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A SIMULATION ANALYSIS OF THE INDIAN CROP INSURANCE PROGRAM

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A SIMULATION ANALYSIS OF THE INDIAN CROP INSURANCE PROGRAM

DISSERTATION

Presented in Partial Fulfilment of the Requirements for the
Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Narendra K. Rustagi, B.Sc., M.A., M.A.S.

* * * * *

The Ohio State University

1986

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To my mother
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TABLE OF CONTENTS

ACKNOWLEDGMENTS ............................................. iii

VITA ........................................................................ v

LIST OF TABLES .............................................. x

LIST OF FIGURES ............................................. xii

CHAPTER PAGE

I  INTRODUCTION ............................................ 1
   Goals of the Indian Crop Insurance Program ....... 4
   Objectives of the Dissertation ....................... 7
   Organization of the Study ............................. 9

II  CROP INSURANCE AND ALTERNATE RISK REDUCING POLICIES 10
   Why do Governments Choose Crop Insurance? ......... 11
   Adverse Effects of Crop Insurance ................... 16
   Alternatives to Crop Insurance ....................... 18
   Role of Subsidies in Indian Agriculture .......... 24

III CONCEPTUAL ISSUES OF CROP INSURANCE .............. 27
   Demand for Insurance .................................. 28
   Supply of Insurance ................................... 41
   Equilibrium ............................................. 47

IV  INSURABILITY AND ALTERNATIVE PROCEDURES .......... 51
   Insurability of Agricultural Risks ................. 52
   A Critique of Literature on Noninsurability ........ 59
   Alternative Procedures of Crop Insurance ........... 74
   The Indian Program .................................... 82

V  AVAILABLE DATA AND THE SIMULATION APPROACH .... 95
   The Data ................................................ 99
   The Demand Curve ................................... 102
   The Supply Curve .................................... 110
   The Simulation Approach ............................... 119

VI  MONTE CARLO SIMULATION OF THE INDIAN PROGRAM ... 125
   Supply and Demand Curves of Insurance .......... 125
   The Farmer's Mean Yield and the Mean Area Yield .. 135

- viii -
Standard Deviation of Farmer's Yield and the Area Yield ......................................... 141
Relative Risk Aversion .................................. 145
Correlation ............................................... 149
Farm Size.................................................. 156

VII SUMMARY, CONCLUSIONS, AND LIMITATIONS .................. 158
Summary .................................................. 158
Conclusions ............................................. 163
Limitations and Recommendations for Further Research ....................... 169

REFERENCES AND SELECTED BIBLIOGRAPHY .................. 173

APPENDICES

A  NORMALITY OF CROP YIELD DISTRIBUTION .................. 185
Arguments for Normality .................................. 185
Arguments for Nonnormality ............................... 188
Limitations of the Method of Moments .................. 192
Nonparametric Procedures to Test for Normality .................. 194
Discussion .............................................. 197

B  TABLES ................................................... 202

- ix -
### LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Description</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Premium Collected by the General Insurance Corporation, 1979-80 to 1983-84</td>
<td>58</td>
</tr>
<tr>
<td>4.2</td>
<td>Frequency Table for Coefficient of Variation in Each Taluk for Rice, Andhra Pradesh, India, 1978-1981</td>
<td>89</td>
</tr>
<tr>
<td>4.3</td>
<td>Indemnity Paid by the General Insurance Corporation in the Three States in which Crop Insurance was Offered Since 1979-80</td>
<td>92</td>
</tr>
<tr>
<td>5.1</td>
<td>Data Base for Estimating Crop Yield Distribution</td>
<td>103</td>
</tr>
<tr>
<td>5.2</td>
<td>Number of Taluks for Which Yield Estimates were Available for Dry Season Rice, by Number of Years</td>
<td>104</td>
</tr>
<tr>
<td>5.3</td>
<td>Uses and Sources of Funds for Selected Agricultural Insurance Programs</td>
<td>112</td>
</tr>
<tr>
<td>5.4</td>
<td>Administrative Expenses Charged in Stock Companies in Selected Lines of Insurance in the U.S., 1983</td>
<td>116</td>
</tr>
<tr>
<td>6.1</td>
<td>Pure Premium and Estimates of Administrative Expenses Under the Homogeneous Area Yield and the Individual Approaches</td>
<td>128</td>
</tr>
<tr>
<td>6.2</td>
<td>Pure Premium and Estimates of Supply Prices with Low and High Administrative Costs Under the Homogeneous Area Yield and the Individual Approaches</td>
<td>130</td>
</tr>
<tr>
<td>6.3</td>
<td>Demand Curves for the Homogeneous Area Yield and the Individual Approaches Under the Base Case Scenario</td>
<td>134</td>
</tr>
</tbody>
</table>
6.4 Shift in the Demand Curve due to Changes in the Correlation Between the Farmer's Yield and the Area Yield........................ 154

A-1 Percentage of Yield Distributions that are Normal at Various levels of Time and Geopolitical Aggregation, Andhra Pradesh, India, 1978-81..................................... 198

B-1 Effect of Error in Estimation of a Farmer's Mean Yield on his Demand Curve when Indemnities are Estimated on an Individual Yield Experience................................. 203

B-2 Effect of Error in Estimating a Farmer's Mean Yield on the Demand Curve of Insurance, the Homogeneous Area Yield Approach......................... 204

B-3 Effect of Error of Estimation in the Standard Deviation on the Demand Curve of Insurance When Indemnities are Based on an Individual Basis... 205

B-4 Effect of Error in Estimation of Standard Deviation (s.d.) of a Farmer's Yield on the Demand Curve of Insurance................................. 206

B-5 Effect of Error in Estimation of the Relative Risk Aversion on the Demand for Insurance, the Individual Approach................................. 207

B-6 Effect of Error in Estimation of the Relative Risk Aversion on the Demand for Insurance, the Homogeneous Area Yield Approach......................... 208
<table>
<thead>
<tr>
<th>FIGURES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 The Utility Curve</td>
<td>31</td>
</tr>
<tr>
<td>3.2 The Demand Curve of Insurance</td>
<td>37</td>
</tr>
<tr>
<td>3.3 The Supply Curve of Insurance</td>
<td>46</td>
</tr>
<tr>
<td>3.4 The Equilibrium in the Insurance Market</td>
<td>48</td>
</tr>
<tr>
<td>4.1 Risk Aversion and Insurance Premium</td>
<td>63</td>
</tr>
<tr>
<td>4.2 Shifts in the Supply Curve Due to Additional Administrative Expenses</td>
<td>67</td>
</tr>
<tr>
<td>4.3 Welfare Gains to Producers and Consumers</td>
<td>73</td>
</tr>
<tr>
<td>4.4 Graph of Taluk Level Yield Estimates Over Time, Shahada, Maharashtra, India</td>
<td>91</td>
</tr>
<tr>
<td>6.1 Supply Curves with Low Administrative Expenses and Demand Curves in the Base Case Scenario, Both Approaches</td>
<td>136</td>
</tr>
<tr>
<td>6.2 Effect of the Difference in Mean Yield on the Probability of Filing a Claim</td>
<td>138</td>
</tr>
<tr>
<td>6.3 Decrease in the Demand Price When the Insurance Company Treats Mean Yield as Rs 2839 (Underestimated by 25 Percent), While the Farmer's Mean Yield is Rs 3785, Both Approaches</td>
<td>140</td>
</tr>
<tr>
<td>6.4 Effect of the Difference in Standard Deviation on the Probability of Filing a Claim</td>
<td>142</td>
</tr>
<tr>
<td>6.5 Effect of the Standard deviation on the Demand Curve of Insurance, the Individual Approach</td>
<td>144</td>
</tr>
<tr>
<td>6.6 Effect of the Standard deviation on the Demand Curve of Insurance, the Homogeneous Area-Yield Approach</td>
<td>146</td>
</tr>
</tbody>
</table>
6.7 Effect of the Error in Estimation of the Relative Risk Aversion on the Demand for Insurance, the Individual Approach

6.8 Effect of Error in Estimation of the Relative Risk Aversion on the Demand for Insurance, the Homogeneous Area Yield Approach
CHAPTER 1

INTRODUCTION

Farmers face various kinds of risks: yield and price risks, uncertainty about the timing of input application, breakdown of machines, loss of animal draft power, and illness and accidental hazards for individuals. Yield risk is one of the major risks affecting farmers' incomes. Vulnerability of yields to weather factors, such as drought and hail, can also severely affect their income. Severe crop damage affects farm growth, income of nonfarm households dependent on agriculture, and may result in widespread default on loans.

Traditionally, farmers have learned to cope with risks through various management practices, for example, the selection of an appropriate cropping pattern. Several rural institutions, such as land tenural systems like sharecropping, rural moneylenders, and extended family systems, have evolved over time. They perform the services of spreading the farmers' risks over other economic participants.
In cases of severe declines in farm output, and hence farmers' incomes, governments have volunteered to help alleviate their negative impact. For example, ever since 1843 in India, there has been evidence of government involvement in the free distribution of grain, free kitchens, remission of revenue and other taxes, payment of advances, construction of public works, and irrigation projects. The introduction of the 'Dahsuri tax' in the sixteenth century by the Mughal emperor Akbar is another good example of a disaster relief measure taken by the Indian government. It was an in-kind tax paid to store grain during good harvests for later use in years of bad harvest (Vyas and Khanna, n.d.). Relief measures, such as the rescheduling of loans and the provision of food and shelter in disaster years, have been provided in recent years in India. Such programs are also common in many other countries. For example, under the disaster payment program in the United States (discontinued in 1981), if the yields of the farmers were less than 75 percent of the normal yield, or if the farmers were delayed in or prevented from planting due to causes beyond their control, payments were made to compensate for their losses.

Crop insurance is another way of reducing the impact of agricultural disasters. Under crop insurance, depending upon the extent of risk protection sought, a farmer pays a given amount as a premium. If the crop damage is due to the
insured cause, the farmer receives an indemnity compensation to partially compensate for the loss. The premium charged and the indemnity paid depend upon the estimation procedure used. These may be estimated using the yield experience of each individual or a group of individuals.

Crop insurance was first introduced by private companies in agriculturally oriented economies. Most private companies, however, were not able to face the disasters in their initial years and failed. Since agriculture was the backbone of these economies and direct assistance to farmers in disaster years was politically attractive, crop insurance was later introduced in the public sector.

In the crop insurance programs of most countries, premiums and indemnities are estimated on the basis of the yield experiences of individual farmers. These programs suffer from severe problems of moral hazard and adverse risk selection. Moral hazard refers to a less than optimal level of input utilization by farmers after purchasing insurance and/or the problem of verifying the claims of the insured regarding the causes of the loss in the yield. Adverse risk selection exists when a larger number of higher risk farmers join the program, and the insurance company is unable to identify them. Due to these problems, many crop insurance programs are expensive to operate and have either failed or depended heavily upon government subsidies.
Goals of the Indian Crop Insurance Program

The overriding goal of the Indian agricultural policy has been to "lead the country away from the menace of famine to a new vigor and prosperity" (Department of Agriculture, 1946; quoted in Sarma, 1982). After India's independence in 1947, agriculture was given top priority in the First Five Year Plan in 1951. Indian planners realized that without a substantial increase in food production, it would not be possible to sustain the high rate of investment needed to increase industrial output. Specific policies regarding the level of food production and prices were introduced.

The major objective of the first plan was to achieve equity and social justice in rural areas by reducing disparities in wealth and income, by eliminating exploitation, and by providing security for tenants, equity of status, and opportunities for different sections of the population. The principal aim of the Third Five Year Plan was to achieve self-sufficiency in foodgrains and increased agricultural production.1/ The price policy was designed to ensure that relative prices adjusted so that there was no excessive increase in prices of essential goods consumed by

1/ The second plan had the major objective of rapid growth through the promotion of public sector and heavy industries. Growth with stability was the major objective of the fourth plan. The fifth plan emphasized the removal of poverty and the attainment of economic self-reliance.
low-income groups (Sarma, 1982). This was reiterated in the Sixth Plan: the aim was "to generate agricultural production as well as employment in the rural sector" (Government of India, 1981).

To achieve eventual self-sufficiency in food, the Indian government provides various kinds of subsidies to the agricultural sector. It finances agricultural research centers, subsidizes the prices of agricultural inputs, spends money on irrigation works, and subsidizes many other agriculture related activities. To reduce the income instability of farmers, the government reduces land taxes in disaster years, provides credit at a concessional rate to farmers, and, in extreme cases, provides direct help.

It has been argued that since India is predominantly an agricultural economy, a large-scale crop failure could have an adverse effect on the national economy. As a result of such a failure, the farmers, most of whom are small or marginal, would lose not only their investment but also their purchasing power and would not have money to invest the next year. The provision of crop insurance could help the farmers maintain their purchasing power and retain their ability to pay back crop loans (General Insurance Corporation, n.d.).
The need for crop insurance has been debated since 1947, the year India became independent. Pilot schemes were drawn up by the government of India and circulated to the states for adoption. However, due to financial limitations, none of the states adopted the schemes. During the early 1960s, the Government of Punjab submitted a proposal as a part of the Third Five Year Plan. This was not implemented because the central government could not finance its share. However, efforts by various states to introduce crop insurance continued.

In Andhra Pradesh, for example, a committee set up by the state government recognized that the farmers' cooperatives would not be able to set up insurance programs because they lacked the necessary capital and the technical skill. It also recognized that private companies would not be able to acquire the administrative machinery needed to set up an insurance program, and that the profits were not sufficient to attract private companies, given the risks involved. The committee recommended that the government enter the crop insurance market, bear the administrative expenses, and provide the initial capital. It also recommended initially to subsidize premiums because most farmers were unable to pay actuarially sound premiums (Government of Andhra Pradesh, n.d.). The program was to be a compulsory program based on a homogeneous area yield
approach where premiums and indemnities would be determined using the average yields of the area.

Even though the need for crop insurance in India had been debated for a long time, it was not introduced until 1973. The program was offered in the public sector to insure cotton in a district in Gujarat. It was later extended to other states (Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, and West Bengal) and to more crops (wheat, groundnuts, and potatoes). The program was based on the individual approach and proved to be very expensive because of the problems of moral hazard and adverse risk selection. The program was stopped in 1976. The present program, based on the homogeneous area yield approach, was started in 1979. Under this approach, if the area yield is less than the guaranteed yield, all insured farmers in the area, irrespective of their actual yields, are compensated on an equal basis. If the area yield is more than the guaranteed yield, no indemnity is paid even if some farmers have low yields.

Objectives of the Dissertation

Problems of moral hazard and adverse risk selection are avoided in the present Indian program because in the homogeneous area yield approach premiums and indemnities are estimated on the basis of area yields. However, unless
farmers' yields are highly correlated with the yield of their area, they may not be compensated adequately in times of disaster. Thus the demand for insurance under the homogeneous area yield approach and its effect on insurability need to be analyzed further. Since the variance of area yields is less than the variance of the yield faced by individual farmers, the effect on the demand for insurance by the high- and low-risk farmers also deserves attention.

More specifically, the objectives of this dissertation are to:

1. Review the literature to draw implications for the crop insurance programs based on the individual yield approach.

2. Do a Monte Carlo simulation of the Indian program to study
   (a) the effect of relative risk aversion, and of under/over-estimation of the mean and the standard deviation of the yield distribution expected by the farmer on the demand curve for insurance;
   (b) the effect of less than perfect correlation between the area and the farmer's yield (r<1 under the homogeneous area yield approach) on insurability in the
homogeneous area yield approach; and
(c) the insurability of crop risks for the
various levels of administrative costs and
alternative demand curves.

Organization of the Study

This study is divided into seven chapters. The
Introduction describes crop insurance as a risk-reducing
strategy, gives a brief overview of the Indian crop
insurance program, and lists the objectives of the study.
Chapter II discusses the benefits and adverse effects of and
alternatives to crop insurance. A utility approach to the
demand and supply of crop insurance is discussed in the
third chapter. The insurability of agricultural risks, a
critique of the literature on noninsurability, and
alternative procedures of crop insurance are reviewed in the
fourth chapter. The fifth chapter focuses on the available
data and the simulation approach used in the study, while
the sixth chapter presents the results of the simulation
exercise. Chapter VII contains the summary of the
dissertation, conclusions, limitations of the study and
recommendations for future research.
CHAPTER II

CROP INSURANCE AND ALTERNATE RISK REDUCING POLICIES

Farmers have to face disasters due to natural calamities beyond their control. As stated in the previous chapter, governments have used several ways to alleviate the impact of these disasters, such as rescheduling loans, writing off the interest or the loan itself, and starting soup kitchens. Lately, however, increased attention has been focused on the introduction of crop insurance. The U.S. and Japan were the first to introduce crop insurance in the early 1930's, and during the last two decades many developing countries have introduced crop insurance. Most of these programs depend upon heavy subsidies from the government, which also subsidizes various other programs. An attempt is therefore made to throw some light on the role of crop insurance and various other subsidies in agricultural development.

The first section of this chapter summarizes the factors influencing the choice of crop insurance as a tool of risk reduction. This is followed by a discussion of the negative effects of, and alternative to, crop insurance. The
chapter concludes with a discussion of the role of various types of subsidies in India in general, and in agriculture in particular.

**Why Do Governments Choose Crop Insurance?**

Public policies in general have multiple objectives; agricultural policies for disaster assistance are no exception. Two major objectives of such programs are (1) to help individual producers adjust to the income instability caused by natural hazards and (2) to maintain the productive capacity of the agricultural sector.

Governments also want their programs to be cost-effective and they want to treat producers equitably. It has been argued that crop insurance is cheaper than disaster assistance programs because disaster programs are a form of insurance with no premium (U.S. Congress, 1978). There are several other economic and noneconomic factors that encourage governments to favor crop insurance. These reasons are summarized below.

**Production Benefits**

Binswanger's study (1980) of the risk behavior of farmers in a few villages in semiarid India as well as at least three others studies (Sillers, 1980, in Thailand;
Walker, 1980, in El Salvador; and Grisley, 1980, in the Philippines), assert that farmers in developing countries are poor and universally risk averse. In addition, Binswanger (1986) shows that the lack of well-developed credit markets in developing countries causes farmers to act as if they are risk averse even if they are not.

Since farmers are generally risk averse, they may pursue socially sub-optimal strategies, such as choosing overdiversified cropping patterns, using inputs conservatively, or failing to adopt high yielding technology that involves higher risk. Hence it is argued that crop insurance may lead to the increased use of inputs and may accelerate the modernization of agriculture. With insurance, farmers may use high risk and higher yielding strategies and thereby increase production. This argument is discussed in greater detail using the utility theory in Chapter III.

Welfare Benefits of Stabilized Consumption

Risk-averse consumers will also derive welfare benefits when the intertemporal instability of their consumption stream is reduced. These benefits would accrue especially during periods of calamities. Insurance stabilizes income and consumption for each individual through intertemporal transfers and for a group through interpersonal transfers. In agriculture, access to liquidity is especially important since farmers with insurance can reestablish their
operations and fulfill their obligations towards creditors without drastically reducing their consumption levels. These welfare benefits can be substantial when yield variability is the major cause of income variability and when a high percentage of the population is employed in agriculture. Arrow (1963) has argued that "the welfare case for insurance of all sorts is overwhelming. It follows that the government should undertake insurance where the market for whatever reason has failed to emerge."

Complementarity with Credit Policy

Governments in various countries have been extending credit to farmers on concessional terms. Official agencies in general have found it difficult to recover loans, and credit agencies have therefore demanded that crop insurance be used as a way of reducing their risk and improving their loan collection performance in rural financial markets. For example, in the Philippines, crop insurance was initiated by the Land Bank of the Philippines (LBP). First, the Central Bank introduced guaranteed credit operations, called the Agricultural Guaranteed Fund (AGF), to induce lending institutions to participate in small-farmer-oriented, low-cost, and non-collateralized lending schemes. However, high loan arrears accumulated, which led to reductions in the amount of loans granted under the AGF-covered credit programs. The LBP then formed an interagency committee,
which recommended implementing crop insurance to protect both the lending institution and the farmer (Philippines Crop Insurance Corporation, 1982). Crop insurance was introduced in the Philippines in 1981.

In India the terms of credit to farmers are adjusted in cases of natural disaster. If the crop yield is below 50 percent of the normal, a short-term loan is changed to a medium-term loan. If the crop in the subsequent year is also affected, the loan is further rescheduled into a long-term loan, and in extreme cases the short-term loan and the interest on it are written off. However, with the limited budgets of various small and marginal farmer development agencies, it may be difficult to write off loans when disasters occur two or three years consecutively. Because of these continued problems, a study team was constituted to study the loans of cooperative credit institutions. It recommended a crop insurance scheme linked to crop loans (Dandekar, 1976).

Binswanger (1986) argues against the complementarity of credit and crop insurance. According to him both crop insurance and rural credit suffer from problems of poor information. Both the banker and the insurer need information on returns from various activities of the farmer: the banker to assess credit worthiness and the insurer to obtain the yield distribution. Both have problems
in assessing the extent of the disaster that strikes their clients. This leaves the banker uncertain regarding the need to reschedule loans, and the insurer uncertain as to the extent of damage and whether it was caused by an insured disaster. Binswanger further argues that it may be easier to solve the problem of poor credit repayment by changing the credit system rather than by introducing crop insurance.

**Patronage Benefits of Insurance**

Von Pischke (1983) argues that the government in power also enjoys several patronage benefits by introducing crop insurance. He maintains that since insurance program costs can be widely spread and their accounting delayed in time, whereas benefits are immediate and highly concentrated, crop insurance is politically attractive. It becomes especially so because farmers facing high risk are often in marginal agricultural areas.

Insurance programs can also be structured to transfer resources to high-risk, wealthy producers through compulsory participation in insurance programs, supplemented by contributions from budgetary subsidies for insurance. Alternatively, if some group is better organized politically, for example, the large farmers in certain countries, it can capture most of the benefits. Thus the
government in power may also enjoy the political benefits by transferring resources to a certain group or region.

Adverse Effects of Crop Insurance

As stated earlier, whereas farmers face many risks that affect their income, crop insurance can help reduce only the yield risks. Even if the income from crops alone is considered, the income variance will be a function of the yield variance, the price variance, and the covariance between yield and price. If most of the variance comes from price and not yield, as is observed in irrigated areas of India (Barah and Binswanger, 1981), price stabilization policies will be most effective. It is also possible that even though crop insurance reduces the impact of yield variance, the covariance between price and the yield is adversely affected and therefore the income variability increases, as observed in Mexico (Hazell, Bassoco, and Arcia, 1982). Other negative effects of crop insurance arise from the problems of moral hazard and adverse risk selection. The potential negative effects of crop insurance on crop production and credit institutions are described below.

Impact on Food Production

Crop insurance can have a negative impact on food production if it is not properly administered. For example,
a scenario can be considered in which a typhoon is forecast, the crop is ready for harvesting, and the insured farmer does not have adequate drying and storage facilities. The farmer is faced with making the decision whether to harvest his crop or not. If he goes ahead with the harvest, he will salvage only part of the crop because he lacks proper storage and drying facilities. However, he would not get an indemnity for the lost harvested crop because the damage which occurs after harvesting is not covered. Thus, he is more apt not to harvest the crop because he will receive compensation only if the unharvested crop is destroyed. If crop insurance had not been available, the farmer would have tried to salvage a part of the crop.

If insured farmers in a large area choose not to harvest their crops but allow their crops to be destroyed so that they may collect an indemnity, a significant negative impact on total food production may result from crop insurance programs that increase moral hazard problems. Similar moral hazard problems can also occur because of price variability. For example, if a farmer is expecting market prices to be less than the price elected for indemnification purposes, it would be to his advantage to have no yield and be indemnified by the insurance company. In cases such as these, crop insurance lowers the production of food because a program that has been poorly designed and
administered encourages farmers to opt for indemnities rather than to attempt to produce better harvests.

**Impact on Credit Institutions**

In a study on Panama, Pomareda (1986) observed that improvement in the earnings and growth of agricultural development banks does not come from reductions in the variability of loan returns. It is due rather to reduction in the collection costs, prompt repayment, lower loan turnover, and more efficient use of staff and other resources. He argues that a part of the gain could be achieved simply by improved management and better loan approval and supervision procedures in the credit programs. He also shows that a two percentage point increase in the interest rate charged on loans would provide benefits to the banks that are comparable to the benefits of better repayment of loans due to crop credit insurance, and at a much lower cost. Thus crop insurance would work as a means of subsidizing credit and of hiding the negative impact of cheap credit policy.

**Alternatives to Crop Insurance**

Price support policy is another measure used to support farmers' incomes. If the price of grain falls below a certain level, the government enters the market and buys commodities at the support price. In developed economies
market institutions, such as the futures market and efficient credit markets, exist. However, these are at a rudimentary stage in the developing countries. The Income Equalization Scheme and the Variable Amortization Scheme in Australia are two other examples of alternatives to crop insurance. Some alternatives to crop insurance are described below.

Input Subsidy Policies

Subsidizing the prices of agricultural inputs is one way of supporting and stabilizing the income of farmers. However, benefits in general have not reached the intended beneficiaries. For example, fertilizer has been supplied at low prices in various countries, but the amount of the subsidy, and hence the supply at a lower price, is limited, and most of it generally goes to large and influential farmers who are usually not the publicly stated targeted group.

Governments ignore the fungibility\(^1\) of money as well as inputs like fertilizer. They assume that an input supplied for a particular crop will be used for that crop alone. However, like credit issued for certain commodities,

\(^1\) Fungibility—a prime characteristic of currency—is the interchangeability of money which enables it to serve as a numeraire and medium of exchange, and makes monetized transactions more efficient than barter. (Von Pischke and Adams, 1980).
inputs may also be used for other commodities or sold on the market. Thus if it is not economical to use a certain input for a certain crop, subsidizing an input may not lead to increases in use for that crop. Hence the objective of increased production of that particular crop may not be achieved.

Output Price Support Policy

A major factor affecting the income variability of the farmer is output price. In Australia, for example, the problem of unstable rural income is mainly due to the rising proportion of farm output sold on export markets which are very volatile (Lloyd and Mauldon, 1986). However, it is also argued that if changes in prices and production move predominantly in opposite directions, they offset the effect of each other. In these circumstances the introduction of a guaranteed price could further destabilize income if the covariance between yield and prices is adversely affected.

Efficient Credit Policy

Under crop insurance, farmers are compensated for losses in bad years while they make premium payments in both good and bad years. If the insurance program is self-sustaining, premiums paid by farmers cover the indemnities received and the cost of administration incurred by the insurance company. If the farmer could sustain a loss from
his own savings or by borrowing money, he would not need insurance. These approaches to sustaining a loss might be even cheaper as he would not have to pay for the administrative costs incurred by crop insurance programs. Thus if an efficient financial market exists, need to purchase insurance may not be as much. However, efficient and unsubsidized formal credit markets are almost absent in the rural areas of developing countries.

A lack of agricultural credit is considered to be one of the major factors inhibiting agricultural growth. Therefore, many donor agencies and governments in developing countries aggressively promote cheap agricultural credit. These policies are being implemented to compensate for price and investment policies that have hurt farmers' interests, and to spread the use of new technology among poor farmers in order to increase their productivity (Adams, Graham and Von Pischke, 1984).

However, it has been observed that these subsidized credit programs typically suffer from low recovery rates and that very little credit goes to small farmers—the target group of most programs. Gonzalez-Vega (1984) argues that these low interest rate policies repress savings mobilization and formal financial intermediation in general. As a result of the suppression of savings mobilization, the total volume of lending declines. Thus in a market with
excess demand, non-price-rationing mechanisms are needed to clear the market. As a result of the high risks and cost associated with lending to small borrowers, banks discriminate against them and more credit goes to large and influential farmers.

**Variable Amortization Schemes.** As described by Lloyd and Mauldon (1986), the Variable Amortization Scheme (VAS) used in Australia allows the borrower to be partially or totally relieved of his debt repayment in low-income years. In return, he makes larger payments in high-income years. In one form of VAS, borrowers undertake to deposit money in prosperous times to be used solely for the purpose of making debt repayment in bad times. This approach is called the Debt Reserve Approach.

In the other approach, called the Equity Credit Reserve, a farmer does not use all his credit line and keeps increasing his line of credit to use in times of disaster. Many banks informally extend the terms of the loan in disaster years. However, an extension depends upon the local bank manager, the policy of the bank, and the government's monetary policy. A VAS eliminates this uncertainty. However, in the absence of credit availability to the rural sector in many developing countries, neither of these approaches is very relevant.
Income Equalization Scheme. This is another scheme used in Australia to help farmers in times of disaster. In good years farmers deposit money in interest bearing deposits with the Federal Treasury and this income is not taxed until the farmer withdraws money from the account (Lloyd and Mauldon, 1986). However, this approach also is not of much use in developing countries. In countries like India, for example, agricultural income is not taxed. Even in other developing countries, small farmers pay very little tax because their incomes are low.

Disaster Assistance Programs

Various disaster assistance programs to support incomes of farmers affected by natural causes beyond their control have been introduced in various countries. These moves are obviously appreciated by farmers; however, benefits under these policies are limited by the government policies. For example, the U.S. Disaster Assistance Program was stopped in 1981 (Gardner and Kramer, 1986). And in India after three successive crop failures in Maharashtra during 1970-1973, it was realized that the program did not have enough resources to write off the short-term loan and interest; therefore, only 50 percent of the interest only was written off (Dandekar, 1976).
Role of Subsidies in Indian Agriculture

Both direct and indirect subsidies have been offered in Indian agriculture since before its independence. The five year plans in independent India have institutionalized them and have increased their scope and amount. The agricultural sector abounds in various types of subsidies, such as the most readily identifiable ones of price supports, fertilizer subsidies, and cheap credit. Other examples of these types of programs are subsidized irrigation rates, reduced tariffs on electricity, reduced excise duties on diesel fuel, differential freight rates for agricultural outputs and inputs, free extension services, and incentives offered for agro-processing industries or exports of agricultural commodities.

An example of direct subsidies is of below-market clearing fertilizer and food prices and an example of indirect subsidies is the allowance of operating losses in irrigation. These subsidies are offered both by the state and the central governments. Total direct subsidies by the Indian government in the financial year 1981-82 were Rs 3,161 crores — approximately U.S.$ 2,431m (Central Statistical Organization, 1984). During the same year, direct subsidies to the agricultural sector by the central government were estimated to exceed Rs. 1,270 Crores.
(approximately U.S.$ 980m). This constituted about 6.8 percent of the total budgetary outlay. However, as stated above, both the state and the central governments also provide indirect subsidies to various sectors. For example, indirect subsidies by the central government to the irrigation sector were estimated to be about Rs. 500 Crores (approximately U.S.$ 385m) in the fiscal year 1981-82 (Sambrani, 1982). Thus, even though estimates of subsidies to various sectors are not freely available, it is clear that the agricultural sector receives a very large proportion of the total.

Sambrani gives a number of reasons for the justification of the subsidies. First, even though improvement in the physical and institutional infrastructure is considered to be the best way of achieving self-sufficiency in the long run, subsidies and price supports are considered to be attractive alternatives in the short run since the former requires large investments and long gestation periods. Second, it can be argued, at least on an a priori basis, that subsidies help an agricultural economy consisting of an overwhelming number of subsistence farmers to overcome bottlenecks of production and market uncertainties. Third, subsidies can also be considered instruments of interpersonal transfer of resources, in as much as they are met from a taxation-financed exchequer. The
acceptable social justification for such transfers is that they eventually lead to a more equal distribution of income in the society. Fourth, subsidies are needed to enhance the risk bearing potential of farmers and to offer at least a partial correction for the secular decline in the terms of trade between agriculture and other sectors.

However, Sambrani cautions that, although started as temporary and emergency phenomena, subsidies have continued indefinitely and have become a permanent part of public programs. They have not only become permanent, but have also been considered as a right by affected groups. Sambrani goes on to emphasize the Barker-Hayami thesis that short-term measures such as subsidies are not a substitute for long-term improvements in social and physical infrastructures.
CHAPTER III

CONCEPTUAL ISSUES OF CROP INSURANCE

Even though the insurability of yield risk has not been formally established, many countries have introduced some type of yield insurance. Most of these programs estimate premiums and indemnities on the basis of individual yields and are dependent upon heavy government subsidies. In Brazil and Mexico, for example, subsidies account for 50 percent and 80 percent, respectively, of the total expenses of the programs (Siamwalla and Valdes, 1982). This continued subsidization of yield insurance has raised questions about the feasibility of a viable program. If a viable yield insurance program cannot be established without a subsidy, then the appropriateness of yield insurance on welfare grounds needs to be analyzed.

In the first section of this chapter basic concepts of the utility theory are reviewed and the demand curve for insurance is derived. This is followed by a discussion of the supply of insurance and problems in insuring agricultural risks. The chapter concludes with a section on equilibrium in the insurance market.
Demand For Insurance

A farmer has to make decisions about which crops to grow and the quantity of each input to be used, along with various other management decisions. These decisions are based on the returns he expects and the impacts of various factors on the distribution of his returns. Buying insurance is one such factor which may reduce the variance of his returns. However, on the average, the farmer pays more in premiums than he gets back in indemnities if there is no subsidy involved.

If returns under two scenarios (with and without insurance) were computable with certainty, a comparison would be easy: the farmer, however, has to make decisions in an uncertain world. Expected utility is one of the ways of comparing the risky choices. Under this approach it is assumed that the farmer wants to maximize his expected utility. He buys insurance if the expected utility with insurance is more than without it. Thus, a point on the insurance demand curve would be the value of the insurance cost for a given guaranteed yield for which expected utilities with and without insurance are equal.1/

1/ This is an unusual way of defining the demand curve. However, a direct definition is not possible since the demand price is implicit and it cannot be expressed as an explicit function of the guaranteed yield.
Utility Basis of Insurance

The existence of a utility function was first postulated by Bernoulli. It became more widely known when von Neumann and Morgenstern showed that Bernoulli's Principle (known as the expected utility theorem) was a logical deduction from a set of axioms that were considered reasonable. Anderson, Dillon, and Hardaker (1977) state that a set of three axioms — ordering and transitivity, continuity, and independence — is a sufficient basis for deducing Bernoulli's principle: a utility function exists for a decisionmaker whose preferences are consistent with the axioms stated above.

According to this principle, a utility function $U$ associates a single real number with any prospect and has the following properties (where the utility value of 'a' is denoted by $U(a)$): (1) if 'a' is preferred to 'b', then $U(a) > U(b)$ and vice-versa; (2) the utility of a risky prospect

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2/ Ordering: An individual either prefers one of the two risky prospects 'a' and 'b', or is indifferent between them.
Transitivity: If an individual prefers 'a' to 'b' and prefers 'b' to 'c' then he prefers 'a' to 'c'.
Continuity: If an individual prefers 'a' to 'b' and prefers 'b' to 'c' then there exists a nonzero probability $p$ such that he is indifferent between 'b' with probability 1 and a lottery with outcome 'a' with probability $p$ or 'c' with probability 1-$p$.
Independence: If an individual prefers 'a' to 'b' and 'c' and probabilities of 'a' and 'b' are equal, then a lottery with 'a' and 'c' as outcomes would be preferable to 'b' and 'c' as outcomes.
is its expected utility value; and (3) properties of the utility function relevant to choice or decision analysis are not changed under a positive linear transformation.

Bernoulli's principle provides one of the means of comparing risky prospects. The principle shows that the prospect having the highest expected utility has the highest rank. In fact, the following can be inferred using the expected utility theorem: (1) if the three assumptions (axioms) above are satisfied, a utility function that reflects an individual's preferences for consequences exists; (2) a subjective probability distribution that reflects his personal judgement about the chances he faces exists; and (3) an individual chooses the risky prospect that maximizes his expected utility (Anderson, Dillon, and Hardaker, 1977).

To simplify, if wealth (W) is the only commodity, then the utility function is a function of wealth alone, i.e., \( U=U(W) \). It is also assumed that there are only two possible levels of wealth, \( \text{AB} \) with probability \( p \) and \( \text{AD} \) with probability \( 1-p \). Utilities of \( \text{AB} \) and \( \text{AD} \) are shown by \( \text{OB} \) and \( \text{PD} \), respectively (Figure 3.1). The utility curve of the risk-averse individual is shown by \( \text{OU} \text{LP} \) for various levels of wealth between \( \text{AB} \) and \( \text{AD} \).
FIGURE 3.1. THE UTILITY CURVE.
If given a choice of earning AC with probability 1, or earning AB with probability p and AD with probability 1-p (where the expected value of his income is AC)\(^3\)/, an individual will prefer AC with probability 1 instead of taking the chance because \(U(AC) > pU(AB) + (1-p)U(AD)\), the expected value of utility under the chance situation. In fact, he would be willing to pay up to a maximum of \(CC'\) as a premium to choose AC. This is so because for any \(C''\) between \(C'\) and \(C\), \(U(AC'')\) is greater than the expected utility under the chance situation.

The behavior of risk-neutral and risk-seeking individuals can be similarly explained. The curve OP represents the utility function of a risk-neutral individual. At any point \(C\) between \(B\) and \(D\), \(U(AC) = pU(AB) + (1-p)U(AD)\). Thus this person is indifferent between a chance and a nonchance situation.

The utility function of a risk-seeking individual can be denoted by OU2P. This person draws more utility by taking a chance rather than earning a definite income. Unlike the case of risk-averse individuals, here \(U(AC) < pU(AB) + (1-p)U(AD)\). Such an individual would have to be paid to prefer the certain situation to the uncertain one. If he

\(^3\)/ Hereafter, unless otherwise stated, the expected income is assumed to be the same in both the certain and the risky situation.
were paid any amount less than CD', he would prefer the chance situation.

Arrow's (1971) utility boundedness theorem can be used to show that a utility function satisfying assumptions of the expected utility theorem is bounded both from above and below. If it is further assumed that the utility function is strictly an increasing function of W, then it can be easily shown that $U'(W)$, the marginal utility of wealth, must be diminishing, i.e., $U''(W) < 0$. This implies that an individual is predominantly risk-averse (Arrow, 1974).

In practice, however, it is observed that individuals buy insurance and take chances at the same time. The individual buys insurance if the marginal disutility increases with an increase in the amount of loss. Thus, in relative terms, small losses are less important. The individual makes adjustments in his income to buy insurance if the loss implies a significant change in his wealth position. If, on the other hand, the possible gain is very large, the chance situation may be preferred to the nonchance situation. An example might be that of an individual who wants to escape his present subsistence level of living.

In a country like India most farmers own small pieces of land and farming is a major source of their income.
Farmers use several devices to reduce risk. These include diversify their farm enterprise by growing more than one crop and by intercropping (growing more than one crop in the same farm at the same time). It is highly probable that most of them are risk-averse and are potentially interested in buying insurance. However, a market for this insurance exists only if a supply function intersects the demand curve in the positive quadrant. If the two curves do not intersect, as is probably the case, the government has to decide whether or not to subsidize the insurance company. This subsidization is explained below, after first deriving the demand and supply curves for individuals and the insurance company, which show the relationship between premiums and coverage (the guaranteed yield).

The Demand Curve

A farmer buys crop insurance if it reduces the adverse impact on his crop returns (the value of crop output denoted by I), due to causes beyond his control. For him to buy a specific level of guaranteed yield C, it has to be available at a price for which the expected utility of total wealth with insurance is equal to or more than the expected utility without insurance. Thus the demand curve is the maximum price DP (i.e., the demand price of insurance) that he is willing to pay for the various levels of the guaranteed yield. In the simplified example in the previous section,
the individual is willing to pay a maximum amount $CC'$ to obtain a definite return $AC$ (Figure 3.1). Thus the demand curve is a locus of points representing $DP$ and the guaranteed yield ($C$) for which the expected utility after purchasing insurance ($EUI$) is equal to the expected utility without insurance ($EUN$).4/

It should also be noted that the commodity here is insurance coverage. Since this is different from the usual commodity used in economics literature, the shape of the demand curve may also be different. The demand price consists of the expected value of the loss - which he gets back as indemnity - and the risk premium. The expected value of loss (which is equal to the pure premium) increases with an increase in the insurance coverage. Therefore, even though the risk premium for each additional dollar of insurance coverage declines, the total demand price may increase with an increase in the insurance coverage.

A farmer's returns function with insurance can then be specified as $f(I) = C - DP$ when $I$ is less than $C$, and $f(I) = \ldots$ 

4/ The demand curve usually represents the quantity that an individual is prepared to purchase for a given price. If the quantity is the guaranteed yield then this expressed as a function of premium is the demand curve. It can also be expressed as the relationship between the maximum demand price that a farmer is willing to pay for a given level of guaranteed yield. However, because of the nature of the utility function, the demand price as function of guaranteed yield cannot be stated explicitly. The demand curve, therefore, is implicitly defined as above.
I-DP when I is greater than C. The expected utility of the individual buying an insurance for guaranteed yield C is then equal to
\[
EUI = \int_0^C U(C - DP) g(I) \, dI + \int_C^\infty U(I - DP) g(I) \, dI, \quad (3.1)
\]
where \( g(I) \) is the probability density function of returns and \( U \) is the utility function. The individual buys insurance if the expected utility with insurance (as calculated above) is greater than the expected utility without insurance:
\[
EUN = \int_0^\infty U(I) g(I) \, dI. \quad (3.2)
\]

The premium \( P \) that the farmer is willing to pay consists of two parts: the pure premium \( PP \), an amount just sufficient to cover indemnities, and the cash equivalent of the reduced risk (the amount for which he would reduce the risk). Since the marginal utility of each additional dollar is positive and declining, a farmer is willing to pay a higher cash equivalent to insure a dollar at a lower level of income than to insure a dollar at a higher level of income (for example, levels AB and AD in Figure 3.1). In other words, the marginal cash equivalent for each additional dollar in the guaranteed yield is declining. Thus the cash equivalent curve, as represented in Figure 3.2, is concave to the origin.

The pure premium as a function of the guaranteed yield is expressed as follows:
FIGURE 3.2. THE DEMAND CURVE OF INSURANCE.
As $C$ increases, the pure premium increases at an increasing rate as shown below.

$$PP = \int_0^C (C - I) g(I) dI > 0.$$  \hspace{1cm} (3.3)

where $G(C)$ is the value of the cumulative density function at $C$. By differentiation,

$$\frac{d\text{PP}}{dC} = G(C) + Cg(C) - Cg(C),$$ \hspace{1cm} (3.5)

$$\frac{d^2\text{PP}}{dp^2} = g(C) > 0.$$ \hspace{1cm} (3.6)

Thus the pure premium curve is convex from below (Figure 3.2).

The demand price for a given guaranteed yield is the sum of the pure premium and the cash equivalent for this level of guaranteed yield. As described above, the pure premium is convex from below and the cash equivalent curve is concave from below. Therefore, the demand curve, obtained by adding the two curves vertically, has an inflection point (Figure 3.2). A procedure for estimating the demand curve, using the utility function of the type described below, is explained in Chapter V.
Estimation of the Utility Function

To estimate a demand curve, an empirically estimated utility function is needed. Depending upon the conditions imposed on the behavior of the individual, a utility function can be chosen. Anderson, Dillon, and Hardakar (1977) specify that the following two conditions need to be satisfied: (1) the marginal utility of wealth should be positive and it should decline with an increase in wealth; (2) risk aversion should decline with an increase in wealth.

In the theoretical literature, several measures have been used to estimate risk aversion. However, the following two measures have received the most attention: (1) the coefficient of absolute risk aversion, defined as $RA(W) = \frac{-U''(W)}{U'(W)}$, where primes denote derivatives and $W$ denotes the total wealth of the farmer, and (2) the coefficient of relative risk aversion, which is a product of wealth and absolute risk aversion ($RRA$), i.e., $RRA(W) = RA(W) \times W$ (Arrow, 1965; Pratt, 1964).

Pratt and Arrow argue that absolute risk aversion declines with increasing wealth. Although no definite empirical evidence has been found for some time, the assumption about declining absolute risk aversion has routinely been made. Hamal and Anderson (1982) report in
their study on risk behavior of farmers in Nepal that "absolute risk aversion is strongly and negatively related to wealth". They also infer that relative risk aversion remains about constant (the median value was observed to be approximately 3.75 in the Nepal case).

Thus if, in addition to the two assumptions stated above, it is also assumed that (3) the relative risk aversion coefficient is constant, then a utility function satisfying these properties can be derived by the following method.

By definition, absolute risk aversion is given by
\[ RA = \frac{RRA}{W}. \]
Also, \( RA \) can be expressed as equal to
\[ RA = \frac{-U''(W)}{U'(W)} = -\frac{d}{dW} \ln(U'(W)), \quad (3.7) \]

which implies that
\[ U(W) = \int e^{-\frac{RRA}{W}} dW \]
\[ = \int e^{-RRA} W \]
\[ = -(RRA-1) \quad \text{for } RRA>0. \quad (3.8) \]

Since the properties of the utility function relevant to choice or decision analysis are invariant to positive linear transformations, this utility function would be similar to
\( U(W) = B - kW \) \hspace{1cm} (3.11)

In other words, a utility function of the form

\[ U(W) = B - kW \] \hspace{1cm} (3.12)

has a relative risk aversion equal to \( a+1 \).

**Supply of Insurance**

The Law of Large Numbers is used to explain the supply of insurance. According to this law, if similar risks are pooled, the risk faced by the group as a whole is smaller than the sum of risks faced by all the individuals separately (i.e., the variance of the mean is less than the sum of the variances of individual components). The larger the number of participants, the greater the probability with which the loss can be predicted, and the smaller the risk faced by the group.

**Law of Large Numbers**

The Law of Large Numbers can be formally stated as follows: If \( X_1, X_2, \ldots, X_n \) form a random sample from a distribution for which the mean is \( m \), then

\[ \lim_{n \to \infty} \frac{X_n}{n} = m, \] \hspace{1cm} (3.13)

where \( X_n \) is the sample mean. In simple terms, the law implies that as the number of participants increases, (1) the possibility of a total loss for every individual decreases, (2) the possibility of no loss decreases, and (3)
the density of the distribution around the mean increases (Lee, Boehlje, Nelson, and Murray, 1980). Thus if the number of participants is infinitely large, then $X_n$ is very close to $m$. The example that follows explains this.

It is assumed that there are $n$ farmers ($n$ is very large), each owning one hectare of land. There is no technological innovation and the yields are not related over time; thus, the yield of each farmer can be considered as an observation from the same distribution. Since the average yield and variance faced by each farmer is the same ($\text{mean}=m$ and $\text{variance}=v$, say) after pooling, the variance faced by each farmer would be less than $v$, by the Law of Large Numbers. Under insurance, farmers pay in all years, good or bad, and if their yields fall below a certain preselected level, the affected farmers are indemnified for the shortfall. Thus the variance and hence risk faced by each farmer is less.

In practice, however, all the assumptions underlying the Law of Large Numbers are not satisfied. There are technological innovations, yields of farmers are not independent of each other because some causes of yield variation (for example drought) are the same for a group of farmers, and yields may be related over time. Also, a large number of farmers may not have the same risk exposure, especially in agriculture where the yield is vulnerable to
several different kinds of hazards and farmers have different resources and follow different management practices. This makes it almost impossible for all farmers to have the same risk exposure.

**Homogeneous Risk Classes Versus the Number of Participants in Each Class**

If the premium is estimated with farmers with different risk exposure grouped together in one class, farmers who are better risks may be paying more than they should while farmers who are poor risks may be paying less. It is therefore essential to categorize farmers exposed to similar risks in one class. Although classes cannot be perfectly homogeneous, they should contain relatively homogeneous risks.

The issue before the insurance company then is to decide on the number of categories it wants to establish. A large number of categories would contain a small number of persons in each category, in which case (a) the Law of Large Numbers would be inapplicable and premium estimates would be inaccurate and (b) the costs of estimating insurance premiums for the insurance company would rise. The insurer, therefore, has to compromise between keeping a large number of individual risks in each class so that the losses can be predicted with reasonable accuracy and keeping individual
risks in a class reasonably homogeneous so that the difference between poor risks and better risks is small.

If classes are not homogeneous, farmers who are better risks subsidize those who are poor risks, or they simply may not buy insurance. As a result there would be a larger proportion of poor risk farmers in the program, and the program would be more likely to fail.

The Supply Curve

An actuarially sound premium is a sum that is just enough to pay for expected losses, administrative expenses, and capital costs, and to establish a prudent reserve over a long period of time. It can be divided into two components: (1) the pure premium and (2) the loading. The pure premium is the amount of money needed to pay indemnities. This curve is the same curve as used in the derivation of the demand curve. The loading constitutes administrative expenses and profits, and is discussed below.

If profits are assumed to be zero, the administrative expenses consist of the cost of estimating premiums and indemnities, the cost of selling insurance policies, and the cost of estimating damages and settling claims. These costs depend on the number of policies underwritten, the number of claims settled, and the procedure used to sell policies and settle claims.
Once the design of insurance scheme is decided, the cost of estimating premiums and indemnities as a function of the guaranteed yield is constant. The number of policies underwritten may be a function of the guaranteed yield offered because more farmers may insure their crops at higher guaranteed yields, and the per person cost of selling insurance may therefore decline. The extent of the decline would depend on the demand elasticity. However, for the sake of simplicity these costs are assumed to be invariant to the level of guaranteed yields.

The cost of estimating damages and settling claims is an increasing function of the guaranteed yield and can be shown as follows:

$$\Pr(I<C) = \int_0^C f(I) \, dI$$

and

$$\frac{d\Pr(I<C)}{dC} = f(C) > 0,$$

(3.14)

where $\Pr(I<C)$ is the probability of $I$ being less than $C$. Thus the probability of loss is an increasing function of $C$, the guaranteed yield. An increase in $C$ leads to an increase in the administrative cost of settling claims. To determine the rate at which the cost increases requires the shape of $f(I)$, which is an increasing function for values of $C$ less than the average yield if the yield distribution is normal.

The discussion above can be summarized as follows (Figure 3.3): (1) the pure premium as a function of $C$ is
FIGURE 3.3. THE SUPPLY CURVE OF INSURANCE.
convex to the origin; (2) the administrative costs attributed to the number of claims settled increases at an increasing rate with increases in C; and (3) the administrative cost of selling policies does not depend on C. Thus if the normal profit is either considered constant or an increasing function of C, the shape of the supply curve of insurance (which can be obtained by vertically adding the three curves—pure premium, administrative expenses, and normal profits—can be derived as an upward sloping curve, with the premium increasing at an increasing rate. Since most of the programs do not earn a profit, the normal profit curve is not shown in the diagram.

In the homogeneous area yield approach there are no adjustment costs. Therefore, if the homogeneous area yield approach is used, then the increase in the administrative costs with increase in the guaranteed yield may be insignificant because the claims are settled on an area basis. Thus, these costs, as a function of the guaranteed yield may be treated as constant. The supply curve, however, would still be upward sloping (Figure 3.3).

**Equilibrium**

The equilibrium value of C can be obtained by the intersection of the demand and supply curves of insurance. As shown in Figure 3.4, the two curves may intersect at more
FIGURE 3.4. THE EQUILIBRIUM IN THE INSURANCE MARKET.

DEMAND CURVE
SUPPLY CURVE

DEMAND/SUPPLY PRICE

GUARANTEED YIELD
than one point. They can be tangential at one point, or not intersect at all. These curves may not intersect due to high administrative costs, problems of moral hazard and adverse risk selection, or other reasons. If they do not intersect, the government has to decide whether or not to subsidize the program (The amount of subsidy required for various levels of guaranteed yields and risk aversion coefficients is estimated using the Monte Carlo simulation in Chapter VI). Some reasons for nonintersection are examined below.

One way for an insurance company to obtain all the relevant information is to appoint a large number of adjusters and agents. The supply curve therefore shifts up because of high administrative expenses and may not intersect the demand curve. Alternatively, the insurance company obtains only the essential information and relies on the truthfulness of farmers on such matters as their use of inputs and their decisions in times of loss. Farmers, however, may take advantage of the information difficulties of the insurance company. In case of rainfall, for example, an inappropriate drainage decision can give the impression of a flood, allowing the farmer to file for an indemnity. When the insurance company takes these expenses into account, it raises the premium for the same guaranteed yield over a period of time. In other words, the supply curve shifts up. This shift causes more farmers to leave the
program; usually the low-risk farmers are the ones who leave.

This has two consequences: (1) administrative cost per insured farmer rises as the number insured declines, and more importantly (2) only the high-risk farmers remain in the program. These changes lead to a further upward shift in the supply curve and the ultimate failure of the insurance program. The issue of insurability in general and in the Indian program in particular are discussed in Chapter IV.
The importance of risk reduction in the production of crops has been stressed in the literature and its importance is clear in everyday life from the commercial availability of insurance for various risks. Crop production, an important sector for most economies, is especially essential to an economy like that of India, which has a major part of its population associated with agriculture. To reduce risk in crop production, several countries have therefore instituted crop insurance programs.

In accordance with insurance procedures used in other sectors of the economy, most countries estimate crop insurance premiums and indemnities using individual yield experience. However, because of the atypical nature of crop production, these programs suffer from severe problems of moral hazard and adverse risk selection and either have failed or have existed only with heavy government subsidy.

To avoid the problem of adverse risk selection, insurance programs were made compulsory in some countries. Similarly, to reduce administrative costs, programs were
restricted to a certain group of farmers, e.g., borrowers from official sources in the Indian case. To avoid problems of moral hazard, insurance based on area yields was proposed. However, this posed problems from the demand side because purchasing insurance is not attractive when the yields of farmers are not highly correlated with area yields. These problems of insurability are discussed below, followed by a critique of the literature on noninsurability, by a description of alternative insurance procedures, and by a review of the Indian program and its associated problems.

**Insurability of Agricultural Risks**

Farmers have to face various kinds of risks, some of which are due only to natural phenomena. Some risks may be within the means of farmers to avoid and/or control, while others may not. The function of insurance is to reduce the impact of losses that are beyond the control of the farmer by distributing the losses over area, time, and individuals. For an individual this involves the regular and deliberate accumulation of funds in small installments in good years to pay for losses in bad years. An individual buys insurance if he has a desire to purchase it and if it is available at a price at which he finds it attractive. On the other hand, an insurance company sells insurance if it can earn a reasonable profit after covering all costs. Thus certain
conditions have to be satisfied for a viable crop insurance program to operate.

**Conditions of Insurability**

Some of the factors that determine insurability are as follows: (1) Calculability: the risk must be one which, when considered in aggregate, has some uniformity so that it is possible to measure and predict the possible loss in the future. (2) Accidentalness: the peril should be such that it cannot be willingly caused without involving some sacrifice on the part of the insured. (3) Definition of loss: the amount of loss for which the company is liable should be clearly defined. (4) No excessive catastrophic loss: the probability of a very large loss should not be large enough to destroy the financial stability of the company. (5) Importance: the loss resulting from a calamity should be large enough to cause significant reduction in income or wealth. (6) Psychological urge: people should have a psychological urge to reduce the consequences of risk and should be mentally and economically capable of satisfying that urge. In other words, the cost of insurance should be appropriate. (7) Randomness of losses over time: losses in one year should be independent of losses in other periods. (8) Large Number: a large number of individuals should be exposed to the loss so that the insurance company can obtain
good estimates of the loss probabilities (Bickelhaupt, 1979).

Problems of Moral Hazard and Adverse Risk Selection

The conditions of insurability stated above are based on the implicit assumption that the indemnities are based on an individual basis. Thus, risks like drought and excessive rainfall which are catastrophic in nature may require a large number of adjusters in disaster years; hence, the cost of administering such a program may be high. For example, if a large number of farmers are affected by a loss due to drought or typhoon, a large number of adjusters will be required to settle claims. Thus an insurance company is obliged to keep many adjusters on its payroll or pay an indemnity that may be higher than one paid had the losses been estimated sooner.

In the all-risk insurance approach, a given guaranteed yield is insured against essentially all perils. However, it is difficult and expensive for an insurance company to obtain information on yield losses due to uninsured causes. Many farmers take advantage of these problems in the identification of insured causes of damage and the measurement of losses. If for some reason the farmer expects yields to be less than the guaranteed yields, he may stop incurring expenses for future inputs and may neglect
following other related management practices because he will be indemnified for the loss anyway.

If these problems are present, the insurance company may increase the administrative cost component in estimating a premium, leading to an upward shift in the supply curve. This shift can make the purchase of insurance uneconomic for farmers who are better risks. Furthermore, since some farmers can take advantage of the information difficulties of the insurance company, the demand curve of these farmers shifts up. This may lead to a higher participation of such farmers. If more adverse risks (farmers who are high risks for the insurance company) join the program, the supply curve may shift further up and may lead to the failure of the program.

**Insurability of Risks Under the Homogeneous Area Yield Approach**

The homogeneous area yield approach, in which the problem of moral hazard is avoided, is considered a potential alternative to the estimation of indemnities based on individual yields. The supply side conditions of insurability are satisfied if this approach is used for losses that are widespread in nature, the insurance is sold over agro-climatically diverse areas, and the traditional approach is used for risks that occur randomly over space and time. However, issues about the relationship between
farmers' yields and the average yields of the area have been raised (Roumasset, 1978; Siamwalla and Valdes, 1986). It is also felt that the agency estimating the average yield may be under political pressure to adjust yields downward in periods of disaster.

There are two categories of disasters that a farmer faces: those that are widespread in nature and those that are not. The first category includes drought, typhoon, and cyclones. If time-series data on yield are available, the frequency distribution expected by farmers can be estimated along with the premiums for various levels of guaranteed yields. Thus, the yield loss due to these disasters is calculable. The disaster is also accidental as far as the farmer is concerned, since he cannot influence the cause of damage over the whole area and hence cannot predict the loss. The loss to the company is up to the maximum of the total value of the crop in the area. Thus, the first three conditions of insurability are reasonably well-satisfied for the homogeneous area yield approach.

Since agriculture is the major source of income for many people in developing countries, agricultural risks play an important role in these economies. Farmers will want to buy insurance to minimize the income loss from crop failure. If insurance is available at a reasonable price, a greater number of farmers may buy it. This is clear from the
increase in the amount of insurance sold in the initial years of the crop insurance program in various states of India (Table 4.1). The willingness to purchase insurance was also observed in a survey of 5,000 farmers conducted in 1978-79 by the Gujarat State Fertilizer Company. About 48 percent of the wheat farmers were willing to pay between 6-10 percent of the guaranteed yield as a premium. Because of the higher risk involved with groundnuts, 34 percent of the farmers surveyed were willing to pay 11-15 percent of the guaranteed yield as a premium. For cotton, another high risk crop, 30 percent and 11 percent of the farmers surveyed were willing to pay 11-15 percent and 16-20 percent, respectively, of the guaranteed yield (Maharaja, 1980). Because there is no conclusive evidence showing a definite relationship among losses that recur over time, risks may be considered independent of each other. Exposure of a large number of farmers to crop risks is obvious. Thus, the last four conditions are also satisfied.

The biggest problem faced by most crop insurance programs is that the fourth condition the of catastrophic nature of some of the risks is not satisfied. However, if the insurance in India were sold in geographically diverse regions of the country, such risks may not pose a problem for the insurance program. The probability of the entire country being affected by drought would be very low (more
Table 4.1
Premium collected by the General Insurance Corporation, 1979-80 to 1983-84.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of States</th>
<th>Amount of Premium ('000 Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979-80</td>
<td>3</td>
<td>552.9</td>
</tr>
<tr>
<td>1980-81</td>
<td>3</td>
<td>693.2</td>
</tr>
<tr>
<td>1981-82</td>
<td>8</td>
<td>755.2</td>
</tr>
<tr>
<td>1982-83</td>
<td>9</td>
<td>1,564.8</td>
</tr>
<tr>
<td>1983-84</td>
<td>11</td>
<td>2,114.7</td>
</tr>
</tbody>
</table>

Note: US$1=Rs 13 (Approximately)

Sources: Rao (1982).
than 70 percent of India was affected only once in the past 100 years [Chowdhury, n.d.].

The second category comprises risks that are not widespread in nature, including hail and wind, which normally affect only a few farmers. If indemnities are based on an individual basis, the individual is obviously indemnified if he suffers a loss. However, if indemnities are based on the homogeneous area yield approach, an affected farmer is not indemnified so long as the loss is not widespread. Therefore, under the homogeneous area yield approach it might be advisable to use a separate procedure for estimating premiums and indemnifying against these losses. For example, in the U.S. all-peril insurance is provided by the government and crop hail insurance is sold through the private sector. The insurability of these risks is not discussed here because it is evident from the availability of insurance on the market.

A Critique of Literature on Noninsurability

Because of the problem of moral hazard and adverse risk selection, an insurance program with an indemnity based on an individual basis is difficult to administer. Some of the

This obviously is not so for small countries. An insurance in those countries would have to buy reinsurance either from a private underwriter or from the government.
reasons advanced against crop insurance programs are the noncalculability, the nonaccidentalness of the causes of damage, the possibility of losses being catastrophic, and the problems of moral hazard and adverse risk selection arising therefrom. As explained earlier, because of these problems, administrative costs are very high and heavy subsidies are required to run some programs. These heavy subsidies suggest that a study of their cost-effectiveness is important.

Tsujii (1983), for example, analyzed the crop insurance program in Japan and found a very low benefit-cost ratio. He estimates that at the world market price, the long-term benefit-cost ratio for the government subsidy to the program is .39. The amount of subsidy in the Japanese case is about two-thirds of the total indemnity. Similar subsidies are required for keeping various programs afloat. In the U.S. a subsidy of about 25 percent is required, as compared to 50 percent in Brazil and 80 percent in Mexico (Hazell, Pomareda, and Valdes, 1986).

It is argued that farmers cannot pay higher premiums (Ray, 1981; Pathak, 1981; and Dandekar, 1976). Since administrative costs of individual programs are high, lower guaranteed yields are offered to keep premiums at lower levels. Conservative estimates of expected yields are also
used to estimate premiums. This poses problems on the
demand side. Lee and Djogo (1984) found that in the U.S. if
Northwestern Ohio test trials were used as sample yields,
then no indemnity would have been collected over the period
1972-81 for wheat and soybeans if guaranteed yields offered
by the FCIC had been used to estimate indemnities. Even if
the test yields were reduced by 20 percent (assuming that
the test yields were higher than the yields of average
farmers), an indemnity would be claimed only once for
soybeans and not even once for wheat during this period. Lee
and Djogo also found that the program's attractiveness
improves if individual yields are used to estimate
guaranteed yields. They concluded that 75 percent of the
average yields as the upper limit of the guaranteed yield
was a major impediment to increased participation.

Noninsurability on theoretical grounds has also been
argued (Roumasset, 1978; Ahsan, Ali, and Kurian, 1982;
Bardsley, Abey, and Davenport, 1984; and Siamwalla and
Valdes, 1986). However, the first three of these studies
suffer from logical fallacies. The fourth one does not take
the administrative cost into account. These studies are
reviewed below.

2/ For example in the Indian program yields in the past ten
years are used to estimate premiums, even though yields
have been rising during this period.
Roumasset (1978) used Arrow's (1971) result "that resource allocation will be Pareto optimal so long as the risk is completely diffused through the economy" to support his conclusion that risk neutrality among farmers causes resource misallocation. He derives a theorem stating that "as the number of individuals sharing the returns of a risky asset goes to infinity, if the returns of the asset are independently distributed from the rest of social wealth, then the total risk premium summed over all individuals in the society goes to zero." This theorem is based on the result \( \lim_{n \to \infty} n \cdot k(n) = 0 \), where \( n \) is the number of individuals sharing the risky project and \( k(n) \) is the individual's cost of bearing the risk of the project (Arrow and Lind, 1970).\(^3\)

Roumasset (1978) provides the following heuristic explanation: "Figure 4 (reproduced here as Figure 4.1(a)) illustrates a fifty-fifty gamble involving outcomes A and B and the utility function for a risk averse individual.... Figure 5 (reproduced as Figure 4.1(b)) illustrates the risk premium for the same individual when he shares the risk and now owns one-half of the risky asset and faces returns A and B." The heuristic explanation, however, is erroneous.\(^4\)

\(^3\) This is erroneous, however, and so is the heuristic proof of this theorem as interpreted by Roumasset (1978).

\(^4\) For mathematical details, please see Rustagi and Price (1982).
FIGURE 4.1. RISK AVERSION AND INSURANCE PREMIUM
According to the explanation above, a farmer reduces his risk to half by selling half of his land. However, this is not the intent of the theorem. This is also clear from Figure 4.1(b) which shows that the expected returns of the farmer after sharing the risk (=E(Y)) are the same as before.

If the returns distribution of the farmers are independent of each other and if they pool their returns and share them equally, then their expected returns after the pooling are the same as before and the risk is reduced. However, farmers do not pool their resources to reduce the risk. The insurance company achieves the objective of risk pooling to some extent. In this case, each farmer contributes and those who suffer a loss are indemnified. Thus the heuristic explanation used by Roumasset is false and the theorem does not hold. The theorem should, in fact, read: as the number of individuals sharing the returns of a risky asset goes to infinity, if the returns to the asset are independently distributed from the rest of the social wealth, then the total risk premium summed over all individuals in the society goes to the expected value of total loss. In such a case, each farmer's premium is the same as his expected loss.
Ahsan, Ali, and Kurian (1982) develop a model of crop insurance which recognizes the information difficulties and the consequent market failure. They show that on the average, the premium charged equals the indemnity paid, excluding administrative expenses. They then discuss problems of moral hazard and adverse risk selection arising from the information difficulties faced by the insurer. They show that because of these problems, the insurance company charges the same premium from both the high and the low risk farmers. This leads to greater participation by high-risk farmers. Thus the program may suffer from the problem of adverse risk selection and may fail.

As an alternative, Ahsan, Ali, and Kurian develop a model of the provision of subsidized crop insurance in the public sector. The insurance policy guarantees a minimum level of income (instead of a certain percentage of the average or the expected yield). They argue that factor utilization in risky farming is smaller under public crop insurance than under competitive conditions. However, this arises because in the public insurance model used in the study, a minimum income is guaranteed, that is, if the yield guarantee is less than the minimum income, then an amount of money to compensate for this is also paid in addition to the loss that would have been indemnified under insurance alone. This proposed insurance would be the same as crop insurance.
(again it is assumed that crop returns are the only source of a farmer's income) if crop returns valued at the guaranteed yield are at least equal to the minimum income specified under the program. Thus the difference is observed because the additional coverage described above leads to a higher premium. This, in turn, leads to the purchase of less insurance and hence the impact on factor utilization is also less.

The effect of additional coverage on the amount of insurance can be explained using Figure 4.2. Demand I and Supply I depict the demand and supply curve under the competitive conditions. Under the proposed public insurance program, farmers whose income measured as their crop returns at the guaranteed yield is less than the income assured also receive money so that they have at least the minimum level of income. Thus these farmers are prepared to pay more because of the additional coverage and their demand curve shifts up, and is represented by Demand II.

The insurance company, however, has to increase the insurance premium because of the additional coverage. Since it does not discriminate between farmers whose incomes at guaranteed yield are less than their assured incomes and those whose incomes are more, it charges the same high premium to all farmers. In other words, the supply curve of all farmers shifts up. Let the new supply curve be denoted
FIGURE 4.2. SHIFTS IN THE SUPPLY CURVE DUE TO ADDITIONAL ADMINISTRATIVE EXPENSES.
by Supply II. Under the new situation, the program may be expensive for farmers whose demand curve did not shift, causing them to leave the program. As a result the program may suffer from the problem of adverse risk selection, i.e., farmers whose incomes are high may leave the program and those whose incomes are low may stay on, and more low income farmers may join. Thus less area may be insured, leading to a lesser impact on factor utilization.

Bardsley, Abey, and Davenport (1984) derive supply and demand curves of insurance and show that crop insurance would be sold only when administrative costs are very low and the correlation between damages to crop and indemnity are very high. They conclude that if administrative costs are more than 5 percent of the total premium, then no insurance would be sold. This appears to be very conservative. The administrative costs in most insurance programs are in general higher than this. In the U.S., the administrative costs for most insurance companies is in the neighborhood of 40 percent of the total premium. It is 35.9 percent for private passenger auto and physical damage and 54.7 percent for burglary and theft (A. M. Best Company, 1984).

Also both the supply and demand curves derived by Bardsley et.al. are downward sloping. However, as shown in
Chapter III, the downward-sloping supply curve is illogical. Since the administrative costs increase with the increases in the guaranteed yields, the supply curve would be sloping upwards. The downward slope of the supply curve they arrive at is due to the dual definition of Y, returns from insurance, and θ (0 < θ < 1), the risk insured.

In their paper Y and X are defined as returns from one unit of insurance taken on and returns from one unit of land, respectively. It is further assumed that insurance is an actuarially fair bet. The unit of measurement of Y is chosen so that $V(Y) = V(X) = r$. However, throughout the paper the units for X and Y are treated as the same. Under this assumption the variance of Y cannot be r, as is shown below. Here

$$Y = \text{Indemnity} - \text{Pure Premium}.$$  

As is clear, Y is a function of θ and is not equal to θY. Therefore

$$V(Y) = V(\theta X - X \mid X < \theta X)$$
$$= (\theta - 1) V(X \mid X < \theta X)$$

5/ Bardsley, Abe, and Davenport exclude pure premium from both the supply and the demand curves. Their supply curve is comprised of administrative expense and the risk premium of the insurance company as a function of risk insured.

6/ Besides the administrative costs and profits of the insurance company, on an average, the farmer receives as indemnity the amount which is equal to the premium.
\( \leq V(X) = r, \quad (4.1) \)
since \((\theta - 1)^2 < 1.\) Thus, \(V(Y) \leq r.\)

Similarly, \(\theta\) is defined as the amount of insurance purchased with its value lying between 0 and 1. It is clear that \(\theta\) is the ratio of the guaranteed yield and the average yield. The premium and indemnity are functions of \(\theta\) but are not linear functions as treated by the authors.

No indemnity is paid if the actual yield \((X)\) is more than the guaranteed yield \(\theta X\), and an indemnity equal to \(\theta X - X\) is paid if \(X\) is less than \(\theta X\). Thus \(Y\), the indemnity, is a function of \(\theta\) but not \(= Y\theta\). The premium can also be shown to be a function of \(\theta\) and not equal to \(p\theta\).

Siamwalla and Valdes (1986) argue that even though it is recognized that prices and quantities move in opposite directions, for practical purposes it can be assumed that prices and quantities move relatively independently because of government interventions that drive prices too high or too low. Prices move more in line with government cost calculations. Most crops are subject to some form of price intervention, either in the form of directly administered prices or indirect controls through trade measures.

Even though some of these measures might have destabilizing price effects, this falls outside the predictable risk situation for which actuarial calculations
can be made. Also if prices and quantities are negatively correlated, then provisions of either price stabilization or of crop insurance by itself destabilizes income. According to Siamwalla and Valdes in such a case the correct policy is to provide neither or both.

Siamwalla and Valdes also argue that the increase in production induced by crop insurance benefits consumers as well as producers. If demand is inelastic, average farm incomes may actually decline, and consumers may reap all the benefits. They further argue that these distributional effects may require that governments, rather than private companies, establish crop insurance programs. Private insurance companies can only collect premiums from farmers, while a government, acting in the interest of society at large, can subsidize insurance for farmers only if the cost can be recouped from consumers through taxation or other means.

However, instead of the government itself establishing a crop insurance program, subsidizing a program offered by private companies may serve the same purpose. Thus the conditions for which a case for a government program could be made, as put forth by Siamwalla and Valdes, are in fact conditions for a subsidy; a case for or against may be made by using welfare analysis.
Siamwalla and Valdes use welfare analysis to demonstrate that a case for insurance cannot be made. In their analysis, shown in Figure 4.3, $DD$ is the demand curve and $S_0$ is the original supply curve without insurance. $Q_0$ is the quantity of commodity sold at price $P_0$. Insurance is offered to farmers at full price. After the farmer buys insurance, the new supply curve $S_1$ is lower than the old supply curve $S_0$, since farmers reserve a lower premium for risk. This leads to a new price, $P_1$, and quantity, $Q_1$. Consumers gain an extra surplus of $P_0ADP_1$. The gain in producer surplus would be $OED-P0AEP1$. For the society as a whole the net gain is $OAD$. The amount of gain depends on the magnitude of the shift from $S_0$ to $S_1$ and its elasticity.

Siamwalla and Valdes argue that a reduction in the cost of production is incentive enough to buy insurance even without a subsidy. According to them if a subsidy is introduced, the supply curve further shift down to $S_2$ and an additional consumer surplus of $P1DGP2$ and producer surplus of $OGP2 - OAP0$ is generated, and society as a whole has a net loss of $P2P3FG-ODG$.

The case against subsidy as advanced by Siamwalla and Valdes holds if insurance could be sold at the pure premium. In practice, however, administrative costs and/or costs due to problems of moral hazard and adverse risk selection are
FIGURE 4.3. WELFARE GAINS TO PRODUCERS AND CONSUMERS (SOURCE: SIAMWALLA AND VALDES, 1986).
very high. It is possible, and it is observed in cases of most crop insurance programs, that because of these expenses it may not be possible to sell crop insurance. Thus a subsidy may be required to sell insurance and, therefore, the shift in the supply curve from S0 to S1 may not take place without a subsidy. This same phenomenon is also observed in the Japanese case (Tsujii, 1983).

The initial shift in the supply curve takes place only if the risk premium of the farmer is more than the administrative expenses and profits charged by the insurance company, and the amount of shift is a function of the difference between the two. The amount of subsidy required to generate a given level of shift in the supply curve (S1 to S2) varies from country to country and needs to be analyzed on a case by case basis. A country would suffer a net loss if the net surplus is less than the total subsidy. Thus the belief that society is always a net loser when crop insurance is subsidized is not entirely correct.

Alternative Procedures of Crop Insurance

Several procedures for insuring crops are used in various countries. The programs can be voluntary, as in the U.S. and India; compulsory, as in Japan; compulsory for a certain class, as in the Philippines where all farmers getting loans from the bank must buy insurance; or available
to a certain class only, as in India where only those farmers who have borrowed from formal financial institutions are eligible to buy crop insurance. Similarly, the program can be designed to insure only one risk or more than one risk (e.g., the all-risk crop insurance in which essentially all yield risks are covered). The method for estimating premiums and indemnities also differs from one program to another. However, various programs may be classified in broad categories using the following three criteria: (1) specific-risk versus the all-risk insurance, (2) individual versus the group approach, and (3) compulsions and restrictions.

Specific-Risk versus All-Risk Insurance

Risks faced by farmers may be "local", i.e., affecting a very small area, such as hail and fire, or widespread due to causes such as drought and typhoons. Insurance for local risks has been successfully sold in the private sector using the individual approach. This was also tried for all-risk insurance. Private insurance companies attempted this approach in the U.S. earlier in the century, and later the Life Insurance Corporation of India in collaboration with the Fertilization Corporation of India initiated an all-risk program (GIC, n.d.). The companies suffered huge losses and the programs were subsequently dropped.
For local risks, an indemnity is assessed on a specific-risk basis and paid at the time of the loss. However, in all-risk insurance, an indemnity is paid if the yield of the farmer is lower than the guaranteed yield he opted for when buying insurance. A reduced indemnity is paid if the crop is totally damaged early in the season and replanting is difficult. In this case, protection is reduced and the land is released for planting to other crops. Protection is gradually increased for losses during later periods (Gardner and Kramer, 1986). This is done to reduce incentives to claim an indemnity for a total loss and at the same time save on the inputs and labor that would have been used. In the Philippines, for example, a total loss is compensated to the extent of the actual cost of production inputs applied or the preestimated cost of inputs that would have been used at the time the loss occurred, whichever is lower (Philippines Crop Insurance Corporation, n.d.).

In the recent literature, insurance for risks of major significance in an area is proposed, instead of the present multiple-risk insurance (Binswanger, 1986; Lloyd, 1984; Bardsley, Abey, and Davenport, 1984). For example, typhoons in the Philippines and drought in Australia could be insured against. Again, if the indemnity is estimated on an individual basis, the program still suffers from the problem of a very large area being affected. The program may also
suffer from the problem of moral hazard. However, the severity of the problem is less than it is in the case of all-risk insurance.

For risks which are widespread in nature, the company faces the following problems if it uses the all-risk approach: (1) the inability of separating damage due to insured causes from those due to uninsured causes; (2) lack of information about management practices used by the farmer; and (3) higher expenses if the indemnity is based on the individual approach, because either the administrative expenses or indemnities—due to the waiting time involved in adjusting claims—are high. In the case of insurance for a specific widespread risk, the first two problems are not very severe. However, as explained below, the third problem is severe.

In all-risk insurance a given guaranteed yield is assured and the individual approach is used for indemnification. If at the end of the cropping season the yield of the farmer is less than the guaranteed yield, then the farmer is indemnified for the loss. However, it is conditioned on the fact that the farmer has used appropriate farming practices, and has used required levels of inputs.

In practice, it is difficult to verify the input levels used and the farming practices followed by a farmer. Also,
losses may be due to some of the uninsured risks. At the end of the season, it may be difficult to distinguish losses due to insured causes from those due to uninsured causes and, therefore, the farmer may be indemnified for all losses. These problems could be avoided if the indemnities were based on a specific risk approach.

A disaster covering a large area requires a large number of adjusters. If they are not available, it may take longer to make adjustments. The consequent damage to farmers may be higher because they may wait for the adjuster's visit to settle their claim before salvaging what they can. The possibility of collusion between agents and farmers cannot be ruled out either. Thus the losses due to waiting are high as is the cost of maintaining a large pool of adjusters. This problem is equally severe for both the all-risk and the specific-risk approaches.

Thus, an insurance program for a specific widespread risk faces fewer problems than all-risk insurance.

**Individual versus the Group Approach**

To reduce the problems of moral hazard and adverse risk selection, the past experience of farmers is used. The premium is determined by his own loss experience adjusted by the loss experience of the county. The Federal Crop Insurance Corporation in the U.S. has tried this approach
for selling multiple-risk crop insurance and found that it was impractical because of both the inadequacy of the data and the moral hazard involved. This method was also tried in India by the General Insurance Corporation (GIC) which reached the same conclusion. This type of program is also difficult to implement in a developing economy because administrative costs are higher when many small farmers are involved.

The Federal Crop Insurance Corporation (FCIC) of the U.S. sells insurance to cover 75 percent of the average yield. It has modified the program by introducing the Individual Yield Certification (IYC) option for farmers whose average yield is more than that used by the FCIC. To qualify for this, the producer must document that his yields have been more than the area average for the last three or more years. This option provides added coverage with no increase in premium. It is observed that with a 75 percent IYC option, the probabilities of realizing a yield less than the guaranteed yields increase to 15.6 percent from 2.3 percent for soybean, 11.5 from 1.1 percent for corn, and 10.8 from 0.8 percent for wheat (Lee and Djogo, 1984). However, problems of moral hazard still exist. This program would also be very difficult to administer in a country like India where the average farm size is small.
To avoid problems of moral hazard and to reduce administrative costs, estimating premiums and indemnifying losses on the basis of area yield was introduced in India. In this approach, if the average losses of the group are high, the whole group is indemnified. Since the yield of each individual is not monitored, administrative expenses are low. And since the yield of an individual does not affect the indemnity that is paid to him, the problem of moral hazard is reduced. However, if the yield of the farmer is not highly correlated with the yield of the area, he may be indemnified when his yield is good and may not be indemnified when his yield is low. In this approach causes of damage like hail cannot be insured because they affect a very small area at any one time. The individual-experience-based approach has to be used for such cases.

Compulsions and Restrictions

To avoid certain problems, reduce expenditures, or ease administrative burdens, or all three, programs have been made compulsory or benefits have been restricted to a certain group. To avoid the problem of adverse risk selection, a program may be made compulsory for all farmers or a certain group of farmers. For example, crop insurance is compulsory for all farmers growing more than a certain area of insured crops in Japan and for all farmers borrowing
from official sources in the Philippines. However, depending upon the political will and resources of the government and the political strength of its constituents, program coverage is reduced and/or the subsidy increased to keep the program afloat.

These problems created by a compulsory crop insurance program can best be illustrated by examining the experience of the Japanese crop insurance program. Japan introduced crop insurance in 1939 with a modest subsidy of 15 percent of the total premium. The program was reorganized in 1947 with coverage extended to more crops and the subsidy increased to about 50 percent. The new program was compulsory for all farmers growing insured crops on more than 0.1 hectares of land. Guaranteed yields were fixed on an area basis, and farmers expecting higher yields were underinsured while farmers in high-risk areas were overinsured. For example, in the village of Fujishima which had stable yields, only 24 percent of the farmers received enough indemnities to offset their premiums during the period from 1949 to 1958 (Yamauchi, 1986).

This underinsurance of low-risk farmers and overinsurance of high-risk farmers led to bitter criticism of the insurance program which had to be dropped in certain areas because of problems in collecting premiums. The program was again modified in 1957 to introduce flexibility
in determining the insurable value of each plot. Instead of averaging the yield for the village, the average yields for areas within a village were estimated and guaranteed yields for farmers in those areas estimated. The minimum area for compulsory insurance was also increased from 0.1 hectares to 0.3 hectares. Currently, the subsidy in the Japanese program is around two-thirds of the total premium.

Similarly, the program may be restricted to a certain group. In India only those farmers who have borrowed from government agencies are eligible to buy insurance. The program is handled through banks to reduce administrative costs. But because of this restriction, problems of the credit program also filter down to the insurance program. Since most of the official credit goes to large and influential farmers, it is mainly these farmers who are eligible to receive the benefits and, hence, the subsidy of the crop insurance program.

The Indian Program

The need for crop insurance has been debated in India ever since its independence in 1947. In that year an officer on special duty, Mr. G.S. Pirolkar, was appointed to study the issue and devise approaches for selling crop insurance. However, no state agreed to implement either of the two schemes proposed by Pirolkar mainly because of a shortage of
funds. In 1961 the Punjab government asked the central government for financial assistance to start a compulsory crop insurance program in the state. The central government introduced a draft bill and circulated a model plan in 1965 for adoption by the states. By that time, Punjab was no longer interested in the plan because most of the areas in its jurisdiction after the reorganization of the state were irrigated. Other states were not willing to sell insurance without substantial assistance from the central government.

In 1970 an expert committee on crop insurance, with Dharm Narayan as chairman, was appointed. This committee recommended that crop insurance should not be sold. The committee agreed with Pirolkar on the homogeneous area yield approach with compulsory participation of farmers, but felt that the government might have to bear a heavy financial burden if crop insurance was introduced. It also felt that the purpose of insurance could be served by encouraging farmers to save in formal financial institutions and by providing credit on liberal terms in cases of crop failure.

The central government did not accept the findings of the expert committee. It felt that with an insurance program farmers would claim benefits as a right and, therefore, crop insurance would be preferred over induced savings. The government also recognized that some variability in crop yield would always remain and it would not be possible to
rule out bad yields in some areas. The government, therefore, asked that the issue of introducing a crop insurance program on a voluntary basis be further examined.

In 1972, the Gujarat State Fertilizer Company in collaboration with the Life Insurance Corporation (LIC) of India introduced crop insurance in a district in Gujarat. The objective of the scheme which was voluntarily undertaken was to provide insurance coverage for loans required for the input intensive cultivation of cotton. As a consequence of the nationalization of general insurance, this scheme was taken over by the General Insurance Corporation (GIC) on January 1, 1973. Based on the pattern set by the LIC, the GIC implemented several other experimental crop insurance schemes for cotton, wheat, groundnuts and potatoes in selected areas of a few states. However, the GIC found that these schemes were uneconomic and unsuitable for implementation on a large scale.

The Present Program

The GIC contracted with Professor Dandekar of the Indian School of Political Economy in Pune to study the crop insurance program and suggest an alternative. In 1976 he recommended a homogeneous area yield approach with participation limited to borrowing farmers only.
Based on his recommendations, the GIC proposed to implement the program for a period of two to three years as a part of its research work in selected areas of the country. If any state or the central government wanted to continue the program beyond this period it would have to take the responsibility for the program beyond the pilot stage. The GIC stated that its role in crop insurance would be limited to conducting research with the aim of devising schemes suitable for implementation on a country-wide scale, building up an appropriate base for transacting crop insurance along scientific lines, and building up the technical expertise required for managing future crop insurance programs.

The GIC proposed to sell insurance in states that agreed to participate as coinsurers to the extent of at least 25 percent,²/ provide all necessary technical and administrative assistance, and accept responsibility for the program beyond the pilot stage.

The present program was started in 1979 with the GIC underwriting crop insurance in three states—Gujarat (for paddy, groundnuts, and cotton), West Bengal (paddy), and

²/ It was pointed out in an 'All India Seminar' that present laws do not permit states to be even the coinsurers. These laws would either have to be changed or a separate organization formed.
Tamil Nadu (paddy). The program is designed to protect both the farmers and the banks. Insurance policies are issued in favor of the District Cooperative Banks (or the commercial banks if the cooperative credit system is not operative in that area), which advance loans to farmers for the crop specified by the GIC. Only those farmers who borrow from official sources are covered under the present program. The coverage is limited to 110 percent of the principal amount of a loan up to a maximum of Rs. 2,000 (approximately $154 U.S.), per farmer.

There are separate schemes for different crops in both the Rabi (dry) and the Kharif (wet) seasons. Schemes are designed to cover production costs from unavoidable losses due to or arising from natural calamities, such as flood, drought, cyclones, hailstorms, frost, insect infestation, and plant diseases. The overall financial limit of insurance coverage for each crop and for each season in a state is fixed by the GIC. For example, the limit on the total sum that can be insured is Rs 20 million for the State of West Bengal with a sublimit of Rs 200,000 per police station.

Financial institutions are responsible for (1) paying crop insurance premiums to the GIC along with sending crop insurance proposals and normal credit eligibility statements and (2) receiving policies as well as indemnities when they
become payable and crediting the amount of the indemnity to
the loan accounts of their insured farmers.

Problems in the Indian Program

The homogeneous area yield approach used in the Indian
program uses the following crucial assumptions: (1) the only
factors affecting yields are natural hazards, (2)
homogeneous areas can be defined, (3) crop yields are not
increasing over time, and (4) appropriate risk classes can
be constructed using the coefficient of variation of area
yields. The exclusion of any of these may cause operational
problems for the program.

The first of these assumptions could have been true in
traditional agriculture where the use of cash inputs was
small. In modern agriculture, however, yield is partially a
matter of choice. The use of inputs can decrease because of
input shortages, high input prices, or lower prices of the
crop. Hazell (1982) has observed that the more likely cause
of yield variability in India is the unreliable supply of
irrigation (due to the unreliability of the electric power
supply) and fertilizer. This fluctuation in input supply
leads to lower area yields, making farmers in a region
eligible for compensation without the occurrence of natural
hazards. Thus, the insurance company would also be
indemnifying for market hazards.
The problem with the second assumption lies in defining homogeneous areas. Roumasset (1978) is skeptical about the existence of such an area. This view is also shared by Siamwalla and Valdes (1982), Newberry and Stiglitz (1981; quoted in Siamwalla and Valdes, 1982), and Walker and Jodha (1982), among others. To test for homogeneity in Andhra Pradesh, India, the coefficients of variation of the rice yield from the crop-cutting experiments in each taluk8/ and the year of the available data are summarized in Table 4.2. The coefficient of variation in both cases is quite high, confirming skepticism about taluks being homogeneous areas. If the correlation between the farmers' yields and the area yields is less than 1, the farmer may not be compensated in times of disaster and thus his demand for insurance may decline.

Problems with the third and the fourth assumptions arise from the procedure used to estimate premiums and indemnities. Yield estimates at the taluk level for the past ten years are used to classify areas into homogeneous risk classes, and uniform premiums are charged and indemnities paid to all farmers participating in the program in the area. Yield estimates are treated as observations from a normal distribution and standardized values for each taluk are estimated. These values are then pooled for all taluks

8/ A taluk is a revenue circle within a district.
Table 4.2
Frequency Table for Coefficient of Variation \(^1\) in Each Taluk for Rice, Andhra Pradesh, India, 1978-81.

<table>
<thead>
<tr>
<th>Coefficient of Variation (Percentage)</th>
<th>Wet Season</th>
<th>Dry Season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
</tr>
<tr>
<td>0 - 10</td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td>10 - 20</td>
<td>25</td>
<td>9.1</td>
</tr>
<tr>
<td>20 - 30</td>
<td>23</td>
<td>8.4</td>
</tr>
<tr>
<td>30 - 40</td>
<td>29</td>
<td>10.6</td>
</tr>
<tr>
<td>40 - 50</td>
<td>25</td>
<td>9.1</td>
</tr>
<tr>
<td>50 - 60</td>
<td>26</td>
<td>9.5</td>
</tr>
<tr>
<td>60 - 70</td>
<td>23</td>
<td>8.4</td>
</tr>
<tr>
<td>70 - 80</td>
<td>23</td>
<td>8.4</td>
</tr>
<tr>
<td>80 - 90</td>
<td>24</td>
<td>8.8</td>
</tr>
<tr>
<td>90 - 100</td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td>100 - 110</td>
<td>12</td>
<td>4.4</td>
</tr>
<tr>
<td>110 - 120</td>
<td>9</td>
<td>3.3</td>
</tr>
<tr>
<td>&gt;= 120</td>
<td>25</td>
<td>9.1</td>
</tr>
</tbody>
</table>

\(^1\) Coefficient of variation is equal to the standard expressed as a percentage of the mean yield.
and indemnity schedules obtained. However, no attention is given to the increase in yields over time; therefore, the risk classification is inappropriate.

There are a number of reasons why yields may appear to increase. Since the use of inputs, such as fertilizer and better seeds, that increase yield are increasing along with inputs that reduce variability and/or increase yield, such as pesticides and irrigation, farmers may expect and want to insure higher yields. Thus, the mean yield obtained from the past ten years may be an underestimate. In Maharashtra, for example, the guaranteed yield (75 percent of the mean taluk yield) of groundnuts in 1974 was less than the average yield in all years as far back as 1967 (Figure 4.4). This problem is also clear from the fact that not a single farmer participated in the insurance program in 1981 in Gujarat, one of three states where the pilot project to sell insurance was started in 1979, because the guaranteed yield was very low (Table 4.3). This is in spite of the tremendous increase in the amount of insurance sold as insurance coverage was extended to more areas in more states. This low coverage was also observed in a survey of 5,000 farmers in the Gujarat state. For example, for groundnuts, the farmers felt that the guaranteed yield proposed by the GIC would cover about half of the output per hectare (Maharaja, 1980).
FIGURE 4.4. GRAPH OF TALUK LEVEL YIELD ESTIMATES OVER TIME, SHAHADA, MAHARASHTRA, INDIA
Table 4.3
Indemnity Paid by the General Insurance Corporation in the Three States in which Crop Insurance was Offered Since 1979-80.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gujarat</td>
<td>7.5</td>
<td>15.6</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(0.27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Bengal</td>
<td>70.4</td>
<td>169.0</td>
<td>443.4</td>
<td>159.8</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>(0.31)</td>
<td>(0.38)</td>
<td>(3.91)</td>
<td>(7.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>451.2</td>
<td>141.9</td>
<td>25.2</td>
<td>369.4</td>
<td>248.8</td>
</tr>
<tr>
<td></td>
<td>(1.52)</td>
<td>(0.75)</td>
<td>(0.16)</td>
<td>(1.33)</td>
<td>(0.75)</td>
</tr>
</tbody>
</table>

Note: Values in brackets are loss ratios (= indemnity paid/premium collected).

Sources: Rao (1982).
The GIC classifies areas on the basis of the coefficient of variation. If it is assumed that farmers in one area are in the same risk category, i.e., farmers expecting higher yields as well as higher variability, some farmers may have more yield variability than others. This may be due to the use of better management practices, such as the use of high yielding variety (HYV) seeds and/or fertilizer. Thus farmers who are getting above average yields (and hence are in the same risk class, paying the same premium and receiving the same amount of indemnity), but who have a higher variability in their yield, would have little or no use for insurance because the loss covered by insurance in the absolute sense would be much less. For example, in the case of two farmers, one may get yield $X$ because he uses ordinary seeds while another may get $2X$ using the HYV seeds. If a calamity strikes, the first farmer would get yield $.5X$ and the second farmer would get yield $X$. If the coverage is 75 percent of $X$, the average yield of the area, then both would pay the same premium and get the same compensation of $.25X$. However, this is half of what the second farmer would expect for the same percentage of the mean coverage.

2/ The GIC defines it as the Mean Deviation expressed as a percentage of the mean yield. In the statistics literature it is equal to the standard deviation expressed as a percentage of the mean yield.
Farmers who feel that they are not adequately covered may not be willing to participate in the program, yet these progressive farmers may be better risks from the point of view of the insurance company. As some farmers leave, administrative costs per farmer rise. This makes the program more expensive for the remaining farmers, and may cause even more farmers to leave. As the number of participants declines, the insurance company may put a larger number of farmers in the same category to keep the program viable, or may drop the program altogether. Either way the resulting coverage may not be favorable to the farmers. The program could finally fail due to adverse risk selection.
CHAPTER V

AVAILABLE DATA AND THE SIMULATION APPROACH

The supply curve for insurance can be generated using the yield averages in a given area. However, the estimation of the demand curve requires information on the risk behavior of individual farmers. A utility function expressing this risk behavior can be used to obtain farmers' expected utility with and without insurance. A demand curve for insurance is then the maximum price a farmer is willing to pay as a function of the guaranteed yield, i.e., the risk protection.

Several utility functions have been used in the literature. This study uses the utility function

\[ U(W) = \frac{-K}{W}, \]

where \( W \) is the wealth of the individual farmer, and \( K+1 \) is the his coefficient of the relative risk aversion (RRA). It is shown in the section on the demand curve that this utility function satisfies the properties listed in Chapter III. The estimation of the expected utility using this function requires information on a farmer's total wealth which, in this study, is taken to be the sum of the net
value of harvest (the value of the harvest - the cost of inputs), denoted by I, and "other wealth" denoted by W0.1/ Thus, the total wealth of the farmer is W0+I. If the crop is damaged, the total wealth may decline because the reduced returns may not be enough to cover the input expenses. With insurance, a farmer receives an indemnity if his actual yield is less than the guaranteed yield in the individual approach or if the area yield is less than the guaranteed yield in the homogeneous area yield approach.

If the farmer is willing to pay a demand price DP for a level of insurance protection, C, and if f[I] denotes the indemnity as a function of return from the crop, then the expected value of his utility after purchasing insurance (EUI) is the expected value of

\[-(RRA-1)\]
\[(W0+I-DP+f[I]).\]  \hspace{1cm} (5.2)

The farmer buys insurance if the expected utility obtained above is more than the expected utility of wealth prior to purchasing insurance (EUN) which is the expected value of

\[-(RRA-1)\]
\[(W0+I).\]  \hspace{1cm} (5.3)

The maximum price that the farmer is willing to pay for a guaranteed yield is the value of DP for which the two

1/ "Other wealth" is the sum of the values of land, house, livestock, machinery, durable households, financial assets, and dues receivable minus the dues payable.
expected utilities are equal. A locus of points depicting this DP and the corresponding guaranteed yield is the demand curve of insurance.

The estimation of the expected utility, and hence the demand curve, requires data over time on the net returns and the "other wealth" of individual farmers on a regular basis. Such detailed data are usually very difficult to obtain, especially in developing countries where farm management data are not formally kept. In India, however, information on the average wealth of farmers in various farm size groups is available. Moreover, information on the risk behavior of farmers from other studies can be used as proxy for the RRA required for this utility function.

Information on yield distributions can also be obtained for most countries. For example, in India, data on crop-cutting experiments, which are conducted by the State Bureaus of Economics and Statistics for the purpose of estimating area yields, may be used to estimate yield distributions. The averages of farm management expenses at the state level, available from a survey conducted in 1971 by the Reserve Bank of India (1977), may be used to derive the estimates of the variable costs and returns per acre. This can be used in the simulation program to generate the crop returns for a representative farmer, which can then be used to simulate the demand curve.
This can be used in the simulation program to generate the crop returns for a representative farmer, which can then be used to simulate the demand curve.

The empirical distributions used in deriving the premium schedules are available after a crop insurance program has been in operation for several years. Information on wealth and crop returns may also be available from the past clients of the insurance company. Consumer surveys may still be needed to estimate the risk preferences and their relationship to wealth.

In the absence of available information on farmers' total wealth and net returns, computer simulation can be used to generate these numbers. Risk behavior from a study conducted by Hamal and Anderson (1982) in Nepal is used as a proxy for the risk behavior of Indian farmers. The data on crop-cutting experiments obtained from the Andhra Pradesh Bureau of Economics and Statistics are used to test the shape of the yield distribution for normality. Based on these tests the yield distribution at the taluk and lower levels can be treated as normal.2/

The estimation of the supply and the demand curves as well as the simulation approach and its appropriateness along with the procedure used are discussed below. Preceding 2/ For details, see the Appendix A.
this discussion, the data gathered for this study are described.

The Data

In India, crop-cutting experiments are conducted to obtain the estimates of the average yield per acre and the total production of the principal crops for the individual districts or group of districts important for the crop and for the state as a whole. The data on the crop yield estimates at the district level are regularly published and are available for a sufficiently long period of time. The data at the taluk and lower levels are not published and are not readily available. This information is, however, available from the state governments for the past few years and is used by the General Insurance Corporation (GIC) in developing the crop insurance program.

The first crop estimation surveys (CES) were done in 1939 by the Indian Statistical Institute (ISI) in Bengal. Initially, these surveys were done on jute alone, but their scope was later extended to cover rice and other crops. However, in most states, the present CES's have their origin in the technique of crop-cutting experiments initiated in 1943 by the Indian Council of Agricultural Research (ICAR). These surveys were started in the Punjab and the United provinces. Wheat was the only crop surveyed. Rice was
subsequently added and the scope was also extended to most other states (except Bengal and the then Princely states). In 1953 the National Sample Survey Directorate took over the coordination of the surveys and extended their scope to all nonfood crops. These surveys now cover all the principal crops in the major crop-growing districts in the country.

Depending on the administrative convenience and work-load, the surveys are conducted by the State Departments of Revenue and Agriculture. In some states the State Department of Statistics and the State Bureau of Economics and Statistics also help in conducting the surveys. In the case of paddy, for example, 15 percent of the experiments are conducted by the Bureau of Economics and Statistics and 25 percent by the Agriculture Department.

**Design of Surveys and the Sample Size**

The surveys were conducted by using a multistage stratified random sampling with the taluk as the stratum, and the village, the field, and a plot of specified size\(^3\/\) within the field as the primary, secondary, and the ultimate units of sampling, respectively. Random sampling without replacement was used in each stratum. Detailed procedures for conducting crop estimation surveys are specified in the manual issued by the Bureau of Economics and Statistics,

\(^3\/\) 5m x 5m approximately for rice, groundnuts, and sorghum.
Government of Andhra Pradesh (1975). The manual also describes procedures for selecting the plot, harvesting the crop, and reporting the results on appropriate forms.

To obtain a certain level of precision in the estimates, the Bureau decides on the total number of villages to be sampled. About 80 to 120 experiments per district are planned for each major crop-growing district. In minor crop-growing districts, the average number of experiments planned is about 45. For the state of Andhra Pradesh, 65,000 samples are generally planned. For the country as a whole about 198,000 crop cutting experiments are generally planned per year, 152,000 on food crops and 46,000 on nonfood crops. This is done on the basis of the analysis of the data from the previous year.

The number of villages to be sampled in a taluk is obtained by distributing the total number of villages over several taluks in proportion to the area used to grow a particular crop in those taluks. Villages from each taluk are then randomly selected, and from each selected village two fields growing the crop are then chosen at random. In the selected field a plot of specified size is further chosen randomly. The crop in this plot is cut and measured. In a specified number of cases the produce so obtained is sorted and dried to determine the weight of the dried produce. This procedure of selecting a plot and harvesting,
Available Data

The data on the district and the state level yield estimates are published and are available on a regular basis. Since these estimates are derived from the taluk-level yield estimates, which in turn are derived from the data on crop-cutting experiments, the latter two may also be available from the Bureau. However, because these may be destroyed after the publication of the district-level estimates, the number of years for which these are available differs from state to state.

Years for which the raw data for this study could be obtained on crop-cutting experiments for rice, groundnuts, and sorghum are summarized in Table 5.1. Information on the taluk-level yield estimates for the three crops was not available for a very long period. The number of years for which it was available for dry season rice is summarized in Table 5.2.

The Demand Curve

As explained above, the demand curve is the locus of points between the guaranteed yields and the corresponding values of insurance costs for which the expected utilities of wealth with and without insurance are equal. The determination of the price of insurance requires the shape
Table 5.1
Data Base for Estimating Crop Yield Distribution

<table>
<thead>
<tr>
<th>Crop</th>
<th>Season</th>
<th>Years 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice (Irrigated)</td>
<td>Wet</td>
<td>1978 to 1981</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>1978 to 1981</td>
</tr>
<tr>
<td>Rice (Unirrigated)</td>
<td>Wet</td>
<td>1978 to 1981</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>1978 to 1981</td>
</tr>
<tr>
<td>Groundnut</td>
<td>Wet</td>
<td>1978 to 1981 2/</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>1975 to 1981</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Wet</td>
<td>1978 to 1981</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>1978, 79, 81</td>
</tr>
</tbody>
</table>

1/ Crop years 1977-78, 1978-79, 1979-80, and 1980-81 were classified as good, good, very poor, and average years, respectively.

2/ Except 1979.
### Table 5.2

Number of Taluks for Which Yield Estimates were Available for Dry Season Rice, by Number of Years.

<table>
<thead>
<tr>
<th>Number of Years</th>
<th>Number of Taluks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>9</td>
<td>37</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
</tr>
</tbody>
</table>
of wealth with and without insurance are equal. The determination of the price of insurance requires the shape of the utility function. If it can be assumed that the farmer is a rational decision maker and that his preferences can be represented by a utility function \( U=U(W) \), then

\[ U = B - kW \quad \text{where } k > 0, \quad (5.5) \]

can be shown to satisfy the conditions stated in Chapter III, in the following way.

The first condition is that the marginal utility is positive, and it declines with increases in wealth. Using calculus, the marginal utility for the utility function used here can be obtained by differentiating the utility function with respect to wealth (i.e., \( U'[W] \)). The value of marginal utility so obtained can be differentiated again (i.e., \( U''[W] \)), and if the value so obtained is negative then the marginal utility is increasing. Its value is decreasing if the value obtained above is positive. The marginal utility obtained equals \( kAW \). Its value is positive since \( k, A, \) and \( W \) are all positive. Differentiating the marginal utility with respect to wealth the second time gives \( -KA(A+1)W \). Since \( K, A, \) and \( W \) are all positive, this term is obviously negative. Thus, the marginal utility increases at a declining rate with increases in wealth.
The second condition states that the absolute risk aversion coefficient declining with an increase in wealth, i.e., \( RA = \frac{-U''(W)}{U'(W)} \) is a declining function of wealth. The coefficient of absolute risk aversion (RA) for the utility function used equals \( A+1 \). Since \( W \) is in the denominator, it is a decreasing function of wealth. Finally, the third condition states that the relative risk aversion, which equals \( W^*RA \), is constant (as observed by Hamal and Anderson [1982]). The value of the RRA for the utility function is \( A+1 \). This is constant because \( A \) is constant. Thus the utility function satisfies all the properties stated above.

The total wealth of the farmer, \( W \), consists of net returns and "other wealth". For the purposes of this study, the total wealth is assumed to be known, except for the net returns from harvest. Thus the expected utility without insurance for RRA=3.75 is given by

\[
EUN = \int_0^{\infty} K \frac{e^{-\frac{(z^2/2)}}}{\sqrt{2\pi} (W^{*})} \, dz,
\]

(5.6)

where \( z \) is the standardized normal value of \( W \) for \( W>0 \).

After buying insurance, the farmer is indemnified if his yield is less than the guaranteed yield in the individual approach, or if the area yield is less than the
guaranteed yield in the homogeneous area yield approach. The indemnity can be denoted by \( f(I) \). The maximum amount that he is willing to pay for buying insurance being \( DP \), his wealth in the insured situation equals \( W_0 + I - DP + f(I) \), and the expected utility with insurance (EUI) is expressed by

\[
EUI = \int_0^\infty \frac{-(z/2)^2}{\sqrt{2\pi} (W_0 + I - DP + f[I])} dz ,
\]

where \( z \) is the standardized value of \( (W_0 + I - DP + f[I]) \), and the integral equals the expected utility with insurance.

The wealth of the farmer in the homogeneous area yield approach is the sum of two variables, \( I \), which is distributed as normal, and \( f(Y) = C - Y \), when \( Y \), the area yield, is less than \( C \); otherwise \( f(Y) = 0 \). Also, \( I \) and \( Y \) are not perfectly correlated. In other words, the farmer may not be indemnified when his individual yield is less than the guaranteed yield and vice versa.

Walker and Jodha (1982) graphically report correlations between farmers' yields and the village level average yields for a few crops for three villages in Andhra Pradesh, India. They estimated these correlations for yields for the years 1975 to 1981. The sample size for each crop was about 20. The median values of the correlations for sorghum, pearl

\footnote{The area yield is also expressed in rupees per hectare.}
millet, pigeon pea, and rice lie between 0.6 and 0.75. Since the Indian insurance program uses taluk yields (a taluk comprises several villages), an approximate value of 0.6 is used as the correlation between a farmer's yield and the taluk yield.

Since in the homogeneous area yield approach the individual farmer is indemnified on the basis of the area yield, an estimate of EUI requires a joint distribution of the two variables: the farmers' yields and the area yield. For the sake of simplicity it is assumed that the two yields have a bivariate normal distribution. The value of EUI in the homogeneous area yield approach can then be expressed by the formula

$$EUI = \int_{0}^{\infty} \int_{0}^{2.75} K \cdot h(I,Y) \frac{1}{\sqrt{2\pi|\Sigma|}} \exp\left(-\frac{1}{2} (W0+I-\text{DP}+f[Y]) \right) dI dY, \quad (5.8)$$

where $h(I,Y)$ is the joint distribution of $I$ and $Y$, and $\Sigma$ is the matrix of variances and covariances of $I$ and $Y$.

Once a procedure to estimate the expected utility is established, an estimate of EUI can be obtained by using the wealth of the farmer, which has been adjusted for the insurance cost, and the indemnity in the utility function. The insurance cost is increased to find its value for which EUI and EUN are equal. As stated earlier, a curve depicting this as a function of the guaranteed yield is then the
demand curve of insurance under the homogeneous area yield approach.

Use of the above function requires an estimate of K. Estimates of A and B are not needed since the preferences are invariant under linear transformations. Hamal and Anderson (1982) have observed that the RRA and the level of wealth did not have any relationship and have concluded that the RRA remains constant for all levels of wealth. In their data from Nepal, values of the RRA were scattered between 0 and 8 with the median value around 3.75; therefore, a value of 3.75 is used in this study. Its sensitivity for values of 2, 6, and 8 is also presented.5/

Wealth of a representative farmer in Andhra Pradesh is obtained using the farm management surveys conducted in 1971 by the Reserve Bank of India. These surveys provide information on the wealth of farmers by landholdings for all the Indian states (Reserve Bank of India, 1977). The average value of the wealth of the farmers in Andhra Pradesh is used as the wealth of the representative farmer in this study. Values for 1981 are obtained by inflating these values using the consumer price index.

The variance of the yield is obtained from the taluk level yield observations available for the various taluks.

5/ For RRA=1 the utility function is logarithmic.
The coefficient of variation (CV) for most taluks is observed to be around 1/4. Therefore an assumed CV of 1/4 is used to derive the values of the variances. For example, the mean values of the rice crop for the year 1981 is Rs 3,785 per hectare; thus, the standard deviation of the returns is then equal to Rs 946.\(^6\) These values are used to estimate the demand curve.

The Supply Curve

The pure premium can be derived using the formula described in Chapter III. However, since it is almost as easy to generate this in the simulation program, the pure premium schedule is also simulated in the study. An observation for the area yield is generated using the procedure described above. If the area yield is observed to be less than zero, its value is set equal to zero. Even though the probability of obtaining a value less than zero under the assumption of Mean Return=Rs 3785 and a standard deviation of 3785/4 is very low (.00003), the value of the yield is set equal to zero since the yield cannot be negative.

To estimate the premium for a guaranteed yield C, the following procedure is used. If the yield is less than C, an indemnity equal to C minus the yield is paid. The indemnity

\(^6\) Standard deviation = Coefficient of variation x mean returns.
is zero otherwise. This process is repeated 1,000 times. The average indemnity then is the pure premium needed for this level of guaranteed yield. The value of C is varied from 0 percent of the guaranteed yield to 100 percent in intervals of 10 percent to generate the entire curve.

The next step is to decide on the administrative expenses in order to obtain the supply curve. These costs vary with the procedure used to estimate the premiums and to pay indemnities. If the individual approach is used, the administrative expenses are high, and they are low if the homogeneous area yield approach is used. The administrative costs per farmer can also be reduced by making the program compulsory.

The administrative expenses and pure premiums of various programs, where available, could be used to derive the estimates of the administrative expenses for the Indian program. What is usually available, however, is information on the premiums paid by farmers and on the direct subsidies by the governments of a few countries to insurance companies in those countries (Table 5.3). Most programs also have some reinsurance arrangement with the government whereby the government provides additional subsidies to tide the company over in the case of a catastrophic loss. Farmers would have to pay an additional premium if this reinsurance were formally bought.
Table 5.3
Uses and Sources of Funds for Selected Agricultural Insurance Programs.

<table>
<thead>
<tr>
<th>Country</th>
<th>Currency and Unit</th>
<th>Period</th>
<th>Indemnity</th>
<th>Administrative cost (A)</th>
<th>Premium (B)</th>
<th>Subsidy (C)</th>
<th>(B+C-A)</th>
<th>(B+C)</th>
<th>(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>100 m Pesos</td>
<td>1963-78</td>
<td>8.2</td>
<td>1.1</td>
<td>4.2</td>
<td>5.1</td>
<td>12.0</td>
<td>13.6</td>
<td></td>
</tr>
<tr>
<td>Costa Rica</td>
<td>m Colones</td>
<td>1970-82</td>
<td>715.1</td>
<td>49.2</td>
<td>175.6</td>
<td>588.7</td>
<td>6.4</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>1000 m Cruzeiros</td>
<td>1975-80</td>
<td>22.2</td>
<td>1.4</td>
<td>6.1</td>
<td>13.9</td>
<td>7.1</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>m US $</td>
<td>1977</td>
<td>148.9</td>
<td>23.2</td>
<td>101.8</td>
<td>12.0</td>
<td>20.4</td>
<td>25.6</td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>m Pounds</td>
<td>1976/8-</td>
<td>237.6</td>
<td>15.2</td>
<td>165.0</td>
<td>65.0</td>
<td>4.6</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>billion Yen</td>
<td>1976-79</td>
<td>246.0</td>
<td>284.8</td>
<td>654.6</td>
<td>26.0</td>
<td>35.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>m Pesos</td>
<td>1981</td>
<td>7.5</td>
<td>13.7</td>
<td>9.2</td>
<td>11.9</td>
<td>64.6</td>
<td>185.0</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>1000 Rupees</td>
<td>1979/80-</td>
<td>855.7</td>
<td>1246.2</td>
<td>0.0</td>
<td>42.0</td>
<td>72.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: Pomerada (1986).
Rao (1982).
These values, therefore, have to be used with caution since there are many unreported costs, such as research work done by government departments, or data gathering as in the Indian case. Because of these hidden expenses, the reported administrative expenses as a proportion of total premium may be very low (see last column in Table 5.3).

Administrative expenses differ from country to country and, within a country, from crop to crop. For example, inspection costs, and hence overall administrative expenses, for fruit crops are higher than for food crops. Economies of scale, farm size, and infrastructure also affect administrative costs. All these factors make it difficult to estimate the costs for any program. Administrative costs for the U.S., the Philippine, and the Japanese programs are reviewed below, followed by the discussion of the estimation of these costs for the Indian program.

In the U.S. the insurance is sold by the Federal Crop Insurance Corporation (FCIC), a government agency, and also by private companies. The insurance is sold on a voluntary basis and farmers are indemnified on an individual loss basis. The FCIC pays 30 percent of the pure premium as administrative expenses to private companies. In addition it also incurs other administrative and actuarial expenses. According to Nelson Maurice, an ex-Vice President of the
Federal Crop Insurance Corporation, such expenses are about 10 percent of the pure premium. Thus administrative expenses for FCIC would be about 40 percent of pure premium (Maurice, 1985).

In the Philippines the indemnities are also based on the individual approach. The premium, however, is uniform over the whole nation (11 percent of the average yield). In 1981 (the first year of the program), the administrative expenses were 13.7 m Pesos ($1=18 Pesos). The premium written for that year was 21.2 m Pesos. Thus if the pure premium is taken as the premium minus the administrative expenses, then the administrative expenses are almost 183 percent of the pure premium. It should be noted, however, that these costs might be biased upwards since they are just for one year.

In Japan the program is compulsory for all farmers. Indemnities are based on individual yields. The information on premiums and indemnities is available for a long period of time. The average of the administrative expenses as a percentage of the pure premium (obtained by subtracting the administrative expenses from the total premium) over the period 1976-79 is 35.5 (Table 5.3).

From the experience of various countries' programs, it is obvious that administrative expenses are high. These
would be still higher in countries where farm sizes are small. Thus only a rough estimate of these expenses for the different levels of the guaranteed yields can be made for the Indian program.

Total administrative expenses can be broken into two components: (1) adjustment expenses and (2) "other" administrative expenses. Adjustment expenses are incurred when an indemnity payment is settled. "Other" costs comprise office administration expenses, commissions to sales agents, advertisements, taxes and brokerage, etc. Table 5.4 summarizes the ratios of the indemnities paid (loss incurred) and the adjustment expenses to the premiums earned and of the "other" costs to the premiums written for various lines of insurance in the U.S.

The adjustment costs increase with the increases in the number of cases settled, while "other" administrative expenses do not increase with the increases in the number of cases settled. Also, the probability that a farmer would suffer a loss and file for indemnity increases with the increase in the guaranteed yield for which he buys insurance.

7/ The premium written is the premium income minus the payment for reinsurance, and the premium earned is the premium written adjusted for unearned premiums.
Table 5.4

<table>
<thead>
<tr>
<th>Insurance Line</th>
<th>Loss Incurred/ (1)</th>
<th>Adjustment Expenses/ (2)</th>
<th>Other Expenses/ (3)</th>
<th>Administrative Expenses (2)+(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>55.9</td>
<td>4.5</td>
<td>41.4</td>
<td>45.9</td>
</tr>
<tr>
<td>Allied Lines</td>
<td>73.3</td>
<td>7.0</td>
<td>38.1</td>
<td>45.1</td>
</tr>
<tr>
<td>Home Owners Multiple-Peril</td>
<td>63.8</td>
<td>8.1</td>
<td>31.4</td>
<td>39.5</td>
</tr>
<tr>
<td>Farm Owners (Multiple-Peril)</td>
<td>74.2</td>
<td>6.2</td>
<td>36.8</td>
<td>43.0</td>
</tr>
<tr>
<td>Commercial (Multiple Peril)</td>
<td>70.4</td>
<td>12.6</td>
<td>40.0</td>
<td>52.6</td>
</tr>
<tr>
<td>Private Passenger Auto Liability</td>
<td>74.6</td>
<td>11.7</td>
<td>27.4</td>
<td>39.1</td>
</tr>
<tr>
<td>Private Passenger Auto and Physical</td>
<td>62.5</td>
<td>7.8</td>
<td>28.1</td>
<td>35.9</td>
</tr>
<tr>
<td>Reinsurance</td>
<td>82.3</td>
<td>5.4</td>
<td>32.4</td>
<td>37.8</td>
</tr>
</tbody>
</table>

1/ Indemnity paid as a percentage of premium earned.
2/ Adjustment expenses as a percentage of premium earned.
3/ "Other expenses" as a percentage of premium written.

This increase in the guaranteed yield leads to an increase in the adjustment cost incurred by the insurance company. Thus if an insurance company sells higher guaranteed yields, the adjustment expenses in the individual approach increase while "other" expenses remain the same. The adjustment expenses do not increase in the homogeneous area yield approach since indemnities are estimated on an area basis and not on the basis of an individual loss experience.

If insurance could be sold with the ratio of the administrative expenses to the pure premium the same as that in the U.S. programs (the total expenses as an average of the eight categories listed in Table 5.4), then administrative expenses would be around 42 percent of the total premium. Since adjustment expenses are high in crop insurance, they are assumed to be 12.6 percent of the total premium (the maximum value in Table 5.4). It is also assumed that these percentages of the total premium hold when the guaranteed yield is 75 percent, as offered in the Indian case.

Using these percentages, administrative costs for higher levels can be derived as follows. If it is assumed that administrative expenses, A, at various levels of
guaranteed yields is a linear function of \( P \), the probability of the farmer filing a claim, then \( A \) can be expressed by

\[
A = a + b \cdot P, \quad (5.9)
\]

where \( a \) and \( b \) are to be estimated.

At 75 percent of the mean yield as the guaranteed yield, the pure premium is Rs 77. If this is treated as 58 percent of the total premium, then the total premium is Rs 133. The adjustment expenses, which are 12.6 percent, will be Rs 17. Thus \( b \cdot P \) equals 17. At 75 percent coverage, \( P = 0.16 \) and therefore \( b = 106 \). The value of "\( a \)" can be estimated by subtracting 17 from 56 (133 - 77). Thus the administrative expense function can be specified as

\[
A = 39 + 106 \cdot P. \quad (5.10)
\]

The administrative expenses for various coverages can thus be calculated for a program in which the indemnity is calculated on an individual basis. If it is calculated on an area basis, as is done in the case of India, then the administrative expense would be almost constant, irrespective of the coverage offered.

8/ For example, at a guaranteed yield which is 75 percent of the mean yield if the standard deviation is .25 times the mean yield, the probability of a farmer claiming indemnity is 0.16.

9/ Most crop insurance programs offer this coverage level.
For the Indian case, when the administrative expenses are 72 percent of the pure premium for the present program, expenses for the individual approach could easily be assumed to be double (144 percent of the pure premium). However, following the Philippine experience, expenses may be still higher. Therefore, the lower level of administrative expenses in the individual approach is obtained by doubling the expenses obtained using equation 5.10. An estimate for a higher level of these expenses is obtained by tripling the value of 'A' obtained using equation 5.10. Similarly, for the homogeneous area yield approach, 72 percent of the pure premium (for a guaranteed yield equal to 75 percent of the mean yield) is used as an estimate of the lower level of administrative expenses, and 144 percent of pure premium as an estimate of the higher level of such expenses.

The Simulation Approach

The modern use of the word simulation traces its origin to the term "Monte Carlo Analysis" used in the late 1940s by von Neumann and Ulam who applied a mathematical technique to solve certain nuclear-shielding problems that were either too expensive for an experimental solution or too complicated for analytical treatment. The Monte Carlo analysis involves the solution of a nonprobabilistic mathematical problem by the simulation of a stochastic
process that has moments or a probability distribution satisfying the mathematical relations of the nonprobabilistic problem (Naylor, Balintfy, Burdick, and Chu, 1966).

With the advent of high speed computers in the early 1950s, simulation took on still another meaning because it had become possible to experiment with mathematical models, describing some system of interest, on a computer. Its use in social science research grew as laboratory-like experiments could be conducted using computers. Simulation may, thus, be defined as "a numerical technique for conducting experiments on a digital computer, which involves certain types of mathematical and logical models that describe the behavior of a business or economic system (or some component thereof) over extended periods of real time" (Naylor, Balintfy, Burdick, and Chu, 1966).

Relevance of Simulation to the Study

The integrals shown above in equations 5.6 and 5.7 are not easily integrable analytically even when $W_0$ has a simple normal distribution. The process is further complicated when the correlation is introduced in the homogeneous area yield approach (Equation [5.8]). Therefore a numerical procedure, like numerical integration and simulation, has to be used to obtain expected utilities, and hence insurance costs, at
various levels of guaranteed yields. A simulation approach, as opposed to numerical integration for solving the integral, is preferred in this study because empirical yield distributions (generally available after some years of experience with crop insurance) can be used for estimating premiums using the approach developed below.

The Approach

In this study, observations from the normal yield distribution are generated by using a random number generator and by appealing to the central limit theorem. Two sets of observations from the normal distribution are used to generate observations from a bivariate normal with a given correlation by a transformation procedure called the "square root method." This method is described below following the discussion of the approach used for obtaining observations from the normal distribution using random numbers generated on the IBM personal computer.

*Central limit theorem and the generation of a normal variable.* The central limit theorem states that if $x_1, x_2, ..., x_n$ are independently and identically distributed random variates with mean $m$ and variance $s_2$, then as $n$, the number of $x_i$'s, becomes very large, the sample mean of $x_i$'s approaches the population mean $m$ and variance $s_2$. Hence observations from the normal
distribution can be generated by averaging the independent observations from any distribution.

Random numbers between a and b are observations from a uniform distribution with the probability density function $\frac{1}{(b-a)}$. \hfill (5.9)

In this study numbers between 0 and 1 are used. The distribution has mean 0.5 and variance $\frac{1}{12}$. An observation from the normal distribution is obtained by adding 24 such numbers.\textsuperscript{10} This sum of 24 observations is distributed normally with mean 12 and variance 2. An observation of a standard normal variable can be obtained by subtracting 12 and dividing the result by $\sqrt{2}$.

**Generation of the bivariate normal variable.** The bivariate normal distribution can be generated from the identically and independently distributed normal variables by the use of the following theorem. If $\mathbf{z}$ is a standard normal vector, i.e., one containing independently distributed normal variables with zero mean and unit variance, then there exists a unique lower triangular\textsuperscript{11} matrix $\mathbf{C}$ such that

$$\mathbf{x} = \mathbf{Cz} + \mathbf{m},$$ \hfill (5.10)

\textsuperscript{10}Naylor, Balintfy, Burdick, and Chu (1966) suggest 12 or, for greater accuracy, 24 observations.

\textsuperscript{11}A lower triangular matrix has elements above the diagonal as zeros, i.e., $c_{ij} = 0$, where $c_{ij}$ is the $i$ and $j$ th element of the matrix, and $i < j$. 
where \( \mathbf{m} \) is the vector of means.

In this case the vector \( \mathbf{x} \) has mean vector \( \mathbf{m} \), and variance covariance matrix \( \mathbf{V} = \mathbf{C}\mathbf{C}' \). Here the vector \( \mathbf{m} = (m_1, m_2)' \) has two elements, the mean of the yield distribution expected by the farmer \( (m_1) \), and the mean yield of the distribution of the area yields \( (m_2) \). The matrix

\[
\mathbf{V} = \begin{bmatrix} v_{11} & v_{12} \\ v_{12} & v_{22} \end{bmatrix}
\]

(5.11)

has variances of the two yield distributions \( (v_{11} \text{ and } v_{22}) \) and the covariance \( v_{12} = r \times \sqrt{v_{11} \times v_{22}} \).

In order to obtain \( \mathbf{C} \), the square root method can be used which provides a set of recursive formulas for the computation of the elements of \( \mathbf{C} \).

\[
C_{11} = \sqrt{\text{Variance of } x_1},
\]

\[
c_{22} = \sqrt{(v_{22} \times [1-r])}, \text{ and }
\]

\[
c_{21} = r \times \sqrt{v_{22}},
\]

(5.12)

where \( r \) is the correlation coefficient. The values of \( X \) so obtained are observations from the yield distribution of the farmer \( (x_1) \) and from the area \( (x_2) \).

**Insurability and Subsidy**

As discussed earlier, if the program is available on an individual basis, the farmer is always willing to pay the
pure premium. However, a nontrivial equilibrium in the market exists if he is also willing to pay at least the administrative costs. As also discussed earlier, the administrative costs decline if the program is based on the homogeneous area yield approach. The demand for insurance, however, may decline depending upon the correlation between the area yield and the farmer's yield. These issues are analyzed in the next chapter using the simulation approach described above under the alternative values of various parameters.
CHAPTER VI

MONTE CARLO SIMULATION OF THE INDIAN PROGRAM

In this chapter the simulation approach described in Chapter V is used to estimate the levels of the guaranteed yields at which insurance could be sold under the various levels of administrative costs. The impact of under- or overestimation of the mean yield and/or the variance on the demand for insurance is examined along with the analysis of the relationship between r (the correlation between a farmer's yield and the area yield) and insurability, and the impact of relative risk aversion (RRA) on insurability. The effect of farm size on insurability is also discussed.

Supply and Demand Curves of Insurance

As explained in Chapter III, both the supply and the demand curves are upward sloping. The demand curve represents the maximum price that a farmer is prepared to pay to reduce a given amount of uncertainty about crop yields. At higher levels of guaranteed yields, the risk covered is significant and farmers may be willing to pay a higher insurance premium (cost). On the other hand, for lower levels of risk coverage they may be willing to pay
very small amounts or nothing at all. For example, since the probability of getting a yield less than 35 percent of the mean yield is less than one percent, farmers may be willing to pay almost zero insurance cost for this guaranteed yield.

On the supply side, even though the pure premium for the lower levels of the guaranteed yields is low, the administrative cost has still to be incurred and therefore premium costs are relatively high. Thus at the lower levels of the guaranteed yield, even though the demand price is close to zero, the supply price is relatively high. With an increase in the guaranteed yield, both the supply and the demand prices increase. However, crop insurance without a subsidy can be sold only if the demand curve intersects the supply curve in the positive quadrant. The simulated demand and supply curves and the possibility of equilibrium are discussed below.

The Supply Curve

As discussed in Chapter V, the supply curves for the individual and the homogeneous area yield approaches differ in administrative costs only. In the homogeneous area yield approach there are no inspection and settlement costs. In other words, administrative expenses do not increase with the increase in the guaranteed yield offered. Therefore, the present level of administrative expenses, which is 42
percent of the total premium or 72 percent of the pure premium (at a guaranteed yield equal to 75 percent of the mean yield), is treated as constant for all yields. The present level is Rs 56 per hectare and an upper level is obtained by doubling these expenses (columns 3 and 4 in Table 6.1).

In the individual yield approach, the administrative costs for the various levels of the guaranteed yields are obtained using the equation

\[ A = 39 + 106*P, \]  

(6.1)

where \( A \) is the administrative cost and \( P \) is the probability of the farmer's yield being less than the guaranteed yield. As also stated in the previous chapter, Equation (6.1) is derived using the administrative costs in the Indian crop insurance program adjusted for the reported expenses of selected lines of insurance in the U.S. It is also argued that since the costs obtained use the administrative expenses of the present Indian program, which is based on the homogeneous area yield approach, the expenses for the individual program might be at least double those obtained using Equation (6.1). These values (lower estimates of administrative expenses) for the various levels of the guaranteed yields are reported in column 5 of Table 6.1. As derived from equation 6.1, these costs are much higher at higher coverage levels. For example, for the guaranteed
Table 6.1
Pure Premium and Estimates of Administrative Expenses Under the Homogeneous Area Yield and the Individual Approaches.

<table>
<thead>
<tr>
<th>Guaranteed Yield (Rs/Ha)</th>
<th>Pure Premium</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 0</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(2) 10</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(3) 20</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(4) 30</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(5) 40</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(6) 50</td>
<td>4</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(7) 60</td>
<td>17</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(8) 70</td>
<td>50</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(9) 80</td>
<td>113</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(10) 90</td>
<td>217</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>(11) 100</td>
<td>376</td>
<td>56</td>
<td>112</td>
</tr>
</tbody>
</table>

1/ Guaranteed yields are expressed as a percentage of the mean area yield, Rs 3785.
yields of 80 and 100 percent, the administrative expenses in the individual approach are Rs 123 and 184, respectively, as opposed to Rs 56 in the homogeneous area yield approach.

To the extent that additional expenses have to be incurred, the total administrative expenses faced by the company would be even higher. These additional expenses may arise, for example, because the company has to bear or share some of the tasks now done by the banks or the government. The administrative expenses (A) obtained using Equation (6.1) are, therefore, tripled to obtain a higher estimate of these expenses and are reported for the corresponding values of the guaranteed yields as column 6 in Table 6.1.

Once the administrative expenses are ascertained, the premium for a certain guaranteed yield is obtained by adding the expenses for this level to the corresponding pure premium. As explained earlier, the pure premiums for the various levels of the guaranteed yield are also generated using the simulated program as described in Chapter V. These are summarized as column 2 in Table 6.2. As expected, pure premiums for the low levels of the guaranteed yields are zero.1/

1/ The actual value could be less than a rupee. However, values of the premiums were incremented by one rupee. Therefore, premiums less than one rupee are reported as zero.
Table 6.2
Pure Premium and Estimates of Supply Prices with Low and High Administrative Costs Under the Homogeneous Area Yield and the Individual Approaches.

<table>
<thead>
<tr>
<th>Guaranteed Yield (1)</th>
<th>Pure Premium (2)</th>
<th>Area</th>
<th>Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low (3)</td>
<td>High (4)</td>
</tr>
<tr>
<td>(Rs/Ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
<td>56</td>
<td>112</td>
</tr>
<tr>
<td>50</td>
<td>4</td>
<td>60</td>
<td>116</td>
</tr>
<tr>
<td>60</td>
<td>17</td>
<td>73</td>
<td>129</td>
</tr>
<tr>
<td>70</td>
<td>50</td>
<td>106</td>
<td>162</td>
</tr>
<tr>
<td>80</td>
<td>113</td>
<td>169</td>
<td>225</td>
</tr>
<tr>
<td>90</td>
<td>217</td>
<td>273</td>
<td>329</td>
</tr>
<tr>
<td>100</td>
<td>376</td>
<td>432</td>
<td>488</td>
</tr>
</tbody>
</table>

1/ Guaranteed yields are expressed as a percentage of the mean area yield, Rs 3785.
The supply curve is obtained by adding administrative expenses and the pure premium for each level of the guaranteed yield. To obtain the insurance premium at the low levels of administrative cost using the homogeneous area yield approach for a yield guarantee of 80 percent, the administrative cost of Rs 56 is added to the pure premium of Rs 113 for a supply price of Rs 169 (=113+56). These values are summarized in column 3 of Table 6.2. The supply prices for the higher levels of the administrative costs are similarly obtained by adding Rs 112 to the pure premium and are summarized in column 4.

The derivation of the supply curve under the individual approach is similar to the homogeneous area yield approach. However, unlike the homogeneous area yield approach, the administrative expenses in the individual approach increase with the increases in the guaranteed yield. The supply price in the individual approach, therefore, increases faster than it does in the homogeneous area yield approach with an increase in the guaranteed yield. The values for the individual approach are summarized in column 5 for low levels, and in column 6 for the higher levels of the administrative costs.
The Demand Curve

As discussed in the previous chapter, the demand price for a guaranteed yield is the value of insurance cost for which the expected utilities of the net returns with and without insurance are equal. The mean and standard deviation of the individual farmer's yield in the individual approach and area estimates of these parameters in the homogeneous area yield approach are used to estimate the premiums and indemnities. The area estimates of the mean and standard deviation may be different from those of the individual farmer. However, for the sake of comparison between the estimates of the demand prices using the two approaches, estimates of the mean and variance for both the farmer's yield and the area yield are treated as equal. The correlation between the farmer's yield and the area yield is equal to 0.6 for the homogeneous area yield approach, and it is obviously equal to one for the individual approach. The value of RRA used in the utility function is Rs 3.75 in both approaches.

2/ The standard deviation of the area yield will be the same as the standard deviation of the yield expected by the farmer only if the area is perfectly homogeneous. In general, depending upon the correlation between the farmer's yield and the area yield, the standard deviation of the area yield is less than that of the individual farmer's yield.
To simplify the estimation process, it is assumed that the farmer incurs the cost of inputs every season and the yield (expressed in rupees per hectare) is distributed as normal with a mean yield of Rs 3785 per hectare and a standard deviation of Rs 946. The values of the demand price for the two approaches at the guaranteed yields of 0 percent, 10 percent, ..., and 100 percent of Rs 3785 (the mean yield per hectare) are reported in columns 2 and 3 in Table 6.3.

As expected for the base case scenario, the demand prices in the individual approach are much higher than those in the homogeneous area yield approach. For example, for a guaranteed yield of 70 percent in the individual approach, farmers are willing to pay about 50 percent more than they are willing to pay in the homogeneous area yield approach. At the higher levels of coverage, the increase that they are prepared to pay declines in percentage terms. It is still significant in absolute terms—Rs 143 for 100 percent coverage as opposed to Rs 69 for a coverage level of 80 percent.

**Equilibrium**

Equilibrium in the insurance market exists if the supply and the demand curves intersect in the positive quadrant. To check this, the supply curves with lower levels
Table 6.3
Demand Curves for the Homogeneous Area Yield and the Individual Yield Approaches Under the Base Case Scenario. 1/

<table>
<thead>
<tr>
<th>Guaranteed Yield (Rs/Ha)</th>
<th>Area Yield Approach</th>
<th>Individual Yield Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>41</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>60</td>
<td>31</td>
<td>42</td>
</tr>
<tr>
<td>70</td>
<td>77</td>
<td>104</td>
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<tr>
<td>80</td>
<td>156</td>
<td>204</td>
</tr>
<tr>
<td>90</td>
<td>272</td>
<td>346</td>
</tr>
<tr>
<td>100</td>
<td>437</td>
<td>541</td>
</tr>
</tbody>
</table>

1/ Guaranteed yield is expressed as a percentage of the mean area yield, Rs 3785 per hectare.

2/ Base case scenario means that mean and standard deviation for both the area yield and the farmer's yield are the same (mean=Rs 3785 and s.d.=Rs 946 per hectare).
of administrative expenses and the demand curves in both the area and the individual approaches are plotted in Figure 6.1. The curves in the individual approach do not intersect at all, and those in the homogeneous area yield approach intersect at an insurance coverage of more than 90 percent. Thus, without a subsidy, insurance can barely be sold for a guaranteed yield of 90 percent or more using the homogeneous area yield approach, and it cannot be sold at all without a subsidy using the individual approach.

The Farmer's Mean Yield and the Mean Area Yield

Insurance companies essentially use area yields to estimate premiums and the individual farmer's yield to estimate indemnities in the individual approach. Since the same distribution is used in the homogeneous area yield approach, the premium and indemnity are, on an average, equal except for the cost of administration. If a farmer's mean yield is higher than the area yield, he is paid a lower and/or less frequent indemnity than he needs. In such a case, under the homogeneous area yield approach, he is also charged less than he should be for the same coverage (provided that the distribution differs in mean only). However, under the individual approach he is charged more than he should be charged because indemnities are based on his yield experience and the premiums are based on area yields.
FIGURE 6.1. SUPPLY CURVES WITH LOW ADMINISTRATIVE EXPENSES AND DEMAND CURVES IN THE BASE CASE SCENARIO, BOTH APPROACHES.
This difference in the two approaches is demonstrated in Figure 6.2, where B denotes the yield distribution of the farmer, and A denotes the yield distribution as perceived by the insurance company. It is obvious that the mean yield of B is higher than the mean yield of A. If C is the guaranteed yield, the shaded area below the curve, which represents the probability of loss, is greater for A than for B. This shows that the farmer is paying a higher premium than he should be. In the homogeneous area yield approach, distribution A is used for indemnification also, and therefore the farmer is paid more than his loss. Thus, on an average, except for administrative charges, the farmer is paid back the same amount as was charged from him as a premium. On the other hand, in the individual approach, distribution B is used for indemnification and thus the farmer is paid less than his actual losses, but is charged for a higher coverage of losses. The demand curve, therefore, would be expected to shift much lower for the individual approach than for the homogeneous area yield approach. The opposite would be expected when a farmer's yield is higher than the area yield.\(^3\)

\(^3\) In the individual yield certification option, as used in the U.S., the individual farmer's yield experience is used to estimate his mean yield. However, since this approach is not used in India, because smaller farm sizes in India and most other developing countries make this type of program very expensive to operate, it is not discussed here.
FIGURE 6.2. EFFECT OF THE DIFFERENCE IN MEAN YIELD ON THE PROBABILITY OF FILING A CLAIM.
The demand prices for the various levels of the guaranteed yields, when a farmer's mean yield is more or less than the area mean yield used by the insurance company, are estimated for the individual and homogeneous area yield approaches for guaranteed yields which are 0, 10, 20, . . . , 100 percent of the average yield. The demand price that the farmers are willing to pay for a guaranteed yield when the area yields used by the insurance company are Rs 2839, 3785, and 4731 (for the same variance), are also estimated.4/

The demand curves for the actual mean (Rs 3785) and with 25 percent underestimation (Rs 2839) under the two approaches are drawn in Figure 6.3. The guaranteed yield is on the X axis and demand prices are on the Y axis. The demand curves simulated using the individual approach with no underestimation and 25 percent underestimation are at the top and bottom, respectively. Two curves simulated using the homogeneous area yield approach lie between the two curves described above.

From Figure 6.3 it is clear that the difference in demand price (because of the difference between the mean yield of the farmer and the area yield) is much more in the

4/ These are summarized in Appendix B, Tables B-1 and B-2 for the individual and homogeneous area yield approaches.
FIGURE 6.3. DECREASE IN THE DEMAND PRICE WHEN THE INSURANCE COMPANY TREATS MEAN YIELD AS RS 2838 (UNDERESTIMATED BY 25 PERCENT), WHILE THE FARMER'S MEAN YIELD IS RS 3785, BOTH APPROACHES.
individual approach than in the homogeneous area yield approach. For example, if the insurance company perceives the yield to be Rs 2839 (25 percent less than Rs 3785), then for a guaranteed yield equal to 80 percent of the mean area yield, a farmer is prepared to buy insurance if it is offered for Rs 5 less (158-153) in the homogeneous area yield approach, as compared to Rs. 181 less (204-23) in the individual approach. Thus, if individual yields are not used for estimating premiums, the impact is much more serious in the individual approach than in the homogeneous area yield approach.

**Standard Deviation of Farmer's Yield and the Area Yield**

Since the same yield distribution is used for estimating indemnities and premiums in the homogeneous area yield approach, while in the individual approach different distributions are used, the effect of underestimating the standard deviation faced by the farmer is more severe in the case of the individual approach. The impact of this under- and overestimation in the two approaches is illustrated in Figure 6.4 and then analyzed below.

It is assumed that A denotes the yield distribution faced by the farmer, that the insurance company uses distribution B with a smaller variance to estimate premiums and indemnities, and that C denotes the guaranteed yield. The shaded area below the curve denotes the probability of a
FIGURE 6.4. EFFECT OF THE DIFFERENCE IN STANDARD DEVIATION ON THE PROBABILITY OF FILING A CLAIM.
farmer filing a claim. In the individual approach the farmer is charged a lower premium since the insurance company estimates that he faces a lower risk than he actually does (the shaded area below curve B being lesser than in A). In the homogeneous area yield approach, however, the farmer is also paid a lower indemnity since it is based on the same yield distribution with a lower estimate of the yield variance. The opposite happens when the roles of curves A and B are reversed.

The simulated demand curves for both approaches, when the standard deviations used by the insurance company (in rupees per hectare) are 710 (25 percent less than 946, the standard deviation faced by the farmer), 946, and 1180 (25 percent more than 946), are estimated for the guaranteed yields which are 0, 10, 20, ..., and 100 percent of the average yield. In the individual approach, the effect of underestimation is very significant. This is clear from the demand curves with a 25 percent underestimation of the standard deviation and the supply curves with high and low administrative expenses graphed in Figure 6.5.5/ The farmer is prepared to buy insurance coverage of 70 percent even when the administrative expenses are high. If the administrative expenses are low, the farmer is willing to

5/ The data used in this and the next figure for the area yield approach are summarized in Appendix B, Tables B-3 and B-4 for the individual and the homogeneous area yield approach, respectively.
FIGURE 6.5. EFFECT OF THE STANDARD DEVIATION ON THE DEMAND CURVE OF INSURANCE, THE INDIVIDUAL APPROACH.
buy coverage even for 60 percent of the mean yield, though he was not willing to buy any insurance when there was no underestimation. On the other hand, if the standard deviation is overestimated, the case for buying insurance is weakened.

The effect is not as dramatic in the homogeneous area yield approach. This is clear from the simulated curves showing the demand and supply prices in the homogeneous area yield approach (Figure 6.6). The farmer is still not willing to buy insurance if it is offered at a higher level of administrative expense. However, he is willing to buy insurance coverage for 75 percent of the mean yield if it is sold at the low levels of the administrative costs. The demand curve intersects the supply curve at a guaranteed yield of about 75 percent of the mean yield.

Relative Risk Aversion

As stated earlier, the risk behavior of the farmer is assumed to be expressed by the coefficient of relative risk aversion (RRA). Under the assumption of a constant RRA, the utility function is expressed by

\[ U(W) = \frac{-(RRA-1)}{W} \]

The higher the coefficient of risk aversion, the more the farmer is prepared to pay for the same risk exposure.
FIGURE 6.6. EFFECT OF THE STANDARD DEVIATION ON THE DEMAND CURVE OF INSURANCE, THE HOMOGENEOUS AREA YIELD APPROACH.
The value of RRA was speculated by Arrow (1965) to be equal to one and by Little and Mirlees (1974) between zero and four. For a sample of Nepalese farmers it was observed that the absolute risk aversion varied markedly between individual farmers and was significantly related to wealth, but that the relative risk aversion was unrelated. The value of RRA ranged between 0 and 8, and 75 percent of total observations were between 2 and 5, with a median value of 3.75 (Hamal and Anderson, 1982).

The demand prices for an RRA=6 and 8 at the guaranteed yields 50, 60, 70, ..., and 100 percent of the average yield for the individual approach are plotted in Figure 6.7. Supply prices with low and high administrative expenses are also graphed. It was shown earlier in this chapter that the farmer was not willing to buy any insurance when the RRA equals 3.75 (the base case scenario). However, he is willing to buy insurance for a coverage of 75 percent or more at the low levels of the administrative expense when the RRA equals 6. For an RRA equal to 8, he is willing to buy similar coverage even at the higher level of administrative expense.

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6/ The simulated values of the demand price for RRA=2, 3.75, 6 and 8 at guaranteed yields 0, 10, 20,..., and 100 percent of the mean homogeneous area yield are summarized in Appendix B, Tables B-5 and B-6 for the individual and the homogeneous area yield approaches, respectively.
FIGURE 6.7. EFFECT OF THE ERROR IN ESTIMATION OF THE RELATIVE RISK AVERSION ON THE DEMAND FOR INSURANCE, THE INDIVIDUAL APPROACH.
For the homogeneous area yield approach, the demand prices for an RRA equal to 6 and 8 are plotted in Figure 6.8, along with supply curves with low and high administrative expenses. It was shown earlier in the chapter that for RRA=3.75, a farmer is willing to buy insurance coverage for 90 percent or more, when it is offered at low levels of administrative expenses. For an RRA equal to 6 and 8, he is willing to buy insurance coverage of 75 percent or more at the low levels of the administrative expenses. At the high levels of the administrative expenses, he is willing to buy insurance only if the guaranteed yield is 90 percent or more.

From this simulation, it can be concluded that a good estimate of an RRA is crucial to determine the utility function and, hence, the demand for insurance. If this model holds, only highly risk averse farmers will buy insurance. The program would have to be subsidized to induce others to buy.

Correlation

The problem of the correlation between area yields and a farmer's yield being less than one arises in the homogeneous area yield approach only. In this approach a farmer is indemnified only if the area yield is less than the guaranteed yield. The more heterogeneous the area on
FIGURE 6.8. EFFECT OF ERROR IN ESTIMATION OF THE RELATIVE RISK AVERSION ON THE DEMAND FOR INSURANCE, THE HOMOGENEOUS AREA YIELD APPROACH.
which the area yield is estimated, the lower the correlation. The low correlation increases the probability of the failure to indemnify farmers who suffer losses, or to indemnify those who do not suffer losses. In the extreme case of zero correlation, the insurance becomes a lottery. At the beginning of the season, the farmer buys a lottery in the form of insurance, and if the area yield is less than the guaranteed yield, he is paid the winnings in the form of an indemnity.

At the other extreme, the homogeneous area yield approach would be the same as the individual approach (in which a farmer is always indemnified when his yield is less than the guaranteed yield) if the area yield is always the same as the individual yield. In other words, the two approaches are the same if a farmer's yield is perfectly correlated with the area yield, and the mean yield and the standard deviation of the farmer's yield are the same as those of the area.

To study the effect of correlation on the demand curve, the demand price for guaranteed yields 0, 10, 20, ..., and 100 percent of the mean area yields are estimated for correlations 1, .8, .6, .4, .2, and 0. Since the only objective here is to study the effect of correlation, the mean and variance of the farmer's yields are kept equal to those of the area yields.
If the correlation is less than one, the farmer is indemnified sometimes when he suffers a loss and is not indemnified at other times when he has not suffered a loss. He may also be indemnified for a loss different from his actual loss. As explained in Chapter II, if a farmer is risk averse, the marginal utility of a dollar in bad times is greater than the marginal utility of a dollar in good times. Thus the higher the correlation between his individual loss and the indemnity, the higher the premium a farmer would be willing to pay. Similarly, for the homogeneous area yield approach, the higher the correlation between the farmer's yield and the area yield, the higher the premium he would be willing to pay.

In the case of zero correlation, a farmer would never be willing to pay more than the pure premium for a certain level of a guaranteed yield. In fact he would only be willing to pay less than the pure premium since the marginal utility of a dollar in times of loss is more than the marginal utility of the same dollar when the harvest is good. The higher the correlation, the more the risk premium a farmer is prepared to pay. Thus for each farmer there is a certain critical level for which he would be willing to pay the pure premium only. For guaranteed yields above this level, his willingness to buy insurance would depend upon the administrative costs.
The simulated demand curves for correlations 1, .8, .6, .4, .2, and 0 which illustrate this relationship are summarized in Table 6.4. The guaranteed yield as a percentage of the mean area yield is in the first column, and corresponding values in Rupees per hectare are in the second column. The demand prices for insurance for correlations 1, .8, .6, .4, .2, and 0 are in columns 3 to 8, respectively. Supply prices using the homogeneous area yield approach with low and high administrative expenses are in columns 9 and 10, respectively.

At correlation 1, the same as the individual approach, the farmer is prepared to pay Rs 541 per hectare (14.3 percent of the average yield) per crop season for a guaranteed yield the same as the average yield. This declines to Rs 437 (11.5 percent of the average yield) for correlation .6, and to Rs 299 (7.9 percent of the average yield) for correlation zero. At correlation .6, the demand price is marginally more than the supply price at the present levels of administrative expenses. For correlations less than .6, the farmer is not prepared to buy insurance even if it is available at the low levels of administrative cost. He is also not prepared to buy it if the guaranteed yield is less than 90 percent of the mean yield. For the lower correlation of .4, he is prepared to pay Rs 387 for a
Table 6.4
Shift in the Demand Curve due to Changes in the Correlation Between the Farmer's Yield and the Area Yield.

<table>
<thead>
<tr>
<th>Guaranteed Yield</th>
<th>Demand Price of Insurance at Correlation</th>
<th>Supply Price With Administrative Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) (2) (3) (4) (5) (6) (7) (8)</td>
<td>Low (9) High (10)</td>
</tr>
<tr>
<td>(Rs./Ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>56 112</td>
</tr>
<tr>
<td>10</td>
<td>379</td>
<td>56 112</td>
</tr>
<tr>
<td>20</td>
<td>757</td>
<td>56 112</td>
</tr>
<tr>
<td>30</td>
<td>1136</td>
<td>56 112</td>
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<td>3028</td>
<td>169 225</td>
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<td>90</td>
<td>3407</td>
<td>273 329</td>
</tr>
<tr>
<td>100</td>
<td>3785</td>
<td>432 488</td>
</tr>
</tbody>
</table>
coverage level same as the mean area yield, which is marginally more than the pure premium of Rs 376 (Table 6.1).

For the high correlation of .8, the farmer is prepared to buy insurance at a higher level of administrative expenses if the guaranteed yield is equal to the mean area yield. He is prepared to buy insurance for lower levels of guaranteed yields if the administrative costs are low, but he is not prepared to buy even that if the guaranteed yield is less than 70 percent of the mean yield. For correlation =1.0, when the program is the same as the individual approach and administrative expenses are those of the homogeneous area yield approach, the farmer is prepared to buy insurance for higher levels of administrative expenses if the guaranteed yield is at least 90 percent of the mean yield. For the lower levels of the administrative expenses, he is not prepared to buy insurance if the guaranteed yield is less than 70 percent of the mean yield.

For correlation =0.6, the farmer is prepared to buy insurance only if the guaranteed yields of 90 percent (or higher) of the mean yield are sold and lower levels of administration costs are used. For correlation =0.4 and the guaranteed yield equal to the mean yield he is prepared to pay Rs 387, marginally more than the pure premium of Rs 376 (Table 6.1). For the lower correlations the farmer will not even pay the pure premium.
It is assumed that farmers are risk averse and that the coefficient of absolute risk aversion declines with an increase in wealth. Since risk aversion determines the amount of premium a farmer is prepared to pay, it can obviously be inferred that for the same land size a wealthier farmer is less risk averse and therefore prepared to pay a smaller premium for similar coverage. However, as his returns portfolio, and hence risk in relation to "other wealth", increases a farmer is willing to pay more to purchase the same insurance coverage. Thus, the difference between the demand prices that farmers are willing to pay depends upon the risk portfolio held by them. If large farmers are highly leveraged, then, even though they have more wealth, they may be willing to pay more premium than small farmers for the same coverage because of the higher risk faced by them. On the other hand, if small farmers hold a riskier portfolio, then they will be willing to pay more than large farmers.

The information on average wealth of farmers by classes of farmsize is available. However, as the number of farmers in each class declines with the increase in the farmsize, it would be inappropriate to take the midpoint of the farmsize classes an an estimate of average farmsize corresponding to
average wealth. Therefore an attempt to estimate the demand curve of farmers in various farmsize categories, and hence the impact of farmsize on the demand curve, is not made. These results were, however, observed in a survey of Gujarat farmers, and are summarized below.

The Gujarat State Fertilizer Company Limited surveyed 5,000 farmers during the crop year 1977-78 in Gujarat state to study the demand for insurance. Results of their survey for the three main crops, groundnuts, cotton, and wheat, grown on 20.78, 17.4, and 13.7 percent, respectively, of the total area are summarized below.

In the case of groundnuts, only 8 percent of the growers in the marginal group were interested in purchasing insurance. On the other hand 33 percent of the medium sized holders and 36 percent of the large sized holders were interested in buying insurance. In the case of light soil cotton, as many as 40 percent of the large and medium cotton growers were interested in purchasing insurance, as compared to only 20 to 30 percent of the farmers in the marginal and small holding group. In the case of wheat also, only 37 percent of the marginal land holders were interested in purchasing insurance whereas 45-50 percent of the medium and large farmers were interested in purchasing insurance (Maharaja, 1980).
Agriculture is the predominant sector in most of the developing countries. In India, for example, 80 percent of the population is associated with agriculture. The income of farmers, therefore, is of great importance to the governments of the developing world. Since crop yields are, to a large extent, dependent on weather conditions, and farm families continuously face economic uncertainty because of risks beyond their control, crop insurance has been perceived in many countries as a way of managing risks in agriculture.

Summary

In the individual approach to crop insurance, a farmer is compensated whenever his yield is less than the guaranteed yield. Premiums and indemnities are estimated using area yields and are adjusted using the actual crop yields of the individual farmer. Because it is difficult and expensive to separate crop losses due to insured causes from those due to uninsured causes, either farmers are compensated for both or the insurance company incurs high
administrative costs as a result of investigation expenses. Because of these expenses, the insurance companies might increase premiums, forcing farmers who are good risks for the insurance company to leave the program. These problems of moral hazard and adverse risk selection have severely affected the viability of insurance programs based on the individual approach.

In the homogeneous area yield approach, both indemnities and premiums are estimated on the basis of area yields. All insured farmers in the area are indemnified irrespective of their actual yield if the area yield is less than the guaranteed yield. Similarly, no indemnity is paid if the area yield is greater than the guaranteed yield, even to those farmers who have very low yields. Unless a farmer's yield is highly correlated with the area yield, he may be over- or undercompensated. This erratic compensation pattern may lead to a decline in the demand for insurance by farmers.

Thus the demand for insurance under the homogeneous area yield approach and its effect on insurability need to be analyzed further. Since the variance of area yields is less than the variance of the yield faced by the individual farmer, the effect on the demand for insurance by the high and the low risk farmers also deserves attention.
In addition, to understand the demand for and supply of insurance, the following relationships need to be analyzed: the effect of relative risk aversion (RRA) and of under- or overestimation of the mean and the standard deviation of the yield distribution expected by the farmer on the demand curve of insurance; the effect of lower values of the correlation on insurability in the homogeneous area yield approach; and the insurability of crop risks for the various levels of administrative costs and alternative demand curves. These are reviewed in Chapter I of this dissertation.

The benefits of crop insurance include a potential increase in food production, welfare benefits of stabilized consumption, and its complementarity to the credit policy. If crop insurance is not properly introduced, it can have adverse effects on both food production and credit programs. It should also be noted that crop insurance is only one of the risk reducing strategies used by governments. Various other programs, such as subsidies on inputs and outputs, disaster programs, and efficient credit programs, have also been used. The benefits and adverse effects of crop insurance and the alternatives to it are discussed in Chapter II.
The demand curve for insurance can be established using the expected utility theorem and assuming that farmers are risk averse. However, estimating the demand curve of insurance requires an estimate of the curvature of the utility curve. In this study, the curvature is derived using the assumption of the declining absolute risk aversion found in the literature and the estimate of the RRA from the results of the Hamal and Anderson study.

The supply curve can similarly be established by using the law of large numbers and by obtaining the estimates of the administrative expenses. Once these two curves are established, a market for insurance can exist only if the two curves intersect. This equilibrium is discussed in Chapter III.

The noninsurability of crop risks is argued on theoretical grounds in the literature. Roumasset was the first to present a theoretical argument against the insurability of crop risks. However, he uses the Arrow-Lind result, which can be shown to be erroneous, and thus his argument against crop insurance proves false. A critique of this and other studies arguing against crop insurance is presented in Chapter IV.

Chapter IV also has a review of alternative procedures used for selling crop insurance. Country programs can be
classified using factors such as specific-risk versus all-risk insurance, individual versus the group approaches, and compulsory versus voluntary participation. The Indian program and its potential problems are also reviewed.

The Indian program uses taluk level yield estimates from data collected by state Departments of Agriculture and state Bureaus of Economics and Statistics. The data at the district level and at higher levels are published. Since these are derived using the taluk level yield estimates, which in turn are derived using crop cutting experiments, data on the latter two are sometimes available from the state authorities. The data that the author was able to gather for the state of Andhra Pradesh are summarized in Chapter V.

The demand curve can be derived using estimates of the RRA and the average wealth of the farmer and the assumption of normality of the yield distribution expected by the farmer. However, it is very difficult to obtain the expected utility analytically because of the complexity of the integrals. Therefore, the simulation approach is used to derive the demand curve. This is also described in Chapter V.

In Chapter VI the Monte Carlo Simulation of the Indian Program, taking the approach described in Chapter V, is used
to estimate the levels of the guaranteed yields at which insurance can be sold under the various levels of administrative costs. The amounts of the subsidy required for the various levels of the guaranteed yield are also mentioned. The effects of under- or overestimation of the mean yield and/or variance on the demand curve are examined, along with the analysis of the relationship between $r$ (the correlation between the farmer's yield and the area yield) and insurability. The impact of the RRA and farm size on insurability is also discussed.

Conclusions

More and more countries, especially in the developing world, are introducing crop insurance. As a result, research is raising the following three questions:

1. Is there a case for crop insurance?
2. How well can crop insurance be implemented with the data available at the present time, and what additional data would be required?
3. Under what conditions can insurance be sold and when can subsidies to insurance be justified?

Is There a Case for Crop Insurance?

Governments of various countries consider the introduction of crop insurance important, while researchers feel that the introduction of crop insurance is not
economically efficient. The World Bank, in a policy statement, argues that the political benefits might outweigh the economic benefits and suggests that further research should be done in this area (Von Pischke, 1983). It takes the position that it should assist governments in developing measures that could provide them with a better basis for evaluating the suitability of proposals for crop insurance schemes.

The viability of an insurance program in the long run depends on whether the insurance company can sell insurance for a guaranteed yield that farmers will demand and at premiums farmers will find economically attractive. Insurance can be sold only if the farmers' demand curve for insurance intersects the supply curve.

Crop insurance programs, except those based on the homogeneous area yield approach, generally suffer from severe problems of moral hazard and adverse risk selection. However, programs based on the homogeneous area yield basis, like the one in India, suffer from difficulty in identifying homogeneous areas, the problem of a downward shift in the insurance demand due to a lower correlation between farmers' and area yields, and difficulty in isolating losses due to natural hazards from those due to market or moral hazards.
The simulation analysis conducted in this dissertation shows that insurance cannot be sold without a subsidy. The demand curve is below the supply curve even for low administrative expenses under the individual approach. However, the demand curve of highly risk averse farmers intersects the supply curve indicating that these farmers would be willing to buy insurance. Demand barely meets supply if, under the homogeneous area yield approach at the present level of the administrative expenses of the Indian program, the following conditions are met: (1) the guaranteed yield is the same as the mean area yield, and (2) the mean and standard deviation of the farmer's yield distribution are the same as those of the area yield. If it is assumed, however, that (1) Indian farmers have the same relative risk aversion (RRA) as was found for the Nepalese farmers by Hamal and Anderson, and (2) the correlation between their yields and the area yields is 0.6, then the insurance program is not viable.

A case for crop insurance could also be made on economic grounds if the benefit/cost ratio is more than one. However, the Japanese are involved in crop insurance even though the benefit/cost ratio of their insurance subsidy is observed to be about one-half. On the other hand, rates of return on other investments like irrigation and agricultural
research are observed to be very high. It may be advisable, therefore, to invest money in such projects.

Is Insuring with Available Data Feasible?

Most developing countries suffer from the problem of not having a reliable data base over a long time period (Ray, 1981). Even in a country like India, where the crop cutting experiments to estimate the district level yield have been conducted for some time, the data for yield estimates at the taluk (subdistrict) and lower levels are available for only a few years.

Data for longer time periods are required to estimate actuarially sound premiums, particularly for crops having a high yield variability (usually those with which lower input levels are used). The same would hold true for areas where variability is high. Thus, at the beginning, the chances of the success of a program would be higher in low risk areas, and the insurance company would therefore sell insurance in only those areas. In India, for example, the GIC sells insurance only in low risk areas.

To sell insurance successfully on the area yield basis, crop-cutting experiments or similar procedures would have to be conducted to estimate the area yields for various crops. Only then would a viable insurance program be possible. The government may also find it appropriate to set up an
independent organization to make these estimates. This could be done to avoid the possibility of an insurance company biasing estimates in its own favor. However, the added costs of gathering this data would also have to be taken into account. If the data are already collected for other purposes, then the marginal cost of conducting more surveys may not be that significant. This, however, would differ from country to country.

In India, for example, production and yield data at the district and higher levels are available. However, the present data are not sufficiently accurate at the taluk level. Therefore, more crop cutting experiments are required if the taluk level yield estimates are to be used for estimation of premiums and indemnities.

Under What Conditions can Insurance be Sold?

As shown in Chapter VI, insurance based on the individual approach can be sold only to high risk farmers. It could also be sold if the yields of the farmers are either overestimated or if their variances are underestimated or both. Farmers are also willing to buy insurance if their RRA is high (=8).

Using the homogeneous area yield approach, insurance can be sold if farmers' yields are highly correlated with the area yields and if the RRA is 3.75 or higher. Insurance
can also be sold at low levels of administrative costs if the guaranteed yield is the same as the area yield and the mean and standard deviation of farmers' yields are the same as those of the area. If these extreme conditions are not fulfilled, the program must be subsidized by the government.

If insurance is sold at lower levels of administrative expenses and RRA=3.75 and \( r \) (correlation between farmers' and area yields) = .6, subsidies of Rs 29, 13, and 0 per hectare would be required for guaranteed yields of 70, 80, and 100 percent of the mean yield. Since the area under small farms is 1178.4 thousand hectares in Andhra Pradesh, the total subsidy would be Rs 34.17, 15.32, and 0.00 million for the above levels of guaranteed yield.

If \( r=0.8 \) or if the RRA is at least 6, then no subsidy would be required for guaranteed yields of 80 percent or more. For a guaranteed yield of 70 percent a subsidy of Rs 16.15 million would be required if \( r=0.8 \) and RRA=3.75; and a subsidy of Rs 14.14 million to small farmers alone would be required for RRA=6 and \( r=0.6 \). 1/ These subsidies would be even higher if the administrative expenses were higher. Thus insurance can be sold if the RRA or the correlation or both are high.

1/ The total planned outlay for agriculture for Andhra Pradesh during the Sixth Plan (1980-85) was Rs 697 million.
The decision to subsidize crop insurance has to be looked at in the context of subsidies to agriculture in general and to crop insurance in particular. Various arguments have been put forward to make a case for subsidies to agriculture. For example, it has been argued that crop insurance is a short-run alternative to improvements in physical and institutional infrastructures, which require large investments and long gestation periods. To decide in favor of subsidizing crop insurance, a government has to determine if the same subsidy given in the form of other farm-related programs, such as disaster assistance, can show better results. The government may also be willing to subsidize crop insurance if it wants to promote the production of a certain crop, or the production of crops in general, in certain higher risk regions. Subsidies may also be justified if there are political motives to produce the crop domestically, instead of importing it.

Limitations and Recommendations for Further Research

Farmers face various types of risk. These include personal risks like illness or death in the family; damage to property and illness or death of livestock; risks due to the availability and variability in prices of inputs; variability in prices of farm produce; and risk due to yield variability. Crop insurance helps reduce only the risk to a
farmer's income due to yield variability. Thus this study addresses only the impact of a reduction in yield variability on farmers' incomes. Other risk management strategies, such as intercropping and the diversification of the farm enterprise by growing more than one crop or by using livestock, are also used by farmers. Incorporating these alternatives into the analysis would provide further insight in understanding farmers' attitudes to crop insurance.

Several key assumptions have been made in this study. In using the simulation approach to estimate demand and supply curves, the yield distribution of farmers is assumed to be normal. The coefficient of variation is obtained by averaging the coefficients of variation of the crop yields for individual taluks for rice. The mean yield of rice (Rs 3785 per hectare) for 1981 is obtained from the data on the value of the output in Andhra Pradesh as reported by the Indian Ministry of Agriculture. The coefficient of variation obtained above is multiplied by the mean value to obtain the standard deviation of the yield (Rs 947 per hectare).

To estimate the demand curve, it is assumed that (1) the marginal utility of wealth is positive and it declines with an increase in wealth; (2) the absolute risk aversion (as measured by Pratt [1964]) declines with increases in wealth; and (3) the relative risk aversion is constant.
Under these assumptions the utility function satisfying these assumptions can be derived. Different utility functions from the one used in this analysis would give different results. Thus there is some concern over the extent to which the results derived using this utility function can be generalized.

The average wealth of farmers for various income groups is obtained from the Debt and Investment Surveys conducted by the Reserve Bank of India in 1971. The value of wealth is inflated using the consumer price index to obtain the wealth of farmers in 1981. The value of the RRA is obtained from the Hamal and Anderson study done on small farmers in Nepal. Alternative assumptions about the value of the RRA can lead to different conclusions. The constancy of the RRA is also a limiting factor. As shown in Chapter VI, it plays a crucial role in estimating the demand curve. An error in its estimation can lead to very different results.

Further research could involve generalizing the simulation approach by using the yield distributions of intercrops grown in regions and by introducing the different yield correlations in these crops. In this way exact relationships faced by farmers could be introduced. The model could be further generalized by introducing the different correlations between the farmers' yield and area yields. A more general picture of the risks faced by farmers
could be obtained by introducing aggregations at the district and state levels and by introducing the correlations between them.

The model could be generalized further by introducing the time trend in the yields. A logistics curve has generally been used to explain the adoption of the high yielding varieties and other technologies. This curve could be used to generate the mean yields of the farmers over time. The yield distribution around these means could then be used to simulate the supply and demand curves.
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Appendix A

NORMALITY OF CROP YIELD DISTRIBUTION
NORMALITY OF CROP YIELD DISTRIBUTION

Crop yield distribution has received a great deal of attention in the recent literature. It was assumed to be normal until Day (1965) showed that crop yields follow a Pearson-type distribution. Since then a number of studies have shown that the crop yield distribution is not normal. As shown below the nonnormality observed is either not significant or is observable due to the time trend present in the data used for estimating the crop yield distribution. Thus there is not enough evidence to show that the crop yield distribution is nonnormal.

Arguments for and against normality are summarized below. This is followed by a discussion of the appropriateness of the method of moments and a description of the nonparametric tests used in the study. Empirical results are discussed last.

Arguments for Normality

The concept of normal distribution was first discovered by De Moivre in 1733. It arose in connection with the theory

Crop-yield distribution refers to the probabilities of a farmer achieving various yield levels once he makes the appropriate input and input-related management decisions.
of errors of observations. A theoretical explanation of the observance of normality of a large number of demographical and biological distributions is given by the central limit theorem, which states that if the errors are committed due to a large number of mutually independent elementary errors, the total error should be approximately normal (Crammer, 1956). Crammer further argues that even if the causes are not strictly additive and independent, the modifications of the central limit theorem may still be used to show that the distribution is approximately normal, or some distribution closely related to normal.

The normal distribution is symmetric about the sample mean and has a certain level of peakedness. These two behaviors of the distribution, the symmetry and the peakedness, can be measured by the coefficients of skewness.

\[ f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2\sigma^2}(x-\mu)^2} \]

where \( \mu \) and \( \sigma \) are mean and standard deviation, respectively.
(b1) and kurtosis (b2). The theoretical value of the higher moments for the normal distribution can be similarly obtained.

Day (1965) used the method of moments to show that the crop yield distribution is nonnormal. Since then several authors have tested the crop yield distribution for normality (Roumasset, 1976; Dandekar, 1977; Sun, 1980; and Thattil, 1980). Almost all the studies (except Dandekar's) used the method of moments and considered skewness and kurtosis as a measure of departure from normality. However, as Day has explained, these tests are in fact almost powerless in detecting alternative distributions whose b-coefficient values are similar to the normal distribution values of b1 = 0 and b2 = 3. If estimated values of these parameters are statistically significantly different from the ones stated above, then the distribution would be nonnormal. But so long as it is not different from the values expected under the null hypothesis of the underlying distribution being normal, the movement of skewness either

\[ \text{Skewness} = b1 = \frac{m_3}{m_2^2}, \text{ and kurtosis} = b2 = \frac{m_4}{m_2^2}, \]

where \( m_2 \), \( m_3 \), and \( m_4 \), are second third and fourth central moments, respectively. \( m_i \) can be defined mathematically as follows:

\[ m_i = \frac{1}{n} \sum_{j=1}^{n} (x_j - \bar{x})^i \]
way cannot be considered as a proof that the underlying distribution is nonnormal.

Dandekar (1977) used the chi-square test of goodness of fit. The test is good when the number of observations is large so that the whole range can be divided into several class intervals, and the test is powerful if most of the classes have a high expected frequency. The test is not considered to be very sensitive in measuring deviations from normality (Pearson and Hartley, 1970).

**Arguments for Nonnormality**

Several arguments have been advanced for the positive or negative skewness of the yield distribution. There are several reasons for the various shapes of the distribution as well as several reasons for wrongly observing the distribution as skewed when it is symmetrical. The two main reasons advanced for assuming that the yield distribution is positively skewed are the "common sense" and "biological lower limit" arguments. The former argument is put forward by Day (1965) who expects the crop yield distribution to be positively skewed because the likelihood of less than an average yield is greater than the likelihood of a higher than an average yield. This argument rests on the conjecture that good weather throughout a crop season occurs only in a few years while bad weather in one or more of the critical
stages of the crop season can occur more often. The biological lower limit argument is based on the fact that the yield cannot be negative, while the yield can be high when the weather is favorable. Thus the yield will be high in fewer cases, resulting in a yield distribution that is positively skewed.

A case for **Negative skewness** is based on the argument that just as the yield cannot be negative, it cannot be more than a certain limit either. Yields can be low in bad years, but when the field is irrigated, input levels are high, and management practices are good, the chances of getting larger yields are high. But they cannot be much more than average even in very good years because of the biological upper limit. This concept of the yield not being more than a certain limit despite increases in the level of inputs was stated as the "law of the minimum" as early as 1850 by von Liebig (Landzer and Paris, 1981). This negative skewness at high levels of inputs and labor has been observed by Thattil (1980) and is also mentioned in a study by the International Rice Research Institute (1980).

However, a significantly positive value of skewness can also be observed when the underlying distribution is normal due to the presence of a time trend or due to inappropriate pooling. It can be analytically shown that if the distribution is normal (except for the time trend), zero
skewness may be observed if the time trend is constant and a nonzero skewness if the time trend is not constant (Rustagi, 1983).

The analyses of Dandekar (1977) and Yeh and Sun (1980) seem to suffer from this problem. Dandekar uses taluk-level estimates of yield for the period 1965-66 to 1973-74. The yield estimates for one of the taluks (Shahada Taluk of Dhulia district in Gujarat), for which he gives the data in his paper, show a clear trend when plotted (Figure 4.4). This can also be shown for the whole state as the input use during this period rose at a very fast rate (Fertilizer Association of India, 1981). Yeh and Sun observe as well that the distribution is nonnormal after examining wheat yield data for 14 crop districts of Manitoba, Canada for 1920-70. The crop yield during this period similarly increased because of mechanical innovations and the use of better inputs.

A nonzero skewness can also be observed when an unequal number of observations from two or more places (with data from each place having normal distribution) are pooled. For example, a district with two taluks can be considered. The number of observations from one taluk can be very large (say 100) while the number of observations from the second taluk can be very small (say just 25). Also it can supposed that the distribution in both taluks is normal and the mean and
variance for the first taluk is higher than the mean and variance for the second taluk. When the data from these two taluks are pooled, negative skewness may be observed because of pooling. The opposite would be observed if the taluk with a large number of observations had very low yields as compared to another taluk with a large number of observations.

The results gained by Roumasset (1976), Thattil (1980), and the International Rice Research Institute (1980) use time series and cross-sectional data to test normality and observe nonnormality because of inappropriate pooling. Roumasset assumes the nonnormality of yield distribution. Since his sample does not support his hypothesis, he argues that the observance of values (of $b_1$ and $b_2$) not being statistically significantly different from normal may be because of the small sample size. To test whether $b_1$ and $b_2$ show significant departures from normality, he regresses $N$ (Nitrogen Level) on $b_1$ and $b_2$. He hypothesizes that if the yield distribution is normal then the coefficients of $b_1$ and $b_2$ would be zero. He rejects the hypothesis of normality on the grounds that the coefficients of $b_1$ and $b_2$ are not zero.

Although normality requires that skewness be zero, a skewness close to zero would be acceptable for practical purposes, e.g., crop insurance and, probably, risk studies. The changes in skewness with changes in nitrogen level
within this narrow band (as used by Roumasset) cannot be used to conclude that the crop yield distribution is nonnormal.

Day's (1965) results could also be coincidental. He shows that the Pearson family of distributions best fits the yield data. However, the probability levels of skewness and Geary's standardized mean deviation indicate that, except in the case of cotton, the skewness and kurtosis values are not statistically different from their respective values under the null hypothesis. Also, the graph of the time series in Day's study shows that a very good or a very bad year (which may occur once or twice in the whole century) could have caused the distribution to be positive or negatively skewed.4/

**Limitations of the Method of Moments**

In the method of moments, the first few moments only are considered and tested for their closeness to their respective values under the null hypothesis. For example, in the studies cited above, only the third and the fourth

4/ It is also worth noting that the fitting of Type I Pearson distribution—which takes almost any shape, depending on the value of the parameters—does not help in calculating insurance premiums (the main focus of this study). The insurance company is interested in a distribution that closely approximates the actual distribution and is stable over time so that the company does not have to change the procedure for calculating premiums every year.
moments are tested for their closeness to zero and three, respectively. For this reason, this method is powerless in detecting alternative distributions having the same b values (b1=0 and b2=3) as the normal distributions (Day, 1965).

Geary (1947), while proposing the test commented that the inferences based on the first few moments are too rough for statistical analysis when a high degree of efficiency is required. Moreover, while adjusting tables on sample moments when the universal normality cannot be assumed, Geary clearly states that any probabilistic inference derived using sample moments must be accepted with reserve. He states that this procedure is open to the objection that the moments derived from the sample may, in fact, differ substantially from the generally unknown universal moments.

Pearson and Hartley (1970), while describing the test of skewness, state that "for large samples, rough tests of normality may be obtained by comparing b1 and b2-3 with the approximate values of their standard errors, viz. \( \sqrt{\frac{6}{n}} \) and \( \sqrt{\frac{24}{n}} \), respectively." Similarly, for the test of kurtosis, Geary (1947) writes that for the power of the test to have a practical effect, certain compromises are necessary. Two such compromises are: (1) the sample size is large and (2) the set of alternative hypothesis is restricted.
Nonparametric Procedures to Test for Normality

The method of moments and the method of chi-square have been used to test the data for normality. Day (1965), Roumasset (1976), Thattil (1980), and Walker (1982) use the method of moments and Dandekar (1977) uses the chi-square test to test for normality. Except for Day, none of the authors who have used the method of moments take note of the fact that skewness and kurtosis only test whether the distribution is symmetric and $b_2=3$. In addition none of them take into account the fact that the above tests are not very powerful even when the tables for these tests are published (Geary, 1947).

Several nonparametric tests are, however, available in the statistical literature that compare the whole distribution with the distribution specified under the null hypothesis, and at the same time do not group the observations into classes. Two such tests are used for testing for normality in this study: the Shapiro-Wilks $W$ statistic and the Kolmogrov-Smirnov $D$ statistic. When the sample size is small (less than 60), the $W$ statistic is used, and when the number of observations is large, the $D$ statistic is used. The $W$-test is better than other parametric tests as it offers good power against a large number of alternative hypothesis even when the number of
observations is small (Reinhardt, 1979). This test, however, has to be modified when the number of observations is large (Royston, 1982).

When the sample size is greater than 60 the Kolmogrov-Smirnov D statistic is used. In the Kolmogrov-Smirnov test, cumulative values of the observed and the theoretical distribution are specified. The point at which the divergence between the two distributions is maximum is calculated. This divergence is then compared with the divergence that could have occurred due to chance. If the difference is small, the sampled observations are said to have come from the theoretical distribution.

The procedure used to conduct the test is as follows. Let, (1) $F_0(x)$ is the theoretical cumulative frequency distribution for all values of $x$ (i.e., $F_0(x)$ specifies the probability of getting a value of $x$ less than or equal to $x$); (2) $S_n(x)$ is the observed cumulative frequency distribution of the random sample of $n$ observations; and (3) $D(x)=F_0(x)-S_n(x)$. The distribution of $D$ under the null hypothesis $H_0$: $F_0(x)=S_n(x)$ is known, and the table giving critical values of $D$ are available. The value of $D$ so calculated is compared with the critical value. If the calculated value is larger than the critical value, the null hypothesis of agreement between the two hypothesis is rejected.
The Shapiro-Wilks test is based on an ANOVA type procedure. A ratio of the squared slope of the probability plot regression line, and the sum of squares around the mean is obtained. The statistic so calculated is a scale and origin invariant and hence it is appropriate to test a composite hypothesis of normality. The Shapiro-Wilks test involves the following procedures. Assume that the random sample of observations is $x_1, x_2, ..., x_n$. These observations are then arranged in an ascending order. The ordered observations can then be represented by $y_1 \leq y_2 \leq y_3 ... \leq y_n$.

To obtain the $W$ statistic, the following are computed:

$$S = \sum_{i=1}^{n} (y_i - \bar{y})^2$$

$$b = \sum_{i=1}^{n-1} a_{n-i+1} (y_{n-i+1} - y_i)$$

where $n$ is even. Table for values of $a_{n-i+1}$ are available for $n$ less than or equal to 50. If $n$ is odd then $b$ is calculated as follows

$$b = a_n (y_n - y_1) + ... + a_{k+2} (y_{k+2} - y_k)$$

where $k = (n-1)/2$.

Once $S$ and $b$ are obtained, $W$ can be obtained as follows:

$$W = \frac{b^2}{2S}$$
The value of $W$ is small when the sampled observations are from a normal distribution. If the value of $W$ is large, the null hypothesis of normality is rejected. Shapiro and Wilks (1965) compared various tests of normality with a sample of 20. They found the tests to be quite sensitive against a wide range of alternatives. They also found this test to be especially sensitive to asymmetry, long-tailedness, and short-tailedness.

Discussion

To study the behavior of normality at various levels of aggregation—over time and across geopolitical boundaries—the data for each crop and season is pooled at various levels and tested for normality. The results are summarized in Table A-1.5/ The table shows the percentage of the cases that can be considered normal (a sample is considered normal if H0: Normal cannot be rejected at alfa level .2). For the purpose of analysis the Table could be divided into two groups: irrigated and rainfed crops.

5/ Results obtained using the test of skewness also show a similar pattern. However, using the skewness test, the percentage of cases for which normality could not be rejected is relatively small. For example, for irrigated rice, the null hypothesis of zero skewness could not be rejected in 40.0, 51.2, 31.7, and 0.0 percentage of cases, respectively, when pooled over years by taluk, by taluk and by year, by district and by year, and by year for the state of Andhra Pradesh.
Table A-1
Percentage of Yield Distributions that are Normal/ at Various Levels of Time and Geopolitical Aggregation, Andhra Pradesh, India, 1978-81.2/

<table>
<thead>
<tr>
<th>Crop 3/</th>
<th>Pooled over years by taluk</th>
<th>Pooled by taluk by year</th>
<th>Pooled by district by year</th>
<th>Pooled by state by year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice, irrig. d.s.</td>
<td>85.0</td>
<td>59.2</td>
<td>50.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Rice, irrig. w.s.</td>
<td>78.6</td>
<td>66.2</td>
<td>37.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Rice, rainfed w.s.</td>
<td>27.0</td>
<td>58.6</td>
<td>30.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Groundnut d.s.</td>
<td>37.2</td>
<td>68.0</td>
<td>27.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Groundnut w.s.</td>
<td>38.3</td>
<td>57.0</td>
<td>22.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Sorghum d.s.</td>
<td>22.3</td>
<td>48.0</td>
<td>2.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Sorghum w.s.</td>
<td>22.3</td>
<td>43.5</td>
<td>1.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

1/ Normal not rejected at $\alpha \leq .2$.
2/ For groundnut, 1975-81.
3/ d.s. stands for dry season, and w.s. stands for wet season.

Note: Number of taluks tested for normality is 630 for rice over the four year period, 54 for groundnut over the six year period, and 23 for sorghum over the three year period.
In the case of irrigated rice, the number of taluks having a normal distribution is at a maximum when the data are pooled for each taluk over time. This is to be expected because of the absence of the effect of drought or some other major cause of damage, the occurrence of which in one year might lead to the observance of nonnormality. However, when the data are pooled at the district level, normality is observed in a much smaller percentage of cases. The distribution is observed to be nonnormal in all cases when the data are pooled at the state level for each year and at the state level over all years.

The behavior of normality in rainfed crops is similar to that of the irrigated crops when aggregated over geopolitical boundaries. However, unlike the case of irrigated rice, the percentage of cases having normal yields when the data are pooled over time for each taluk is less than the corresponding percentage when the data are not pooled over time.

For rainfed rice, the distribution is normal in 27 percent of the cases when pooled over time at the taluk level, and 58.6 percent of the cases when pooled for each year. In other words, pooling over time has caused nonnormality in a larger number of cases. This can occur because of extremely poor weather in one year. If the data
were extended over a very long period of time, the impact of poor weather in one year on the yield distribution would be reduced. However, looking at pooling at wider geopolitical levels, it can be observed that the percentage of cases in which the distribution is normal is reduced from 58.6 percent to 30.5 percent when pooled at the district level, and to 0 percent when pooled at the state level.

In the case of groundnuts, the percentage of cases having a normal distribution when the data are pooled at the taluk level is about the same as the corresponding percentage in the case of rice, and higher than the corresponding percentage for sorghum. The percentage of the cases with a normal distribution declines when the data are pooled at either the geopolitical boundary (district or state) or over time. The decline in the percentage, as in the cases of other unirrigated crops, is in sharp contrast to corresponding percentages in the case of irrigated rice. However, for groundnuts, the decline in the percentage of the cases having a normal distribution, while pooling geopolitically, is steeper than corresponding percentages for irrigated rice and less than for sorghum. For groundnuts in the dry season (when a larger area is irrigated), the percentage of cases having normal distribution is greater than for groundnuts in the wet season, when pooled geopolitically.
Like the case of groundnuts, percentages in the dry season for the other crops are higher than the corresponding figures in the wet season. While aggregating geopolitically, the decline in percentages in the case of sorghum is much steeper than the corresponding percentage for groundnuts or rice.

In summary, it is observed that the smaller the geographical region over which the aggregation is done, or the better the agroclimatic region, the higher the percentage of cases for which the yield distribution is normal. For crops like sorghum, which are grown in poor soils and under poor climatic conditions, bad weather in one year can distort the observance of normality. The nonnormality in a larger number of cases is also observed for rainfed rice, as compared to irrigated rice. However, if data for a longer time period were available, results closer to normality may be observed. Thus, on the basis of the above analysis, it can be concluded that the yield distribution expected by the farmer is normal.
Appendix B

TABLES
Table B-1
Effect of Error in Estimation of a Farmer's Mean Yield on his Demand Curve when Indemnities are Estimated on Individual Yield Experience.

<table>
<thead>
<tr>
<th>Guaranteed Yield (Percentage of Mean Yield)</th>
<th>Demand Price When the Area Mean Yield is 4732</th>
<th>3785</th>
<th>2839</th>
<th>Supply Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>78</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>78</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>78</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>79</td>
</tr>
<tr>
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<td>14</td>
<td>0</td>
<td>87</td>
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<td>60</td>
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<td>42</td>
<td>0</td>
<td>107</td>
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<td>0</td>
<td>104</td>
<td>6</td>
<td>152</td>
</tr>
<tr>
<td>80</td>
<td>0</td>
<td>204</td>
<td>23</td>
<td>236</td>
</tr>
<tr>
<td>90</td>
<td>0</td>
<td>346</td>
<td>64</td>
<td>368</td>
</tr>
<tr>
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<td>0</td>
<td>141</td>
<td>141</td>
<td>560</td>
</tr>
</tbody>
</table>
Table B-2  
Effect of Error in Estimating a Farmer's Mean Yield on the Demand Curve of Insurance, the Homogeneous Area Yield Approach.

<table>
<thead>
<tr>
<th>Guaranteed Yield (Percentage of Mean Yield)</th>
<th>Demand Price When the Area Yield is</th>
<th>Supply Price with Administrative Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4732</td>
<td>3785</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
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<td>0</td>
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<td>50</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>60</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td>70</td>
<td>85</td>
<td>81</td>
</tr>
<tr>
<td>80</td>
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<td>158</td>
</tr>
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<td>274</td>
</tr>
<tr>
<td>100</td>
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<td>437</td>
</tr>
</tbody>
</table>

(Rs/Ha)
Table B-3
Effect of Error of Estimation in the Standard Deviation on the
Demand Curve of Insurance when Indemnities are Based on an
Individual Basis.

<table>
<thead>
<tr>
<th>Guaranteed Yield (Percentage of Mean Yield)</th>
<th>Demand Price of Insurance when the insurance company uses s.d of 710</th>
<th>Supply Price with administrative cost (Rs./Ha)</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>78</td>
<td>117</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>78</td>
<td>117</td>
</tr>
<tr>
<td>20</td>
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<td>117</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>1</td>
<td>78</td>
<td>117</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
<td>11</td>
<td>79</td>
<td>118</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
<td>29</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
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<td>128</td>
</tr>
<tr>
<td>70</td>
<td>5</td>
<td>42</td>
<td>134</td>
<td>151</td>
</tr>
<tr>
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<td>104</td>
<td>232</td>
<td>152</td>
<td>204</td>
</tr>
<tr>
<td>90</td>
<td>363</td>
<td>368</td>
<td>236</td>
<td>297</td>
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<tr>
<td>100</td>
<td>530</td>
<td>368</td>
<td>444</td>
<td></td>
</tr>
<tr>
<td></td>
<td>560</td>
<td>652</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table B-4
Effect of Error in Estimation of Standard Deviation (s.d.) of a Farmer's Yield on the Demand Curve of Insurance.

<table>
<thead>
<tr>
<th>Guaranteed Demand Price of Insurance when the Insurance Company Uses s.d.</th>
<th>Supply Price with Administrative Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (Percentage of Mean Yield)</td>
<td>Low</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
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<td>50</td>
<td>8</td>
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<tr>
<td>60</td>
<td>25</td>
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<tr>
<td>70</td>
<td>66</td>
</tr>
<tr>
<td>80</td>
<td>137</td>
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<tr>
<td>90</td>
<td>245</td>
</tr>
<tr>
<td>100</td>
<td>401</td>
</tr>
</tbody>
</table>

(Rs/ha)
Table B-5

<table>
<thead>
<tr>
<th>Guaranteed Yield (Percentage of Mean Yield)</th>
<th>Demand Price of Insurance with Relative Risk Aversion</th>
<th>Supply Price with Administrative Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand Price</td>
<td>Supply Price</td>
</tr>
<tr>
<td></td>
<td>with 2</td>
<td>with 3.75</td>
</tr>
<tr>
<td>Rs/Ha</td>
<td>(Rs/Ha)</td>
<td>(Rs/Ha)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
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<tr>
<td>30</td>
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<td>81</td>
<td>104</td>
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<tr>
<td>80</td>
<td>167</td>
<td>204</td>
</tr>
<tr>
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<td>346</td>
</tr>
<tr>
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<td>477</td>
<td>541</td>
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</table>
Table B-6
Effect of Error in Estimation of the Relative Risk Aversion on the Demand for Insurance, the Homogeneous Area Yield Approach.

<table>
<thead>
<tr>
<th>Guaranteed Yield (Percentage of Mean Yield)</th>
<th>Demand Price of Insurance with Relative Risk Aversion</th>
<th>Supply Price with Administrative Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2  3.75  6  8</td>
<td>Low  High</td>
</tr>
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<td>56  112</td>
</tr>
<tr>
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<td>56  112</td>
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<td>0  0  0  0</td>
<td>56  112</td>
</tr>
<tr>
<td>40</td>
<td>40  1  2  3</td>
<td>56  112</td>
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<td>60  116</td>
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<tr>
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<td>77  94  110  162</td>
<td>73  129</td>
</tr>
<tr>
<td>70</td>
<td>139  156  179  201</td>
<td>106  162</td>
</tr>
<tr>
<td>80</td>
<td>156  179  201  225</td>
<td>169  225</td>
</tr>
<tr>
<td>90</td>
<td>251  272  301  328</td>
<td>273  329</td>
</tr>
<tr>
<td>100</td>
<td>414  437  467  495</td>
<td>432  488</td>
</tr>
</tbody>
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