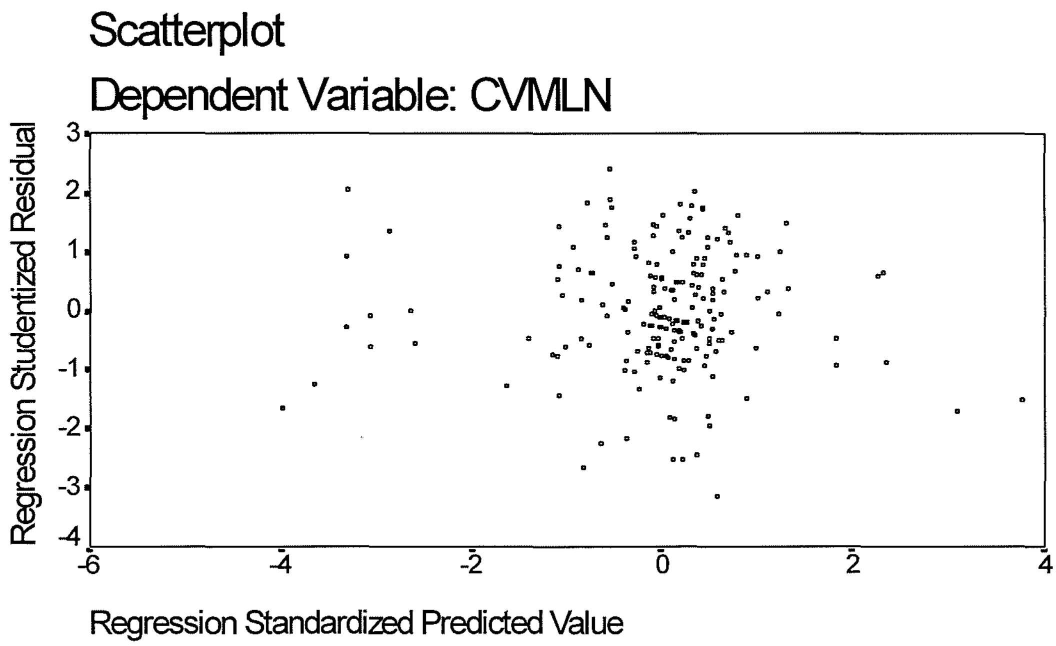


Figure:7.5

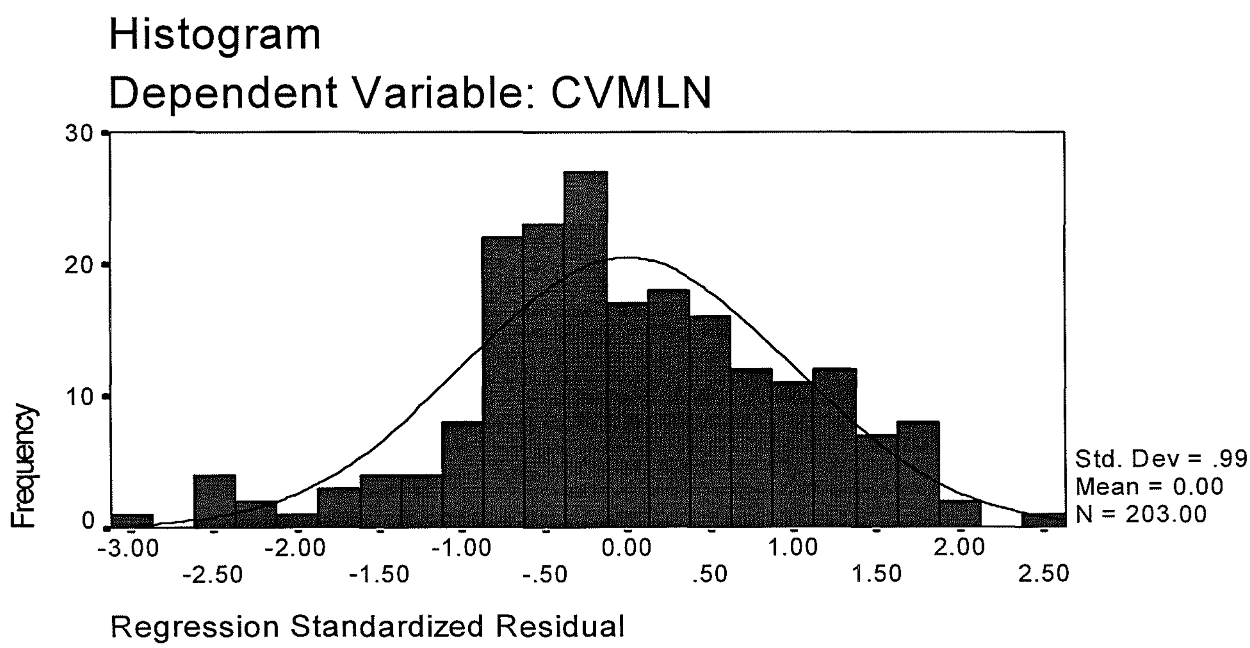
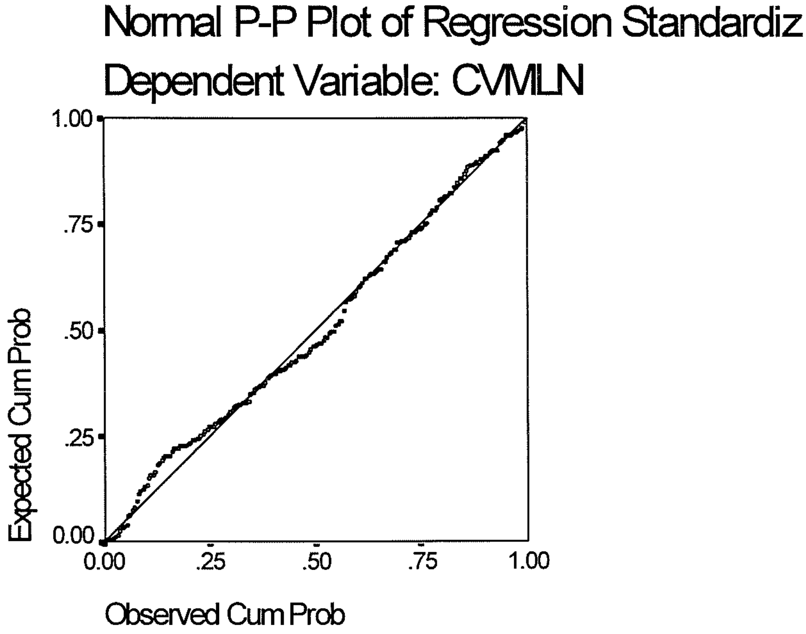


Figure:7.6



Normal P-P Plot of Regression Standardiz
Dependent Variable: CVMLN
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob

CHAPTER 8

AN EMPIRICAL ESTIMATE OF PRIVATE COSTS OF ILLNESSES ARISING FROM DIRECT EXPOSURE TO PESTICIDES

Introduction

This chapter tries to estimate some of the private costs to farmers arising from ill health due to direct exposure to pesticides using the cost of illness approach. For the estimation of these costs, the data collected from the field study carried out in 1996 for this Ph.D. thesis is used. The private costs considered are both direct and indirect costs. In this chapter, only the private costs are considered because hospital health care is provided free of charge in Sri Lanka. The private costs included in this study are any privately purchased medical care, dietary expenses resulting from a pesticide exposure related illness, travel costs associated with medical treatment, time spent on traveling/seeking treatment (hours/visit), loss of work days/hours on farm, loss of efficiency, leisure time losses (hours/days), hired labor due to inability to work, and any other losses incurred due to illnesses from direct exposure to pesticides (for example, crop damage due to inability to look after crops such as from theft and damage from wild animals). The estimation of costs is for one year. These private costs are incurred by farmers on pesticide spraying days and non-spraying days arising mostly from acute short-term symptoms. An attempt has also been made to include the costs incurred from long-term illnesses arising from exposure to pesticides for one year[1] as well.

A study of this nature is useful in many ways in that they tell us about the extent and severity of direct exposure to pesticides and the costs to the individual and society in general arising from illnesses due to such direct exposure to pesticides. Such a study will also give us an indication of public costs or in other words the costs to the hospitals. Although this Ph.D. study does not consider the public costs, the various hospital costs that should be considered in estimating the public costs are discussed in detail in this chapter. In terms of foregone earnings, such measures not only tell us about the loss of income to the affected individual, but also shows how much the family and the production processes can be affected. Furthermore, the estimation of costs can give us an idea of the probable benefits of minimizing or even avoiding such illnesses, especially important in the context of pollution control. By comparing the costs, both direct (e.g. medical expenditures) and indirect (e.g. foregone earnings) and benefits of pesticide use, we can also show the welfare gains of a reduction in pesticide use. Of course, the estimates can also be used to infer willingness bids/values to pay to bring about a reduction in pollution, for example, direct exposure to pesticides.

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[1] Here, the various costs incurred by farmers suffering from long-term illnesses for a given year are estimated - i.e.1995-1996. For example, a farmer can suffer partial blindness due to exposure to pesticides. In such a case he would be incurring costs for the rest of his life. We try to estimate the costs incurred by such persons for a given year.

Before presenting the empirical estimates of the field study, the cost of illness approach will be discussed in detail where the advantages and disadvantages will be highlighted. Furthermore, other relevant studies carried out based on the cost of illness approach will be discussed, followed by a discussion of the cost of illness estimates of this Ph.D. study.

The first section begins with a review of the cost of illness approach, dealing with the advantages and disadvantages of the cost of illness approach and discussing studies that have been carried out using this approach. The problems associated with data and the quality of costs of illness estimates will be described, together with a discussion on previous estimates of direct and indirect costs. The chapter then examines the application of the cost of illness approach to measure the costs of pesticide pollution and then go on to present and discuss the private costs arising due to morbidity effects that can be attributed to direct exposure to pesticides. The last section of this chapter determines what factors are responsible for the very high levels of direct exposure to pesticides which results in numerous morbidity effects among the farmers handling and spraying pesticides on the farms.

The Concept of the Cost of Illness Approach

One of the many techniques that have been developed to measure the costs arising from an illness is the cost of illness approach. This approach is and has been widely used in the estimation of costs arising from an illness or illnesses and has been particularly useful in showing the costs arising from pollution, food poisoning[2], water contamination[3] and hence the benefits accruing from such control. The cost of illness approach in many studies has been called by different titles such as 'the damage avoidance' approach (which health professionals and some health economists like to call), the 'earnings expenditure' approach [for example, Berger et al. (1987, p.967)] and the burden of illness studies [Jefferson et al. (1996)]. The cost of illness approach, however, is different to the human capital (HK) approach[4]. While the cost of illness approach takes into consideration all expenditures from an illness, human capital approach considers lost earnings overtime. Rice (1976) estimates the cost of illness by using the human capital approach to calculate indirect costs in the form of foregone earnings due to illness and then adding the direct costs based on medical expenditures for prevention, diagnosis and treatment [Landefeld and Seskin (1982)]. Koopmanschap and Rutten (1993), too, point out in their review of indirect costs in economic studies that "virtually all studies used the human capital approach which estimates the value of potentially lost production (or potential lost income) as a consequence of disease". The cost of illness approach may or may not estimate all the costs (both direct and indirect) arising from an illness depending on the availability of data and the objectives of the study. A large number of studies estimating the costs of

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[2] For example, see Todd (1985); Roberts (1985); Roberts (1989); Cohen et al. (1979); Shandera et al. (1985); Roberts and Sockett (1994).
[3] For example, see Harrington et al. (1989).
[4] The human capital approach is based on the value to society of an individuals life which is measured by future production potential, usually calculated as the present discounted value of expected labour earnings [Landefeld and Seskin (1982)].

morbidity and mortality have been based using the cost of illness approach since the early 1950s[5].

Studies conducted in the 1950s by Renolds (1956) on the cost of road accidents in England and Fein's (1958) analysis of the cost of mental illness established the conceptual approach of this method effectively [Hu and Sandifer (1981)]. In the 1960s a further development of the method occurred at a time when interest among economists was turning to "human resources" as a neglected and under supported component of a nations economy. Some of the articles during this period include: Weisbod (1961) in his work on economic benefit of health programs, Mushkin's (1962) article titled 'health as an investment' and Klarman's (1964) article on syphilis control. The empirical application of the cost of illness approach was effectively demonstrated by Rice (1966), who provided the basic framework as well as detailed procedures for estimating the direct and indirect costs of illness [Hu and Sandifer (1981)]. Other well known studies using basically the same methodology of Rice are: Rice and Cooper (1967); Weisbrod (1971); Brody (1975); Cooper and Rice (1976); Paringer and Berk (1977); Mushkin (1979). The U.S public Health service also uses this approach for studies conducted under its authority [Hodgson and Meiners (1979, 1982)]. Drummond (1992)[6] discuss the merits and demerits of the COI approach. For another good description of the methodology of the COI, see Jefferson et al. (1996).

The cost of illness approach is based on the notion that people are productive and therefore have value. Hence, it is implicitly assumed that productivity and value are associated with good health. Hence, any illness is deemed to result in costs not only for medical expenditure but also due to foregone earnings and other expenditures related to the illness. Therefore, any action taken to improve health is interpreted as an investment not only in terms of minimizing or even avoiding medical expenditures but also in preventing foregone incomes and other calculable expenditures and of course contributing towards yielding a continuing return in the future. As Mushkin (1962, pp. 130 and 136) points out " the yield for improvements in health is the labor product created plus any savings in health care expenditures due to any reduction in disease".

The cost of illness approach is therefore based on the notion that an illness prevented means costs averted. Therefore, such estimates are useful for many reasons. For example, by looking at the cost of an illness, it is possible to get an idea of the severity and extent of the illness and hence calculate the possible benefits of minimizing or preventing such illnesses. With regard to pollution, such estimates are very useful because such estimates enable us to show the severity and magnitude of the problem and begin to question the viability of a particular production process that

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[5] It is thought that Malzberg (1950) carried out one of the earliest studies estimating the indirect cost of mental illness based on this technique, although the basic ideas have been in existence since the seventeenth century. Jefferson et al. (1996) point out that the first COI study mentioned in modern bibliographies dates back to 1920. As Hu and Sandifer (1981) point out in their review prepared for the National Centre for Health Services Research, studies carried out in the 1950s such as Reynolds (1956) work on the cost of road accidents in England and Fein's (1958) analysis of the costs of illness established the conceptual approach effectively.

[6] This is a good resume of the controversy on the role of COI studies.

is responsible for causing the pollution. Of course, from these estimates, we can also infer the willingness to pay bids/values for a reduction in ill health or for pollution control, for example, direct exposure to pesticides that cause ill health among users. In other words we can use the cost of illness approach to show the welfare benefits of reducing exposure to pollution and the resulting health effects. In health studies this approach is a widely used technique and is commonly used to compare with the results of other valuation approaches. For recent studies that have used the cost of illness approach to compare with other valuation techniques please see Chestnut et al. (1996); Dickie and Gerking (1991); Murdoch and Thayer (1990); Berger et al. (1986). For a theoretical comparison of the cost of illness approach with other valuation techniques used please see Harrington and Portney (1987); Cropper and Freeman III (1991).

The costs considered by this approach are divided into two categories, namely direct and indirect. The direct costs refer to all the medical care and allied expenditures for diagnosis, treatment, other medical as well as non medical expenditures occasioned by illness or disease [Hodgson and Meiners (1982, p.432)]. According to them, medical care expenditures may be incurred for hospitalization, outpatient clinical, nursing home and health care services of primary physicians, specialists and other health professionals, drugs and drug sundries, laboratory and other investigation costs and other facilities provided by the hospital. Other health sector direct costs relevant to the estimation of the costs of an illness to society are those for research, training, construction and administrative functions. Hodgson and Meiners (1982) also point out that direct costs borne by patients and other individuals (which is not shown up in the national health accounts) include costs of transportation to health providers (both the sick and the person accompanying), certain household expenditures, costs of relocating (such as moving expenses) and certain property losses. Other expenses include: caring and providing for the sick member of the family. These include: extra expenditures for household help, cleaning, laundering, cooking and baby-sitting; special diets, special clothing, items for rehabilitation, counseling, etc. [For a more detailed account, please Hodgson and Meiners, p.434)]. Furthermore, they also mention care provided by family and friends as costs that should be treated as direct costs.

In addition to the direct costs, Hodgson and Meiners (1982) also point out to indirect costs arising from an illness[7]. These are of course the foregone earnings. The indirect costs result from output lost because of work days lost or reduction of productivity due to morbidity and mortality. Absenteeism increase costs of production with the result that the value of output per unit of input declines while an illness can also reduce productivity. Housekeeping days or hours lost also fall into this category. The value of other non-market activities in addition to housekeeping services, include loss of leisure hours. Other indirect costs categorized by Hodgson and Meiners (1982) are the time a patient and/or family members spend visiting physicians, other health professionals, hospitalized persons and time lost from work by family members when someone in the family is ill. For a more detailed list of indirect costs, see Hodgson

[7] Also see Koopmanschap and Rutten (1993) for a detailed discussion of indirect costs and their estimation using the COI approach.

and Meiners (1982, p.434-435). The value of any health improvement or pollution control, therefore, is the sum of the reductions in both the direct and indirect costs of illness. In other words the costs that are avoided.

Drawbacks of COI Approach

The appeal of the cost of illness approach is due to its straightforward estimation of well defined and observable data. However, despite the strong points and advantages discussed in the last section, this approach has been shown to have several drawbacks. This approach does not take into account the indirect costs of unemployed people, retirees, and children. In other words, the estimates of this approach as mentioned in the last section are based on the notion that individuals are productive and have value. Therefore, a cost of illness study lays less emphasis on the activities outside the market place since the approach considers only direct expenditure and foregone earnings. As a result, this approach can leave out certain segments of society from being included in the calculation of costs arising from an illness. For example, the indirect costs of a retired farmer suffering from an illness due to past direct exposure to pesticides will not be recorded simply because he is no longer in the work force. Some of the other deficiencies pointed out by Berger et al. (1987, p.24) are that: (a) an arbitrary decision has to be taken about foregone consumption expenditures, that is, gross or net labour earnings; (b) individuals are viewed as having no control over their health or health expenditures; and (c) there is little basis in economic theory for the use of the costs of illness in benefit-cost analysis. Drummond (1992); Jefferson et al. (1996), too, discuss the drawbacks of the COI approach in detail.

Another major criticism of cost of illness approach is that it does not cover intangible costs such as discomfort, pain and suffering which a patient would like to avoid sometimes even more than the tangible costs. Hence, in cost-benefit analysis a study based on this approach does not show or measure the benefits of reduced pain and suffering associated with health improvements or preventing an illness due to, for example, pollution control. In other words, such a study captures only the visible and calculable costs. Hence, under estimates can be derived and the real costs missed out. It is due to this very reason that measures from this approach are treated as lower bounds.

There are real dangers arising from these drawbacks. The shortcomings can lead to an under allocation of resources for the prevention and the treatment of an illness because all the true costs have not been included in the calculation and above all under estimate the gravity of the problem. The real dangers posed as a result of underestimation of costs is all the more serious, when pollution related illnesses are considered. Direct exposure to pesticides is a very good example. We know that exposure to pesticides is very dangerous, especially because of the long-term effects to humans which are usually not reversible. Furthermore, the damage done to the fauna and the environment (spillover effects) of pesticide use can also be very large. Also we know that pesticides once released in to the environment can accumulate and hence cause more damage. In this instance if we use the cost of illness approach to calculate the costs arising to human health from pesticide handling and spraying we may easily underestimate the real costs involved with such pollution and hence ignore the seriousness of the problem. This problem is dealt with later in the chapter.

Hence, in this context the cost of illness estimates fail to highlight the dangers of pollution related illnesses because it merely considers only the direct and indirect calculable costs. It does not capture the magnitude and severity of the problem, which is well illustrated with the case of direct exposure to pesticides. These estimates do not properly highlight the real dangers. Hence, intervention (such as pollution control) may be slow or the problem may be totally ignored or less attention paid. As a result real dangers exist. In short, the cost of illness approach, as was shown above, is unable to capture all the costs arising from an illness and hence may be inadequate to show the real costs of an illness and hence the benefits of preventing such an illness or control pollution. Hence, the benefits that accrue from a particular pollution reducing program may not be properly estimated. As a result, policy decision-makers can give a low priority to such programs.

However, it must be noted that while the cost of illness approach takes into consideration only the costs that have been incurred, the contingent valuation willingness to pay approach considers individuals willingness to pay bids which are highly correlated with income, information available to the respondent and many other factors. Hence, while the contingent valuation bids can differ according to income, information available, and many other factors, it is only a hypothetical measure of the value of a commodity or good which an individual thinks is worth and is willing to pay for as shown in the last chapter. There is no real payment involved in a contingent valuation study. On the other hand the cost of illness is based on real facts and expenditure that has been actually incurred rather than an expected value of what a good would be worth. In the contingent valuation approach, bid values can change dramatically according to the above mentioned factors. A good example is the contingent valuation bids given to avoid direct exposure to pesticides. Individuals with higher exposure (and incurring higher costs) gave higher bids while those less affected or those who were not affected gave lower bids. This is a dangerous trend because individuals who are not directly exposed to pesticides will have a tendency to give lower bids. This is a dangerous trend because pesticides can accumulate in the environment and cause long-term damage. Some of the long-term illnesses such as cancers are irreversible. The inter and intra generational externalities and the damage done to fauna can be high. Therefore, if there is no foresight involved especially when a pollutant like pesticides is invisible, then the damage done to human health and the environment can be significant. On the other hand, cost of illness estimates which are based on incidence of illness were free from the hypothetical constraints mentioned above and are not linked to an individuals income, availability of information, level of education, etc. Such an estimate is above such barriers.

Quality of Costs of Illness Estimates

In addition to the conceptual problems discussed in the last section which were associated with the cost of illness approach, there are also many problems in measuring the value of improved health or pollution control, etc. due to none availability of data, the methodology used, computing of weights for various expenditures, the definitions used and many other factors which affect the quality of estimates derived using the cost of illness approach. Furthermore, defining the objectives of the study is also important. However, despite the conceptual and estimation problems associated with this approach, it is still widely used as mentioned above as a standard approach to valuing health, to measure benefits of pollution control and to make damage assessments. They at least do not suffer from the biases found in some other approaches such as the contingent valuation approach. In the next section, we discuss the various health estimates that have been carried out using this approach and the problems associated with such estimation. Next the quality of the estimates of medical and foregone incomes is discussed.

Empirical Estimates of Cost of Illness Approach

Basing on the cost of illness approach, comprehensive estimates of costs of many illnesses have been carried out. Paringer and Beck (1977) and Hodgson and Kopstein (1984) have carried out estimates for all illnesses, while estimates of costs have also been carried out for a specific illness or group of illnesses. They include: infective and parasitic diseases (Hodgson and Kopstein, 1984), Neoplasms (Hartunian, Smart and Thompson (1980), diseases of the circulatory system (Hodson and Kopstein 1984), cerebreovascular diseases (Hodson and Kopstein, 1984), Emphysema (Freeman et al. 1976), and Myocardial infarction (Scitovsky and McCall, 1976). Studies have also been carried out in recent times for migraine (Sterhaus, et al. 1992); Aquired Immunodeficiency Syndrome (Scitovsky et al. 1992); benign prostrate hyperplasia (Drummond et al. 1993); salmonella enteritides infection (Roberts and Sockett, 1994); Epilepsy (Senanayake et al. 1997). They cover all medical expenditures and foregone earnings arising from the above mentioned diseases. Furthermore, many studies have also been carried out to estimate only indirect costs. Since 1987-1992 alone, Koopmanschap and Rutten (1993) identify 49 articles appearing in refereed journals. They point out that all disease categories have been covered in these studies. Specific studies are useful, in that, the medical related expenditures and earnings lost due to a specific illness can be known, whereas in the case of comprehensive studies only provide general estimates to a general category of illnesses. It is also claimed that specific studies employ a different methodology that can be particularly relevant for the estimates of health expenditures. Furthermore, for the study of a specific illness, estimates of costs maybe based on dis-aggregated data such as the observation of actual cases. For example, the Hartunian, Smart and Thompson (1980) study is based on an incidence-based approach measuring medical expenditures and reports foregone earnings due to morbidity and mortality combined. For a review of the methodology and quality of over 200 studies that estimate costs of illnesses, please see Hu and Sandifer (1981). Kenkel (1994, p.62) lists all the respective expenditures of different authors in his work.

From the total estimates derived for various illnesses, per case estimates of medical expenditures and foregone earnings can also be derived easily. Kenkel (1994, p.64-68) discusses in detail various per case estimates of various problems associated with such estimates for various illnesses and the shortcomings of the various studies that have been carried out and suggests possible solutions to overcome these drawbacks. The basic procedure of estimating per case costs of an illness is simply to divide the total cost figure for a year by the appropriate number of cases (patients) of that that illness in that year. Essentially, a per case study estimates the average cost of a disease i.e. it takes into account the total cost of medical expenditure and foregone earnings and divide it by the number of patients treated. This can easily be done with dis-aggregated data such as in the observation of actual cases. However, the disadvantage in this method is that one tends to categorize the more serious and less serious patients into one group. Furthermore, with these estimates it is also possible to derive the costs of illness per day spent ill. These estimates are derived by dividing the per-case costs [which is defined in Kenkel (1994)] by the per case of illness per year.

In the next two sections we undertake a brief discussion of the estimation of health expenditures (direct costs) and the estimation of forgone earnings (indirect costs). Although we do not estimate the public costs of medical care such as hospital care, physicians services, drugs and medical services, nursing care, etc. we undertake this brief discussion to show the extent of the costs that are involved which have to be taken into account if public costs were to be considered. This exercise was also useful in determining some of the private medical costs[8] incurred by farmers such as for physicians services, drugs and sundries, laboratory costs, etc. as described in sections four and five of the questionnaire.

Estimates of Health Expenditures (Direct Costs)

A thorough review of the methodology of COI estimates is undertaken by Kenkel (1994, p.53-61) in evaluating the quality of COI estimates of health expenditures. They consider in detail the methodology developed by Rice (1966) and the comprehensive studies carried out by Paringer and Berk (1977) based on the work of Rice. The medical expenditure is broken down into various services provided such as: hospital care, physicians and other health professionals services, drugs and medical sundries, nursing home care, non personal health care service, etc. and costs are assigned to each medical service provided for a given illness (for a full description of the methodology of COI estimates, please see Kenkel (1994, p.53-57).

Kenkel then goes onto discuss the problems highlighted and the various shortcomings encountered in the estimation of costs by various authors, for example, Scitovsky (1982); Hodgson and Meiness (1982); Institute of Medicine (1977); Rice (1966); Cooper and Rice (1976); Hodgson and Kopstein (1984); Paringer and Berk (1977); Rice and Hodgson (1978). For a thorough description, see Kenkel (1994, pp. 53-57). The problems highlighted are centered around the allocation of the two largest expenditure categories namely hospital services and physicians' services. Some of the specific problems discussed are the computing of weights for the allocation of expenditures for physicians' services, the estimation of the days of care by diagnostic group, the omission of accounting the inpatient/outpatient mix in the allocation of expenditures, the implicit assumption of equal charges for all types of physicians'

[8] Although government hospital treatment in Sri Lanka is free, farmers have to incur costs on purchasing certain prescribed drugs outside the hospital, pay for laboratory costs, etc. Farmers also seek private treatment from private clinics and thus have to incur considerable costs including medical charges, etc.

services, the improper and poor treatment of the expenditures for drugs and medical sundries, the non allocation of personal health care expenditures, the problems of estimating costs in the case of multiple conditions, etc.

Another major criticism that has been pointed out is the category of non-health expenditures that is omitted. That is, expenditures in the non-health sector such as transportation to and from medical providers, special diets and so forth. These expenditures are defined as medical expenditures and not preventive expenditures, because they follow the incidence of a disease and do not prevent or lessen the probability of illness (Kenkel, 1994, p.54). It is, however, stated that a comprehensive estimation of these expenditures is quite difficult because of the many different types of goods and services that could be involved. Mushkin (1979, pp. 384-85) has made an attempt to capture some of these costs and states that including the non health-sector costs of illness would increase total expenditure estimates by 10%-16%.

Estimates of Foregone Earnings (Indirect Costs)

In the last section we dealt with direct medical expenditure estimates and the problems that are associated with making such estimates which could affect the quality of health estimates. In this section, the estimation of foregone earnings and other indirect costs arising from an illness is examined. The calculation of such estimates pose several problems although it has been stated that such estimates are more straightforward than that of medical expenditures [Kenkel (1994, p.57)]. In order to follow the manner in which such estimates are carried out, the methodology adopted by Paringer and Beck (1977) quoted in Kenkel (1994, p.57) is followed. In the estimation of foregone wages, it is typical to sub group the population into four groups as follows:

(1) currently employed individuals
(2) individuals keeping house
(3) non-institutionalized individual unable to work because of ill health
(4) the institutional population

Within each group, detailed information is obtained for each of the groups to estimate the foregone wages (incomes) for an illness or illnesses. The cost of illness approach following the human capital approach takes into consideration all production or working days/hours and efficiency hours lost due to illness. The problem, however, is that the approach tries to measure only the foregone earnings of output or production lost. Hence, this approach can leave out those not involved in the production process[9]. Furthermore, this measurement does not capture all the costs that an individual would be willing to pay to avoid. Kenkel (1994, p.58) also argues that leisure hours lost should be included to make the cost of illness approach complete. Clearly, Paringer and Beck's measure is incomplete. The reason given by Kenkel is that "utility-maximizing behaviour implies that work and leisure will be traded off until at the margin leisure time is just as valuable as working time. Additional time spent ill,

[9] Harrington et al. (1989) consider the working hours lost of persons doing household work in addition to those employed in the labour market.

whether it comes out of leisure time or is lost from work, is valued at the wage rate by the individual"[10]. Otherwise, by only valuing the time actually lost from work, the cost of illness measure of foregone earnings implicitly values leisure time at zero.

A detailed description of estimating foregone earnings is found in Kenkel's work where he discusses the various studies on this topic as well as dealing with the problems associated in measuring such estimates. Some of the works cited are Paringer and Beck (1977), Cooper and Rice (1976), Institute of Medicine (1981), Salkever (1985).

Using Cost of Illness Approach to Measure Costs Due to Direct Exposure to Pesticides in Sri Lanka

The last few sections discussed the concept of the cost of illness approach, its advantages and disadvantages, the quality of costs of illness estimates and the problems associated with the estimation of the medical related costs, foregone earnings and other indirect costs. The objective of the next section is to show how costly the use of pesticides can be to the users involved in agricultural production. For this purpose, the cost of illness approach is used. It is important to work out the costs of direct exposure to pesticides in agriculture because from such estimates, it is possible to show the severity of the problem and the damage that is being done to human health, wildlife and the environment in general. It should be mentioned here that the costs estimated for illnesses arising from direct exposure to pesticides have been estimated from answers given by respondents. This was the only option available since subsistence farmers do not have health insurance cover nor do they maintain receipts of expenditures, records of days lost at work, etc. No study has been carried out to determine the damage done to wildlife or the environment, but given the large-scale use of pesticides in the countryside there must be considerable damage. This is an area that needs to be investigated. The absence of studies, however, does not mean there are no pesticide poisoning impacts. The absence of studies is partly due to lack of funding for such work that is a common problem faced by developing countries. The cost of illness estimates can then be used to infer willingness to pay bids for a reduction in ill health due to direct exposure to pesticides as shown in chapter four. It is then possible to go on to work out the welfare effects of a reduction in pesticide use. In other words, it can be shown that a reduction in illness from direct exposure to pesticides yields benefits equal to the costs saved and show the welfare gains of reducing pesticide use.

The cost of illnesses for a sample group of individuals (farmers) surveyed in 1996 for this Ph.D. study using the questionnaire discussed in chapter six is used. From this, the average cost of illnesses due to direct exposure to pesticides is calculated for illnesses arising on pesticide spraying days, non-spraying days and long-term illnesses.

In the section preceding the last section of this chapter, we consider all the private costs that accrue to farmers during and after pesticide use. The costs are divided into

[10] This is only true if not at a corner solution in the labour market (for example, fixed hours).

three categories. They are costs arising on pesticide spraying days, pesticide non-spraying days and the long-term costs. The costs on pesticide spraying days are sub divided further into costs arising due to hospitalization and other private costs, those who consult a doctor and incur private costs and those who are affected but take home made self-treatment but nevertheless incur private costs. Before the private costs are estimated, the problems associated with estimating the costs of direct exposure to pesticides are described.

Problems Associated with Estimating Direct and Indirect Costs of Direct Exposure to Pesticides

Earlier we discussed some of the problems associated with estimating the direct and indirect costs of illnesses. Similarly there are many problems associated in estimating the costs of direct exposure to pesticides among farmers that prevent the calculation of the true health costs to farmers. There is very little doubt that the estimates presented in the next section are underestimates due to various problems associated with data collection. In Sri Lanka, as mentioned in chapter six, health care in hospitals is free of charge. Therefore, it is difficult to calculate all the medical costs arising to a farmer from direct exposure to pesticides from a sample survey. Farmers, in addition to taking treatment from government hospitals, also take treatment from private clinics. Most of these private costs such as physician consultation fees, drugs purchased from pharmacies, laboratory costs are considered in this thesis (please see questionnaire, sections 4 and 5). In order to calculate the hospital costs, hospital records have to be examined. This is not easy since hospital costs are not maintained for the treatment of different categories of illnesses. Hence, decomposing the costs of pesticide poisoning treatment from total hospital expenditure data is a difficult task. Thus, such costs are not considered in this chapter. Furthermore, apart from the medical expenditures, other hospital costs mentioned in Hodgson and Meiners (1982) classification are also omitted in this study for lack of data. As a result, only the private direct and indirect costs are estimated in this study. Even in the estimation of private costs, all pesticide exposure related costs are not estimated. The private direct and indirect costs are measured according to the definitions given by Hodgson and Meiners (1982) with suggested improvements taken from the work of Kenkel (1994). The study interviewed only farmers who were using pesticides at the time of the study to record the private direct and indirect costs. However, there were many farmers who had prematurely retired from farming due to medical reasons directly attributed to direct exposure to pesticides. The damage done to retired farmers suffering from long-term illnesses as a result are not covered, nor are the farmers recovering in hospital have been interviewed. There were many farmers who were unable to work because of an illness attributed to direct exposure to pesticides. Their loss of earnings and other costs too are not recorded. The study also did not cover farmers who were sick due to direct exposure to pesticides at the beginning of a cultivating season. A delay in cultivating adversely affects the crop due to lack of water, weather conditions, etc. The loss of income in such cases is high, which is not considered for this study. Mortality rates among farmers resulting from direct exposure to pesticides are also high. In this study, the cost of a loss of life is also not considered.

The survey data show that the private medical costs incurred are low because the expenses are borne by hospitals and hence underestimate the real costs. Furthermore, the costs to the family, the indirect costs of the person accompanying the patient to hospital have not been estimated. It should also be mentioned that psychological costs have not been considered nor are other intangible costs (such as pain and suffering) calculated. Furthermore, the health costs to those living around nor have the costs of externalities been taken into account. There were many instances of external costs. Hence in this study, only farmers who were in a sense 'physically fit' and cultivating at the time of the study were randomly interviewed. As a result, the costs estimated are lower bounds.

Procedure Used to Estimate Losses

The survey estimated losses in the following categories under direct and indirect costs. The estimated direct private costs were: any privately purchased drugs, laboratory and other investigation costs done privately, costs of transport to the patient and costs involved with special diets, hired labour due to inability to work on sick days, and other losses due to direct exposure to pesticides (such as crop damage due to inability to look after crops such as from theft and damage from wild animals). A major portion of the losses resulting from direct exposure to pesticides were from imputed value of lost time rather than from out-of-pocket expenses. Thus, the valuation of time is critical. The indirect private costs are: loss of working days, loss of efficiency, the time a patient spends visiting hospitals or a doctor. We tried to estimate the loss of efficiency for the farmers on their farm resulting from direct exposure to pesticide related illnesses because most farmers during the pilot survey complained that their efficiency decreased following a direct exposure to pesticides related illness which was substantial. While this procedure is subjective, it addresses a real economic consequence of illnesses of this sort. The inclusion of leisure hours is also no doubt subjective, but it also shows the economic consequences of the illnesses. The inclusion of leisure hours is all the more important when we consider that loss of leisure hours affects productivity. It must be mentioned that estimating the number of leisure hours lost as well as lost productivity is a difficult task. Leisure hours were taken to be any time spent at home after work such as: reading a newspaper, watching television, listening to the radio, pursuing a game or a hobby or time spent with the family. Sleeping hours is not included nor was the time spent attending to domestic chores. Loss of efficiency was defined as the lessening of one's productivity while working. The estimation of work hours lost and time spent traveling to hospital and seeking treatment is less troublesome to calculate. Once the lost time has been calculated, the conversion to monetary terms was straight-forward. This is because, as noted by Harrington et al. (1989, p.128) the losses in many of these categories depend to a considerable extent on the value of time. Following Becker (1965) lost work time, efficiency, leisure hours, time spent traveling to hospital was calculated, at the prevailing hourly average wage rate in the areas for the interviewed farmers. The hourly wage rate was derived by dividing an average days' labour wage by the number of hours worked. The average cost of labour for a day in the study area was taken as Rs 150 and the number of hours worked for this sum was 8 hours. The average cost of labour was arrived by dividing the wage rates prevalent in the study areas to spray pesticides by the number of hours worked per day.

Sections four and five of the questionnaire obtained data on the hours worked and also the wage rates paid. Hence, we arrived at a wage rate of Rs 18.75 per hour. This figure was then used to arrive at the estimates shown in Table 8.1.

Estimates of Total and Average Losses Due to Illness

Table 8.1 provides estimates of the total and average cost to farmers arising from direct exposure to pesticides. As can be seen, the direct average total cost due to direct exposure to pesticides for a year is more than an average months salary (the average monthly salary is Rs 4,748.17). The direct private out-of-pocket costs for medical care are a small portion of the total cost. Time costs (indirect costs) make up the rest, with loss of productivity and leisure time accounting for more than half the loss. Once these costs are added, the private costs of direct exposure to pesticides bill is more than an average farmer's monthly income. In other words, a farmer on average suffers costs which amounts to more than a month's income per year. It must be noted here that a very large portion of the medical direct costs have not been included for this estimation for lack of hospital data. The medical costs are no doubt very large.

Table: 8.1 Private Out-of-Pocket and Time Costs Due to Direct Exposure to Pesticides

Item	Direct		Indirect	
	Total Costs	Average Costs	Total Costs	Average Costs
Time spent on traveling/seeking treatment				70,856.25
349.04				
Hired labour due to inability to work	82,072	404.28		
Other costs: Private medical expenditure Special diets, travel costs	212,584	1047.21		
Loss of work days/hours on farm			312,121.85	1,537.54
Loss of efficiency on farm			164,709.35	811..37
Leisure time losses			176,414.08	869.03
Long-term	90,750	447.04		
Total	385,404	1898.53	724,101.53	3,566.98

Survey Period: July to September, 1996

Note:

(1) The costs considered are for one year. The costs incurred by farmers for the period June, 1995-June 1996 were considered for this study.

(2) Long-term costs are those costs arising from a permanent nature as opposed to the short-term illnesses described in the questionnaire (please see section three of questionnaire). The long-term illnesses considered were those diagnosed by a physician as arising from direct exposure to pesticides. Suffers have to incur costs on treatment, etc. every year due to long-term illnesses. For this study only the costs incurred from long-term illnesses for one year (June 1995-June 1996) were considered.

In the contingent valuation willingness to pay study, as discussed in the last chapter, the average estimates for private costs exceeded two months average salary. It must also be noted that the costs to the family and external costs, etc. have not been taken into account for the above mentioned estimates. A breakdown of the costs incurred on pesticide spraying and non-pesticide spraying days is shown in Appendix 8.1. In addition to the direct and indirect costs from illnesses, farmers incur costs on avertive behavior as well. Such costs are discussed in the next chapter.

Total Losses to Farmers in the Country from Direct Exposure to Pesticides

In the last section, we presented total and average estimates for costs of illnesses for the 203 samples selected from the field study. From these figures it is possible to estimate the approximate total losses to farmers in Sri Lanka using pesticides.

The procedure used to estimate total costs from illnesses from direct exposure to pesticides is straightforward. We assume that the sample of 203 respondents is representative of the farmers using pesticides in Sri Lanka. No one knows for certain (including the Department of Agriculture) how many farmers are currently using pesticides. According to the 1978 employment survey, it is estimated that there are 472,435 agricultural workers in Sri Lanka[11]. However, these figures include plantation workers such as tea, rubber and coconut where the use of pesticides are minimal and that all of them are not employed to spray pesticides. It is the self-employed farmers (often on a small-scale) growing vegetable crops and rice who over use pesticides most. In order to provide estimates for the entire country, we provide cost scenarios for 50,000, 100,000, 150,000 and 300,000 agricultural workers, who we believe use pesticides on a regular basis. 25,000 is considered a minimum and 300,000 is considered a maximum. We believe that the true figure lies in between this range. We have to resort to scenarios because no government agency in Sri Lanka, including the Department of Agriculture and the Department of Health or the Pesticide Poisons Bureau know the number of farmers affected by direct exposure to pesticides during handling and spraying on the farms.

Table: 8.2 Cost of Ill Health Scenarios Due to Direct Exposure to Pesticides in Sri Lanka

	A		B		C		D	
	Di	In	Di	In	Di	In	Di	In
Time spent on traveling/seeking treatment		17452000		34904000		52356000		104712000
Hired labour due to inability to work	20214000		40428000		60642000		121284000	
Other costs:	52360500		104721000		157081500		314163000	
Loss of work days/hours on farm		76877000		153754000		230631000		461262000
Loss of efficiency on farm		40568500		81137000		121705500		243411000
Leisure time losses		43451500		86903000		130354500		260709000
Long-term	22352000		44704000		67056000		134112000	
Direct Cost (Di) Total	94926500		189853000		284779500		569559000	
Indirect Cost (In) Total		178349000		356698000		535047000		1070094000
Total		273275500		546551000		819826500		1639653000

Survey Period: July to September, 1996

Note: The average cost of illness costs 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.

[11] Jeyaratnam et al. (1982a) uses 1978 employment survey data for his study. The reasons for using this data was given in chapter seven.

Table 8.2 shows four scenario costs for direct exposure to pesticides. The minimum total cost estimate shows that farmers in Sri Lanka loose around 273 million Rs (scenario A) in the form of private out of pocket costs and the high cost scenario (scenario D) shows that farmers loose more than 1,639 million Rs as out-of pocket-private costs due to direct exposure to pesticides. These estimates are, by any standard, conservative. These figures, are however, very large considering the income of these farmers. Furthermore, not all of the private costs incurred on a typical spraying day, non-spraying day and the long-term costs were estimated. Many costs were not accounted for due to the non-availability of data as described earlier.

Ill Health Resulting from Exposure to Pesticides: Determining the Relationships

Exposure to pesticides[12] causes many acute and chronic symptoms among the users (farmers) as shown in chapter three. This chapter showed that the acute and chronic symptoms are many and have been well established from the various field studies that have been carried out [for example, Chandrasekera et al. (1985); Jeyaratnam et al. (1987); Gnanachandaran and Sivayoganathan (1989); Dharmawardena (1994); Sivayoganathan et al. (1995); Hoek et al. (1997)]. They range from faintish feeling, headaches to blurring vision to tremors. It has been pointed out by Jeyaratnam (1982b) that each year, five out of every 1000 agricultural workers in Sri Lanka are hospitalised due to pesticide pollution of an occupational origin and that these stated figures are underestimates. In the field study that was carried out to collect the required data for this Ph.D. study, 96% of the respondents had suffered from some form of illness during spraying or soon after spraying during the last one year (please see Table 6.6). As a result of direct exposure to pesticides, sufferers need hospitalisation, take treatment from a physician (but no hospitalisation is needed) or simply resort to home made self-treatment. All these involve both private and public/social costs.

As shown by the cost of illness approach that valued the costs of ill health resulting from direct exposure to pesticides, the private costs in terms of out-of-pocket expenses (direct costs), foregone earnings-time costs (indirect costs) and intangible costs were very large. According to the private cost scenarios presented by the cost of illness approach, the minimum estimate from the cost of illness approach puts the cost at Rs 273 million per year. In per capita terms, according to the cost of illness estimates, direct exposure to pesticides cost more than a month's salary to an average farmer per year. These estimates, as was shown, are lower bounds. Judging from the large number of hospitalisations and out-patient's seeking treatment, the public costs are also very large, although no estimates have been carried out. Public costs, if estimated, would also run into millions of rupees. Apart from these measurable costs, victims of direct exposure to pesticides also suffer from intangible costs such as stress (leading to suicides), pain and suffering and psychological effects. The contingent valuation approach (chapter seven) estimated the costs at more than two months income of an average farmer per year. Furthermore, those directly exposed to pesticides also undergo a gradual physical deterioration of the human body and suffer

[12] Exposure to pesticides can be defined as the contact a user has with pesticides during handling and spraying on the farm.

from many long-term illnesses. The costs arising from such wastage of the human body alone [termed human capital[13] by Pearce and Atkinson (1993, p.3)] were not captured in any of the cost estimates mentioned above. The mortality rates are also high as shown in the Appendices, 3.1 and 3.2. Hence the costs are much larger than the estimates shown in this thesis.

Judging from these large costs, if the users direct exposure to these toxic pesticides can be minimized or altogether prevented, then most of the above mentioned costs resulting from ill-health can be minimized or even avoided to a very large extent. Therefore, any action taken to reduce the contact a user has with pesticides during handling and spraying on the farms can be interpreted as an investment, not only in terms of avoiding medical expenditures, foregone incomes and intangible costs but also contributing towards yielding a continuing return in the future by preventing the gradual deterioration of human capital. All these effects, if prevented can be a very large saving both to the nation as well as the sufferers. In other words, any action taken to minimize the direct exposure to pesticides by farmers would increase the welfare of the farmers. Therefore, in order to take preventive action, we must determine what factors are responsible for the very high levels of direct exposure to pesticides which results in numerous morbidity effects among the farmers handling and spraying pesticides on the farms.

The aim of the next section is to examine how ill health which results in many costs due to direct exposure to pesticides are brought about by the above mentioned factors. Such an exercise will also enable us to examine whether precautions prescribed to farmers are being adhered to by the farmers that can explain the reasons for the high levels of mobidity experienced by farmers due to exposure to pesticides. The plan of this section is to first present the hypotheses concerning ill health and direct exposure to pesticides. Cross sectional data used are then discussed and we specify a single illhealth function in terms of the various precautions prescribed. The summary statistics are then presented and the results are discussed followed by a conclusion. Two statistical techniques commonly used in contingent valuation, namely OLS estimation and Tobit analyses are used and the results are compared. Tobit analysis is used mainly because there are a few farmers who have not incurred any costs due to illness and hence there are some zero values in the dependent variable. There were eight farmers who did not incur any costs resulting from ill health due to exposure to pesticides. We use costs of ill health as a proxy for ill health arising from direct exposure to pesticides.

Research Hypotheses

Research carried out by Forget (1991); Siyayoganathan et al. (1995) have shown that the illnesses resulting from direct exposure to pesticides during handling and spraying varies widely, depending on some or all of the following factors: type of formulation (referring to the pesticides used), strength of the formulation, equipment used, method of application, environmental conditions [prevailing wind, temperature (time of day) and humidity], physical posture of the user, and individual constraints caused by

[13] Human capital here refers to the health of humans and the indigenous knowledge of farmers.

variables such as height of crop, duration of work and protective gear used. Some of the other factors mentioned are quantity of pesticides used, user's health and whether a meal has been taken or not before spraying. Hence, advice given by physicians and agricultural extension workers to farmers is to take into consideration the above mentioned factors in order to minimize ill effects resulting from handling and spraying pesticides on the farms. For example, some of the recommendations are to use the recommended dosages, use less toxic pesticides, spray for a limited period of time (i.e limit the acreage sprayed at a given time), spray during early mornings and late evenings (when the sun is not strong), use adequate protective gear (such as protective clothing, masks and gloves) and so on. It should be mentioned here that the most potent of pesticides used are the insecticides followed by herbicides and fungicides[14]. Although age has not been mentioned in any of the research work, we include it in our work to examine whether the age of the user can also be a contributory factor in causing ill health among farmers using pesticides.

The Data

Cross sectional data that will be used in the regressions were collected from the field survey carried out in 1996 that was discussed in detail in chapter six. Twelve variables are used in the empirical analysis which are believed to have an impact on the health of the user which results in numerous costs. The costs resulting from ill health are the out-of-pocket and time costs and is taken to be the dependent variable in the econometric analysis. The costs of ill health are taken to be a proxy for ill health resulting from exposure to pesticides during handling and spraying on the farms. It should be pointed out here that using costs of ill health as a proxy for ill health is not always a good proxy because costs of ill health recorded may not always capture the true costs of ill health. This is partly because we have recorded only the private costs of illnesses. Hospital treatment is free of charge in Sri Lanka and such costs are not included in this regression analysis for lack of data. Furthermore, we also know that although farmers suffer from an illness but are unable to take adequate treatment for lack of medical facilities, transport to and from medical centres, etc. Hence, the recorded costs do not properly capture the magnitude of the illness. The private costs also do not capture the intangible costs. The independent variables are age, acres* hours, months of pesticide use, type of crops cultivated, insecticides, herbicides, fungicides used, pesticides sprayed in the morning (before 10), pesticides sprayed between 10 am 4 pm and pesticides sprayed in the evening (after 4 pm), and precautionary costs. Acres*hours sprayed reflect the extent of direct contact with pesticides. Months of pesticide use show the number of months farmers are engaged in pesticide spraying. Types of pesticides used are insecticides, herbicides and fungicides. Of these three pesticides, the most commonly used pesticide is insecticides, which is also the most toxic as mentioned earlier. Precautionary costs show the extent of defensive/precautions taken. Data on the type of equipment (sprayer) used was also collected. However, as Sivayoganathan et al. (1995) point out, it is the condition of the sprayer (that is whether it was leaking or not) that affects the user than the equipment itself. Unfortunately, the survey was unable to examine

[14] However, there are certain exceptions to this rule when herbicides can be as toxic as insecticides. A good example is Paraquat known as Gramoxone by trade name.

the condition of the sprayers being used and thus determine whether equipment used was faulty or not. This information no doubt would have been a useful variable to be tested in the regression analysis.

Variable Specification

Guided by the data that is available and the research work hypotheses on ill health and exposure to pesticides we give below the specification for the regression analysis normalised in per capita terms.

$$\underset{}{IH} = f(\underset{+}{AGE}, \underset{+}{ASHS}, \underset{+}{MONS}, \underset{+}{CROP}, \underset{-}{MOR}, \underset{+}{AFT}, \underset{-}{EVE}, \underset{+}{INS}, \underset{+}{HER}, \underset{+}{FUN}, \underset{-}{PC})$$

Costs of illness are taken to represent ill health (IH) which is written down as a function of age (AGE), acres * sprayed (ASHS), months of pesticides use (MONS), types of crops grown (CROP), hours of pesticides sprayed in the morning before 10 am (MOR), pesticides sprayed between 10am-2pm (AFT), pesticides sprayed after 4pm (EVE), insecticides (INS), herbicides (HER), fungicides (FUN) and precautions taken (PC). The expected signs of the partial derivatives are indicated beneath each argument in the function.

Despite some important variables being included in the econometric analysis to capture variables that cause ill health among farmers during and after pesticide use, at least six other factors that have been found to cause ill health during pesticide use have been omitted due to non-availability of data. Some of them are: prevailing wind patterns, physical posture during use, health status of the user, condition of the equipment used, method of application and whether a meal was consumed before spraying or not. However, we presume that the variables that are included are representative of some of the major variables that cause ill health among farmers due to direct exposure to pesticides during handling and spraying on the farms and can therefore, shed more light on factors that cause ill health among farmers using pesticides.

Summary Statistics

Reported in Table 8.3 are the means and standard deviations for all the variables that were included in the regression analysis.

The mean age is 40 and the private costs (i.e out-of-pocket and time costs) is Rs 5,465.54 per year. These costs exceed an average subsistence farmers monthly income of Rs 4,748.17. A farmer on average cultivates three different crops a year and sprays pesticides for nine months of the year. Pesticides are used from the time land is cleared for cultivation (herbicides) until crops are harvested. Most of the pesticides used are insecticides used to keep away insect attacks. An average of almost three insecticides and one herbicide per year are used. Fungicides are used during any period of the cultivating season to prevent leaf disease, etc. but are mostly sprayed during the growing season. On average one fungicide is used per year by a farmer. On average nearly five types of pesticides are used during a given year. Farmers on average grow nearly three different crops on their land. On average a farmers spends two and a half hours spraying pesticides in the morning (before 10 pm), two hours between 10 am and 4 pm and another one hour in the evening (after 4 pm). The amount of expenditure on precautions taken is low, which is Rs 405 per year.

Table: 8.3 Means and Standard Deviations for Variables that Cause Ill Health

Variable	Variable Description	Mean	Std Dev
TOTCOT	Private Costs	5,465.54	6,602.60
AGE	Age	40.00	11.00
ACRHS	Acres * hour Sprayed per spraying day	9.24	8.74
MONS	Months of Pesticide Use	8.96	2.10
CROP	Total Number of Crops Grown	2.74	1.74
MOR	Pesticide Hours Sprayed Before 10 AM	2.32	0.51
AFT	Pesticide Hours Sprayed Between 10-2PM	2.18	1.05
EVE	Pesticide Hours Sprayed After 4PM	1.13	0.79
INS	Insecticide Types Used Per Year	2.82	1.33
HER	Herbicide Types Used Per Year	1.11	1.23
FUN	Fungicide Types Used Per Year	0.99	1.11
PC	Precautionary Costs	405.14	667.94
TPEST	Number of Pesticides Used Per Year	4.94	2.32
SPRAYH	Number of Hours Per Given Day	5.71	1.79

Regression Results

There was 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 (SPSS, 1993). Since there are a few respondents who have not suffered any illnesses and hence not incurred any costs[15] it was not possible to use semi logs. The alternative was to take the square root transformation of the dependent variable. This minimised

[15] Hence the reason to include a Tobit analysis as well.

the heteroscedesticity problem and also improved the goodness of fit. Appendix 8.2 shows the results of the tests performed before and after the square root transformation of data. The 'tolerances and variable inflation factor and the collinearity diagnostics' for the variables showed that multicollinearity was also not a problem. The transformed variables were estimated by OLS as well as Tobit estimators using the 203 observations. Needless to say, because of the small sample size, the results should be interpreted with caution. Estimates of the ordinary least squares and Tobit analyses are presented in Table 8.4.

Table: 8.4 Regression Results of a Study Determining the Relationships Between Ill Health and Direct Exposure to Pesticides

Variable	(A)					(B)				
	OLS				Tobit	OLS				Tobit
	B	St Error	Beta	T-Ratio	z = b/s.e.	B	St Error	Beta	T-Ratio	z = b/s.e.
AGE	.527	.233	.148	2.26***	2.26***	.544	.229	.153	2.37****	2.35****
ACRHS	.635	.380	.139	1.67**	1.71 **	.671	.374	.147	1.79**	1.84**
MONS	5.366	1.307	.284	4.10****	4.43 ****	5.503	1.280	.291	4.29****	4.58****
CROP	3.372	1.626	.148	2.07***	2.29***	.851	1.575	.125	1.80**	1.98***
MOR	3.785	5.664	.049	.668	0.59					
AFT	1.339	2.886	.036	.464	0.42					
EVE	4.663	3.520	.093	1.32*	1.34*					
INS	4.058	1.977	.136	2.05***	2.07***					
HER	2.920	2.159	.095	1.35*	1.41*					
FUN	-.210	2.497	-.006	-.084	-0.22					
PC	-2.6E-03	.003	-.054	-.818	1.13	-2.9E-03	.003	-.060	-.924	-1.25
TPEST						2.494	1.202	.146	2.07***	2.04***
SPRAYH						2.988	1.697	.134	1.76**	1.68**
(Const.)	-52.632	20.392	-	-2581	-2.80	-51.196	16.773	-	-3.052	-3.315

(A) R Square: 0.24 Adjusted R Square: 0.19 Standard Error: 35.68 F: 5.49
(B) R Square: 0.23 Adjusted R Square: 0.20 Standard Error: 35.52 F: 8.37
The asterisks *** *, ***, ** and * indicate 1, 2.5, 5 and 10% level of significance respectively for a one tailed test.
8 observations at zero
195 non-zero observations
n = 203

Note: We interpret the beta coefficients in the regression results rather than the B coefficients. This is because the units of measurement of the variables are not the same. Hence the coefficients are not directly comparable. Therefore, when variables differ substantially in units of measurement, the sheer magnitude of their coefficients does not reveal anything about their relative importance. Hence, in order to make the regression coefficients somewhat more comparable, the coefficients have been standardized to take into account the differences in the various units of measurement of the variables. Therefore, the beta coefficients are the standardized coefficients while B coefficients are the unstandardized coefficients. The standardized beta coefficients can be calculated directly from the regression coefficients using the following formula: B_1 (S_x/S_y) where B_1 is the regression coefficient and S_x is the standard deviation of the independent variable and S_y is the standard deviation of the dependent variable (SPSS, 6.0, 1993, p.314, 342).

The goodness of fit is small, but is not uncommon in work of this nature [for example, see the work of Brien et al. (1994) work]. The signs of all but one of the estimated coefficients are consistent with prior expectations and many have large magnitudes. For this regression analysis we interpret the results for a one tailed test. The null hypothesis is $H_0{:}\beta = 0$ and the alternative hypothesis is, $H_1{:}\ \beta < 0$ or $H_1{:}\ \beta > 0$.

Column (A) examines the effect of each type of pesticide, namely insecticides, herbicides and fungicides as well as time of day the pesticides were sprayed, namely morning (before 10 am), between 10 am and 2 p.m. and in the evening (after 4 p.m.) expressed in hours together with the other independent variables. In column (B), all three types of pesticides are combined into one variable (i.e. the number of insecticides, herbicides and fungicides brands used for a year) called 'TPEST' and the three time periods (denoted in hours) during which time farmers spray pesticides are also combined into one variable called 'SPRAYH'. In other words, this variable is the number of hours spent spraying pesticides on a given day on the farm. The remaining variables in column (A) are also shown in column (B).

Discussion of Results

It is interesting to note that OLS and Tobit analyses do not show any significant differences in the levels of significance. Only in the 'CROP' variable in column (B) does the level of significance change from 5% level of significance in OLS to 2.5% level of significance in the Tobit analysis for a one tailed test. The regression results shown in columns (A) and (B) are consistent with the advice given by physicians and agricultural extension workers of the Dept of Agriculture. In fact the regression results support the official guidelines/recommendations set out for the use and handling of pesticides which were mentioned in the previous section. The AGE ACRHS, MONS, CROP, INST, HER variables are significant as shown in column (A). All these results suggest that the older you are, the extent of direct contact an individual has with pesticides, longer are the months of pesticide handling and spraying, larger are the varieties of crops grown and more toxic are the pesticides used, then higher would be the incidence of ill health. The number of hours of pesticides sprayed in the evening denoted by the 'EVE' variable is also significant at the 10% level of significance for a one tailed test. The 'MOR' and 'AFT' variables are insignificant. The hypothesis for the 'EVE' variable was that the more pesticides are sprayed in the evening (after 4.pm.) less would be the ill health arising from handling and spraying pesticides. This was because the temperature begins to drop in the evening and thus the health effects from exposure to pesticides are minimal. However, this is not the case as the results show. This could be due to the prevailing temperatures being high even after 4 p.m. and/or that the farmer had worked the whole day and hence his tiredness made him more prone to ill health from exposure to pesticides. Furthermore, in such a case it is also important to determine whether a farmer consumed a meal or not. Hence, the results suggest that it is important to consider the temperatures (humidity) prevalent at the time of spraying, whether a farmer had worked the entire day before spraying and whether he had consumed a meal just before spraying rather than only examining the hours of pesticides sprayed in the evening (after 4.pm.). In column (B) we examine what impacts the three 'time period' variables discussed in the last section (denoted in hours) and examined in the regression analysis of column (A) combined into one variable called 'SPRAYH' have on the 'health' of the user. The precautionary cost variable is insignificant, suggesting that the amount of protective gear worn is inadequate. The regression results in column (B) show that in addition to AGE ACRHS, MONS, CROP variables, the TPEST and SPRAYH variables, too, become significant. Furthermore, by combining all types of pesticides used into one variable (TPEST) and the time of day pesticides are sprayed (expressed in hours) is combined into one variable (SPRAYH), the level of significance also improves for most of the other variables, as well in the regression analysis.

Conclusion

In this chapter we tried to estimate the private direct and indirect costs arising from direct exposure to pesticides to farmers during handling and spraying on the farms. Despite only specific costs being covered, the costs were found to be very large, exceeding an average farmers monthly income. Most of the costs estimated in this chapter arose from the imputed value of time rather than from out-of-pocket private expenses. This was mainly because hospital medical treatment is provided free of charge in Sri Lanka. The public costs are not calculated in this thesis. Because of the narrowness of the areas of costs covered and the inherent weaknesses of the cost of illness approach, it is believed that the estimates provided in this chapter are conservative lower bounds to the true costs. The real costs are much larger. It is believed that the problem of direct exposure to pesticides is a very serious problem in Sri Lanka, not only because of the large private costs arising from 'direct pesticide exposure related' illnesses but also due to its overall effects on human capital, other production processes, wildlife and the environment in general.

In this chapter we also used data that was collected from the Ph.D. field survey study to test the relationships between the costs of ill health resulting from direct exposure to pesticides and factors that cause such costs from ill health during handling and spraying by farmers on their farms. For a long-time, physicians and agricultural extension workers from the Department of Agriculture have established such a link. Some of the variables (especially the quality variables) could not be included for lack of data. However, the results of the variables that were included were consistent with the hypotheses on direct exposure to pesticides and ill health. The results, however, should be treated with caution (due to the small sample size used), although consistent with official guidelines/recommendations on the handling and use of pesticides on farms. The regression results show that farmers are in clear violation of the precautions prescribed in the handling and spraying of pesticides and hence calls for urgent action to implement recommended safety procedures. If not, the costs both to the country as well as to the users are substantial as shown by the cost estimates generated from the field study.

This chapter showed the various costs incurred by farmers due to ill health resulting from direct exposure to pesticides. It is also possible to use these estimates to infer the willingness to pay bids/values to reduce direct exposure to pesticides and the resulting adverse health effects or in other words to measure the value of reduced ill health resulting from direct exposure to pesticides as discussed in chapter four. In this chapter, we also examined what factors contribute towards farmers ill health resulting from farmers direct exposure to high levels of pesticides during handling and spraying on the farms. The next chapter uses another indirect approach, namely the avertive/defensive behaviour approach to examine the various costs incurred by the user in trying to mitigate and taking precautions in reducing direct exposure to pesticides that cause ill health during handling and spraying of pesticides on the farms.

Appendix: 8.1

Costs on Spraying Days
(Serious Illness Needing Hospitalization)[16]

Item	Total Costs/hours		Average Costs/hours		Total Costs
	Rs	Hrs	Rs	Hrs	Rs
Medical Costs:					
1. Drugs, Consultation and Laboratory Costs					
1.a Consultation Fees	2,180	-	10.73	-	2,180
1.b Hospital admission costs	7,100	-	34.97		7,100
1.c Laboratory and associated Costs	820	-	4.03		820
1.b Medication/drugs	5,820	-	28.66		5,820
2. Other costs associated with an illness					
2.a Dietary expenses resulting from an illness	10,869	-	53.54	-	10,869
2.b Travel costs associated with medical treatment	5,242	-	25.82	-	5,242
2.c Loss of work days/hours on farm	-	4,690	433.18	23.10	87,937.5
2.d Loss of efficiency on farm	-	326	30.11	1.60	6,112.5
2.eTime spent on traveling/seeking treatment	-	777.5	71.81	3.83	14,578.12
2.f Hired labour due to inability to work	20,160	-	99.31	-	20,160
2.g Leisure time losses	-	497	45.40	2.44	9,318.75
Other costs	7,350	-	36.20	-	7,350
Total costs	59,541	6,290.5	874.32	30.97	177,487.90

Survey Period: July to September, 1996

[16] Please see section four of questionnaire that shows how the data were collected.

Costs on Spraying Days
(Moderate Illness-i.e Doctor is Consulted but no Hospitalization is Required)[17]

Item	Total Costs/hours		Average Costs/hours		Total Costs
	Rs	Hrs	Rs	Hrs	Rs
Medical Costs:					
1. Drugs, Consultation and Laboratory Costs					
1.a Consultation Fees	900	-	4.43	-	900
1.b Laboratory and associated costs	200	-	0.98	-	200
1.c Medication/drugs	7,370	-	36.30	-	7,370
2. Other costs associated with an illness					
2.a Dietary expenses resulting from an illness	6,177	-	30.42	-	6,177
2.b Travel costs associated with medical treatment	3,442	-	16.95	-	3,442
2.c Loss of work days/hours on farm	-	1,115	102.98	5.49	20,906.25
2.d Loss of efficiency on farm	-	444	41.00	2.18	8,325.00
2.e Time spent on traveling/seeking treatment	-	390	36.02	1.92	7,312.50
2.f Hired labour due to inability to work	9,675	-	47.66	-	9,675
2.g Leisure time losses	-	158.65	14.65	0.78	2,974.68
Other costs	-	-	-	-	-
Total	27,764	21,07.65	331.39	10.37	67,282.43

Survey Period: July to September, 1996

[17] Please see section four of questionnaire that shows how the data were collected.

Costs on Spraying Days
(Mild Illness-i.e. No Visits to the Doctor, Yet Medication is Taken)[18]

Item	Total Costs/hours		Average Costs/hours		Total Costs
	Rs	Hrs	Rs	Hrs	Rs
Medical Costs:					
1. Drugs, Consultation and Laboratory Costs					
1.a Consultation Fees	-	-	-	-	-
1.b Laboratory Costs	-	-	-	-	-
1.c Medication/drugs	47, 516	-	234.05	-	47,516
2. Other costs associated with an illness	-	-	-	-	-
2.a Dietary expenses resulting from an illness	44,519	-	219.30	-	44,519
2.b Travel costs associated with medical treatment	2,865	-	14.11	-	2,865
2.c Loss of work days/hours on farm	-	7,823.5	722.61	38.53	146,690.60
2.d Loss of efficiency on farm	-	6,089.5	562.45	29.99	114,178.10
2.e Time spent on traveling/seeking treatment	-	-	-	-	-
2.f Hired labour due to inability to work	7, 990	-	39.33	-	7,990
2.g Leisure time losses	-	5,535.3	511.26	27.26	103,786.9
Other costs	1,665	-	8.20	-	1,665
Total costs	104, 555	19448.3	2311.38	95.78	469210.6

Survey Period: July to September, 1996

[18] Please see section four of questionnaire that shows how the data were collected.

Costs on Non Spraying Days

Item	Total Costs		Average Costs/hours		Total Costs
	Rs	Hrs	Rs	Hrs	Rs
Medical Costs:					
1. Drugs, Consultation and Laboratory Costs					
1.a Consultation Fees	2,430	-	11.97	-	2,430
1.b Hospital Admission costs	2,450	-	12.06	-	2,450
1.c Laboratory and associated costs	80	-	0.39	-	80
1.d Medication/drugs	14,799	-	72.90	-	14,779
2. Other costs associated with an illness					
2.a Dietary expenses resulting from an illness	22,224	-	109.47	-	22,224
2.b Travel costs associated with medical treatment	11,581	-	57.04	-	11,581
2.c Loss of work days/hours on farm	-	3,018	278.75	14.80	56,587.5
2.d Loss of efficiency on farm	-	1,925	177.80	9.48	36093.75
2.e Time spent on traveling/seeking treatment	-	2,611.5	241.21	12.86	49,565.62
2.f Hired labour due to inability to work	44,245	-	217.95	-	48,965.63
2.g Leisure time losses	-	3,217.8	297.21	15.85	60,333.75
Other costs	4,985	-	24.55	-	4,985
Total costs	102,794	10,772.3	1,501.35	52.99	304,774.60

Survey Period: July to September, 1996

Appendix: 8.2

Tests for Violations of Assumptions

A diagrammatic (scatter plot) search was conducted on residuals to look for evidence that the necessary assumptions are violated. The studentized residuals which is the residual divided by an estimate of its standard deviation which varies from point to point, depending on the distance of X_i from the mean of X are used. The studentized residuals are used because it is believed that Studentized residuals reflect more precisely the differences in the true error variances from point to point.

A convenient method to check if the assumptions of linearity and homogenity of variance are met is to plot the residuals against the predicted values. If the assumptions of linearity and homogenity are met, there should be no relationship between the predicted and the residual values. Furthermore, the same plots can be used to check for violations of the equality-of-variance assumption. If the spread of the residuals increase or decrease with values of the independent variables or with predicted values, the assumption of constant variance of Y for all values of X should be in doubt.

Figures 8.1 (A) and 8.1 (B) show plots of the studentized residuals against the predicted values. As can be seen the spread of the residuals increases with the magnitude of the predicted values suggesting that the equality-of-variance assumption appears to be violated. It is also important to examine whether the distribution of residuals are normal or not. The distribution of the residuals may not appear to be normal for reasons other than actual non-normality such as mis-specification of the model, non constant variance, a small number of residuals actually available for analysis, etc. Hence, as is recommended, several lines of investigation should be pursued and one of the simplest and easiest to perform is a histogram of the residuals.

A normal distribution is superimposed on a histogram of observed frequencies (indicated by the bars). It is unreasonable to expect the observed residuals to be exactly normal. Some deviation is expected because of the sampling variation. Even if the errors are normally distributed in the population, sample residuals are only approximately normal. In the histograms shown in Figures 8.2 (A) and 8.2 (B), the distributions do not seem normal since there is an exaggerated clustering of residuals toward the centre and a straggling tail toward large positive values. Thus, the normality assumption may be violated. Another way to compare the observed distribution of residuals to the expected distribution under the assumption of normality is to plot the two cumulative distributions against each other for a series of points. If the two distributions are identical, a straight line results. By observing how points scatter about the expected straight line, it is possible to compare the two distributions.

Figures 8.3 (A) and 8.3 (B) are cumulative probability plots of the residuals. Initially, the observed residuals are above the "normal" line, since there is a smaller number of large negative residuals than expected. Once the greatest concentration of residuals is reached, the observed points are below the line, since the observed cumulative proportion exceeds the expected. As shown in the three figures there is evidence of violations of assumptions. In order to correct for violations of assumptions many remedies have been recommended. One strategy is to reformulate the model by using weighted least squares. Another solution recommended is to transform the variables so that the current model will be more adequate. This can be done, for example, by taking logs, square roots, or reciprocals which can stabilise the variance, achieve normality, or linearize a relationship. This can be done only according to the data sets that are available. With a data set that has many zero values, converting the data into log values is not possible. Hence the square root transformation of the data is obtained and this is what is recommended when cross sectional data are used.

With the transformation of data, the scatter plots show a marked improvement in the behaviour of the residuals shown in Figures 8.4 (A) and 8.4 (B). The spread no longer shows a tendency to increase. Furthermore, Figures 8.5 (A) and 8.5 (B) show a near normal distribution. Figure 8.6 (A) and 8.6 (B) also show an improvement over Figures 8.3 (A) and 8.3 (B). The observed residuals are closer to the straight line in Figures 8.6 (A) and 8.6 (B) than before the data transformation. The transformed data has also resulted in a slight increase in multiple R and the outlier plot has also improved. Thus, the transformation appears to have resulted in a better model.

Scatter Plots Before the Square Root Transformation of the Dependent Variable in the A Column Regression

Figure: 8.1 (A)

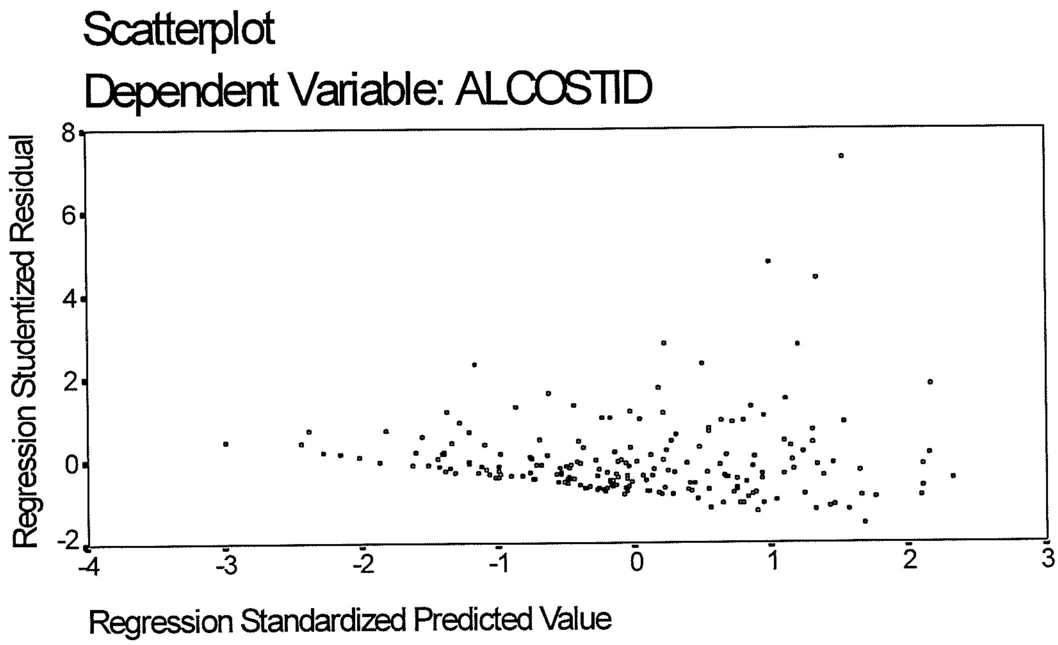


Figure: 8.2 (A)

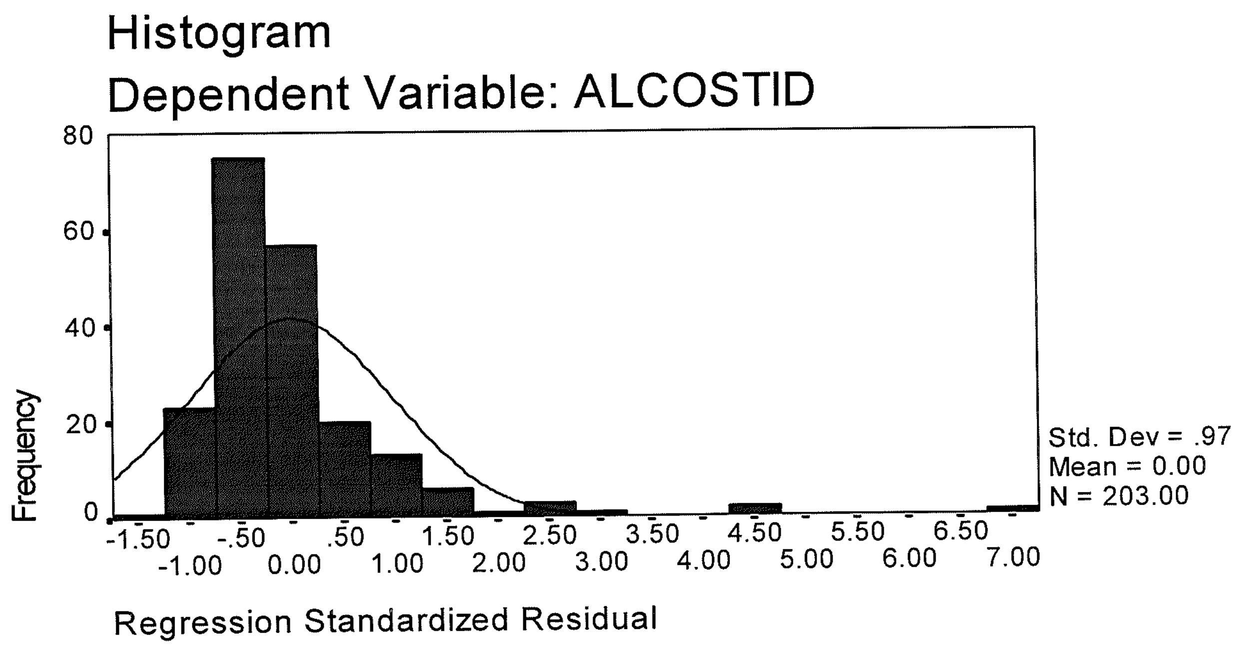
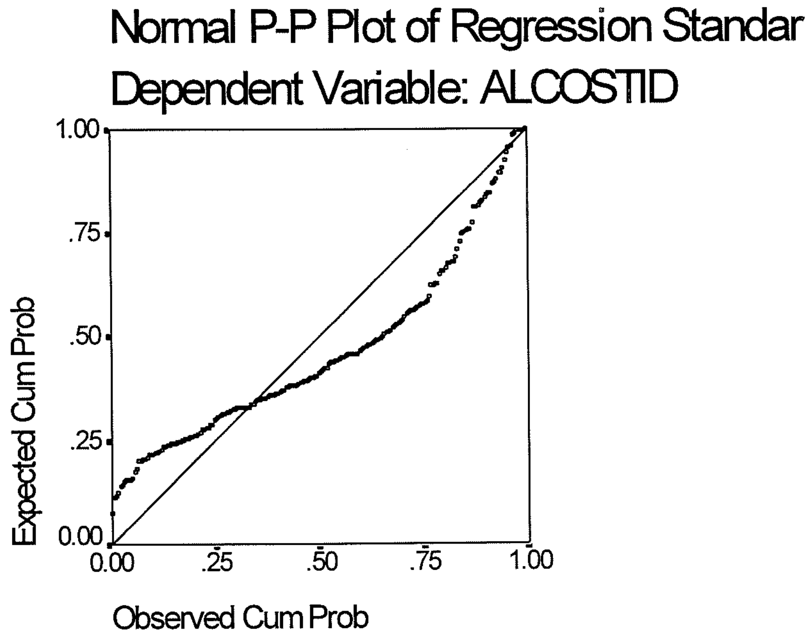


Figure: 8.3 (A)


Normal P-P Plot of Regression Standar
Dependent Variable: ALCOSTID
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob

Scatter Plots After the Square Root Transformation of the Dependent Variable in the A Column Regression

Figure: 8.4 (A)

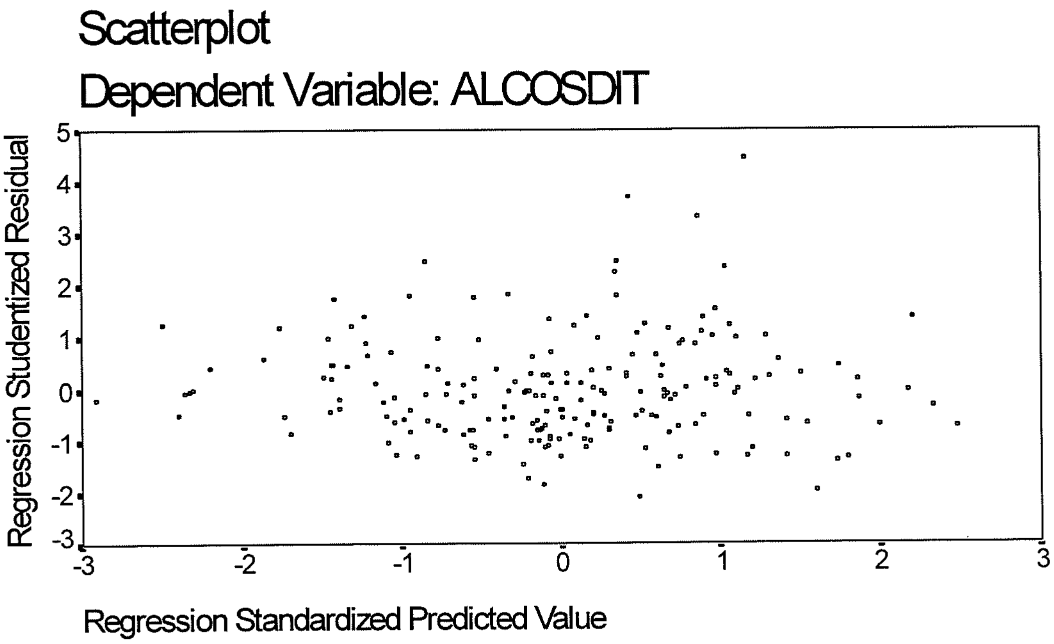


Figure: 8.5 (A)

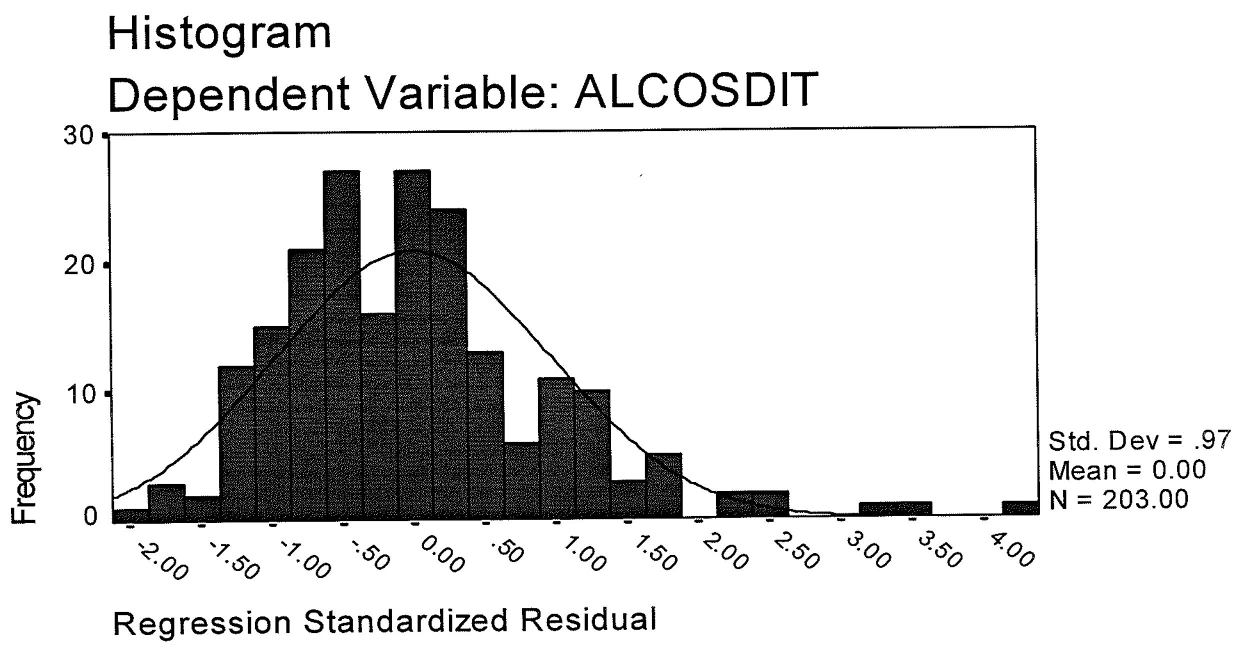
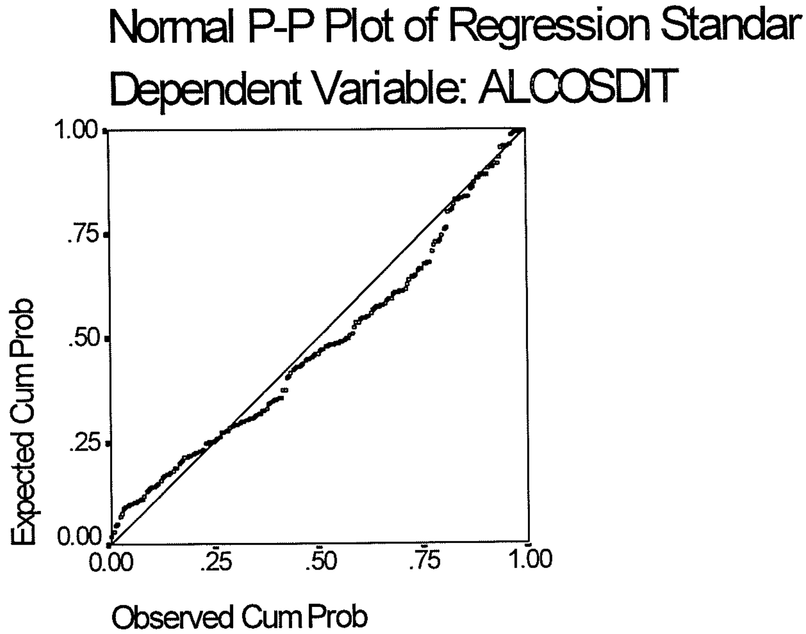


Figure: 8.6 (A)


Normal P-P Plot of Regression Standar
Dependent Variable: ALCOSDIT
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob

Scatter Plots Before the Square Root Transformation of the Dependent Variable in the B Column Regression

Figure: 8.1 (B)

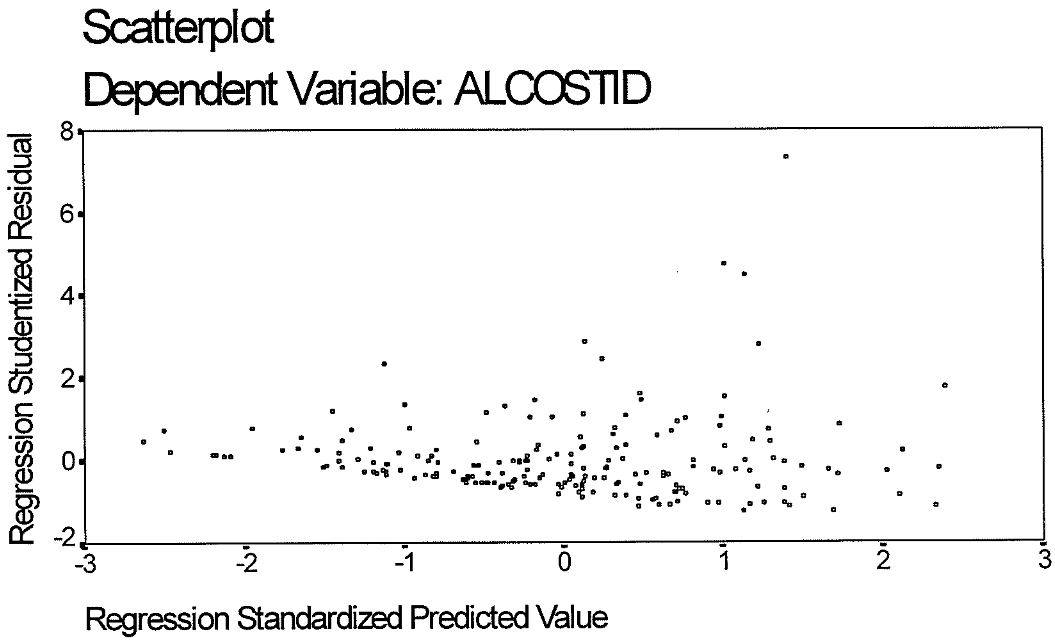


Figure: 8.2 (B)

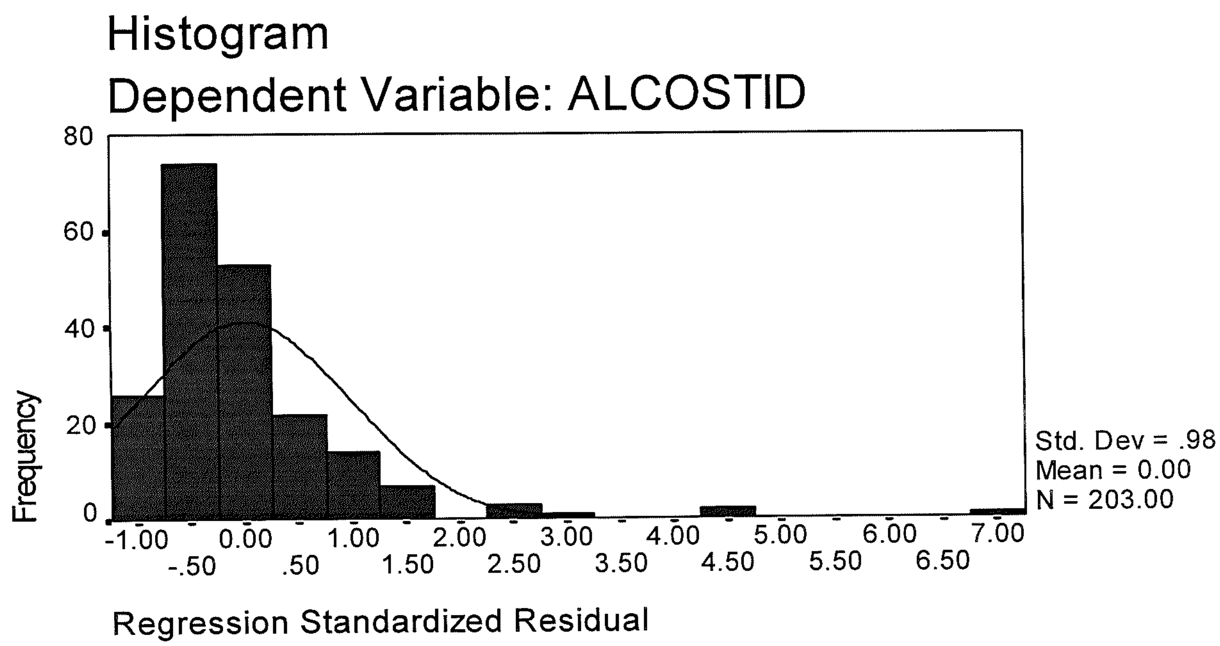
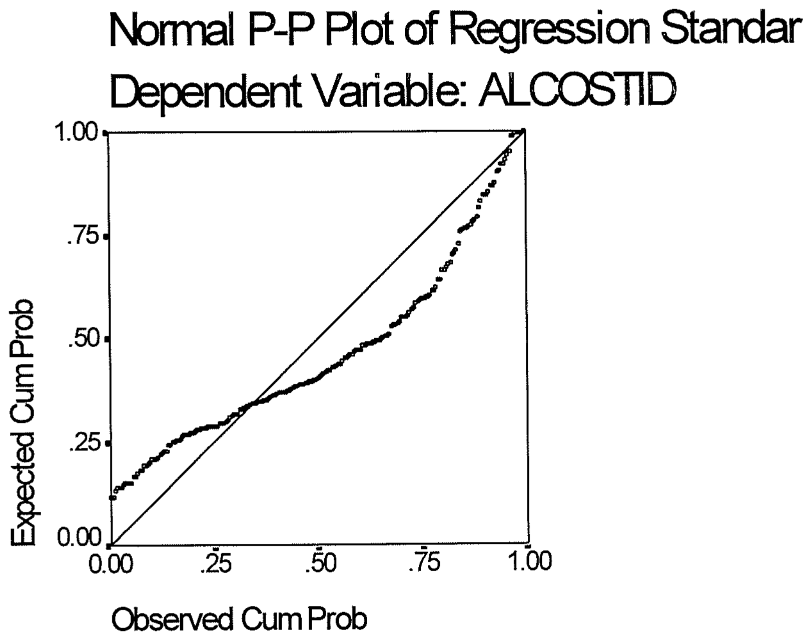


Figure: 8.3 (B)


Normal P-P Plot of Regression Standar
Dependent Variable: ALCOSTID
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob

Scatter Plots After the Square Root Transformation of the Dependent Variable in the B Column Regression

Figure: 8.4 (B)

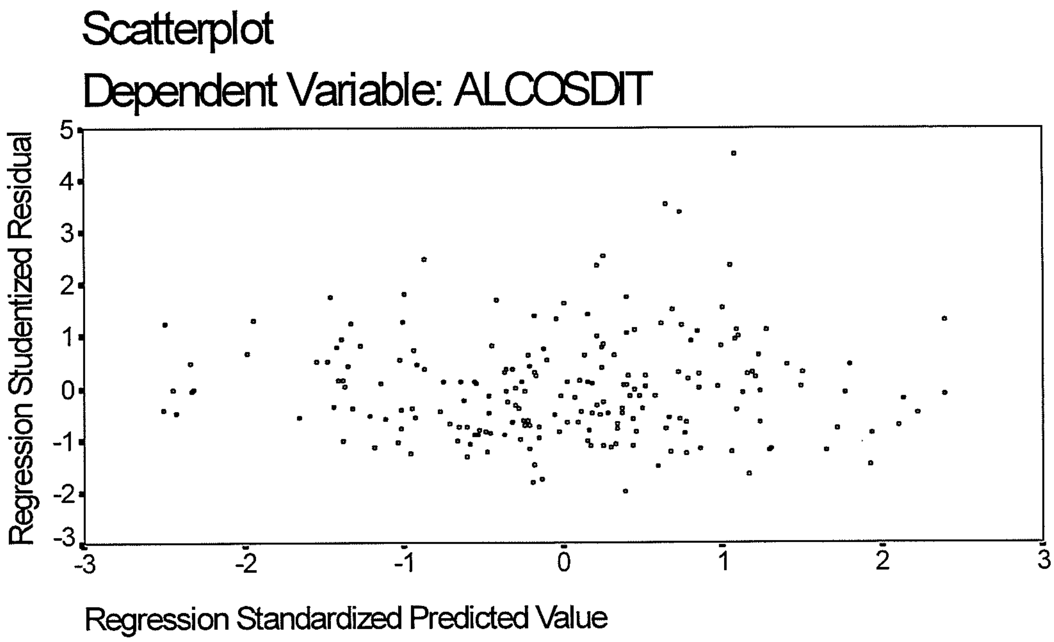


Figure: 8.5 (B)

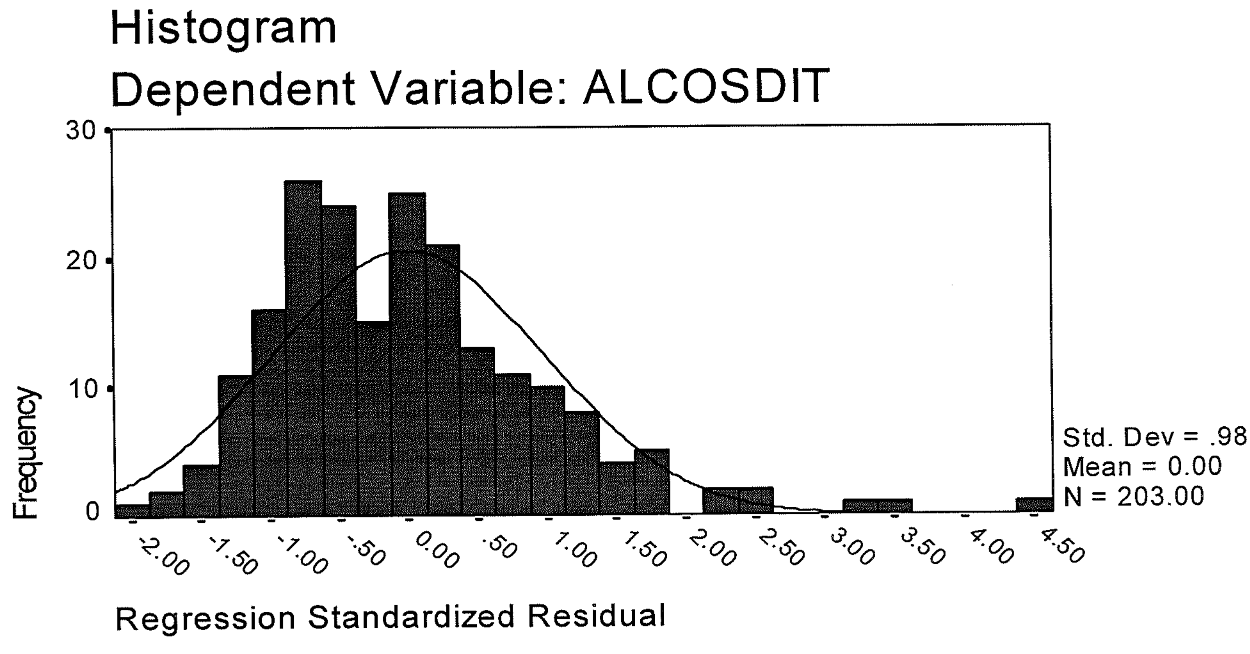
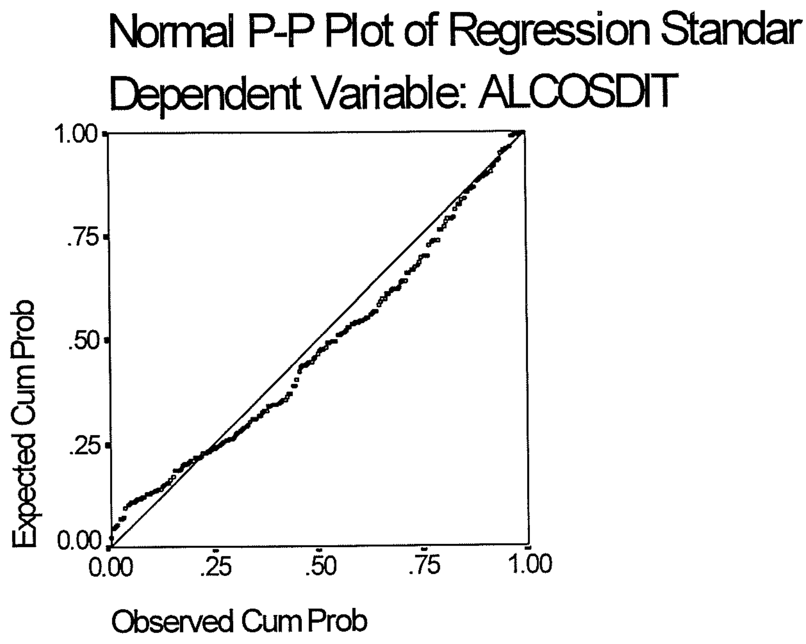


Figure: 8.6 (B)



Normal P-P Plot of Regression Standar
Dependent Variable: ALCOSDIT
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob

CHAPTER 9

ESTIMATING COSTS OF AVERTING ACTION TAKEN TO REDUCE DIRECT EXPOSURE TO PESTICIDES

Introduction

In this chapter we try to estimate some of the costs that have been incurred by farmers to reduce direct exposure to pesticides during handling and spraying on their farms. The data collected from the field study of 1996, discussed in chapter six, are used. Only some of the direct, calculable costs are considered. However, some direct costs[1] which are not so easy to estimate and the indirect costs[2] are not considered due to data, time and financial constraints. The direct private costs considered are: protective clothing, masks, gloves, shoes, storage facilities and hiring of labour.

Any protective gear provided by the Department of Agriculture or pesticide companies are also not considered. As in other two approaches, the estimates of the costs are for one year. These private costs are incurred by farmers on pesticide spraying days during handling and spraying. However, storage costs are also included.

Estimating the defensive/precautionary costs are useful for many reasons and one main reason is to determine whether farmers take adequate precautions during handling and spraying of pesticides, which is highly correlated with ill health resulting from direct exposure to pesticides. This will be tested in a regression analysis in the last section of the chapter. The amount of money spent on defensive behaviour is also an investment, not only to reduce short-term ill health, but also to reduce long-term illnesses described in chapter three. Apart from the above mentioned users, the estimates can also be used to infer willingness to pay bids to reduce direct exposure to pesticides and the resulting after effects (ill health) as described in chapter four [for example, see Cropper and Freeman III (1991)].

Before presenting the empirical estimates of the field study, the avertive behaviour approach will be discussed in detail where the advantages and disadvantages will be highlighted. This will be followed by a discussion of the avertive behaviour estimates of the Ph.D. study.

The first section begins with a review of the avertive behaviour approach dealing with the advantages and disadvantages of the approach discussing studies carried out using this

[1] They include expensive sprayers that are less likely to malfunction which can affect the user. Expensive (but more safe) sprayers have multiple usage apart from being safe. This includes hiring such sprayers for a fee to other users.

[2] An example of an indirect cost would be time spent purchasing, cleaning and maintaining defensive/protective gear. Furthermore, 'reading warnings and instructions' would also fall into this category of costs.

approach. The problems associated with data and the quality of the estimates of the avertive behaviour estimates will be described. The chapter then examines the application of the avertive behaviour approach to measure the costs resulting from direct exposure to pesticides and then go on to present and discuss the private costs arising due to avertive/defensive expenditure undertaken to reduce direct exposure to pesticides. The section preceeding the last chapter examines the factors that influence defensive behaviour. For this purpose regression analysis is used. The last section compares the three approaches from the results of the field study.

The Concept of the Averting Behaviour Approach

An alternative indirect method of determining the affected individuals willingness to pay to reduce direct exposure to pesticides and the resulting health effects is to use the cost of avertive/defensive behaviour approach. Of the three approaches used in this Ph.D. study, the averting behaviour approach is the least employed. However, this approach has been used in many environmental health related studies to value changes in respiratory symptoms arising from air pollution [Gerking and Stanley (1986); Bresnahan et al. (1997)], to avoid additional angina episodes [Chestnut et al. (1996)], to bring about a reduction in the incidence of waterborne diseases [Harrington et al.(1989); Abdalla et al. (1992)], risk of accidents (Dardis, 1980) and has been used to compare with the other two approaches [Berger et al. (1987); Chestnut et al. (1996)]. The averting behaviour approach, like the cost of illness approach, has been referred to by various names such as: the precautionary cost approach, defensive expenditures approach and the mitigating cost approach. It has also been called the willingness to pay for safety (Folland, 1997, p.573). Like in the cost of illness approach, because of the data constraints, the averting behaviour approach may or may not estimate all the costs (both direct and indirect) incurred on defensive behaviour to reduce or even avoid pollution or improve health. As Tolley and Fabian (1993 p.315) point out "taking account of averting behaviour in an adequate way has remained elusive". Furthermore, the existence of this approach implies that damage response relationships may underestimate benefits of environmental improvement (ibid).

Like the other two valuation approaches, the averting behaviour approach has also been used for almost three decades or even more. Courant and Porter (1981) state that economists have long been aware that the averting behaviour is both possible and practiced by the individuals and have suggested that such expenditures can be used to measure the costs of pollution. One of the earliest works that attempted to do this was Stevens (1966) in an article in Water Resources Research. Stevens considered the benefits of avoiding water pollution that would otherwise affect angling success. His main argument was that the quality of fishing was represented by the angling success per unit effort. Water pollution, it was argued, would affect angling success. He tried to show the benefits of water pollution control by estimating a demand function for the sport. In this regard he also considered the expenditures incurred to prevent the deterioration of water quality that would affect angling success. However, his idea was not developed in a rigorous way and hence, the arguments were vague. Maler (1971)[3], however, developed a theory which lent support to the arguments presented by Stevens. Many studies were carried out in the 1970s using the avertive behaviour approach but not as many as those carried out using the other two approaches, especially the cost of illness approach. Examples of the studies that have used the averting behaviour approach in the 1970s are: Jackson et al. (1976); Liu and Yu (1976). Further theoretical work on the avertive behaviour was carried out by Courant and Porter (1981); Smith et al. (1986). Bartik (1988) too considers the relationship between willingness to pay for environmental quality and averting expenditures. Courant and Porter (1981) who investigated the suitability of defensive expenditures alone as a measure of the benefits of environmental improvements show that defensive expenditures to be either a lower or an upper bound to willingness to pay depending on the shape of the dose-response function, although a lower bound would be the most likely out come. Bartik (1988) shows that upper and lower bounds to benefits can be derived with information only on the defensive expenditure technology for non-marginal reductions in pollution. Similar results have been established by Freeman III (1985, chapter 6). Studies carried out in the 1980s using this approach include: Ryan et al. (1981); Berger et al. (1987) and Harrington et al. (1989). Further in depth theoretical discussion is undertaken by Cropper and Freeman III (1991); Crocker et al. (1991); Shogren and Crocker (1991); Tolley and Fabian (1994, ch. 14) and Johansson (1995, pp.89-91). For a brief review, see Folland (1997, ch 24, p.573); Laughland et al. (1996). For empirical work done in the 1990s, see Abdalla, (1990);Akerman et al. (1991); Doyle et al. (1991); Abdalla et al. (1992); Laughland et al. (1993); Bresnahan et al. (1997).

The avertive behaviour approach is based on the notion that any avertive/defensive expenditure incurred (including time) infers an individuals value for the subject in question. In other words, it can be interpreted as the willingness to pay to reduce/avoid ill health, and/or for pollution control, etc. The averting behaviour approach takes into consideration the amount of expenditure an individual has incurred in taking protective measures to reduce/avoid pollution effects and then from such expenditures to infer the willingness to pay to reduce environmental pollution/exposure to dangerous chemicals, such as pesticides. The value of a reduction in mobidity can be inferred either from an averting activity that reduce direct exposure to dangerous chemicals or pollution, such as wearing protective clothing during the use of pesticides or that mitigate the strength or duration of symptoms, such as taking medication before being affected or visiting a doctor for consultation, check up, etc. before an illness or in the case of pesticides, even employing labour to spray pesticides on their farms[4]. As Cropper and Freeman III (1991,

[3] The work of Stevens (1966) considers expenditures on private goods made in order to abet the benefits of a public environmental good. Although the analysis is formally similar, Courant and Porter (1981) prefer to stress on averting expenditures because as they state "fewer people believe abetting expenditures to be a good measure of willingness to pay for public environmental goods" (p.321).

[4] Here, it should be mentioned that hiring labour to do some of the pesticide spraying is a defensive activity and is categorised as a defensive cost. On the other hand, if a respondent suffered from ill health due to exposure to pesticides and hired labour to work on the farms (including spraying pesticides) due to inability to work then it is categorized as a cost of illness (please see questionnaire).

p.182) point out, from the various studies that have been carried out, assuming that these activities are pursued to the point where their marginal cost equals the marginal value of reduced risk of death or an illness, then they can be used to value an individual's willingness to pay to reduce his risk of death or an illness: otherwise, it would be said that such an approach can yield lower bound values of ill health, costs of pollution or risks of accidents. Usually it is correct to argue that most of the values obtained would be lower bounds. For example, see Laughland et al. (1996) who from a validity test comparing contingent valuation to averting costs arrive at a low avertive/defensive cost estimate which they state is "consistent with the lower bound hypothesises" (p.109).

All direct and indirect costs should be considered, as in the case of the cost of illness approach, to estimate the costs of avertive behaviour. Cropper and Freeman III (1991, p.199) point out that to implement the avertive behaviour approach, the following data under the five categories is required

1. Frequency, duration, and severity of pollution-related symptoms.
2. Ambient pollution levels to which the individual is exposed.
3. Actions which the individual takes to avoid or mitigate the effects of air pollution.
4. Costs of avoidance and mitigating activities.
5. Other variables affecting health outcomes (age, general health status, presence of chronic conditions, and so on).

Accordingly, any visits to the doctor (for example, check ups, etc.), any medication taken in anticipation of any risks (medical care), the time spent on such visits, any leisure foregone to devote time for avertive behaviour, any short-term avertive behaviour (for example, such as staying indoors to reduce/avoid air pollution, any protective gear used such as masks), any employed labour, and long-term avertive behaviour (for example, such as air conditioning, using electricity instead of gas to avoid air pollution) and all other precautionary costs are taken into account, in order to infer the willingness to pay for improvements in environmental quality and/or a reduction in ill health. In the case of direct exposure to pesticides, all avertive costs, such as wearing special clothing, masks, any labour employed, etc., will be considered in inferring the individuals willingness to pay to reduce such pollution and hence the numerous morbidity effects. One major advantage of the avertive behaviour approach is that, this approach can be examined in conjunction with the cost of illness and contingent valuation approaches with only some additional sections added to the questionnaire.

Disadvantages of the Avertive Behaviour Approach

In avertive behaviour studies, it is important to determine the exact effectiveness of the avertive behaviour being adopted. Only the costs of the avertive behaviour that have specifically benefited the individual should be estimated. Taking account of averting behaviour accurately and adequately has remained elusive. A good example, cited by Cropper and Freeman III (1991, p.201), is the use of an air conditioner to reduce the effect of air pollution. It is 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. It is absolutely essential to determine the proportion of time the respondents spend indoors in an air conditioned environment on the survey day and the benefits accrued. Even if such data can be collected, it is difficult or even impossible to measure its costs. For example, the question arises about the cost of using an air conditioner during a particular time period when there is air pollution. The problem of using certain avoidance/protective measures is that the use of certain items (e.g. air conditioner, a good safe sprayer in the case of using pesticides) can be influenced by considerations other than reducing exposure to pollution (for example, a safer sprayer could also be more efficient and this involves less spraying time. It could also be hired to other farmers thus earning an income). In other words, some items can have multi-purpose uses rather than only specific pollution/health hazard abatement/prevention functions.

Furthermore, joint effects such as hiring people to repair a car or do the gardening, although reducing risks [for example, air pollution or the pain of angina patients in Chestnut et al. (1996) study], 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. Hence, in such cases, it is important to take away joint benefits and substitutability of products, in order to estimate the real health benefits arising from avertive behaviour. In other words, it is important to isolate the health benefits for which it was intended and thereby estimate only these costs. In the case of using safer pesticide sprayers, it is important to identify the marginal benefits arising from a more safer sprayer and accordingly to calculate the costs. The same problems arise when calculating the losses of growing traditional crops (lower output) in preference to HYVs (higher output) in order to reduce or even avoid using pesticides altogether. However, this is a difficult task, for example, subsistence farmers grow many crops in small quantities and the calculations to be made for all the farmers interviewed would be an almost an impossible task. It has also been pointed out by Cropper and Freeman III (1991, p.201) and (Tolley and Fabian 1994, p.36) that certain defensive/preventive activities may be motivated by considerations other than reducing or avoiding pollution. For example, leaving town to reduce or avoid the effects of pollution may also be motivated by the need for leisure activity in the countryside.

Hence, the difficulties in collecting the necessary data and determining the exact costs to infer the benefits of reducing or even avoiding exposure to pollution, etc. are the main drawbacks of this technique. Data restrictions to use this approach are even greater than using the cost of illness approach because of the problems associated with multiple/joint uses and multiple/joint benefits. Taking into account the farmer beliefs about the effectiveness of their actions is for, example, a more difficult issue than estimating costs arising from an illness. As Cropper and Freeman III (1991, p.191) point out "there is, however, an important difference between the data requirements of the avertive behaviour versus the cost of illness approach. Ideally, to infer willingness to pay using data on averting and mitigating behaviour, each individual's beliefs about the efficacy of these behaviours should be known because these beliefs motivate the individual's observed behaviour" Therefore, it implies that an individual should believe that it is necessary to take precautionary measures in order to reduce or even avoid a pollution related illness. In this context, Rowe and Chestnut (1985) report that half of asthma cases studied were aware that air pollution aggravated their asthma. The study also reports that there was a 20 percent decrease in "active outdoor activities" undertaken by these persons on days with high pollution. While the cost of illness approach measures the costs that are associated with the actual changes in illness that are induced by pollution, the avertive behaviour approach takes into consideration the costs of avoidance and mitigating behaviour with the tacit assumption that individuals correctly perceive the effects of their actions. It is, therefore, extremely important to take into account farmer beliefs about the effectiveness of their actions in reducing the impact of direct exposure to pesticides.

Apart from the lack of adequate data, the inadequacy of more refined conceptual formulations have hampered research efforts to measure cost of averting behaviour. No proper study has been undertaken to account for the difficulties encountered in estimating the various costs, as was undertaken in the cost of illness approach [see for example, Hodgson and Meiners (1982)]. Unlike the cost of illness approach, the avertive behaviour lacks methodology and is devoid of studies based on case study approaches. This is an area that has remained underdeveloped and need to be dealt with if more reliable and complete data are to be obtained. The rather crude measures adopted in surveys are unlikely to reveal the true costs of averting behaviour. In such circumstances (lack of guidelines to gather data on avertive behaviour and costs), it is important to recognize that there is bound to be differences among people in the efficacy and accuracy of obtaining data.

It has also been pointed out by Tolley and Fabian (1994, p.316) that avertive behaviour studies should be analyzed in conjunction with the cost of illness approach. This is because people who make low investments in avertive behaviour also tend to incur lower medical costs when sick because they are less active in seeking appropriate treatment. This behaviour appears to be contradictory because low levels of avertive behaviour should imply higher costs of illness. This relationship holds true for the usual case. However, there are cases where low avertive behaviour has also recorded lower costs of illness. In reality this does not mean that the subject suffered fewer illnesses but rather what it means is that he sought limited medical treatment. Many such cases were recorded during the field study. The reasons for this are many. One reason is because in rural areas of developing countries, the medical facilities are limited or even non-existant. Another reason is that the subject feels that the illness could be cured by home made treatment or even the belief that the illness would soon disappear after some rest.

Questions are still being asked about the calculation of certain avertive expenditures. For example, how to measure the cost of early diagnosis, because of the fact that most doctor visits are made for purposes of being treated for sickness rather than for getting check up calls [Tolley and Fabian (1994, p.316)]. They doubt that people succeed in equating marginal costs and marginal benefits of an averting activity such as obtaining early diagnosis. They go on to point out that people's responses to changes in marginal costs and marginal benefits of averting behaviour, even if observable, are probably not very good benefit measures. Hence, models should avoid attempts to equate marginal costs and benefits of avertive behaviour [Tolley and Fabian (1994, p.316)].

Empirical work carried out, however, have taken steps to make realistic calculations by considering important costs. For example, Harrington et al. (1989, p.129-132) have considered the valve of averting and mitigating expenditures and lost time in their study of Giardiasis, a water borne disease, according to the availability of information about the illness. When water supplies were contaminated and the cause of the illness was unknown, the costs that were considered were the loss of work, mitigating expenditures, and disutility. When the cause of the illness became known, the cost of averting behaviour in the form of bottled water or avoiding contaminated water were also included [for similar studies, see Abdalla (1990); Abdalla et al. (1992); Laughland et al. (1996)]. However, it should be mentioned that the costs mentioned above, together with some costs mentioned in the last section capture only a small part of averting behaviour undertaken by the affected individuals. Bresnahan et al. (1997) using panel data from a survey of the Los Angeles area residents explain defensive responses to air pollution, especially ozone. They show that those subjects who experienced smog-related symptoms spend significantly less time outdoors as ozone concentrations exceed the national standard. These individuals are predicted to reduce outdoor time by about 40 minutes on a day when the ozone standard is exceeded, compared to days when the standard is just met. They also show that people make other behavioural changes too to avoid smoggy conditions and the propensity to do so appears to increase with schooling or if health symptoms are experienced.

Another important shortcoming of the avertive expenditure approach is that, it is a function of factors such as income, education and the availability of protective gear. These are some important factors that should be considered, especially when studies are carried out among low income groups such as subsistence farmers. In the field study, it was revealed that although the farmers were willing to undertake defensive expenditures, they were found unable to afford adequate precautionary/defensive measures. Furthermore, the availability of adequate protective gear was also unavailable. Hence, the true costs of avertive behaviour are not adequately captured. In such a situation, it is very important to ask the respondents what is the ideal avertive behaviour that they would be willing to undertake given sufficient income. In such situations, the contingent valuation becomes invaluable.

Courant and Porter (1981), argue that the averting behaviour approach provides lower bounds for willingness to pay for pollution control. They state, "averting expenditure provide a lower bound estimate of the total costs imposed by pollution". This is because of the divergence between averting expenditures and the total costs of pollution arising from the fact that some consequences of pollution cannot be averted. They point out in their model that some of the costs of pollution cannot be averted through private avertive expenditure alone and that a knowledge of the production function is no longer sufficient to determine whether the level of averting expenditure is an upper bound or lower bound estimate of the willingness to pay. They go on to point out that specific information on the properties of the utility function, as well as the production function is required, if we are to use the averting behaviour approach to impose bounds on willingness to pay. Courant and Porter (1981) further show that the level of averting expenditure may be either a lower bound or an upper bound estimate of the consumer's willingness to pay for less pollution, depending on the properties of the technology under which avertive expenditure achieves its purpose and they also point out that there is no assurance that averting expenditure will be a good approximation of willingness to pay for pollution control.

Estimating Total and Average Costs Due to Averting/Defensive Behaviour

In addition to collecting information on the private costs of illness of farmers using pesticides, the study also obtained information on the various precautions taken by the farmers and the costs incurred to minimize the ill health resulting from direct exposure to pesticides. It was found that sixty one percent of the interviewed farmers had incurred some form of expenditure on protective gear and other defensive behaviour. Table 6.4 of chapter six provides descriptive statistics of protective measures taken by farmers in the sampled group. As shown in the table, farmers in the sampled group resorted to a wide variety of strategies to reduce the impact of direct exposure to pesticides. However, these measures were often found to be inadequate. In order to calculate the costs of the protective gear, the prevailing market prices were used to arrive at the estimates. The cost of these protective measures (both total and average) are shown in Table 9.1 below.

Table: 9.1 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	4,189.5	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

Survey Period: July to September, 1996

It should be noted that there is considerable regional variation in per capita avertive expenditure ranging from 46.45 rupees (Polonnaruwa) to 1,079.22 (Ambana). The regional breakdown is shown in Table 9.2.

Table: 9.2 Breakdown of Regional Costs of Precautions Taken to Reduce Direct Exposure to Pesticides

Region	Total Cost (Rs)	Average (Rs)
[1] Ambana	33,450	1,079.22
[2] Kandalama	23,315	506.84
[3] Yatawatte	16,175	305.18
[4] Beligamuwa	7,864.50	187.23
[5] Polonnaruwa	1,440	46.45
Total	82,244.5	405.14

Survey Period: July to September, 1996

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. On the other hand Polonnaruwa is a predominantly paddy growing area. The paddy crop requires low dosages of pesticides, unless there is an outbreak of pests such as the brown planthopper. Usually for paddy only 3-5 sprayings of pesticides take place for the entire cropping season (3-4 months). However, other factors also influence avertive behaviour. They are: availability of protective gear, agricultural extension advice on the benefits of wearing protective gear, etc. The costs of protective gear is another important factor that can determine their use by farmers.

As can be seen, the costs incurred on avertive/defensive behaviour is low by any standard especially when dealing with dangerous chemicals such as pesticides. Looking at the low figures, it is not surprising that the morbidity and mortality rates due to direct exposure to pesticides is high among farmers in Sri Lanka. The low avertive/defensive costs also confirm the fact that despite the wear and tear of the protective gear, they are repeatedly used. Hence insufficient investment in protective gear and their poor quality (due to wear and tear) increase the incidence of direct exposure to pesticides and therefore is one of the chief causes for the high morbidity rates now prevalent among farmers in Sri Lanka. However, despite these low figures, Rs 405.14 a year constitutes around 12% of a monthly income of a farmer. When these avertive behaviour costs and the private out-of-pocket costs of illness shown in chapter eight are considered, they both become very significant costs to a farmer. These costs become all the more significant when farmers incomes fluctuate a great deal due to adverse weather conditions, crop price fluctuations, pests and disease attacks, damage causedby wild animals, etc. In the next section, we present costs incurred on avertive/defensive behaviour for the entire country.

Total Losses to Farmers in the Country from Direct Exposure to Pesticides

In the previous section, we presented total and average estimates for the avertive/defensive expenditures for the 203 selected samples. From these figures it is possible to estimate the approximate total costs of defensive behaviour to the farmers of Sri Lanka using pesticides.

The procedure used to estimate the total costs of precautionary/defensive expenditure is straightforward. We assume that the sample of 203 respondents is representative of the farmers taking precautionary/defensive action in Sri Lanka. As mentioned in the previous chapter no one knows for certain (including the Department of Agriculture) how many farmers are currently using pesticides. According to the 1978 employment survey, it is estimated that there are 472, 435 agricultural workers in Sri Lanka[5]. However, these figures include plantation workers such as tea, rubber and coconut where the use of pesticides is minimal and that all of them are not employed to spray pesticides. It is the self-employed farmers (often on a small-scale) growing vegetable crops and rice who over use pesticides most. In order to provide estimates for the entire country, we provide scenarios for 50,000, 100,000, 150,000 and 300,000 agricultural workers who we believe use pesticides on a regular basis. 25,000 is considered a minimum and 300,000 is considered a maximum. We believe that the true figure lies in between this range. We have to resort to scenarios because no government agency in Sri Lanka, including the Department of Agriculture and the Department of Health or the Pesticide Poisons Bureau know the number of farmers affected by direct exposure to pesticides during handling and spraying on the farms.

[5] Jeyaratnam et al. (1982a) uses 1978 employment survey data for his study. The reasons for using this data were given in chapter seven.

Table: 9.3 Precautionary/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

Survey Period: July to September, 1996

Note: The average cost of illness costs 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 9.3 shows four scenarios of avertive/defensive expenditures incurred to reduce direct exposure to pesticides. The minimum total cost scenario estimate shows that farmers in Sri Lanka spend more than 20 million Rs (scenario A) in the form of avertive/defensive costs per year and the high cost scenario (scenario D) shows the figure at more than 121 million Rs on precautions taken to reduce direct exposure to pesticides during handling and spraying on the farms. These estimates are by any standard conservative. This was because only some of the avertive/defensive behaviour costs incurred by farmers were considered. Many defensive costs have not been considered due to the non-availability of data as discussed earlier.

Some Factors Influencing Defensive Behaviour to Reduce Direct Exposure to Pesticides

Precautionary measures undertaken during handling and spraying of pesticides on the farms by farmers is an essential component in the safe use of pesticides. As research has suggested, this has a large bearing on the morbidity and mortality effects experienced by farmers using pesticides. It has been shown that the better the precautions taken, then less are the chance of suffering from ill health due to direct exposure to pesticides especially evident in the short-term [Sivayoganathan et al. (1995)]. However, it is known that in developing countries, and especially in Sri Lanka, the amount of precautions taken is inadequate [Chadrasekera et al. (1985); Sivayoganathan et al. (1995); Hoek et al. (1997)]. The amount of money spent on 'precautions taken' is a good indicator of the levels of defensive action taken. The money spent on such precautions in Sri Lanka is very low as shown in the last section. Consequently, as evident from hospital data and several field studies carried out, the levels of morbidity and mortality are very high and is still showing an upward trend. Specific studies carried out [such as Chandrasekera et al. (1985); Jeyaratnam et al. (1987); Sivayoganathan et al. (1995); Hoyek et al. (1997)] on farmers, including this Ph.D. field study in the of summer of 1996, show high levels of morbidity among farmers. Direct exposure to pesticides of such magnitude and the subsequent illnesses, not only incur large costs to the subjects and the hospitals, but also deplete valuable human resources especially through long-term illnesses [for example, see Rola and Pingali (1993); Pingali et al. (1995) who have studied the long-term impacts of pesticide exposure in the Philippines]. Hence, it is essential to determine what factors are responsible for influencing farmers to take adequate precautions so that such knowledge can be used to substantially reduce the high levels of casualties resulting from direct exposure to pesticides. An investment in defensive behaviour, of course, will no doubt reduce the cost of private and public medical bills and other expenses. This can be seen not only as a cost reducing exercise, but also in reducing pain, suffering and discomfort and of course preventing the gradual deterioration and wastage of human health.

In determining the level of precautions taken, we should examine the factors that influence defensive behaviour. Research carried out especially by Jeyaratnam (1982); Forget (1991); Antle and Pingali (1994); Sivayoganathan et al. (1995); Antle et al. (1998) show that the level of precautionary/defensive measures taken depend on many socio, economic, cultural and environmental factors. Some of the factors that have been mentioned are: the level of education, using appropriate (and comfortable) protective gear, availability and affordability of protective gear, availability of repair facilities, awareness on the harmful effects of pesticide use, type of crops cultivated, method of application, type of pesticides used, acreage sprayed, frequency of pesticide use, prevailing temperature, government support to purchase protective gear, extension services provided by the Department of Agriculture, laws governing use of pesticides, availability and affordability of precautions taken, cultural taboos, etc. Sivayoganathan et al. (1995) in his study point out that the most frequent reason cited for not using protective measures was discomfort. In the study they point out that the educated farmers were in a better position to receive and understand information about the health effects of pesticide use. They go on to point out that not all farmers who were aware of the harmful effects used adequate precautions during pesticide use. Their results show that awareness of precautionary practices was necessary but not sufficient. Their study also shows that though some farmers were keen to use protective measures but did not do so due to cultural taboo's such as wearing shoes in the field which is regarded as a temple in some respects because it is the land that produces food. Another cultural taboo mentioned for not wearing trousers while applying pesticides is that farmers, especially the elderly feel reluctant to do so due to their low socio-economic status. Another reason cited was that it is difficult to move freely in the field wearing shoes and trousers.

During the field study to collect data for this Ph.D. thesis it was not possible to gather data on all of the above mentioned variables for lack of interview time. It was thought that gathering all or most of the above mentioned variables would require a separate study. However, the study collected data on some variables which are thought would be useful in determining the factors that influence the level of precautions taken during pesticide handling and spraying on the farms. In this regression analysis, eight variables (seven quantitative and one qualitative) variables are used, which are believed to have an impact on the amount of defensive action taken by a farmer. The extent of defensive behaviour taken is explained in terms of the costs incurred on precautions taken, such as wearing protective clothing, masks, gloves, shoes, building special storage units, hiring labour, etc. The independent variables are education, yearly income, crops cultivated, frequency of pesticide use, type of pesticides used, 'read instructions and warnings' in the bottle (dummy variable) and acres sprayed for a year.

Variable specification

Guided by the data collected from the field survey and research work carried on pesticide pollution (for example, see Jeyaratnam (1982a); Forget (1991); Antle and Pingali (1994); Siyayoganathan et al. (1995); Antle et al. (1998)] the following specification was developed for a regression analysis. The data have been transformed into yearly figures and normalised into per capita terms.

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

Costs incurred on defensive behaviour (DE) are taken to represent the level of precautions taken which is written down 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 in the use of pesticides in the pesticide bottle (RW) and acres sprayed in a year (ACRE). The expected signs of the partial derivatives are shown beneath each argument in the function. As the signs indicate, it is expected that the higher are the years of education, higher would be the level of precautions taken, higher is the level of income, better would be the precautions taken, the larger are the number of crops cultivated[6], the higher would be the precautions taken, the more frequently are pesticides used, the higher are the chances of using protective gear, the higher are the type of pesticides used, the higher would be the level of expenditure on precautions taken, the more a farmer reads warnings on the pesticide bottle, higher would be the use of protective gear use and larger is the acreage sprayed, the better would be the precautions taken.

[6] 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, more crops a farmer sprays, the more likely that he will have to incur large costs on defensive behaviour because of the different precautions that have to be taken.

As mentioned earlier only eight variables have been used in the econometric analysis to examine the factors that influence defensive behaviour, two of which are socio-economic variables. For lack of data, at least eight relevant variables have been omitted, some of which are qualitative variables. Some of the excluded variables include: method of application, temperature levels at the time of spraying, government financial support to purchase protective gear, extension services provided by the Department of Agriculture, laws governing the use of pesticides, availability and affordability of precautions taken, discomfort in wearing protective clothing and cultural taboos. However, we presume that the included data are representative of some of the major variables that can shed some light to the understanding of factors that influence defensive behaviour.

In addition to the exclusion of some important variables for lack of data, some variables such as age, spraying hours per year, individuals health status were excluded from the main regression analysis because they did not perform well in the regression analysis. Furthermore, a regression was also performed including the 'several categories of illnesses' (namely serious, moderate and mild) to examine whether such variables had an impact on the defensive measures taken. However, they too, did not perform well and hence they were also excluded from the regression results presented in this section.

Two statistical techniques are used for the regression analysis. They are the OLS and Tobit analyses. Tobit analysis is also included because there are farmers who have not incurred any defensive costs. There were 59 farmers who did not incur any costs on defensive behaviour. The results of both the statistical techniques are presented and then compared to examine whether any significant statistical difference exists between the two techniques.

Before we go on to report the regression results and analyse the data we give below the summary statistics showing the means and standard deviations for all the variables that were included in the regression analysis.

Summary Statistics

Reported in Table 9.4 are the means and standard deviations for all the variables that were included in the regression analysis.

The mean defensive/precautionary costs taken is 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. Hence, it not surprising to see the high level of morbidity and mortality rates among these farmers (chapter three) and high costs involved as shown in Table 6.6 of chapter six. 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 times using an average of almost five pesticides a year spraying on almost three crops. The average level of income per year is RS 56,978 with almost eight years of schooling.

Table: 9.4 Means and Standard Deviations for Variables that Influence Defensive/Precautionary Behaviour

Variable	Description	Mean	Standard Deviation
PC	Precautionary Costs	405.14	815.00
ACRE	Acreage Sprayed For A Year	45.29	39.67
FOPU	Frequency of Pesticide Use Per Year	33.29	17.98
INC	Yearly Income	56,978.1	53855.01
TPEST	Types of Pesticides Used	4.94	2.32
EDU	Years of Education	7.50	3.32
CROP	Types of Crops Cultivated	2.7	1.7
RW	Read Warnings	0.92	0.26

Regression Results

The results of the ordinary least squares and Tobit analyses of the 203 observations are presented in Table 9.5. Tests carried out show violations of assumptions such as linearity, equality of variance and normality of the distribution of the residuals. A square root transformation of the variables was made to correct these anomalies. Appendix 9.1 shows the results of the various tests performed before and after the square root transformation of data. The 'tolerances and variable inflation factor and the collinearity diagnostics' for the variables showed that multicollinearity was also not a problem among the independent variables. As is the case with other regression results, because of the small sample size the results should be interpreted with caution. The goodness of fit is small but is not uncommon in work of this data [for example, see Brien et al. (1994); Row and Chestnut (1986)]. For this regression analysis we interpret the results 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: $\beta > 0$.

Table: 9.5 Regression Results of a Study Examining Factors Influencing Defensive Behaviour to Reduce Direct Exposure to Pesticides

	OLS				Tobit
Variable	Untandardized Coefficients B	Standardized Coefficients Beta	Standard Error	T-Ratio	z = b / s. e.
ACRE	-2.4E-02	-0.064	.032	-0.734	-0.700
FOPU	.156	0.191	.070	2.228***	2.359****
INC	-2.1E-05	-0.077	.000	-1.025	-1.291
TPEST	.880	0.139	.460	1.913**	1.625*
EDU	.539	0.120	.305	1.766**	1.820**
CROP	1.254	0.149	.609	2.059***	1.603*
RW	-.865	-0.051	3.791	-0.228	-0.834
(Constant)	-.220	-	5.287	-0.042	-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

Note: We interpret the beta coefficients in the regression results rather than the B coefficients. This is because the units of measurement of the variables are not the same. Hence the coefficients are not directly comparable. Therefore, when variables differ substantially in units of measurement, the sheer magnitude of their coefficients does not reveal anything about their relative importance. Hence, in order to make the regression coefficients somewhat more comparable, the coefficients have been standardized to take into account the differences in the various units of measurement of the variables. Therefore, the beta coefficients are the standardized coefficients while B coefficients are the unstandardized coefficients. The standardized beta coefficients can be calculated directly from the regression coefficients using the following formula: $B_1 (S_x/S_y)$ where B_1 is the regression coefficient and S_x is the standard deviation of the independent variable and S_y is the standard deviation of the dependent variable (SPSS, 6.0, 1993, p.314, 342).

Discussion of Results

As shown in Table 9.5 the results from the two statistical techniques do not indicate large differences in the t-ratios. The significant changes are for TPEST and CROP variables. For the OLS estimates, the t-raios are significant at the 2.5 and 5% levels for CROP and TPEST respectively. In the Tobit analysis, the t-ratios are significant only at 10% level for both CROP and TPEST variables. The rest of the variables do not change significantly with the Tobit analysis. Many of the results are consistent with what was expected and has the correct signs. The EDU, CROP, FOPU, TPEST are significant meaning that the higher is the level of education, then better would be amount of precautions taken, the more crops are grown, the better are the precautions taken, 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, although not significant, have negative signs. This is contrary to what would be normally expected. However, the negative signs are not surprising for subsistence farmers. As 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 expenditure on defensive activity, when a larger acreage is sprayed, then the precautions taken are less. Furthermore, a larger acreage sprayed means, larger is the wear and tear of the protective gear. Also 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) and the discomfort in wearing protective clothing for long periods of time. This has been recorded in Siyayoganathan et al. (1995) survey of pesticide users too.

Although the negative income variable is inconsistent with what was expected, 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 his 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 humidty, inability to obtain proper protective gear, cultural taboos, and many other factors as pointed out by Antle and Pingali (1994); Sivayoganathan et al. (1995) and Antle et al. (1998).

Comparing the Three Approaches from the Results of the Field Study

In this section, we show the estimates that were derived from the field study carried out in 1996. Previous studies such as Murdoch and Thayer (1990) show the differences in costs between the avertive behaviour and the cost of illness approaches. Their study was conducted to estimate the benefits of reducing the predicted increases in the rates of nonmelanoma skin cancers. As can be seen in Table 9.6, contingent valuation bids are much larger than the cost of illness or avertive/defensive behaviour bids/values or even both estimates combined together. These results confirm the hypothesis that we made in chapter five that the contingent valuation bids exceed the sum of changes in cost of illness and defensive expenditures combined together. This is because as shown in equation (5-11), a person affected by direct exposure to pesticides when asked how much he would be willing to pay to avoid ill health resulting from direct exposure to pesticides, an affected farmer would consider all the costs of illnesses (including money and time costs), intangible costs (such as pain, suffering and discomfort) and the defensive costs incurred in revealing his true willingness to pay to avoid direct exposure to pesticides. Hence, this is the reason why contingent valuation bids should exceed all costs of illnesses and the defensive costs put together. This result is also another way of confirming the validity of the Ph.D. contingent valuation exercise.

Table: 9.6 Comparing the Three Approaches Using Field Survey Data

Symptom	Sample Size	Mean yearly CVM bid in (RS)	Mean yearly Private COI bid in (Rs)	Mean Yearly Private AB bid in (Rs)
Ill Health resulting direct from exposure to pesticides	203	11,471.18	5,465.54	405.14
		Confidence Intervals = 95%		
		9,726.14 μ_x 13,216.21	4,484 μ_x 6,447.08	293.01 μ_x 517.26

Survey Period: July to September, 1996

Note: What the confidence intervals at 95% tell us is that if we construct intervals like the one shown in Table 9.6, then 95 out of 100 times such intervals will include the true μ_x.
AB = Avertive Behaviour
COI = Cost of Illness
CVM = Contingent Valuation Method

Here, it must be pointed out that the contingent valuation approach obtained willingness to pay bids to avoid direct exposure to pesticides while the cost of illness and the avertive behaviour approach estimates are for a reduction in direct exposure to pesticides. This is because as pointed out in chapters four and five when the defensive behaviour is inadequate, then there are costs arising from illnesses as well. Hence, both avertive behaviour costs as well as costs of illnesses. However, for the Ph.D. study it was not possible to take into account all the costs, especially the time costs for the avertive behaviour approach such as time spent purchasing and maintaining protective gear, etc. Some of the benefits arising from goods that have joint benefits such as an expensive sprayer that is both efficient as well as preventing pesticides leaking into the body of the sprayer, too, could not be taken into account due to difficulties in calculating such costs. However, despite some of these important costs not being taken into account, the estimated contingent valuation bids in this Ph.D. study are still large enough to exceed estimates from both the cost of illness and the avertive behaviour approaches.

Conclusion

This chapter estimated the private avertive/defensive costs incurred by farmers when handling and spraying pesticides on their farms. The average costs per year was approximately 12% of a farmers monthly income. These costs, as mentioned in this chapter, are lower bounds. Furthermore, these defensive/precautionary costs and the costs arising from illnesses per year due to direct exposure to pesticides during handling and spraying by farmers is very large and exceed a farmers monthly income. The contingent valuation approach (discussed in chapter seven) arrived at a figure more than two and a half months salary. All these costs go on to show that farmers using pesticides incur very large costs due to illnesses resulting from direct exposure to pesticides.

The regression results show that among subsistence farmers, the frequency of pesticide use, education, amount of crops cultivated and the types of pesticides used influence defensive/precautionary behaviour. The results of the Tobit analysis affect two variables in a significant manner namely the CROP and TPEST variables. For a one tailed test for OLS they are significant at 5 and 2.5% levels of significance but is reduced to 10% level of significance under the Tobit analysis for a one tailed test. The other variables are not affected significantly. The results also show that income of the farmer is insignificant as well as the number of acres sprayed and the 'read warnings' (RW) variable. An outcome of the results is that (although insignificant), when farmers spray a larger acreage, then the level of precautions taken tend to decrease. This may be due to wear and tear of protective measures taken, the high temperatures, being uncomfortable to use protective measures for long periods of time, and 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 defensive/precautionary actions 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 Jeyaratnam (1982a); Forget (1991), Antle and Pingali (1994); Siyayoganathan et al. (1995); Antle et al. (1998) have regarded as important variables influencing defensive behaviour were left out of this regression analysis for lack of data. Inclusion of such variables to examine their effect on the level of defensive behaviour is necessary in future work. In this chapter we examined the factors that were responsible in influencing the level of precautions taken by farmers handling and spraying pesticides which can no doubt reduce the high levels of direct exposure to pesticides by farmers and the resulting costs. In this section of this chapter we showed the estimates that were derived from the field study carried using the three valuation techniques. As was shown, the average contingent valuation bids are much larger than the average cost of illness or avertive/defensive behaviour bids/values or even both average estimates combined together. These results confirm the hypothesis that was made in chapter five that the contingent valuation bids/values exceed the sum of changes in cost of illness and defensive expenditures combined together.

Appendix 9.1

Scatter Plots Before the Square Root Transformation of the Dependent Variable

Figure: 9.1

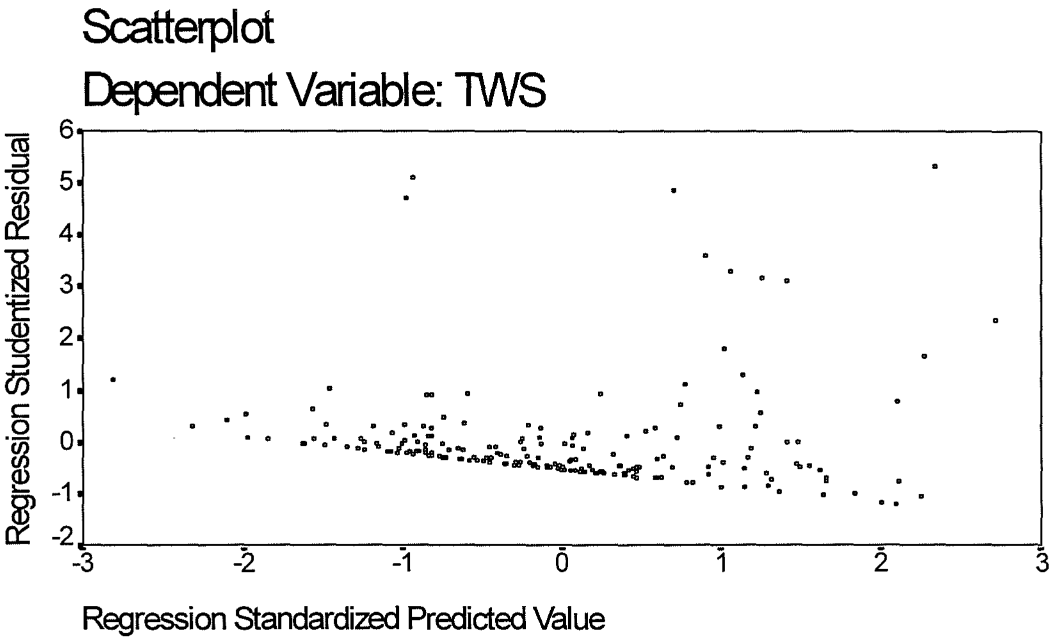


Figure: 9.2

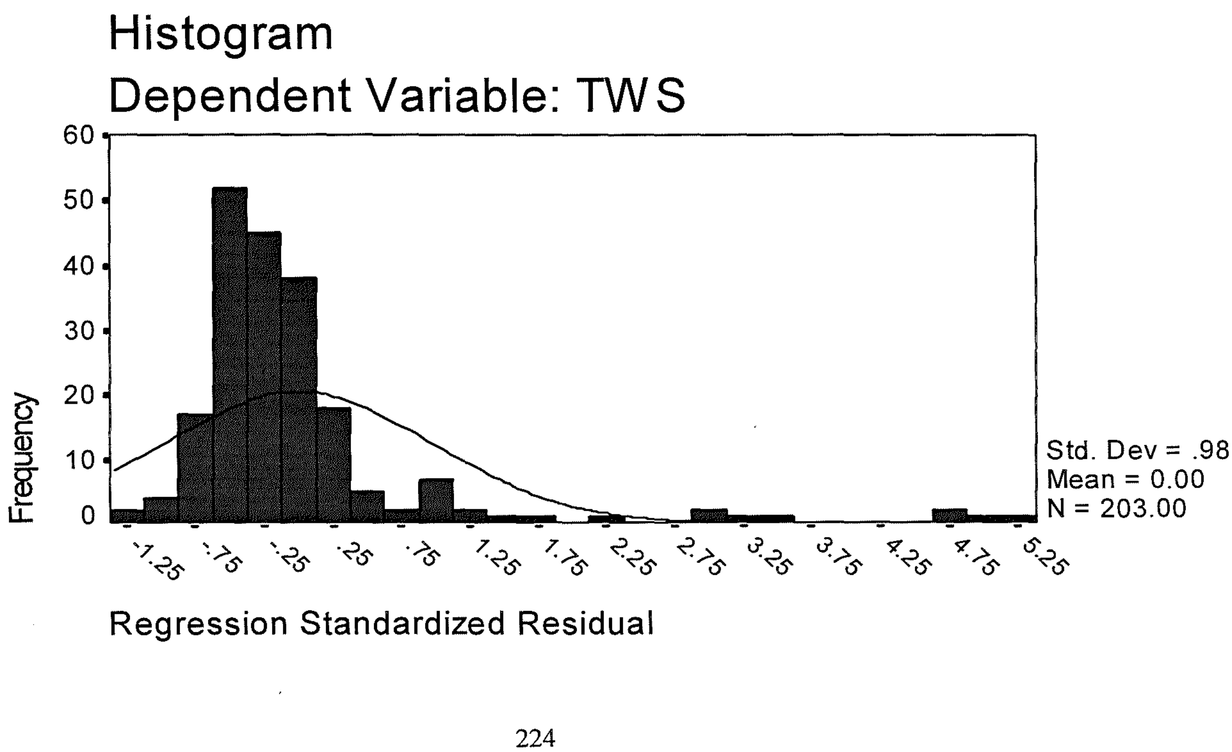
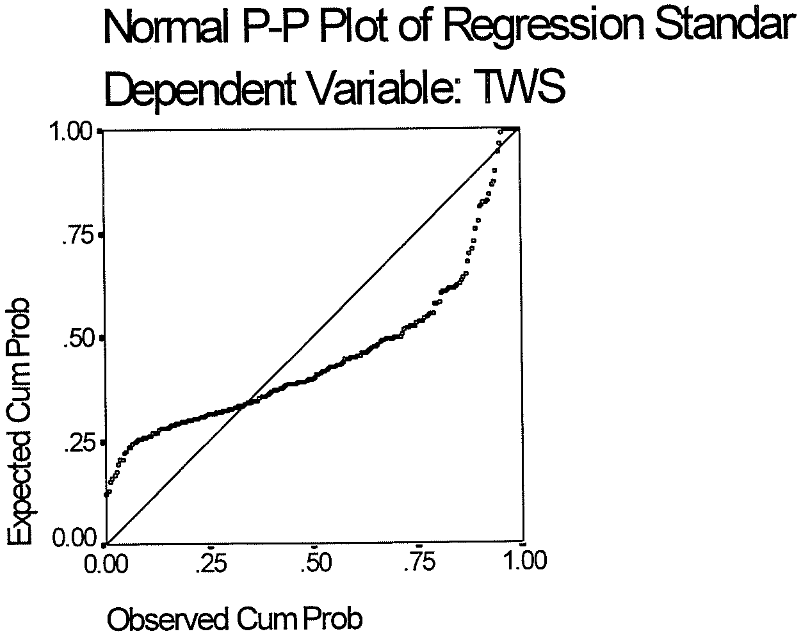


Figure: 9.3


Normal P-P Plot of Regression Standar
Dependent Variable: TWS
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob

Scatter Plots After the Square Root Transformation of the Dependent Variable

Figure: 9.4

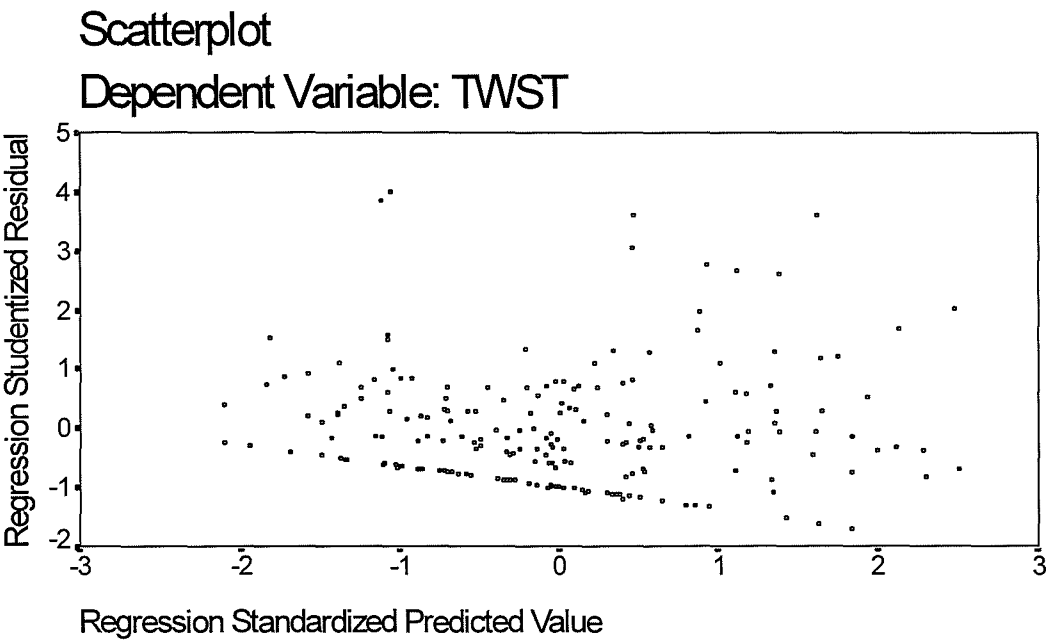


Figure: 9.5

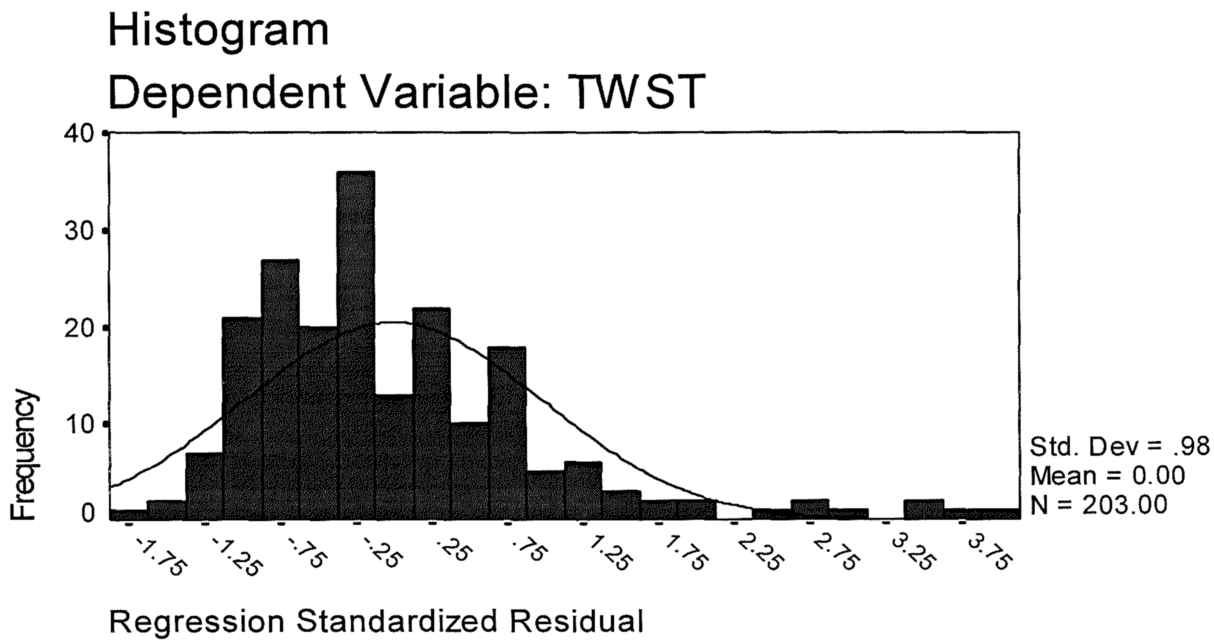
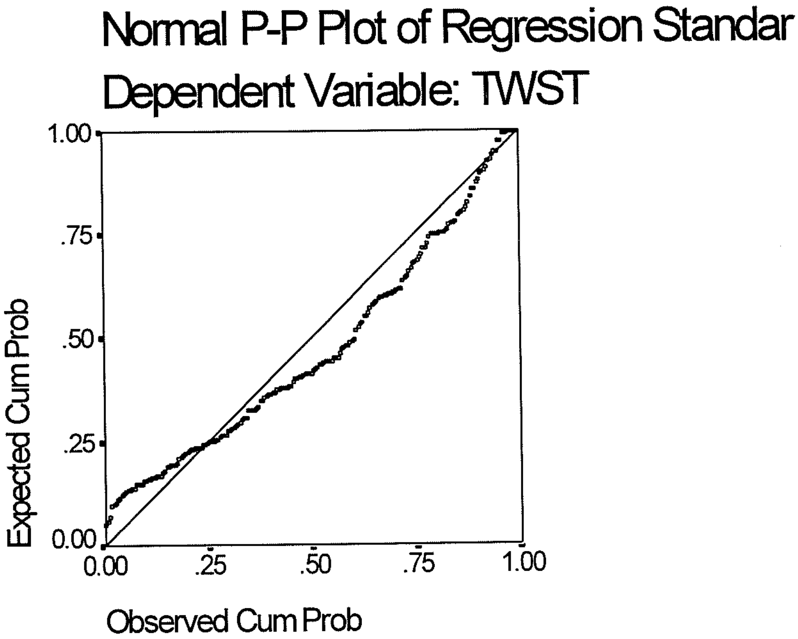


Figure: 9.6


Normal P-P Plot of Regression Standar
Dependent Variable: TWST
1.00
.75
.50
.25
0.00
Expected Cum Prob
0.00
.25
.50
.75
1.00
Observed Cum Prob

CHAPTER 10

CONCLUSIONS

Modern commercial agricultural practices highly dependent on chemical inputs such as fertilizers and pesticides, while increasing production and productivity levels, have also brought about parallel increases in pollution levels. The pollution thus generated from agricultural production, it was shown, have impacted on human health, agricultural land, other production processes, fauna and flora and the environment in general. It was shown that in Sri Lanka, pesticide poisoning is a major health hazard that has been taking place since the 1950s which increased in frequency as the quantity of pesticides increased on the agricultural fields. Large-scale hospital admissions and deaths occur in Sri Lanka due to pesticide poisoning. However, all this is not due to direct exposure to pesticides during handling and spraying on the farms. Numerous deaths occur due to deliberate ingestion (suicides), accidental ingestion and homicides. As a result, most of the attention has been focused on such health effects rather than the health effects arising from direct exposure to pesticides while handling and spraying pesticides on the farms. Such exposure, field studies carried out since the mid 1980s show, results in numerous morbidity effects, as well as deaths. This Ph.D. study confirmed the health effects arising from such direct exposure to pesticides and hence estimated their costs. The costs arising from such pollution is both private and external.

As was discussed, this thesis examined only the private costs of direct exposure to pesticides during handling and spraying by farmers on their farms. The private costs considered were those arising on pesticide spraying days, non-spraying days and from long-term illnesses. These costs were further subdivided into the nature of the illness, namely being serious (requiring hospitalisation), moderate (needing examination by a physician, but no hospitalisation is required) and being mild, where there is no need for hospitalisation or to consult a doctor but nevertheless some form of medication (self-treatment) is taken. Three valuation techniques were used to estimate these private costs. The estimates from these approaches showed that costs arising from direct exposure to pesticides amounted to millions of Sri Lankan rupees each year. On average it was shown from the contingent valuation approach that a farmer incurs a cost of more than two and a half months income a year due to ill health resulting from direct exposure to pesticides. The costs considered in this approach were direct (out-of-pocket costs), indirect (time costs) and intangible costs. The cost of illness approach estimated that a farmer on average incurs costs which amounts to more than a month's income from farming per year. The costs considered were the out-of-pocket private costs for medical care and time costs with loss of productivity and leisure time accounting for more than half the loss. In addition to these costs, farmers also incur costs on precautions taken. The avertive/defensive behaviour approach estimated these costs to be around 12% of a monthly income of a farmer per year. When these precautionary/defensive costs are added to the private costs of illness estimates, the costs become very significant. These costs become all the more significant when farmers' incomes vary a great deal due to adverse weather conditions, crop price fluctuations, pests and disease attacks, damage caused by wild animals, etc. All these costs while affecting the farmers, as well as their families welfare, also reflect the extent of the severity of the problem of pesticide pollution affecting those around, agricultural land, affecting other production processes, wildlife and the environment in general. The cost estimates from the three approaches were then used to infer values in reducing/avoiding direct exposure to pesticides and the resulting health hazards. In other words, to obtain willingness to pay bids/values from individuals to reduce/avoid direct exposure to pesticides and the resulting health hazards. The contingent valuation approach estimated the willingness to pay bids to avoid direct exposure to pesticides while the cost of illness and the avertive behaviour approaches were used to obtain willingness to pay bids to reduce direct exposure to pesticides.

The regression analyses also confirmed certain hypotheses held by agricultural extension workers and physicians and identified relationships connected with pesticide handling/spraying and direct exposure to pesticides. The regression analyses also highlighted many policy implications and was also a test of validity for the contingent valuation exercise.

The regression results of chapter seven determining the factors influencing willingness to pay to avoid direct exposure to pesticides show that income of the respondent is a significant factor influencing willingness to pay to avoid direct exposure to pesticides. The household size variable, too, is a significant factor influencing willingness to pay at the 10% level of significance for a one tailed test.

Education coefficient is small and is insignificant. However, this result is not surprising because in most schools environmental subjects including harmful effects of pesticides are not taught. Hence, the level of awareness is limited. On the other hand the variables showing whether the respondent has suffered an illness or not from exposure to pesticides is significant. The age coefficient has the correct negative sign but is insignificant.

There is ample evidence to show a strong relationship between the respondents' ill health resulting from exposure to pesticides and the amounts bids reflecting increasing marginal disutility of illness. This variable is highly significant. The length of time a farmer is engaged in spraying pesticides for a given year is also significant.

The conclusions of these regression results are useful for policy decision making. The results show that income of the farmer play a significant part in the determination of the willingness to pay bids in reducing direct exposure to pesticides and/or pollution control or environmental protection. This is consistent with general economic theory including for a 'low income' developing country. The size of household is also significant at 10% level of significance. The results also show that education and age do not play a significant part in the determination of the willingness to pay bids while the effects of pesticide exposure on the health of the user and the length of time pesticides are sprayed for a year play a significant role in the determination of the willingness to pay bids to avoid exposure to pesticides. The education variable being insignificant in the determination of the willingness to pay to avoid direct exposure to pesticides has many implications. We know (as shown in chapter three) that exposure to pesticides cause many long-term illnesses, in addition to short-term health effects, most of which are incurable. The level of education here does not play a role in preventing such short-term and long-term illnesses. The problem is even more serious, especially because pesticide pollution that is released into the environment can also be non point in nature and is also very potent. The sum effect of all the pesticide pollution generated by a very large number of users is even more lethal and is made more dangerous because of the stock build up in the environment. Furthermore, another implication that arises out of the results is that, individuals begin to take note of the need to avoid direct exposure to pesticides only after they have suffered from ill health due to direct exposure to pesticides, until which time they may use pesticides. Hence, the damage done from exposure to pesticides not only to human health but to the native fauna and the environment in general is very large. By the time the victims of direct exposure to pesticides begin to pay to avoid such direct exposure because of the adverse effects (ill health), the damage done would be irreversible. Also in such a situation, the results imply that even governments would begin to act only once the damage to human health and the environment has begun to take effect and the damage done is visible. Foresight in avoiding the dangers and the health effects arising from direct exposure to pesticides and/or environmental pollution does not play a role.

The long-term consequences are even more frightening. We know that studies in the United States have shown a probable connection between pesticide poisoning and long-term effects such as various cancers, loss of memory, tumors, etc. [Hoar (1986); Nielson and Lee (1987)]. In such a case, even if a respondent realizes that a chronic illness is due to direct exposure to pesticides and is willing to pay to reduce such exposure, it would be too late since most of these illnesses are not completely curable. Such a trend is very dangerous. As we have seen, not only are the health of users affected but the fauna and the environment in general are also affected due to pesticide use. Furthermore, the effect on those living around must also be considerable since water sources and the entire environment are affected. The entire food chain can be affected as a result. The damage done to consumers of cultivated food crops, though unknown must also be high. It has been shown that pesticides can be taken up by crop roots and end up in the food produced. Furthermore, the residues of pesticides sprayed on crops can end up in the food harvested. Hence, the long-term effects on consumers must be considerable. The cost of other negative externalities (discussed in chapter two) must also be high. Several interesting negative externalities arising from pesticides were noted during the study. Herbicides used on onion plots to destroy weeds when spread to neighbouring farms due to strong winds destroyed other crops which were not resistant to the herbicides used. The damage done was very large since it affected the crop of an entire season. There were several externalities of this nature. The damage done to fish production is unknown, although, in Malasiya, Philippines and Bangladesh declining fish yields have been linked to pesticide pollution (Dinham, 1993, p.69; Sudderuddin and Kim, 1970; Ministry of Finance, Bangladesh, 1992; IAD, March/April, 1990).

The regression results in chapter eight identified the relationship between ill health and direct exposure to pesticides and factors that cause such ill health during handling and spraying by farmers on their farms. For a long-time, physicians and agricultural extension workers from the Department of Agriculture had known of such a link. Some of the variables (especially the quality variables) could not be included for lack of data. However, the results of the variables that were included were consistent with the hypotheses on direct exposure to pesticides and ill health. The results, however, should be treated with caution (due to the small sample size used) although consistent with official guidelines/recommendations on the handling and use of pesticides on farms. The regression results show that farmers are in clear violation of the precautions prescribed in the handling and spraying of pesticides and hence calls for urgent action to implement recommended safety procedures. If not, the costs both to the country as well as to the users are substantial as shown by the cost estimates generated from the field study.

The regression results in chapter nine show that among subsistence farmers, the frequency of pesticide use, education, amount of crops cultivated and the types of pesticides used influence defensive/precautionary behaviour. The results of the Tobit analysis affect two variables in a significant manner namely the CROP and TPEST variables. For a one tailed test for OLS they are significant at 5 and 2.5% levels of significance but is reduced to 10% level of significance under the Tobit analysis for a one tailed test. Other variables are not affected significantly. The results also show that income of the farmer is insignificant as well as the number of acres sprayed and the 'read warnings' (RW) variable. The regression analysis examined only some of the variables that are believed to have an impact on the defensive/precautionary actions 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 Jeyaratnam (1982a); Forget (1991), Antle and Pingali (1994); Siyayoganathan et al. (1995); Antle et al. (1998) have regarded as important variables influencing defensive behaviour were left out of this regression analysis for lack of data. Inclusion of such variables to examine their effect on the level of defensive behaviour is necessary in future work.

In addition to these policy implications it was clear that the present agricultural practices are unsustainable and diametrically at odds with the definition espoused by the World Commission on Environment and Development (WCED) which defines sustainable development as "development that meets the need of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.43). Current production practices are not only unsustainable, but also, as the high costs demonstrated, may well be a factor in explaining poverty (low incomes) among farmers, despite adequate food being produced all year around. This is due to the high costs that have arisen in terms of human and natural capital costs and the increased use of input costs due to pollution. The numerous health effects result in medical as well as time costs as demonstrated in this thesis, both in the short-term and in the long-term. Wasting of human health also reduce the ability to work on farms. The precautions taken, though inadequate, also incur costs. Agricultural pollution also affects natural capital in the form of decimation of natural predators of pests (through the use of pesticides), increase in the proliferation of pests (due to decimation of natural predators/high usage of nitrogenous fertilizer), soil fertility decline (brought about due to continuos chemical use) thus affecting agricultural productivity. As a result of declining agricultural productivity and due to proliferation of pests and diseases, larger quantities of chemical inputs have to be used in the production process, not only thus increasing the level of pollution on the agricultural lands but also increasing the costs of input use. Furthermore, agricultural pollution affects other production processes, such as fisheries (which farmers engage in on a part time basis) thus depriving them of an additional/alternative source of income. Therefore, in conclusion, it can be said that the private costs and externalities resulting from agricultural pollution have not only made resource allocation inefficient but has also made the current agricultural production processes unsustainable, both in the short-term and in the long-term.

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