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Crop Insurance and Agrochemical Use in the Manasi Watershed, Xinjiang, China

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This study investigates the environmental impact of a government subsidy program for crop insurance in China. It looks at how crop insurance scheme in Xinjiang province affects the way cotton farmers use fertilizers, pesticides and plastic agro-film. These three inputs cause significant environmental problems in the region and there is a need to ensure that their over-use is not encouraged.

The study finds that crop insurance helps protect farmers from the economic impact of crop failures, with a minimal negative impact on the environment. The only significant impact is a potential slight increase in agro-film use. In fact, crop insurance helps reduce the amount of pesticides cotton growers use. In light of these findings, the study concludes that a government-subsidized crop insurance program is an acceptable policy and proposes a number of ideas for minimizing any residual environmental impact it might have.

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CROP INSURANCE AND AGROCHEMICAL USE IN THE MANASI WATERSHED, XINJIANG, CHINA

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EXECUTIVE SUMMARY

The Chinese agricultural sector is characterized by two factors: 1) China has to feed 22% of the world's population with only 7% of the world's arable land; 2) farmers still account for roughly half of the country's workforce to date. As a result, the average size of a Chinese farm is about 0.6 hectares, and many farmers are working on poor land, facing low and unstable yields and incomes. Integration into the world market brings further pressure on farm prices, making farmers' lives even more difficult and government help more essential. Yet, policy choices are restricted by established bilateral and/or multilateral agreements. In searching for appropriate policy tools, government subsidies for crop insurance have been advocated as a policy alternative to support agricultural growth and farmers' incomes in China since the country joined the World Trade Organization (WTO). The arguments of the advocates are: 1) a crop insurance program will provide more stable incomes to farmers through indemnity payments (compensation) for crop failures; 2) government-subsidized insurance premiums for farmers will expand crop insurance coverage, helping more farmers; and 3) government subsidies for crop insurance are permitted by WTO rules. Therefore, they believe that a government subsidy for crop insurance is a good policy choice to help farmers and the agricultural sector. However, cautions have been raised as a crop insurance program may impact the environment negatively through increases in agrochemical use. This study explores farmers' behaviors with regard to agrochemical use under the current crop insurance scheme in order to identify if and to what extent participation in crop insurance has influenced the application of agrochemicals.

The research team collected farm household data from the Manasi Watershed, Xinjiang, where crop insurance has been bought by farmers for nearly two decades, and applied that data to a simultaneous equation system consisting of disaggregated input models. It was found that the decisions on fertilizer, pesticide and agrofilm applications did have different impacts on crop insurance participation, and were influenced by the latter in different ways. While agrofilm application is increased if the farmer purchases crop insurance, the application of pesticides is reduced. The application of chemical fertilizers increases as well, but the increase is not statistically significant.

The results imply that a government-subsidized crop insurance program is an acceptable policy alternative. If the government chooses to subsidize crop insurance, the subsidy will reduce the premium payment and hence encourage more farmers to participate in a crop insurance program. Under the current low-premium and low-indemnity policy, a crop insurance program is not likely to induce significant increases in agrochemical use. As a result, the expansion of the program will benefit a larger portion of farmers without costing the environment in any significant way.

1.0 INTRODUCTION

1.1 Problem Statement

The vulnerability of the agricultural sector in China due to lack of economies of scale, especially for bulk commodities, has become a hot topic after the country joined the WTO in 2002. Restricted by prohibitions against price and export subsidies, alternative policy measures to support domestic agriculture have been sought by the Chinese government in accordance with WTO rules. Budget subsidies for crop insurance, as one of the "Green Box" measures [1], have been advocated in expectation of stimulating production and providing more stable and higher expected income to farmers. However, as some previous studies have shown, crop insurance can encourage the application of agrochemicals and hence bring about negative impacts on the environment and jeopardize the future growth of agriculture. If this happens, the outcome of subsidizing crop insurance may contradict its policy goals in the long run. It is obvious that the potential environmental impact of crop insurance depends on farmers' decisions with regard to agrochemical application under current social, economic, and environmental conditions. This study tries to explore if farmers' decisions in favour of crop insurance participation is made simultaneously with those of agrochemical application, and if so, to what extent such decisions may impact the environment.

China, with a population of over 1.3 billion people and a cultivated land base of 130 million hectares, has been able to supply enough food for its growing population in spite of its limited cultivated land endowment. (Cultivated land per capita in China is about one-third of the world's average.) This accomplishment was achieved primarily by increasing the use of modern inputs and advances in agricultural technology. One of the key ingredients in increased agricultural production has been intensive farming on small-scale arable land, implying a corresponding increase in the application of agrochemical inputs, such as chemical fertilizers, pesticides, and so on (Huang et al. 2002).

The intensification of agriculture has greatly enhanced agricultural productivity. However, it has created serious problems of environmental degradation at the same time. Leaching of nitrates, pesticides and other agrochemicals into groundwater; and surface water pollution from soil erosion and nutrients and pesticides runoff have been frequently reported in China and have been found to be linked to intensified farming practice in many cases. Facing continuing deterioration of the quality of the rural environment and agricultural resource base, considerable attention has been given to the environmental effects of government agricultural policies that may encourage the greater use of chemical inputs in agricultural production.

As a consequence of joining the WTO, China may turn to more "Green Box" measures including subsidizing crop insurance. (There was no government subsidy for crop insurance yet, at the time of our study in 2005, but it has been advocated by many.). The

[1] In WTO terminology, subsidies in general are identified by "boxes" which are given the colours of traffic lights: green (permitted), amber (slow down — i.e. reduced), and red (forbidden). Green box subsidies must not distort trade, or at most, cause minimal distortion. They have to be government-funded (not funded by charging consumers higher prices) and must not involve price support (government administered prices, higher than prevailing market prices).

government now intends to encourage the development of crop insurance programs to cover more crops over larger areas, and to provide subsidies as an alternative policy instrument for supporting agriculture. However, any crop insurance program which affects crop production is likely to influence agrochemical use and thereby, has certain environmental impacts (Leathers and Quiggin 1991). There has been increasing agreement that crop insurance programs could potentially influence the environment through changes in agrochemical use (Horowitz and Lichtenberg 1993). It seems likely that crop insurance, which is aimed specifically at averting risks, could affect environmental quality through direct changes in input use decisions on existing crop land, and indirectly through changes in cropping patterns.

Though still not popular, crop insurance programs have been practiced in China for decades, especially in cotton production in the Xinjiang Uighur Autonomous Region. Due to the fragile nature of the environment in Xinjiang and the whole northwestern China, a thorough study of the relationship between crop insurance and agrochemical usage under current circumstances is essential to encourage the designing of an environmental-friendly insurance policy through a specific subsidy scheme, and for the government to make a better overall policy package in general.

1.2 Issues and Significance of the Research

With China entering into the WTO, both policy-makers and relevant interested groups such as economists and environmentalists, are looking for alternative mechanisms to protect farmers' incomes and the environment simultaneously. One often suggested mechanism is crop insurance. From a policy perspective, the issue of interest is the effect of crop insurance coverage on the use of chemical inputs, such as fertilizers, that affect environmental quality. How input decisions change under crop insurance schemes attracts increasing attention as it relates to the policy decision as to whether the government should subsidize crop insurance or leave farmers to rely on commercial schemes for crop insurance. If the application of chemicals increases under insurance, as suggested by Horowitz and Lichtenberg (1993), then it is likely that an insurance subsidy as a substitute for direct government payments will increase agricultural pollution. However, if chemicals use declines significantly under insurance, as concluded by Smith and Goodwin (1996), Quiggin, Karagiannis and Stanton (1993), and Babcock and Hennessy (1996), the environment may benefit from subsidized insurance programs.

As might be expected, the relationship between crop insurance participation and agrochemical application is likely to depend on the actual design of the insurance policy. Therefore, an empirical study on existing crop insurance programs is required to estimate their nature under current conditions. Although some provinces have begun to offer their own crop insurance programs to avert production risk in China, the China United Property Insurance Company (CUPIC) (formerly known as Xinjiang Corps Insurance Company) in the Xinjiang Uighur Autonomous Region, is the only one which has provided crop insurance programs for almost 20 years. The insurance coverage of crop production inside the Xinjiang Production and Construction Corps (XJPCC) has increased significantly in recent years, from 6.65% in 1986 to 83.56% by 2003 (CUPIC, 2004). However, with the increasing coverage of crop insurance, the environmental implications of this policy, such as chemical use, have not been investigated empirically. This research will examine the relationship between crop insurance purchase and agrochemical use decisions in a sample of cotton producers in the Manasi Watershed of Xinjiang, with a population of about 0.8 million and an area of approximately 20,000 km^2.

This study will seek answers to the following questions:

1. Do farmers' crop insurance purchases affect their decision on the type of chemical input used i.e., fertilizers, pesticides or agrofilm, and if so, how significant are the effects on the environment?

2. What factors influence farmers' crop insurance purchases and their decisions on agrochemical inputs?

3. What are the environmental and political implications of the effects of crop insurance?

It is believed that answers to these questions will help provide policy-makers with solid evidence on whether subsidizing crop insurance is an appropriate policy measure in supporting agriculture and farmers' incomes, or whether negative impacts will result. In addition, it is hoped that the findings of this study will provide further insights into farmers' decision-making processes and a better understanding of farmers' production behavior in general.

1.3 Objectives and Hypotheses of the Study

The primary objective of this study is to increase the understanding of the effects of the current crop insurance policy on chemical use along the Manasi Watershed in terms of the direction and magnitude of such impacts on agricultural non-point source pollution, and to discover the leading implications of such a relationship.

Specific objectives are:

1. To identify the factors that affect fertilizer, pesticide and agrofilm input decisions by voluntarily insured and uninsured farmers in the Manasi Watershed;

2. To examine the factors that affect the watershed farmers' crop insurance purchase decisions; and

3. To provide rough estimates of the relationship between each kind of chemical input and crop insurance purchase decisions from a sample of cotton farmers in the Manasi Watershed.

The research aims to test the following hypotheses:

1. A farmer's decision to purchase crop insurance is made simultaneously with that to use agro-chemical inputs; and

2. A farmer's decision to purchase crop insurance and use chemical inputs is either positively or negatively affected by a set of economic and demographic variables.

There are a number of economic and demographic variables influencing farmers' decisions. For example, if the crop is the major source of income and the yield fluctuates significantly, the farmer is more likely to participate in a crop insurance program. On the other hand, if the farmer is more experienced and/or has a larger portion of income from other sources, he is not likely to participate in such a program so as to avoid the cost (insurance premium). The hypothesized relationships between these variables and farmers' decisions are given in the model in Chapter 4.

1.4 Scope of the Research

The empirical research was conducted in the Manasi Watershed, Xinjiang, for practical reasons. Firstly, Xinjiang is one of the most important cotton-producing bases in China, and the Manasi Watershed is one of the three main cotton-producing areas in Xinjiang. Located at the center of Eurasia, the watershed is characterized by insufficient rainfall, drought and high evaporation since it is far away from the ocean. With a large land area, small population and infertile soil, agriculture here relies heavily on chemical fertilizers and other agro-chemicals, and cotton production uses chemicals more intensively compared with other commodity crops. Therefore, increasing attention has been paid to the environmental problems in this watershed. Secondly, farmers have been provided with crop insurance programs for 18 years here. The increased participation rate indicates that farmers are getting familiar with the real costs and benefits of crop insurance and hence are likely to take these into consideration when making production decisions.

The data used in this study came from both primary and secondary data sources. The primary data used to determine fertilizer, agrofilm and pesticide[2] use and crop insurance purchases at the individual level were collected from a sample of farm households. The survey was conducted in the Manasi Watershed (Manasi County, Shawan County, and the No. 8 Agro-Division and the No. 6 Agro-Division of the XJPCC).[3] Four hundred and fifty cotton farmers were randomly selected from the Manasi Watershed and 340 effective samples were used in the study.

The secondary data came from various official statistical publications and a variety of literature published in China. Information was gathered on agricultural production, utilization of agrochemical inputs, the current environmental situation, and agriculture insurance programs at various administrative levels (village, county, and province).

[2] The term 'pesticides' used in this research includes germicides, herbicides, and insecticides.

[3] The Xinjiang Production and Construction Corporation (XJPCC) was established in the 1950s as a semi-military unit, performing multi-roles such as organizing agricultural and industrial production, commerce and service, infrastructure construction and maintenance, and providing government administration, education, health care, etc., as well as supporting government armed forces in guarding the border. Its internal administration system was vertical under the planned economy (before the reform). There were 10 divisions under the XJPCC, and each division was divided into about 15 regiments. The function of the XJPCC has gradually changed towards a commercial enterprise in the last two decades. During the transformation, the regiment was renamed 'Tuanchang' to reduce its original military image, with each Tuanchang consisting of a total population of roughly 20,000 persons with about 10,000 farmers.

1.5 A Brief Summary of the Findings

The findings of this study confirm that the decisions on crop insurance purchase and agrochemical applications are most likely made simultaneously by cotton producers in the Manasi Watershed, Xinjiang. Farmers who apply more chemical fertilizers and agrofilm[4] are more likely to participate in crop insurance programs while those who apply more pesticides will do the opposite. At the same time, farmers who participate in crop insurance programs are likely to apply more agrofilm, and fertilizers, but less pesticides.

The findings also imply that environmental impacts are likely to be quite limited if the government subsidy does not dramatically change the terms currently stipulated in the crop insurance policy. Under the current crop insurance policy in our study area, a farmer who participates in an insurance program for cotton is entitled to receive an indemnity only if the actual yield is below 50% of the normal level, and the indemnity is no more than RMB 260 per mu or 40% of the production costs incurred. A low-indemnity policy is associated with low-premium: in order to participate in the crop insurance program, a farmer needs to pay only RMB 20 for each mu (about US$ 37 per hectare). Such a low-premium and low-indemnity policy is not likely to encourage farmers to increase agrochemical use. According to our study, insured farmers will increase application of agrofilm by 5% compared with those uninsured, while the increase in fertilizer application is insignificant and the application of pesticides is actually reduced.

Therefore, a government subsidy for crop insurance is likely to be an appropriate policy measure in supporting agriculture and farmers' incomes with China joining the WTO. Nevertheless, some remedies are suggested to counter the potential threats of the accumulated agrofilm residuals in the environment.

1.6 Organization of the Report

This introduction section is followed by a brief literature review. Section 3 provides the background of the study, including resources, cotton production, environmental issues and current practices in crop insurance in the Manasi Watershed. Section 4 describes the analytical framework and econometric models used in this research, and the empirical results are presented and discussed in Section 5. Finally, Section 6 summarizes the findings and implications, and provides brief policy recommendations.

2.0 LITERATURE REVIEW

Concerns about the potential impact of agricultural production on environmental quality have become prominent in policy discussions and environmental/economic literature. A number of theoretical and empirical studies have been conducted to analyze the impact of crop insurance on input use (for instance, Quiggin 1992; Ramaswami 1993;

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[4] Agrofilm is a kind of plastic film, widely used by farmers in drought and cold areas, to cover the field before sowing and/or during the growing season. It keeps in soil moisture and raises soil temperature. However, the small broken pieces can remain in the soil for decades, becoming a kind of pollutant and threatening the healthy growth of crops.

Horowitz and Lichtenberg 1993; Smith and Goodwin 1996; and Babcock and Hennessy 1996). Several empirical studies have estimated the intensive-margin effects of crop insurance on input use but have reached contradictory conclusions. The main reason is that production conditions (for example, climate and rainfall) and the parameters of crop insurance programs (i.e. coverage, indemnity and premium levels) are heterogeneous across regions and crops, and the assumptions of farmers' decision-making processes are different i.e., simultaneous or recursive. Some researchers argue that crop insurance purchase will have an impact on farmers' chemical input decisions but that chemical input decisions will not have an impact on the crop insurance purchase decision. That is to say, farmers make the decision to purchase crop insurance first and independently, and then decide their agrochemical uses accordingly. As the decision on agrochemical use depends on if the farmer purchases crop insurance but not vice versa, this decision-making process is known as recursive. On the contrary, others believe that farmers' decisions on crop insurance affects chemical inputs and vice versa, i.e., the two decisions are inter-dependent – this decision-making process is called simultaneous.

Smith and Goodwin (1996), in an econometric analysis on wheat farms in Kansas in which insurance and input decisions were determined simultaneously, concluded that nitrogen fertilizer expenditures decreased by US$ 5.00/acre with crop insurance. Their empirical results are in accord with more conventional views about the effects of insurance on input use. In a similar analysis, Quiggin, Karagiannis and Stanton (1993) concluded that Midwest corn and soybean farmers who purchased crop insurance decreased chemical applications by about 10%.

In contrast, Horowitz and Lichtenberg (1993) found that the purchase of crop insurance induced Midwestern corn farmers to increase their fertilizer applications by approximately 19% and pesticide expenditures by 21%. This relationship reflected a recursive structure in which the crop insurance decision influenced input use (but input use did not influence the crop insurance decision) on the assumptions that farmers were risk averse, that increased applications of fertilizer and pesticides raised the probability of low (below expected average) yields, and that the crop insurance decision had to be made before any inputs were actually applied.

With increased applications of fertilizers, expected yields will increase. At the same time, the probability of both low and high yields will increase as well meaning that the fluctuations in yield will become greater. Without crop insurance, farmers may not find increasing inputs desirable as the benefit of a higher expected yield will be offset by greater fluctuation (risk). However, if the insurance indemnity covers part of the loss when yield fluctuates downwards, the farmer who purchases crop insurance may want to increase agrochemical use in order to capture a high yield and return. This is the rationale behind the potential relationship between crop insurance and agrochemical use. In our case, because the amount of indemnity is small and the probability of receiving it is low, farmers who purchase crop insurance basically want to avoid the worst-case crop failure and not try to maximize their expected returns.

Models developed by Smith and Goodwin (1996) and Horowitz and Lichtenberg (1993) postulate that fertilizers and other chemical inputs have two distinct effects on yield distributions. In particular, the increased application of chemical inputs raises expected yields as well as the variance of yields. To the extent that the effect of the increased variance may be large enough to offset the increase in expected yields, additional chemical inputs may actually raise the probability of low yields. If the losses due to low yields could be indemnified by insurance, farmers may wish to increase their application of chemical inputs. In this case, they will enjoy higher incomes when yields are high while getting indemnity from crop insurance if the yields turn out to be low. Theoretically, therefore, insurance (which reduces the exposure to risk) has an ambiguous effect on chemical application rates, including fertilizers, pesticides and agrofilms, depending on the actual characteristics of the insurance programs.

However, it is widely accepted that pesticides do not increase yield potential but may reduce the probability of low yields caused by disease and pests, i.e., reduce low-end yield fluctuations. They only reduce the probability and extent of losses from low yields when damaging agents such as insects and pests are present (Lichtenberg and Zilberman 1986). Thus, the increased application of pesticides should result in a decreased probability of low yields, which suggests that a farmer who insures against low yields should decrease, not increase, pesticide use (Babcock and Hennessy 1996). As the purpose of purchasing crop insurance and applying pesticides are both to reduce the probability obtaining low returns, they may substitute for each other. Therefore, a farmer who decides to purchase crop insurance may reduce pesticide application; and a farmer who intends to apply more pesticides may not want to purchase crop insurance. As Horowitz and Lichtenberg (1993) point out, fertilizers must be applied at levels that do not adversely impact the yield when growing conditions are bad, for example, nitrogen fertilizers are widely known to cause burning and reduction of yields when there is low rainfall. However, such fertilizers also increase yields when growing conditions are favorable. So, the idea is that as a result of moral hazard[5], the likelihood that the purchase of crop insurance will encourage the use of more chemical inputs seems low.

Babcock and Hennessy (1996), in a Monte Carlo analysis of crop insurance for Iowa farmers, found that crop insurance schemes were likely to lead to relatively minor reductions in the applications of nitrogen fertilizers if coverage levels were at or below 70% of the mean yield. If the coverage level was 90%, a farmer with a high risk aversion will reduce his fertilizer application rate by 10%. Their findings imply that not only risk attitudes, but also the degree of crop insurance coverage influenced the average per acre chemical use dramatically.

A careful comparison of these previous studies suggests that the relationship between crop insurance participation and agrochemical input application depends on farmers' decision-making behavior, production conditions, and the terms of the crop insurance program. Therefore, whether any specific crop insurance program has or does not have a negative environmental impact in specific locations is a problem that requires empirical investigation. However, such empirical investigations will provide insights into farmers' behavior, especially with production decision-making, and useful information in designing environment-friendly crop insurance policies and programs.

[5] Moral hazard arises when input use is altered due to asymmetric information and incompatible incentives (Nelson and Loehman 1987).

3.0 BACKGROUND OF THE RESEARCH

3.1 Resources and Cotton Production

The Manasi Watershed of Xinjiang was chosen for this research for two reasons. Firstly, any empirical research requires relevant data and Xinjiang is the only place where crop insurance has been available to cotton producers for almost two decades. Secondly, the natural conditions for agricultural production are extremely unfavorable in Xinjiang compared with most other regions in China, making it an ideal place for testing if crop insurance programs have negative impacts on the environment. If a crop insurance program benefits farmers in this region without damaging the environment, it is quite likely to do the same in other regions of China.

Xinjiang is the largest inland province[6] in northwest China, but it has limited natural resources and harsh conditions for agricultural production. While the total land area is 1.66 million km^2, accounting for 16.67% of the nation's total land area, the cultivated land in Xinjiang covers 4.12 million hectares, accounting for only 3.17% of the national total. More than 60% of land there is classified as mountains, deserts or saline-alkaline soils, while only 4.47% of the land surface there is under cultivation, less than 20% of the national average. This indicates the fragile nature of Xinjiang's environment. The forest coverage percentage of land area is only 1.9%, also far below the national average of 16.55%. (See Table 3.1 for details.)

Table 3.1 Cultivated and Crop Sown Areas in Xinjiang and China (2002)

	Total land area ('000 km^2)	**Cultivated area (million ha)**	**Crop sown area (million ha)**	**Forest coverage rate percentage (%)**
Xinjiang	1664.9	3.99	3.48	1.9
China	9600	130.04	154.64	16.55

Sources: Xinjiang Statistical Yearbook (2003); China Statistical Yearbook (2003)

Note: 'Cultivated land' is classified as the land primarily used to grow crops while 'crop sown area' is the actual area of cultivated land covered by crops in a certain time period, usually a year in statistics. If a part of the cultivated land is left untended, the sown area is less than the cultivated area. If part or all of the cultivated land is used to grow two or more crops a year, the sown area will be greater than the cultivated one. This is why the sown area is less than the cultivated area in Xinjiang, but greater for the nation as a whole because multi-cropping is practiced in many parts of China.

[6] Actually it is named Xinjiang Uighur Autonomous Region with the same administrative status as a province. As a minority autonomous region (a kind of administrative unit in China where minority races make up the majority of the population), it enjoys greater power in local legislation compared with a province.

A more severe problem than the harsh terrain is fresh water supply. The annual precipitation is only about 150 mm in Xinjiang, compared with the national average of 630 mm, and a large portion of the precipitation falls onto mountains instead farmlands. In contrast, the evaporation in Xinjiang is very high, ranging from 1,500 to 3,000 mm annually. Although there are about 320 rivers in Xinjiang, most of them are short inland rivers with melted ice and snow from the high mountains as their sole water source. Almost no surface water flows in from outside Xinjiang as it is surrounded by mountains. It has been well recognized that the acreage of cultivated land in Xinjiang depends on water supply, and that the total water supply there is limited due to climate and topographical conditions. Groundwater is widely used in northern Xinjiang, often making existing problems such as salination worse, in addition to falling levels of the groundwater itself.

As in most regions in China, crops in Xinjiang comprise the most important sub-sector in agriculture (which also includes animal husbandry, fishery and forestry in China), contributing to about 70% to the total value output of the country's agriculture. However, cotton is very important in Xinjiang. As a high-quality cotton producer, Xinjiang is one of the most important cotton-producing bases in China today. The cotton sown areas increased very rapidly from 181.22 thousand hectares in 1980 to 943.97 thousand hectares by 2002, while the output increased from 79.2 thousand (metric) tonnes to 1,477 thousand tonnes during the same time period (See Table 3.2 for details.). As a result, Xinjiang's shares in cotton sown area and output rose to 22.56% and 30.51%, respectively, of the national totals in 2002.

Table 3.2 Cotton Production in Xinjiang and China

	Sown areas ('000 hectares)			Output ('000 tonnes)		
	China	**Xinjiang**	**Xinjiang's share (%)**	**China**	**Xinjiang**	**Xinjiang's share (%)**
1980	4920	181.22	3.68	2707	79.2	2.93
1985	5141	253.52	4.93	4147	187.8	4.53
1990	5588	435.22	7.78	4508	468.8	10.40
1995	5422	742.99	13.70	4768	935.0	19.61
2000	4041	1012.39	25.53	4417	1500.0	33.96
2002	4184	943.97	22.56	4916	1477.0	30.51

Source: Calculated by authors using data from the Xinjiang Statistical Yearbook (2003) and the Rural Statistical Yearbooks of China (1987, 2002 & 2003)

The XJPCC was established in the 1950s as a semi-military unit, performing multi-roles such as organizing agricultural and industrial production; commerce and service; infrastructure construction and maintenance; and providing government administration, education, health care, etc., as well as supporting formal armed forces in guarding the border. Its internal administration system was vertically structured under the former centrally planned economy. Following the economic reform which started in 1978 in China, the XJPCC gradually shifted to a profit-making organization with a decreasing role in government functions, and decision-making has been slowly decentralized as well.

The XJPCC is, however, still a big agricultural producer. There are currently 14 divisions under the XJPCC, and each division is divided into about 15 regiments ('regiment' has been renamed 'Tuanchang') with each consisting of a total population of roughly 20,000 people including about 10,000 farmers, and of arable lands of approximately 160 thousand mu.[7] The cultivated land under the XJPCC increased from 77.3 thousand hectares in 1954 to 1,057.08 thousand hectares in 2002, accounting for 26.5% of the provincial total. Per capital of cultivated land is 1.55 hectares within the XJPCC, much higher than the provincial average of roughly 0.2 hectares and the national average of 0.1 hectare (XJPCC 2003).[8]

Cotton has become a dominant crop in the XJPCC since the early 1980s, with sown areas increasing from 65.09 thousand hectares in 1980 to 453.59 thousand hectares by 2002. Cotton's share of the total crop area is above 40% within the XJPCC, much greater than the provincial average of 27% and national average of less than 3%.

Because farmers inside the XJPCC may still be under a strong administrative influence when making production decisions, a larger region covering both the XJPCC and ordinary villages with similar production conditions, is desired. As stated earlier, the Manasi Watershed is a specific region consisting of Manasi County, Shawan County, the No. 8 Agro-Division and the No. 6 Agro-Division. Manasi County and Shawan County are home to ordinary rural communities, while the No. 8 and No. 6 Agro-Divisions belong to the XJPCC. The Manasi Watershed was selected for the field survey because cotton is the most important crop here (cotton is the major source of income for farmers in Xinjiang) and the crop insurance program used here has been for cotton production over the last 20 years. Also the Manasi River is an inland river, the protection of which has become an important environmental policy issue. The watershed in northern Xinjiang spreads across Manasi County, Shawan County, Shihezi Township, Shihezi City, 18 Tuanchangs under the No. 8 Agro-Division, and Xinhu Tuanchang under the No. 6 Agro-Division. Cotton is the major crop, accounting for 40-70% of total crop sown area here.

The annual precipitation in this watershed ranges from 85.7 to 272.4 mm (based on 1991 to 2003 statistics) and from 63.9 to 187.1 mm in the growing season from April to September. This is not enough for cotton production. So, agrofilm has played an increasingly important role in protecting the humidity of surface soil from evaporation in order to ensure healthy growth of the crops at the early growing stage. As clearing up the used and broken pieces of agrofilm after harvest is very costly and time-consuming, it has been left to accumulate in the soil, presenting a serious threat to the environment.

[7] 1 hectare = 15 mu

[8] The XJPCC is one part of the Xinjiang Autonomous Region. The administrative system in the XJPCC is different from other local governments in Xinjiang, so all the data relating to the XJPCC comes from the Statistical Yearbook of the XJPCC.

Remaining in the soil for decades before dissolving, the little pieces of agrofilm can hamper the growth of seedling and/or roots of crops with small seeds.

3.2 Agrochemical Inputs and Environmental Problems

As shown in Table 3.3, total fertilizer application increased from 122 thousand tonnes in 1980 to 843 thousand tonnes in 2002 in Xinjiang, representing an annual growth rate of 17.5%. Although chemical fertilizer application per hectare of crop-sown area in Xinjiang was still below the national average in 2003 (256.58 kg/ha versus 289.45 kg/ha respectively), its average growth rate (8.32%) was faster compared with the national average (3.46%) during the time period. As a result, it increased from below 50% of the national average in 1980 to over 85% of the national average in 2003. [9] (See Table 3.3 for details).

Table 3.3 Chemical Fertilizer Application in Xinjiang

Year	Total quantity ('000 tonnes)	Intensity (kg/ha)	National average (kg/ha)
1980	122	40.75	86.72
1985	203	71.31	123.64
1990	395	132.44	174.59
1995	678	222.06	239.77
2000	792	233.57	265.28
2002	843	242.36	280.61
2003	907	256.58	289.45

Sources: Calculated from the Xinjiang Statistical Yearbooks (1999-2002); Xinjiang Huihuang 50 Years: 1949-1999; and Rural Statistical Yearbooks of China (2000-2004)

Note: Data in this table was calculated on 100% effective component bases. For example, different types of nitrogenous fertilizer contain different percentages of the effective content, i.e., nitrogen. In order to measure and compare application levels with those for other crops, areas, and/or years, the quantity must be converted to the same effective component, usually 100%.

To a large extent, the fast growth of chemical fertilizer application in Xinjiang can be attributed to the fast growing and highly concentrated cotton production in the region. Cotton production requires relatively larger quantity of chemical fertilizers compared with most bulk crops (crops grown on a large scale, such as major grain crops). The average expenditure on chemical fertilizers for cotton increased rapidly in Xinjiang, from RMB[10] 2.51 per mu in 1980 to 145.56 RMB per mu in 2003, with the peak level of RMB 172.36 per mu in 1998. Figure 3.1 shows that the average expenditure on chemical fertilizers per

[9] There is a lag of 2-3 years in the publication of statistics in China. For example, the Statistical Yearbook for 2005 will be published in November 2006 and will contain data up to 2004, so the most recent published data for this report is 2003.

[10] The exchange rate has been around RBM 8 to US$ 1 in the last decade.

mu of cotton sown area in Xinjiang has been significantly greater than that of the national average since 1996.

As described earlier, agrofilm application is widely used in Xinjiang. It increased from 26.5 thousand tonnes in 1990 to 104.7 thousand tonnes in 2001, with a per hectare application rate well above the national average. The pesticides application level in Xinjiang was still below 50% of the national average in 2001. However, it also increased relatively faster, from 1.7 kg/ha in 1990 to 3.7 kg/ha in 2001, or by 117% in 11 years as compared with only a 65% increase in the national average during the same time period. (See Table 3.4 for details.)

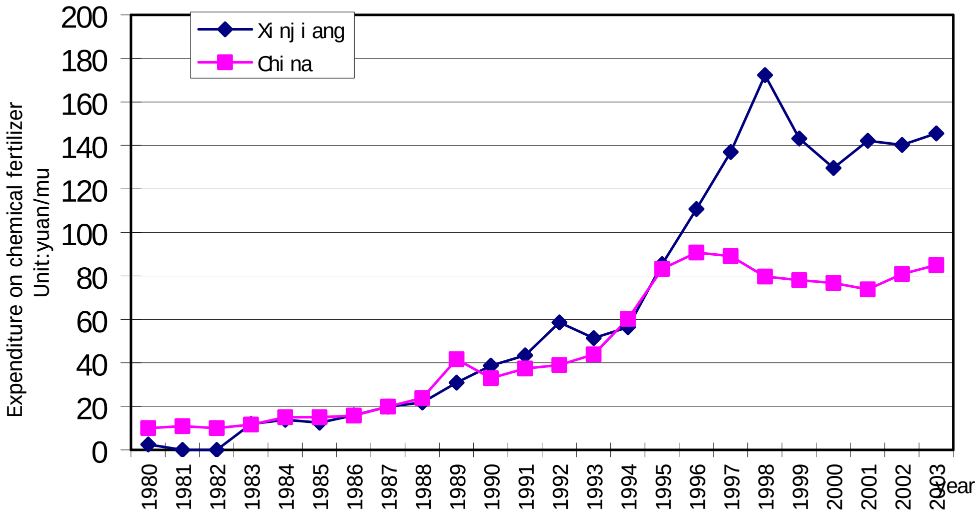

Figure 3.1 Expenditure on Chemical Fertilizers per mu of Cotton in Xinjiang and China
Source: Agricultural Product Cost and Benefit Data Compiles of China (1981-2004)

Table 3.4 Agrofilm and Pesticide Applications

Year	Agrofilm				Pesticides			
	Xinjiang		China		Xinjiang		China	
	Total (‘000 tonnes)	Average (kg/ha)	Total (‘000 tonnes)	Average (kg/ha)	Total (‘000 tonnes)	Average (kg/ha)	Total (‘000 tonnes)	Average (kg/ha)
1990	26.5	8.91.	481.9	3.25	5.1	1.71	733	4.95
1995	55.4	18.16	915.5	6.11	9.1	3.00	1087	7.26
2000	88.1	26.01	1335.5	8.55	13.6	4.02	1280	8.19
2001	104.7	30.76	1449.3	9.31	12.6	3.71	1275	8.19

Source: Rural Statistical Yearbooks of China (1991,1996, 2001& 2002)

It is observed from Figure 3.1 that the fertilizer application level in cotton production has leveled off since the mid-1990s in Xinjiang and in China as a whole. This is consistent with our field investigation. The data collected from the No. 8 Agro-Division, one of our major research areas, indicates that applications of all three major agrochemical inputs (i.e., fertilizers, pesticides and agrofilm) increased quite rapidly in the first half of the 1990s, but more or less stabilized afterwards except in the year 2003. (See Table 3.5 for details.)

Table 3.5 Agrochemical Applications in No. 8 Agro-Division

Year	Area ('000 ha)	Fertilizers		Pesticides		Agrofilm	
		tonnes	kg/ha	tonnes	kg/ha	tonnes	kg/ha
1990	152.4	74,701	490.2	643.0	4.2	2,173	14.3
1991	156.9	78,157	498.1	954.0	6.1	3,036	19.3
1992	149.5	87,996	588.6	845.0	5.7	3,110	20.8
1993	146.0	71,013	486.39 486.4	672.63 672.6	4.6	2,801	19.18 19.2
1994	145.0	80,346	554.3	832.4	5.7	4,091	28.2
1995	146.7	87,051	593.4	907.7	6.2	4,356	29.7
1996	149.0	106,008	711.5	914.8	6.1	4,594	30.8
1997	149.8	116,597	778.5	1,145.4	7.6	5,379	35.9
1998	154.9	125,350	809.4	1,098.1	7.1	7,211	46.6
1999	154.55 154.6	117,773	762.0	937.9	6.1	7,741	50.1
2000	156.5	124,413	795.0	1,035.9	6.6	8,673	55.4
2001	160.5	116,814	728.0	1,125.9	7.0	8,074	50.3
2002	162.2	116,064	715.7	872.9	5.4	8,750	54.0
2003	153.3	124,951	814.9	1,261.2	8.2	9,200	60.0

Source: XJPCC Statistical Yearbook (1991-2004)

It is widely perceived that highly concentrated applications of chemical inputs will not only contaminate the products of the field crops, and lead to yield reduction, but will also pose a serious danger to the ecosystem (for example, the surrounding soil and water quality) and human health (Rola and Pingali 1993). It will be useful to examine the potential impacts of the intensive application of these chemical inputs under current circumstances in Xinjiang. The following analysis will focus on the potential environmental effects of chemical fertilizers and agrofilm only, as residuals of pesticides, though damaging to human and animal health, may not have significant impact on the environment.

One of the most serious problems with the excessive application of chemical fertilizers is the leaching of chemical contents into water bodies. The nutrients can accumulate in the water and contaminate the environment and surrounding eco-system. But there is no obvious evidence that fertilizers are damaging the environment in Xinjiang in this way as rainfall and irrigation water are so limited that no excessive nutrients leach to the surrounding environment under existing conditions. However, the potential negative impacts of intensive application of fertilizers on the physical and chemical characteristics of the soil are not to be tolerated in the long run. Although these effects are not perceptible to the eye, they can accumulate through time and will lead to a serious degradation of the soil and the environment in general.

The super-thin agrofilm (0.5 mm thick) is easily broken into small pieces during the growing season. These small pieces of agrofilm are difficult to pick up and hence a large portion of them is left to accumulate in the soil. The small pieces of agrofilm remaining in the soil can prevent seedlings from sprouting, or the roots of seedlings from growing deep down into the soil. The current technique of cotton sowing by mechanically digging holes enables seedlings and roots to grow smoothly, so no reduction of yields have been reported in experiments designed to test the excessive use of agrofilm. However, other crops, especially small-seed crops, using different techniques may suffer from small pieces of agrofilm remaining in the soil. A survey has shown that the average quantity of agrofilm residues remaining in the soil in Xinjiang is 0.26 kg/ha after some 10 years of accumulation, and the yield losses range from 11-23% for maize, 9-16% for wheat, 5.5-9% for soybean, and 14.6-59.2% for vegetables when agrofilm residues reach 2.5 kg to 3 kg per mu (Agricultural Department of Xinjiang 2004).

3.3 Natural Disasters and the Crop Insurance Program

Its complicated topography, broad expanse, diverse natural environment, inclement weather and low rainfall makes the croplands in Xinjiang Autonomous Region the most threatened region in China. Some observed important indicators of land degradation in the region include loss of vegetation, loss of topsoil, severe droughts during the growing season, and reduction in biodiversity. As such, natural disasters occur frequently here with huge losses to agriculture. The major disasters are droughts, frost and freezing, wind and hail, floods, and snow disasters. (See Table 3.6 for details.)

As shown in Table 3.6, the total areas affected by natural disasters range from 189.51 to 366.12 thousand hectares during the 1990-2002 time period, with a peak level of 841.89 thousand hectares in 1999. Droughts, frost, wind and hail, diseases and insect pests are the major types of natural disasters, with drought, wind and hail being the two most severe disasters. As the total areas affected by natural disasters account for about 10% of the total crop land in the whole region of Xinjiang on average, the losses to some individual producers are significant. Therefore, crop insurance is an appropriate measure for risk management. This is why it has been accepted by farmers, especially cotton producers, for almost two decades.

Table 3.6 Areas Affected by Natural Disasters in Xinjiang Province

Unit: '000 hectares

Year	Flood	Drought	Wind and Hail	Frost	Pests	Others	Total
1990	9.95	61.36	68.28	2.98	39.35	7.52	189.44
1991	16.93	184.46	82.60	15.60	28.46	11.13	339.18
1992	23.40	44.66	146.86	63.46	37.86	27.06	343.30
1993	32.87	34.03	91.46	27.52	30.24	3.83	219.95
1994	32.76	101.31	115.95	31.78	48.50	52.83	383.13
1995	32.47	150.70	145.70	25.29	87.95	6.51	448.62
1996	80.12	58.27	109.64	40.59	41.62	40.15	370.39
1997	18.90	113.80	86.80	4.70	23.60	1.10	248.90
1998	54.88	13.08	235.45	16.47	45.75	7.72	373.35
1999	104.33	33.14	178.04	115.00	352.31	59.04	841.86
2000	32.14	311.95	108.55	4.97	195.89	55.60	709.10
2001	68.79	105.95	248.04	73.13	45.21	10.28	551.40
2002	142.45	13.61	137.76	3.85	5.77	13.09	316.53

Source: Statistical Yearbooks of Xinjiang (1991-2003)

The China United Property Insurance Corporation (CUPIC) started its crop insurance program in 1986, first compulsorily inside the XJPCC. During the last two decades, crop insurance offered by the CUPIC has extended to non-CUPIC farmers in Xinjiang, and even to other provinces in recent years. The participation rate of crop insurance inside the XJPCC increased from 6.65 % in 1986 to 83.56% in 2003.[11] At the same time, the annual crop insurance premium increased from RMB 2.07 million in 1986 to RMB 1620.83 million in 2003 while annual indemnity payments increased from RMB 2.78 million to RMB 1213.46 million. (See Table 3.7 for details.)

[11] The insurance coverage is relatively lower outside the XJPCC, resulting in a 45% coverage for cotton production and roughly 25-30% for all crops in whole Xinjiang Autonomous Region.

Table 3.7 Crop Insurance in XJPCC, 1986-2003

Year	Total crop area ('0000 ha)	Insured area ('0000 ha)	Participation rate (%)	Total premium (RMB '0000)	Indemnity (RMB '0000)	Payback ratio (%)
1986	71.94	4.79	6.65	206.68	278.78	134.88
1987	74.85	24.28	32.43	1067.03	975.59	91.43
1988	74.86	35.34	47.20	2068.39	1569.61	75.89
1989	75.84	40.88	53.90	2591.1	3037.7	117.24
1990	78.08	41.67	53.36	3075	1869.08	60.78
1991	80.78	50.31	62.28	4205.69	2293.53	54.53
1992	81.02	54.56	67.34	4939.5	3474.2	70.34
1993	78.7	50.6	64.30	5303.14	3793.47	71.53
1994	78.74	54.78	69.57	6344.26	3599.59	56.74
1995	81.3	59.4	73.06	8028.06	4549.76	56.67
1996	83.11	59.64	71.75	10109.03	7831.83	77.47
1997	86.42	60.65	70.17	11851.36	7869.64	66.40
1998	89.21	62.8	70.40	13360.79	10356.82	77.52
1999	91.48	66.39	72.57	15670.12	15994.82	102.07
2000	90.98	64.23	70.59	15852.33	10833.81	68.34
2001	91.63	66.89	73.00	17792.02	15343.16	86.24
2002	92.49	67.47	72.95	19057.43	13113.33	68.81
2003	91.2	76.2	83.56	20561.87	14562.07	70.82
Sum	1492.58	940.81	63.03	162083.8	121346.79	74.87

Source: China United Property Insurance Corporation (CUPIC) 2004

The levels of both premium and indemnity in the crop insurance program currently available to Xinjiang cotton producers are quite low, reflecting the fact that low-income farmers can only afford to pay small premiums every year in order to receive minimum coverage. The current insurance scheme[12] is designed to cover part of the material costs to restart production the following year, not to compensate yield losses. As such, this crop insurance is actually cost insurance, and farmers may receive insurance benefits up to 60% of the average material costs (fixed at RMB 250 in recent years) when the yield drops below 50% of the normal yield.

Farmers who purchase their own insurance cannot select the coverage level or premium because the premium is fixed by the insurance company. The equation is as follows:

$$\delta = \delta(\tilde{E}(c), \tilde{E}(y), \omega) = \text{RMB 20 per mu} \quad (3.1)$$

Where, $\tilde{E}(c)$, $\tilde{E}(y)$ represent the proportional actual production history (APH) of costs and yields respectively, ω denotes the damaging events that affect production, and

[12] See details in equation (3.1).

δ is fixed and unchangeable at RMB 20 for the past two years and is the same in different areas. Farmers should sign the crop insurance contract before mid-May[13] when cottonseeds have been germinated.

A payable loss occurs only if the realized yield is less than the trigger yield, i.e., half of the normal yield in recent years. Payable losses on a crop for an insurance unit (which is one Tuanchang) are calculated as:

Payable losses = trigger yield – realized yield

If trigger yield < realized yield, payable losses = 0

The above items indicate that the cotton insurance contracts are not sensitive to quantitative differences in risks and losses at the individual level. If a farmer's realized yield, y, falls below the trigger yield, y^*, he will receive a payment (I) equal to:

$$I = I[\delta, (y^* - y)] \leq \text{RMB 250 per mu} \quad (3.2)$$

I is a notion for the indemnity payment a farmer may receive, which is a function of the difference between the trigger yield and realized yield, with the maximum amount set at RMB 250.

Whether farmers participate in the crop insurance program currently available to Xinjiang cotton producers (not subsidized by the government to date) depends on many factors including if they are able to make the decision themselves or not. Under the old planning system (before China's reform which began in 1978) and within the XJPCC, the Tuanchang leaders used to make such a decision on behalf of the farmers in the regiment collectively. However, now the insurance company has extended its offer to non-XJPCC farmers who are free to purchase the insurance or not.

Even inside the XJPCC, some immigrants have rented land from the XJPCC, farm on this rented land and participate in crop insurance programs on their own initiative. These immigrants are called "private farmers", and the formal employees of the XJPCC are called "local farmers" as they work on land rented to their individual households by the XJPCC. These "local farmers" are officially affiliated with the XJPCC, entitled to pension, health care, and other social security benefits inside the XJPCC, and they are able to obtain low-cost inputs from the XJPCC through large-volume purchases. As such, the XJPCC still has an important influence on decisions made by the "local farmers", including that on crop insurance participation. For the purpose of this study, "local farmers" are excluded from the empirical analysis.

[13] The CUPIC contracts crop insurance with Tuanchangs, not individual farmers, but private farmers can purchase crop insurance directly from the insurance company.

4.0 ANALYTICAL FRAMEWORK AND MODEL

4.1 Theoretical Framework

The typical framework employed to evaluate the impact of crop insurance purchase decisions on cropping patterns and/or agrochemical usage is based on the standard assumption that farmers maximize expected utility of agricultural production profit by choosing production factors such as fertilizers and pesticides, and crop insurance, (crop insurance is treated as a factor in the utility function as it affects the expected returns from the production) subject to physical and technical constraints (Wu 1999; Wu and Adams 2001; Babcock and Hennessy 1996; Horowitz and Lichtenberg 1993; Quiggin 1992). As noted by Smith and Goodwin (1996)), if crop insurance is purchased, the farmer may adopt different farming practices to increase the expected returns from his crop insurance coverage. It is also likely that the opportunity to adjust farming practices will affect the farmer's decision to insure his crops or not (Smith and Goodwin 1996).

There seems to be an agreement that (Smith and Goodwin 1996) crop insurance participation decisions influence input decisions and vice versa. Disagreements among researchers arise as to whether the influence is one way or two ways, i.e., the decisions are made recursively or simultaneously, and how, to what extent and under what conditions such influence takes effect. The argument of researchers such as Horowitz and Litchtenberg (1993), and Mishra, Nimon and El-Osta (2005) who support the recursive hypothesis lies in the timing, or the sequence in decision-making. They argue that farmers purchase crop insurance well before the application of most agrochemicals, so the decision to purchase crop insurance is not dependent on the decision on agrochemical use. However, when they apply agrochemicals, they will take the purchase of crop insurance into consideration. As such, the decisions are made recursively, i.e., one decision made earlier influences the other made later, but not vice versa. Other researchers such as Smith and Goodwin (1996) supporting the simultaneous hypothesis argue that the issue is the timing of decision-making, not the timing of action-taking. When farmers make a decision on crop insurance purchase, no matter how much earlier before the growing season, they have already made decisions on agrochemical use. These decisions, or plans, on later actions must have been taken into consideration in deciding and implementing earlier action. As such decisions have been made year after year, farmers are fully aware of the consequences, and their decisions should be made interdependently, i.e., simultaneously.

To clarify the issue, a simple model of crop insurance and input use is derived from a profit maximization function. Let the production technology be stated as:

$$y = f(x,\omega) \tag{4.1}$$

where vector x denotes n inputs, vector ω denotes k random factors, and $y = f(\bullet)$ is the expected output.

Intuitively, elements of ω, the source of production risk are beyond the control of the farmer (properties of land, weather, etc.,) as well as potentially damaging events (hail, floods, pests and diseases, etc.) that affect production can be associated with inputs.

In general, we expect inputs to raise output at all times, under given conditions, assuming the farmer is a rational decision-maker i.e., $y = f(x,\omega) \geq 0$.

Let p be the random price per unit of output, while input prices denoted by the n-dimensional vector $w > 0$ are presumed non-random. Let $\pi_1 = py - wx$ denote the state-contingent farm profit in the absence of insurance. Suppose the farmer has an insured yield level, y^*, and he can purchase this level of insurance at a fixed premium δ, where y^* and δ are assumed to be determined exogenously. If the actual yield, y, is less than y^*, an indemnity amounting to $I[\delta,(y^* - y)]$ will be paid. The net revenue under crop insurance contract should be $\pi_2 = py + I[\delta,(y^* - y)] - \delta - wx$. Here, for a particular realization of ω, call it the trigger state denoted by ω^*, the insurer's expected payout is determined by the farmer's choice of x. If the insurer cannot perfectly observe ω or write a contract contingent on x, there may be the possibility of moral hazard, and an adverse selection will occur if there exists a parameter of function $y = f(\bullet)$ which is known by the farmer but not the insurer prior to choosing x.

If the farmer is risk averse, he will choose an x which maximizes the expected utility of production profit.

$$\text{EU} = \int_{y_0}^{y^0} U(\pi \quad dG(y) \tag{4.2}$$

where $[y_{\min}, y^{\max}]$ is the bounded support of $G(y)$, which is the cumulative distribution function of y. $y_{\min}$ and $y^{\max}$ denote the minimum and maximum yields respectively, π is the production profit and EU is the expected utility.

Equation (4.2) highlights the connection between the farmer's expected utility of profit and his input and crop insurance purchase decisions.

From the analysis above, the relationship between a farmer's use of x and his insurance contract can be expressed by equation 4.3 below.

$$x = h(p,\omega,\omega^*,w,\delta) \tag{4.3}$$

Equation (4.3) indicates that x is influenced by the output price, p; the factors affecting the output, ω, especially the trigger state under insurance ω^*; the input price, w; and the insurance premium, δ.

$$\omega = \omega(y, x) \tag{4.4}$$

Whenever ω falls below ω^*, the insurer will pay compensation to the farmer. So, the trigger state ω^* determines whether the farmer purchases the crop insurance. Effectively, the insurer is gambling with a farmer who knows the odds of the game that remain hidden from the insurer. Knowing this, the farmer has the incentive to take advantage of the insurer's ignorance with altering or influencing ω through the use of x.

In conclusion, the farmer's choice of x and his insurance purchase interacts simultaneously. Inputs may have different impacts with regard to maximum utility of profit. Some inputs, such as fertilizers, are able to increase the expected yields. However, their application is likely to increase variations in the yield as well. The equilibrium level of application of such inputs is determined by the expected yield and variation, as well as by input and output prices. Other inputs, such as pesticides, are able to reduce yield losses in case of serious infection of pests and/or diseases. As such, they are likely to reduce downward variations, but not upward variations in expected yields. Crop insurance is likely to have the same effect with regard to profit maximization as it provides indemnity when the actual yield turns out to be below the pre-fixed trigger level. Whether material inputs and crop insurance interact simultaneously depends on many factors, but their functions in profit maximization are the key to understanding farmers' behavior.

High levels of fertilizer application make crops more exuberant and vulnerable to unfavorable unexpected natural conditions. Under unfavorable conditions, the losses will be greater for exuberant crops compared with less exuberant ones. Therefore, if the application of one input will increase the vulnerability of the crop's exposure to natural disasters, a farmer who is going to increase that input is more likely to participate in crop insurance in order to get some compensation if and when an extreme outcome occurs. If increased application of one input can lead to a higher expected yield as well as a higher variation in yield, and the crop insurance program promises to provide indemnity to cover at least part of the losses due to increased variation in yield, farmers may take the opportunity to increase their application of the input (from the previous equilibrium level) and purchase crop insurance at the same time. However, if the trigger level is below the realized yield level, the yield variation increases, or the expected indemnity the farmer may receive is smaller than the total costs (actual costs plus increased risks), he may not have the incentive to increase his input. In this case, he may participate in crop insurance to guard against extreme disasters, but will not increase his inputs.

There are considerable factors directly and indirectly influencing farmers' insurance and input decisions. We can investigate such characteristics or variables by doing some empirical analysis about the relationship between the two.

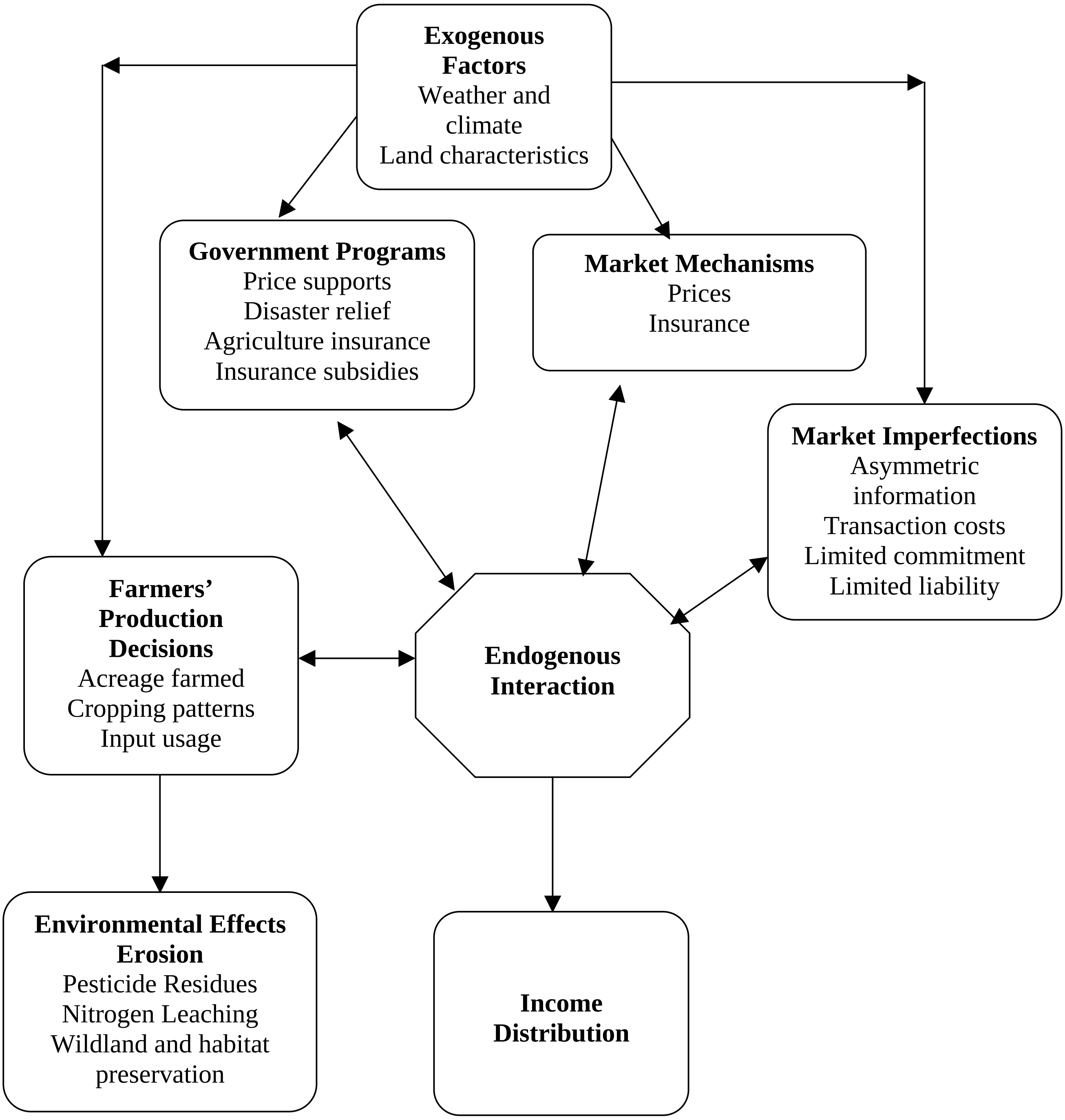

Figure 4.1 Interaction between Crop Insurance, Farmers' Production Decisions and the Environment

Source: Roberts, Osteen and Soule (2004)

Figure 4.1 indicates the complicated interactions between risk, crop insurance, production decisions, and the environment. It shows how exogenous factors determined outside the agricultural production system, such as the weather, climate, population, and so on, feed into endogenous choices and factors, such as the economic environment, for example, perfect versus imperfect markets, market mechanisms, and production choices. The nature of production, in turn, determines environmental consequences. And the culmination of all these factors collectively determines the farmer's final goal: maximization of production profit.

For purposes of this study, a set of exogenous variables is selected along with those representing crop insurance participation and agrochemical uses. To test the relationship between crop insurance participation and agrochemical uses, the impact of the exogenous variables on crop insurance participation and agrochemical uses will be estimated at the same time.

4.2 Econometric Model

Procedures for estimating the relationship between insurance purchase and input use are developed from the profits maximization theoretical framework discussed in section 4.1. In the case of cotton production in the XJPCC, for example, the sign-up date by which crop insurance has to be purchased is in mid-May – cotton farmers may have already applied large amounts of fertilizers and agrofilm by the sign-up deadline. Additional applications also occur later in the growing season. Pesticides may also be applied prior to and after the crop insurance sign-up date. As explained earlier, farmers who apply chemical fertilizers and pesticides before taking on an insurance policy may have already taken this decision into consideration. Therefore, it is appropriate to hypothesize that crop insurance and input decisions may indeed be made simultaneously. Additionally, pesticides, agrofilm and fertilizers may have different risk properties (Pope and Krame 1979; Quiggin 1992) and disaggregating the three is warranted.

Given cultivation practices and the institutional arrangement, the following simultaneous equation system, similar to Smith and Goodwin's (1996) is employed in this research.

$$y_{1t} = \alpha_1 y_{2t}^i + \beta_1 X_{1t} + \mu_{1t}, \qquad (4.5)$$

$$y_{2t}^i = \alpha_2 y_{1t} + \beta_2 X_{2t} + \mu_{2t} \qquad (4.6)$$

where $i = 1, 2, 3$;

y_{1t} represents crop insurance purchase, modeled as a dichotomous choice taking the value 1 if the farmers are voluntarily insured, and 0 if the farmer does not purchase insurance;

y_{2t}^i represents the *ith* chemical inputs use, y_{2t}^1 is fertilizer, y_{2t}^2 is pesticide and y_{2t}^3 is agrofilm – all of the dependent variables assumed to be endogenous;

X_t is a vector of exogenous variables relevant to insurance purchases and agrochemical use;

$\mu_{it}s$ are unobserved disturbances that are assumed to be normally distributed with constant variances; and

α_1, α_2 *and* β_1, β_2 are parameter vectors to be estimated.

The distribution of y_{1t} is discrete such that

$$y_{1t} = \begin{cases} 1 & \text{if } y_1^* > 0 \text{ (farmer purchased crop insurance)} \\ 0 & \text{otherwise (farmer did not purchase insurance)} \end{cases}$$

For identification purposes, it is assumed that exogenous variables included in X_{1t} and X_{2t} are allocated to either X_{1t} or X_{2t} but not both. The simultaneous-equation system of crop insurance and fertilizer, pesticide and agrofilm use decisions are estimated in a two-stage procedure (Maddala 1983).

In the first stage, the reduced form equations for the insurance decision and fertilizer, pesticide and agrofilm use decisions can be written as:

$$y_{1t} = Z_t^{'}\Pi_1 + v_{1t}, \tag{4.7}$$

$$y_{2t}^{i} = Z_t^{'}\Pi_2 + v_{2t} \tag{4.8}$$

where Z_t is an appropriately defined vector.

Equation (4.7) will be estimated by the MLE Probit method, and equation (4.8) will be estimated by the ordinary least squares method (OLS). In the second stage, equation (4.5) will be estimated using the MLE Probit method after substituting $Z_t^{'}\hat{\Pi}_2$ for y_{2it}, and equation (4.6) will be estimated by the OLS method after substituting $Z_t^{'}\hat{\Pi}_1$ for y_{1t}.

This two-stage procedure gives consistent estimates of model coefficients (Maddala 1983). However, the estimates of the variance of the coefficients may be inconsistent because predicted values of endogenous variables are used in the second stage of estimation. Maddala (1983) points out that the appropriate covariance matrix for a structural model with more than two discrete or censored endogenous variables is difficult to derive. So, bootstrap methods (Efron 1979, 1987; Newey 1987) are used to derive consistent estimates of variances in this analysis. Under the bootstrapping approach, a large number of pseudo samples equal in size to the number of observations in the original data is obtained by repeatedly drawing from the original data with replacement. Thus, it is possible that one observation is drawn several times. For each pseudo sample, Nelson and Olson's two–step procedures (Nelson and Olson 1978) are applied to generate a distribution of the consistently estimated structural parameter. Variances of model parameters are then consistently estimated by using the distribution.

Once valid estimates of parameters of the structural model and their respective covariance matrices have been obtained, the Wu-Hausman (Hausman 1978; Wu 1973) specification test will be performed to test the null hypotheses that (a) crop insurance purchase decisions are exogenous in chemical input uses, and (b) chemical input uses are exogenous in crop insurance purchase decisions. These estimates can be compared to those obtained by standard OLS and Probit estimates that ignore simultaneity. Under the null hypothesis that standard OLS and MLE Probit estimates yield correct specifications, Hausman (1978) shows that equation (4.9) has a χ^2 distribution with degrees of freedom equal to the number of coefficients being evaluated, where β_0 and β_1 are estimates of the standard OLS/Probit and instrumental variable parameters, and $V(\beta_0)$ and $V(\beta_1)$ are their respective covariance matrices.

$$q = (\beta_0 - \beta_1)[V(\beta_0) - V(\beta_1)]^{-1}(\beta_0 - \beta_1)' \qquad (4.9)$$

4.3 Data Used in the Research

The primary data used in this study was collected through face-to-face interviews with farmer households in the Manasi Watershed. The questionnaires were designed to acquire information on crop insurance and cotton production practices. The focus of the survey was to link information on agricultural practices and the socioeconomic characteristics of the interviewed farmers to their crop insurance purchase and chemical input decisions. The questionnaire was divided into the following sections.

1. The first section attempted to identify the land allocated to cotton and other crops such as tomato, maize, and wheat; average cotton yield; and income from cotton, other crops, livestock and off-farm work. Questions on irrigation systems used were also included in this section.

2. The second section consisted of questions aimed at investigating production costs, especially agrochemicals such as fertilizers [14], pesticides and agrofilm. We disaggregated fertilizers into nitrogenous fertilizers, phosphate fertilizers, potash fertilizers and compound fertilizers, and pesticides were divided into herbicides, insecticides and other pesticides. All these variables are converted into expenditures (in RMB per mu) on each kind of chemical input.

3. The third section was devoted to the collection of socio-economic data. It was assumed that age, education, farming experience of the farmer, number of family members, and so on, were important determinants in farmers' production behaviors and crop

[14] Pig raising is the major livestock in conjunction with family crop production and a source of farm livelihood in China. It is also a major source of manure used in crop production. However, farmers in our sample and in northwest China in general, do not raise pigs due to religious reasons. As such, they seldom use pig manure in their crop production so manure is not included in our estimations.

insurance purchase decisions.

Consequently, three criteria were set for the selection of the survey site: 1) high importance of cotton production in local agriculture; 2) crop insurance was an important element in farmers' decisions; and 3) the vulnerability of the environment from increasing agrochemical use. Based on these criteria, the research team chose the Manasi Watershed as the area for their study, interviewing farmers in Manasi County and Shawan County, as well as both the "private" and "local farmers" in the No. 8 and No. 6 Agro-Divisions of the XJPCC.

Prior to the implementation of the full-scale survey, a pilot study was conducted in January and February 2004 in the same study site, with the results presented at the EEPSEA Biannual Workshop in May 2004. The full-scale household survey was conducted in July 2004 and preliminary results were presented at the EEPSEA Biannual Workshop in 2005. Based on suggestions received at the workshop, those "local farmers" whose participation in crop insurance was made compulsory by the Tuanchangs were omitted in the final analysis. This is because the Tuanchangs still have a strong influence on decisions made by "local farmers", including that on crop insurance participation. Thus the farmers do not really have full freedom of choice in crop insurance and chemical input decisions. As the farmers' free choice in decision-making is the basis of the issue under investigation, "local farmers" are excluded from the research. Only the information collected from the "private farmers" in the Tuanchangs and "ordinary farmers" (non-XJPCC farmers in Manasi County and Shawan County who make production decisions themselves) were used to derive conclusions.

The sample sites were selected in three steps:

1. Three Tuanchangs (the Shihezi Zongchang, the No. 141 Tuanchang of the No. 8 Agro-Division, and the Xinhu Tuanchang of the No. 6 Agro-Division), the Manasi County and Shihezi Town were selected according to the Shihezi Social Almanac with the assistance of Shihezi University and CUPIC, taking cotton sown acreage as the representative indicator of cotton production.

2. Four towns (Liuhudi, Baojiadian, Beiwucha, and Letuyi) in Manasi County were selected on the equal-interval principle[15] according to cotton yield per unit of sown area. Two Lianduis (sub-unit of a Tuanchang) from Shihezi Zongchang, three Lianduis from No.141 Tuangchang, six Lianduis from Xinhu Tuanchang, four villages from Shihezi Town and seven villages from Manasi County were further selected on the same principle, based on production information provided by the local administration.

3. Farmers, totaling 450, were randomly selected within the chosen sample of Lianduis and villages.

The distribution of the sample is shown in Table 4.1.

[15] The equal-interval principle is widely used in statistical sampling. All observations in the population are ranked according to the value of a selected character, and a sample is chosen by taking a certain number of observations with equal distance in the ranking from the population in order to get a good representative sample.

Table 4.1 Distribution of the Sample

Sample sites	Number of households
Shihezi Township	80
Shihezi Zongchang	50
No. 141 Tuanchang	60
Xinhu Tuanchang	120
Manasi County	140
Total	**450**

Source: Field survey (July 2004)

Three hundred and forty respondents provided sufficiently complete information for the analysis. Among the 340 farmers, 113 of them (33.23%) voluntarily purchased crop insurance while the remaining 227 (66.77%) did not purchase crop insurance in 2003. All of them used fertilizers, pesticides and agrofilm in cotton production.

The specific equations used in our analysis and the variable definitions are presented in Table 4.2.

Table 4.2 Model Specifications and Variable Definitions

Model Specifications
Crop Insurance purchase = *f* (FERTILIZERS, PESTICIDES, AGROFILM, CV, FTF, DISR, CA, EDU, FEXPER，RISKATT)
Fertilizer usage = *f* (COTTINS, EDU, FEXPER, DENSITY, DISEASE, SHRLIVE, LC, AVGCY, RISKATT)
Pesticides usage = *f* (COTTINS, EDU, FEXPER, DENSITY, DISEASE, SHRLIVE, LC, AVGCY, RISKATT)
Agrofilm usage = *f* (COTTINS, EDU, FEXPER, DENSITY, DISEASE, SHRLIVE, LC, AVGCY, RISKATT)

Variable Description

Variable	**Description**
COTTINS	A zero-one discrete variable indicating whether farmers purchased crop insurance in 2003 (1 = yes, 0 = no)
FERTILIZERS	Expenditure on aggregate fertilizers per mu including base fertilizers and late fertilizers in cotton production in 2003 (RMB per mu)
PESTICIDES	Expenditure on pesticides per mu of cotton production in 2003 (RMB per mu)
AGROFILM	Expenditure on agrofilm per mu of cotton production in 2003 (RMB per mu)
DENSITY	Cotton planting density per mu in 2003 ('000s of individual plants per mu)
DISEASE	The degree of losses caused by pests and diseases from 1999 to 2002 (1= average loss above 80 percent of normal yield, 5= average loss below 20 percent of normal yield)
CV	Coefficient of standard deviation of Tuanchang or county level average cotton yield from 1980-2002 (%)
AVGCY	Average cotton yields (from 2001 to 2002) (kg per mu)
CA	Cotton sown area by one farm household (mu)
LC	Land capability (1 = very good, 3 = poor)
SHRLIVE	Share of off-farm income and livestock sales in total net income (%)
DISR	Whether farmer received government disaster relief in the previous four years from 1999 to 2002 (1 = yes, 0 = no)
RISKATT	The farmer's risk attitude (1= lowest risk aversion, 5= highest risk aversion)
FEXPER	Number of years that farmer has occupied an agricultural farm in a Tuanchang or village (no. of years)
FTF	Whether farmer is in full-time farming (1 = yes, 0 = no)
EDU	Number of years farmer has received school education (no. of years)

In addition to crop insurance participation and agrochemical application data, a set of farm household survey data was collected with regard to cropping patterns: acreages planted with major crops including cotton, wheat, maize, potato, and oil-bearing crops. The data was used to construct variables similar to those used in previous studies (Smith and Baquet 1996; Smith and Goodwin 1996) such as total acreages and percentage of total cropland planted with cotton and other crops. The average area planted with other crops for insured and uninsured farmers was 1.28 mu and 9.95 mu per farm, respectively. It is evident that those who purchased insurance allocated almost all their croplands to cotton production.

To obtain consistent estimators, all estimation methods must impose restrictions or identification conditions on the exogenous variables in the simultaneous models. Therefore, it is of interest to impose as many a priori restrictions as are theoretically reasonable and determine the validity of these restrictions. In other words, we must find some variables with their impacts restricted to only crop insurance purchase, and others with their impacts restricted to only agrochemical uses in order to validate the model. If all variables impact both decisions, then the model cannot provide consistent estimates. On theoretical grounds, those variables influencing cotton yield variability (or expectation of variability) inter-temporally (i.e., from year to year) and in a large surrounding area will affect farmers' crop insurance demands as they indicate the potential fluctuation any farmer may face in the region. But they will not influence farmers' chemical and other input decisions as these decisions are more relevant to conditions on individual farms. In contrast, variables influencing yield level (not yield variability) on farmers' individual farms will have an impact on farmers' chemical input decisions, but not on crop insurance.

The cotton acreage (CA) variable was employed to reflect any scale effect. A positive correlation between cotton acreage and participation in crop insurance is possible because losses in cotton production due to extreme weather are greater in larger cotton farms (Goodwin 1993; Goodwin, Smith and Hammond 2000; Goodwin, Vandeveer and Deal 2001). This variable is not used in chemical input equations because chemical inputs are measured by the average amount per unit of sown area rather than total application.

The variable used in this study to measure the yield fluctuation is not the individual farmer's yield variation, but the coefficient of standard deviation (CV) of cotton yields at the Tuanchang and/or county levels for the 1980 to 2002 period.[16] A similar specification was considered in Goodwin (1993), Smith and Goodwin (1996), and Goodwin, Vandeveer and Deal (2001). It is believed that farmers tend to look at the average variation in yield in surrounding farms instead of just in their own farms when making risk management decisions. This variable would therefore reflect the general trend over a large area and may not have a strong impact on a farmer's chemical input decisions on his own land.

As indicated by Smith and Goodwin (1996), the government's disaster relief program may have a negative effect on crop insurance purchase decisions. But it is probable that farmers who received government disaster relief in the previous four years would be more

[16] Under the APH (Actual Production History) insurance program, coverage levels and premium rates are computed based on the insured's expected yield. The expected yield is usually calculated as the average yield at the county level over the preceding 10 years to avoid adverse selection.

likely to participate in crop insurance. This is because the government disaster relief program aims only to provide for the subsistence needs of victims in a natural calamity, not to give full compensation for loss. Thus, crop insurance might be viewed by recipients as a risk management measure complementary to disaster relief provided by the government.

Other factors expected to affect insurance purchase decisions include whether or not the farmer farms full time. Full-time farmers (FTF) may be more willing to purchase crop insurance because they do not have alternative revenue sources. However, as pointed out by Goodwin (1993), a negative effect may be possible because full-time farmers may have a higher degree of specialized expertise in production practices than part-time farmers and thus, may have a lower demand for crop insurance.

Information on different sources of net income including off–farm income and sales derived from livestock was used to calculate the share of off-farm income and net income from livestock (SHRLIVE). Net incomes from the two sources were combined because they played the same role in risk aversion, and most farmers could receive income from either off-farm jobs or livestock production but not both. This variable was used to reflect farmers' budget constraints on chemical inputs. This variable also reflects farm diversification and thus may affect the demand for crop insurance. However, it was more reasonable to use the farmer's employment characteristics (FTF) rather than SHRLIVE to reflect the effect of farm diversification on the demand for crop insurance in order to satisfy the condition of identificability[17] of simultaneous equations.

Farmers' preference for risk-seeking (a term used to describe the attitude of a person who is willing to take higher risks if the expected or average returns are also higher) or aversion, RISKATT, measured by their willingness to purchase health insurance, was used to test if the farmers' stated risk attitude with regard to health care was consistent with their crop insurance purchase. It is expected that if the stated preference is consistent with the revealed or "true" preference across different areas, a negative coefficient may result because the value of this variable measures the farmer's preference for risk aversion, as opposed to risk-seeking.

Farmers' planting practices such as cotton plant density may influence agrochemical application (DENSITY). It is expected that farms with a higher cotton density would apply more pesticides and agrofilm, but less fertilizer, because such higher density would lead to higher insect populations and thus, potential losses from insect infection are likely to be higher.

The losses in cotton production caused by insects and disease (DISEASE) in the four years from 1999-2002, the average cotton yield **(**AVGCY) in the two years from 2001 to 2002, and the land capability (LC) were other direct factors selected in this study as influencing farmers' chemical input decisions. The losses in cotton production caused by insects and disease, from 1999 to 2002, reflect a farmer's individual yield losses under local environmental conditions in a specific region. As this has no obvious relationship with the yield variation in a large surrounding area, the variable DISEASE may only influence a farmer's chemical input decisions.

[17] Identificability is a necessary condition for the simultaneous equation system to produce consistent estimates.

Land capability may have a stable impact on farmers' cotton yields in the long term, and is not obviously correlated with yield fluctuation. For the same reason, the average cotton yield of the past two years is the outcome of chemical inputs in the past, and reflects the production relationship between output and chemical inputs. This lagged yield may affect existing chemical input decisions but not necessarily the crop insurance decision. The variations in AVGCY may reflect differences in actual cotton yields across regions, while the values of LC are subjective numbers assigned by individual farmers that reflect the relative fertility of land within villages. Nevertheless, a simple correlation test was conducted and the resulting correlation coefficient of 0.10 suggests no multicollinearity between the two variables.

Similarly, the socio-economic characteristics of the farmer including his farming experience (FEXPER) and education level (EDU), which may affect production technology and the demand for insurance, were included in the simultaneous model. All these variables may have a positive or negative effect on crop insurance purchase and agrochemical use. The average farming experience and average education levels were eighteen years and seven years respectively.

The reliability of our estimation results hinges on the validity of our instruments (i.e., our exclusion restrictions). We conducted an over-identification restriction test to make sure that our instruments were valid.[18] To statistically examine the validity of our two sets of instrumental variables (one for the crop insurance purchase structural equation and the other for the chemical inputs structural equation, we conducted a likelihood ratio test (LR) (Bollen, Guilkey and Mroz 1995; Wooldridge 2002) for equation (4.5)[19] and a Hausman over-identification restriction test (Wooldridge 2002) for equation (4.6)[20] respectively.

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[18] When we have more instrumental variables (IVs) than we need to identify an equation, we can test whether the additional IVs are valid in the sense that they are uncorrelated with u_{1t} or u_{2t}. This test is an exclusion restriction test (i.e., over-identification restriction test). The number of over-identifying restrictions is equal to the excluded exogenous variables minus the endogenous explanatory variables. The usefulness of the over-identifying restrictions test is that, if we reject the null hypothesis, then the instrumental variables are invalid, leading to biased parametric estimates, and our logic for choosing the instrumental variables must be re-examined. If we fail to reject the null hypothesis, then we can have some confidence in the overall set of instruments used. See footnotes 19 and 20 for details.

[19] The LR test involves a comparison of the value of the log-likelihood function ($L(\beta_{ur})$) from an unrestricted estimation of the reduced form of Eq. (4.5) with the value of the log-likelihood function ($L(\beta_r)$) from the estimation of the structural form of Eq. (4.5) when we use the predicted amounts of chemical inputs in place of the actual amounts. Under the null hypothesis that exclusion restrictions are valid, the test statistic for no significant difference between $L(\beta_{ur})$ and $L(\beta_r)$ that involves –2 times the difference of the two log-likelihoods (i.e. $(-2)\times[L(\beta_r)-L(\beta_{ur})]$) is asymptotically chi-squared with degrees of freedom equal to the number of over-identifying restrictions (the number of excluded exogenous variables minus 3). A statistically insignificant test statistic indicates that the instruments can be safely excluded from the crop insurance demand equation. In this study, the instrumental variables were found to be valid.

[20] The Hausman test is a Lagrange multiplier test (Hausman 1983). The chi-square distributed test statistic with k−1 degrees of freedom**,** where k is the number of Ivs (instrumental variables), is N× R^2 , where N is the number of observations, and R^2 is the measure of the goodness of fit of the regression of the residuals from the second stage equations on the variables which are exogenous to the system. Under the null hypothesis that exclusion restrictions are valid, a statistically insignificant test statistic indicates that the instruments can be safely excluded from the chemical input equations. In this study, the instrumental variables were found to be valid.

The mean and standard deviation of each variable are presented in Table 4.3. As shown in table 4.3, one-third of the surveyed farmers participated in a crop insurance program), and the average expenditures of all farmers on chemical fertilizers, pesticides and agrofilm were RMB 94.09, 26.25 and 31.51 per mu, respectively.

Table 4.3 Summary Statistics of Explanatory Variables

Variable	Mean	Standard Deviation
COTTINS	0.3324	0.4718
FERTILIZER	94.0903	37.1337
PESTICIDES	26.2502	18.8074
AGROFILM	31.5155	8.1560
EDU	7.7412	2.6189
FEXPER	18.6206	11.3228
FTF	0.6265	0.4845
DISR	0.5382	0.4993
CV	16.5813	7.2850
CA	68.6176	75.9404
RISKATT	3.3559	1.3236
DENSITY	15.7342	6.4713
DISEASE	2.5147	1.6428
LC	2.0353	0.7634
AVGCY	206.4651	53.2625
SHRLIVE	8.4543	17.1037

Source: Field survey (July 2004)

The basic statistics are calculated from the survey data. A total number of 450 farm households were interviewed – 30 households participated in crop insurance programs because of the compulsory decision made by the XJPCC, 42 households indicated negative net incomes, and 38 households provided incomplete information. Therefore, information on the remaining 340 households was used in this study.

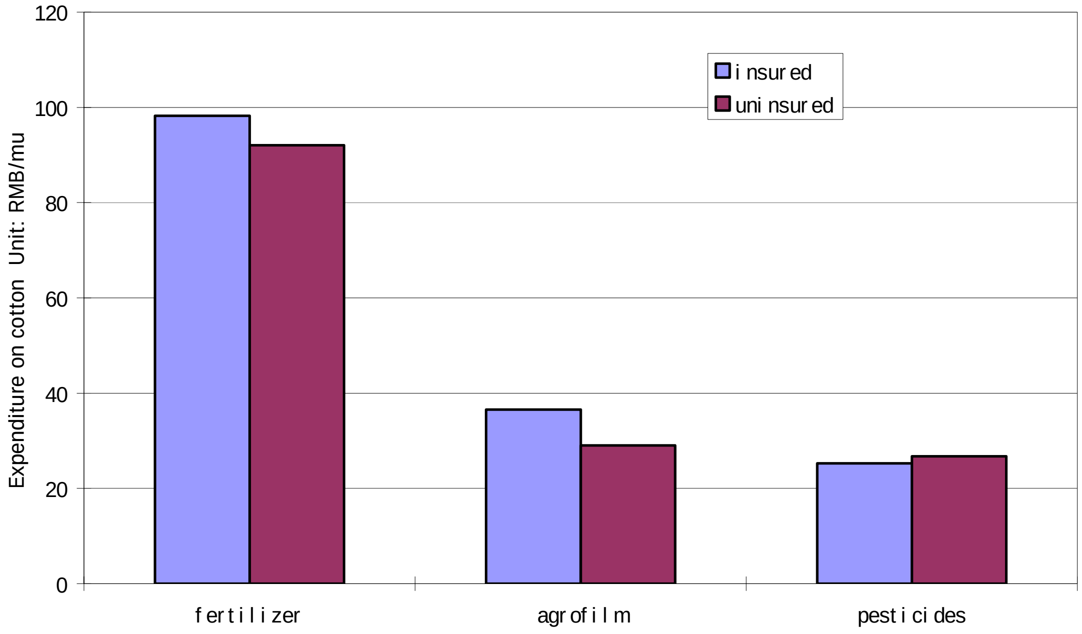

Figure 4.2 Difference in Agrochemical Inputs between Insured and Uninsured Farmers

Source: Calculated by authors

Figure 4.2 pictures the differences in usage of fertilizers, agrofilm and pesticides between farmers with and without crop insurance. The insured farmers were inclined to apply more fertilizer and agrofilm while there was nearly no difference in pesticide application between insured and uninsured farmers. However, the actual relationship between crop insurance and chemical usage is still a research question waiting for empirical evidence.

5.0 EMPIRICAL RESULTS AND DISCUSSIONS

5.1 Endogeneity of Input Decisions

The test of over-identifying restrictions produces a likelihood ratio statistic of 4.11 for the crop insurance structural equation and Lagrange multiplier statistic of 5.54, 5.88 and 2.58 for agrofilm, fertilizer and pesticide inputs structural equations respectively; these do not exceed the chi-square distributed critical value of 4.61 with two degrees of freedom for the crop insurance equation and 6.25 with three degrees of freedom for chemical input equations at 10% level of significance. So we do not reject the null hypothesis that the instruments are uncorrelated with the error term. Four statistically insignificant test statistics indicate that the two sets of instruments can be safely excluded from the crop insurance and chemical inputs equations respectively.

As stated in the theoretical framework, participation in crop insurance is treated as a special kind of input in cotton production in this study. Whether the decision on participation in crop insurance is exogenously or endogenously related to other inputs requires empirical tests. A Wu-Hausman specification test was performed to test the null hypotheses that (a) crop insurance purchase decisions are exogenous in chemical input uses and (b) chemical input uses are exogenous in crop insurance purchase decisions before further application of econometric models. The estimated Wu-Hausman χ^2 statistics are reported in Table 5.1.

The first χ^2 statistic has three degree of freedom while the following three χ^2 statistics have one degree of freedom each. The P-values of the estimated χ^2 statistics indicate that the exogeneity hypothesis is rejected for FERTILIZERS, AGROFILM and PESTICIDES in the crop insurance purchase model at a significance level of 1%, 5% and 10%, respectively, and for the three as a whole at 1% significance level. The exogeneity hypothesis is also rejected for the variable COTTINS in the pesticide inputs equation at 10% level of significance, but not in the fertilizer and agrofilm input equations.

Table 5. 1 Results of Wu-Hausman Specification Test

Null Hypotheses	**Wu-Hausman χ^2 Test Statistics**	**P-Value for the Statistics**
Exogeneity of chemical inputs in crop insurance discrete choice model	33.37	0.0000***
Exogeneity of fertilizer input in crop insurance discrete choice model	32.48	0.0000***
Exogeneity of agrofilm input in crop insurance discrete choice model	4.09	0.043**
Exogeneity of pesticide input in crop insurance discrete choice model	2.97	0.085*
Exogeneity of crop insurance discrete choice in fertilizer input model	0.09	0.76
Exogeneity of crop insurance discrete choice in agrofilm input model	0.59	0.441
Exogeneity of crop insurance discrete choice in pesticide input model	3.11	0.078*

Source: Estimated by authors

Note: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

The results of the Wu-Hausman specification test suggest that farmers' decisions on crop insurance participation are endogenously made with those on agrochemical inputs; however, their decisions on agrochemical inputs, except pesticides, may not be endogenously made with that on crop insurance participation.

However, we think it is appropriate to further test the hypothesis with a simultaneous equation system in this analysis. Because the provision of crop insurance under the same terms has been in effect for more than a decade, farmers who have already made up their minds to purchase crop insurance will apply more fertilizers and agrofilm, and less pesticides accordingly in subsequent months. In such cases, the decisions on agrochemical use and crop insurance purchase are likely to have been made jointly long before being implemented. In other words, they are simultaneous decisions but implemented at different times.

5.2 Impact of Chemical Inputs on Crop Insurance

The bootstrapped parameter estimates and implied marginal probability effects for the Probit model of the discrete cotton insurance purchase decision (see Eq. 4.5 and Eq. 4.6) are presented in Table 5.2. The standard errors of the coefficients are estimated using the bootstrap method with 1,000 replications. The last column of Table 5.2 shows the changes in the probability to purchase the crop insurance given one unit of change in the explanatory variables and are computed using the mean value of all explanatory variables. The whole model highly fits the observations, as the model shows a high predictive power of close to 99%.

The coefficients on variables FEXPER and EDU are negative and statistically significant at 1% and 5% level, respectively. This suggests that farmers who have more farming experience and higher levels of education tend to purchase crop insurance less frequently. One explanation for this is that these farmers have or believe they have better risk management skills, so they need less protection from crop insurance programs. The coefficients on cotton acreage (CA) and whether the farmer is working full-time in agriculture (FTF), as expected, are positive and statistically significant at 1% and 5% levels, respectively. This indicates that the farmers working full-time in agriculture are more likely to participate in crop insurance because they do not have alternative sources of income to disperse risks. At the same time, farmers with larger cotton fields are more inclined to purchase cotton insurance as their losses are likely to be more severe than those who have smaller cotton farms.

Table 5.2 Estimates of the Probit Model of Cotton Insurance Decisions (bootstrap method with 1000 replications)

Explanatory Variables	**Coefficient[a]**	**Standard Error**	**Marginal Probability[b] (dy/dx)**
CONSTANT	-119.3245**	33.7683	n.a.
AGROFILM	1.2775**	0.3741	0.2637
PESTICIDES	-0.4682**	0.1609	-0.0966
FERTILIZERS	0.2165**	0.0797	0.0581
FEXPER	-0.1486**	0.0525	-0.0307
RISKATT	-0.1004	0.2321	-0.0207
DISR	0.6319	0.9272	0.1346
FTF	3.1369*	1.3954	0.7829
EDU	-0.6652*	0.2886	-0.1373
CV	4.1384**	1.2736	0.8543
CA	0.0488**	0.0163	0.0100

LR $\chi^2(9)$= 401.78 Number of observations = 340

Prob > χ^2 = 0.0000 Pseudo R^2 =0.9293

Percent correctly predicted = 98.82

Source: Estimated by this study

Notes:

(1) [a] * and ** indicate statistical significance at the 5% and 1% levels, respectively.

(2) [b] dy/dx is for discrete change of dummy variable from 0 to 1.

As expected, the coefficient of the standard deviation of the average yield at Tuanchang or county level (CV) is positive and highly significant, suggesting that farmers in the Tuanchangs or counties with higher yield variations are more likely to purchase crop insurance than those facing lower yield variations. The positive and significant coefficients on cotton acreage and full-time farming confirm that farmers working on larger cotton fields tend to insure the crop, and that full-time farmers are more risk averse.

However, the coefficient on RISKATT, a five-scale dummy variable using farmers' willingness to participate in health insurance as a proxy for risk attitude in cotton production, has the correct sign though insignificant, which might be explained by the inaccuracy of the proxy used in estimation. At the same time, DISR, a discrete zero-one variable set equal to one if the farmer received government disaster relief in the past four years, has a positive but insignificant impact on insurance purchase. The receipt of disaster relief fund is a clear signal that natural disasters can cause serious reduction in cotton production and farmers' incomes, so some farmers may seek additional protection by participating in crop insurance programs.

The most interesting result concerns the effects of agrochemical inputs on crop insurance purchase decisions. As shown in Table 5.2, both AGROFILM and FERTILIZERS have positive coefficients significant at 1% level, while that of PESTICIDES is negative and significant at 1% level. This suggests that the more fertilizer and agrofilm a farmer applies, the more likely he is to purchase crop insurance. On the contrary, the more pesticides he applies, the less likely he is to participate in crop insurance. One plausible explanation is that the increasing application of chemical fertilizers and agrofilm leads to stronger growth of cotton plants, resulting in higher yields and higher variation in yields. Inevitably, the probability of lower (below expected average) yields will increase. Therefore, farmers tend to purchase crop insurance against increased risks associated with more intensive application of chemical fertilizers and agrofilms. It is widely accepted that pesticides do not increase yield potential, they only affect yield when damaging agents such as pests and disease are present (Lichtenberg and Zilberman 1986). The result of this study confirms that the more pesticides a farmer applies, the less likely he is to purchase crop insurance, as the probability of lower yields is likely to be reduced by the increasing application of pesticides.

The results of this research are consistent with conventional knowledge that fertilizer is a risk-increasing input while pesticides is a risk-reducing input. It is also demonstrated that agrofilm may have the same effect as fertilizers in this regard. The empirical estimates show that, ceteris paribus, each additional RMB spent on fertilizers and agrofilm increases the probability of insurance purchase by 36.11% and 7.46% respectively; however, each additional RMB spent on pesticides lowers the probability of insurance purchase by 12.82%.

5.3 Impact of Crop Insurance on Agrochemical Inputs

Parameter estimates of the structural equations for agrochemical inputs are presented in Table 5.3. Standard errors of these parameters are estimated using the bootstrap method with 1,000 replications.

Table 5.3 OLS and Bootstrap Estimates of Agrochemical Inputs

Explanatory Variables	Explained Variables					
	Pesticides		Fertilizers		Agrofilm	
	Coefficient[a]	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
CONSTANT	18.3145***	7.8097	61.1593***	14.0200	24.2183***	2.5357
COTTINS	-5.0825**	2.6764	2.6714	6.3768	5.8695***	1.0898
EDU	-0.0803	0.3321	2.5650***	0.7777	-0.0157	0.1746
LC	2.1939*	1.4367	4.2422*	2.7169	0.3700	0.5144
SHRLIVE	0.0278	0.0523	0.0343	0.1308	0.0462	2.2116
DENSITY	0.2978**	0.1728	-0.1634	0.2527	0.0097	0.0600
DISEASE	-1.7042***	0.5351	1.9309*	1.2648	0.3794*	0.2609
FEXPER	-0.1767**	0.0968	0.2069	0.1948	0.0027	0.0437
AVGCY	0.0469**	0.0211	-0.0026	0.0486	0.0177**	0.0083
RISKATT	-0.5926	0.8495	-0.6676	1.6139	-0.0269	0.2857
Adj. R^2	**0.0325**		**0.0188**		**0.1704**	

Source: Estimated by authors

Notes:

(1) [a] *, ** and *** indicate statistical significant at 10%, 5% and 1% levels, respectively

(2) Sample size = 340

The coefficients on individual cotton plants per mu (DENSITY) are, as expected, positive in the PESTICIDES and AGROFILM application equations, and negative in the FERTILIZERS application equation, but only statistically significant in the PESTICIDES equation. This result suggests that the higher the cotton density a farmer has, the more pesticides he will apply as the possibility of insect and disease occurrence increases with plant density. On the other hand, in order to ensure the healthy growth of individual cotton plants on densely planted fields, the application of fertilizers must be controlled in order to prevent over-growth of the plants. Due to insufficient rainfall, most farmers along the Manasi Watershed adopt water-saving technologies, for example, dripping irrigation. As agrofilm can prevent the evaporation of moisture from the soil, a higher application rate is required with higher density planting.

The parameter estimate for DISEASE is negative and significant at 1% level in the PESTICIDES equation, and positive and significant at 10% level in both the FERTILIZERS and AGROFILM equations. These indicate that the less the losses caused by insects and disease in the past four years; the less pesticides and the more fertilizer and agrofilm a farmer will apply. These results are consistent with the belief that intensive applications of fertilizers and agrofilm have a positive impact on the infestation of pests (especially aphids) and disease when rainfall is low. Therefore, the occurrence of pests and disease in past years will have an influence on future chemical input decisions.

The performance of soil characteristics (LC) has the expected positive sign in all the three chemical input equations and is significant at 10% level in both PESTICIDES and FERTILIZERS equations. Farmers with lower land productivity tend to apply more pesticides and fertilizers. For the same reason, the average cotton yields in the previous two years (AVGCY) have a positive effect on the application of fertilizers, pesticides and agrofilm, and are significant at 5% level in the PESTICIDES and AGROFILM equations, though not significant in the FERTILIZERS equation. The coefficient for the share of off-farm income and net income derived from livestock (SHRLIVE) is positive, as expected, but not significant for all the three input equations.

The coefficients for education and farming experience indicate that more experienced farmers tend to apply less pesticides, suggesting that pesticides may be over-used due to inadequate information by less-educated and inexperienced farmers. Farmers with higher education tend to apply more fertilizers. This suggests that farmers with more education spend more on fertilizers and this is consistent with the expectation that better educated farmers are more adept at acquiring and processing information that is available from various sources, and then adopting and implementing recommendations and solutions that are relevant to their specific problem (Mishra, Nimon and El-Osta 2005).

Again, the most interesting result of the chemical inputs equations is the coefficient for COTTINS. As shown in table 5.3, the coefficient on COTTINS is negative and significant at 5% level for the PESTICIDES equation, and positive for both FERTILIZERS and AGROFILM equations, but only significant at 1% level for AGROFILM and not significant for FERTILIZERS. The results show that the greater the probability that a farmer purchases crop insurance, the less he will spend on pesticides, but the more he will spend on both agrofilm and fertilizers. This confirms the Horowitz and Lichtenberg's (1993) presumption that fertilizers and agrofilm are risk-increasing inputs while pesticides are risk-reducing inputs.

In reality, rainfall is severely inadequate, land fertility is fairly low, and the occurrence of aphid pests is comparatively frequent in Xinjiang. In particular, the increased application of fertilizers and agrofilm will lead to large amounts of insect populations and thus, large potential losses. There have been reports that pests are becoming an increasingly serious problem in Xinjiang in recent years as opposed to its reputation of low infection of pests in the past. Under such conditions, the increased application of chemical fertilizers and agrofilm inputs raises expected yields as well as the variance of yields. However, the losses due to the increased variance can be large enough to offset the increase in yields. Additional chemical fertilizers and agrofilm inputs may actually raise the probability of low yields, while increased pesticides should result in a decreased probability of low yields, which suggests that a farmer who insures against low yields will increase fertilizers and agrofilm, and decrease pesticide use.

The findings indicate that, on average, farmers with insurance apply RMB 5.87 more agrofilm and RMB 2.67 more fertilizers per mu, about 20.2% and 2.9% higher than the quantities applied by farmers who do not have crop insurance, respectively. At the same time, the farmers with insurance tend to apply RMB 5.08 less of pesticides per mu, or 18.99% below the level observed on other non-insured farms.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The methodology adopted in this study is similar to that of Smith and Goodwin (1996), but the empirical results are different. The results of this study strongly indicate that crop insurance purchase decisions depend on farmers' production behavior: those who apply more chemical fertilizers and agrofilm are more likely to participate in crop insurance programs while those who apply more pesticides will do the opposite. The results also indicate that farmers' agricultural chemical input decisions are influenced differently by the decision to purchase crop insurance: pesticides are likely to be applied less if cotton production is insured, while agrofilm and chemical fertilizers are likely to be applied more, though the latter case is not statistically significant. In contrast, Smith and Goodwin found that farmers with crop insurance will use less intensive chemical fertilizers and they claim that this must be because the expected returns from crop insurance declines with input use.

The difference between our results and those found by Smith and Goodwin might be explained by several factors. Firstly, our estimation is disaggregated for each of the agrochemical inputs and this may have resulted in different findings compared with the results of Smith and Goodwin which were derived from aggregated data. Since the output and environmental impacts of pesticides, agrofilm and fertilizers are not identical, disaggregating the three is warranted. As such, pesticides, agrofilm and fertilizers may have different risk properties and indeed the regression results suggest that the effect of crop insurance on each is not identical.

Secondly, the existing crop insurance program practiced in Xinjiang is designed to compensate for only a portion of the material costs incurred in the event of severe yield losses. The indemnity farmers can receive is much lower than the typical crop insurance program adopted in the US which provides compensation for a relatively larger portion of yield loss. Therefore, moral hazard is not likely to be a big issue in China today under the current crop insurance policy – farmers insure their crop basically against natural disasters, but not the additional yield variation resulting from increased agrochemical applications.

This research has confirmed that fertilizers and agrofilm are risk-increasing inputs while pesticides is a risk-reducing input, so they influence farmers' decisions to purchase crop insurance in different ways. This research has also found, under the current terms of low premium and low indemnity, that crop insurance may not cause serious impacts on the environment except for the accumulation of small pieces of broken agrofilm. The increase in fertilizer application is not statistically significant, but the reduction of pesticide application is significant.

6.2 Implications and Recommendations

The participation rate of cotton insurance in 2003 was 44.84% without premium subsidy. If China were to give 10% premium subsidy to encourage farmers to participate in the crop insurance program, the participation rate will go up to 83.24%, and total pesticide application is likely to be reduced by about 2.21% while the total application of agrofilm is likely to increase by 9.15%. At the same time, if the insignificance is ignored, the total application of fertilizers is likely to be increased by 2.54% in Xinjiang without any change in total cotton sown acreage. (Note: here we assume that the total cotton sown areas remain the same for Xinjiang but that the subsidy will encourage more cotton producers to participate in crop (cotton) insurance. If we assume that crop (cotton) insurance changes farmers' cropping patterns, such as shifting from maize, soybean and other crops to cotton, the calculation will be different as different crops require different amounts of inputs.)

Under the existing insurance program, farmers cannot have a policy which provides a higher indemnity at a higher premium. There is only one policy with a fixed premium and indemnity per unit of cotton sown area. This is why we estimated farmers' potential reactions separately: premium being reduced for the same indemnity, or indemnity being increased for the same premium payment from their own pockets. Our estimates indicate that, an increase in indemnity of up to 80% of the material costs from the 60% in 2003 may induce farmers to apply RMB 1.17 more of agrofilm per mu, RMB 0.53 more of fertilizers per mu, and RMB 1.02 less on pesticides per mu. This implies a total increase of agrofilm application by 3.7% and a total increase of fertilizer application by less than 0.56%, as well as a total decrease of pesticides by 3.89% in Xinjiang as a whole.

It should be noted that farmers in Xinjiang grow one crop in a year while their counterparts in most other regions grow two or more. As agrochemical application rates are calculated for each crop, the chemical residuals in the soil are likely to be much lower in Xinjiang despite higher application rates of some agrochemical inputs in cotton production there compared with other regions.

It also should be noted that the high application rate of agrofilm in Xinjiang is associated with the extreme climate there. As it is used to protect soil moisture from evaporation and to raise soil temperature in the early growing season, its importance and application rates are lower in other regions with better climates, especially in central and south China.

Restricted by water availability in Xinjiang and by the availability of arable land in general in China, as well as the low-incentive (due to the low indemnity) to increase the application of agrochemical inputs, crop insurance is not likely to encourage the expansion of crop production into new land. The proposed government subsidy for general crop insurance is also not likely to induce the shift of production from crops requiring less agrochemical inputs to cotton which usually requires more agrochemical inputs.

Therefore, if the current scenario is not changed dramatically, crop insurance subsidies by the government will not lead to significant damage to the environment. In order to remedy the potential environment threat of the accumulation of agrofilm in the soil, the subsidy policy would be better applied to crop areas where agrofilm is not a necessary input. At the same time, the development and adoption of easy-pickup agrofilm and a special machine to clear the soil at low costs should be encouraged – the adoption of such techniques should be made a pre-condition to receiving government subsidies.

Further studies should be conducted to investigate the actual changes in agrochemical applications, as well as changes in farmers' welfare, under various insurance terms associated with different subsidy schemes. As suggested by this study, the relationship between crop insurance and agrochemical application is setting-dependent (i.e., conditional on the natural environment and terms stipulated in the insurance policy). Obviously, more studies investigating farmers' behaviors under different circumstances are very important in designing appropriate crop insurance programs for different crops under various conditions. It is also believed that the validity and/or desirability of government support in crop insurance lies in the improved welfare of farmers involved in such insurance programs. The farmers' willingness to pay for various insurance policies is a necessary basis to measure any potential change in associated welfare.

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