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# THE ECONOMIC EFFECTS OF ALTERNATIVE INSTITUTIONAL DESIGNS FOR U.S. CROP INSURANCE.

by

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ABSTRACT

THE ECONOMIC EFFECTS OF ALTERNATIVE INSTITUTIONAL DESIGNS FOR U.S. CROP INSURANCE

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This study compares the performance of alternative institutional designs for crop insurance delivery. The aim is to investigate institutional designs that incorporate a role for the government and competitive firms in meeting the goals of actuarial soundness and high coverage levels (low cost) for farmers. In particular, four alternative designs are investigated:

I. Competitive firms deliver all crop insurance without any government reinsurance.

II. The government provides insurance to all farmers with no role for competitive firms.

III. Both the government and competitive firms deliver insurance in a mix determined by the current federal crop insurance program.

IV. Competitive firms deliver all crop insurance with the government providing only reinsurance.

These four designs are investigated with simple stylized models where the government is portrayed as risk neutral with no ability to distinguish between farm risk types, while competitive firms are portrayed as risk averse with full information to distinguish between farm risk types.

Results indicate that, with more than one farmer risk type, a self sustaining federal crop insurance program could provide maximum coverage to all farmers if low risk policies are taxed and high risk policies are subsidized. This does not occur in the current federal crop insurance design. Also, if the government continues to deliver crop insurance under the current design, it

could cut costs if all policies were delivered through private firms without requiring these firms to share in the risk.

For competitive firms, results indicate that high levels of systematic risk are a major reason for the lack of competitive markets for multi-peril crop insurance. The analysis shows that if there were no such markets (due to high levels of systematic risk) then proportional reinsurance schemes without subsidies would not facilitate an equilibrium. The Area-Yield Insurance Plan (currently available only to farmers) has the potential to serve as a reinsurance scheme that facilitates equilibrium without undue burden on taxpayers. Once a competitive crop insurance market is established, proportional reinsurance may be introduced to increase coverage to farmers.

Rebecca, Timothy and Annette

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# 1. Introduction

The government is generally considered to be in a better position than private companies to undertake very risky investments. This is because of the government's ability to pool risk across a large and diverse portfolio of activities, and also its ability to spread risk across a large number of taxpayers such that the risk borne by an individual taxpayer is negligible. Both these risk pooling and risk spreading aspects of the government put it in a unique position to develop programs which private companies will not undertake because they require a higher rate of return to compensate for the higher risk (Arrow and Lind). One example where the U.S. government uses its capacity to pool and spread risks is in the delivery of multi-peril crop insurance.

The U.S. government provides multi-peril crop insurance through the Federal Crop Insurance Corporation (FCIC). No multi-peril insurance exists in the private sector although insurance for individual perils such as hail and fire exist for many crops. Multi-peril crop insurance protects participating farmers against all unavoidable yield risks such as droughts, floods, insect infestations, and other natural disasters. Government involvement in crop insurance is driven not only by the desire to compensate for negative income shocks resulting from farm yield losses, but also the desire to make crop insurance the primary provider of disaster assistance to farmers. This was done because other disaster assistance programs, such as direct cash payments, were considered too expensive and involved the farmer carrying too little of the production risk (GAO/RCED-92-25). Because crop insurance is based on actuarial data, it is argued that an insurance system provides for a more stable funding of disaster losses. Further, with crop insurance there is a pre-commitment of government funds with a contingent plan in place to deal with disasters while other forms of disaster assistance are highly discretionary (GAO/RECD-88-211BR).

The 1980 Crop Insurance Act (Public Law 96-365, Sept. 26, 1980) legislated the FCIC to perform the role of primary disaster assistance provider. The FCIC was directed to: (i) increase crop insurance participation rates in order to abolish other government funded disaster assistance programs; and (ii) reduce the amount of federal costs the government was bearing for unavoidable crop failure. The objective of the government was to convert uncertain disaster payments to a system where the farmers recognized the risks they faced and partially paid to insure such risks. The program was to operate within a budget although federal subsidies were to be provided to reduce insurance costs to farmers while maintaining adequate coverage levels. To increase the efficiency of the program and achieve the above objectives, the FCIC was directed to use the expertise of the private sector in providing federal crop insurance.

A key feature of the 1980 Crop Insurance Act was for the FCIC to involve the private sector in the federal crop insurance program. It was envisioned that the expertise of private insurance firms would maintain and/or improve services to farmers and save money by increasing the "efficiency" of the program. The FCIC did not single out any particular expertise of the private companies that would help the crop insurance program to gain this "efficiency". The path that the FCIC chose was to involve private insurance firms by having them deliver the major share of crop insurance to farmers. In fact, all the crop insurance delivery would take place through two channels: Master Marketers and reinsured companies. Direct crop insurance sales by FCIC employees were terminated in 1983 (GAO/RCED-87-77).

Both Master Marketers and reinsured companies are private insurance firms but there are differences in the ways each participates in the FCIC program. Master Marketers are private insurance firms that sell crop insurance as agents for the FCIC. These firms bear no risk on the policies they sell and do not adjust claims. The federal government retains all premiums and pays all indemnities on policies sold by the Master Marketers. The Master Marketers get approximately 15% of the premiums as fees. Unlike Master Marketers, reinsured firms bear a portion of the risk on the policies they sell. The firms are called "reinsured" because they buy reinsurance from the FCIC through proportional and/or stop-loss reinsurance measures.

In proportional reinsurance, the FCIC and the private insurance companies share specified portions of both the policy premiums and the indemnities, while in stop-loss reinsurance the FCIC agrees to reimburse the private insurance company for all indemnity payments above a predetermined level (see Chapter 6 for a detailed discussion of the reinsurance schemes). Although the reinsured firms sell, service and settle claims on their own crop insurance policies, the policy features and the premiums farmers pay are determined and set by the FCIC. The reinsured firms are allowed to differentiate between high and low risk farmers for proportional reinsurance purposes and have the option to retain less of the high risk policies. The FCIC further reimburses reinsured firms for administrative costs. By 1990, reinsured companies accounted for 89% of the total number of crop insurance policies sold to farmers. Reinsurance, therefore, is currently the primary mode of crop insurance delivery used by the FCIC.

## 1.1 The Problem

Despite federal payments for all administrative expenses and federal subsidies for crop insurance premiums, the FCIC bore losses every year during the 1980-90 decade without any establishment of reserves against catastrophic losses or obtaining the desired level of participation rates in the program. This performance generated serious criticisms of the workings of the federal crop insurance program. Various General Accounting Office reports (GAO/RCED-88-7; GAO/RCED-89-10; GAO/RCED-90-32; etc.), attributed this poor performance mainly to (i) the lack of actuarial soundness of crop insurance premiums and (ii) overgenerous reinsurance agreements with the private reinsured companies[1]. While many studies have addressed the actuarial soundness question (Chambers; Nelson; Nelson and Preckel; Skees and Reed; etc.), there is currently no research addressing the performance of alternative designs of the FCIC reinsurance program, and the way it includes private firms. Preliminary General Accounting Office studies (various issues) claim that the historical involvement of private insurance firms has aggravated the performance of the FCIC rather than helped it.

Related to the problem of insurance provision by private companies is the problem of systematic or catastrophic risk in crop production. The systematic nature of yield risks means that when disaster strikes it generally affects a large number of farmers. Since the proportion of systematic risks is considered extensive in the agricultural sector, an insurance firm could face large indemnity outlays within a short period of time, such that it drives the insurance firm to ruin. In such cases insurance firms may demand a high "risk premium" to provide crop insurance to farmers (Hara). This role of systematic risk has received some attention in the literature (Miranda; Chambers) but not in the context of risk averse firms delivering crop insurance. Given that reinsured firms are now the primary mode of crop insurance delivery in the U.S., it seems particularly important to examine the role of such firms in providing insurance services in the presence of systematic risks.

[1]Other criticisms include too rapid an expansion of the program, and the continued existence of other disaster assistance programs such as Direct Cash Payments and Emergency Loan Programs.

## 1.2 Objectives of the Study

The purpose of this study is to compare the performance of alternative institutional designs for crop insurance delivery in the context of simple stylized models. The aim is to study institutional designs that incorporate a role for the FCIC and competitive firms in meeting the federal crop insurance policy goals of actuarial soundness and high participation rates (low cost). In particular, four alternative stylized designs are investigated.

I. Competitive firms deliver all crop insurance to farmers without any reinsurance role for the government. Such a design would involve risk averse competitive firms who face a trade off between profits and risk in their decision to provide insurance. The evaluation of this design would include studying the "risk premium" charged by these firms given their degree of risk aversion. It is of interest to see the conditions under which this market is viable and, if it is viable, how the resulting coverage meets the government's objective of providing adequate coverage to all farmers. In the absence of any subsidization, this design has no cost to taxpayers.

II. The government (through the FCIC) provides insurance to all farmers directly with no role for competitive firms. Here, the FCIC acts as if it is a giant insurance firm that sells and services crop insurance for the whole country but is mandated to operate at zero expected profits. Unlike competitive firms, the FCIC is assumed to be a risk neutral insurance provider (there is no "risk premium") but it is expected to face higher costs of providing insurance and have less information on farmer risk classification.

III. Both the government and competitive firms deliver insurance in a mix determined by a reinsurance agreement between the two institutions. The purpose of this design is to study how well the current FCIC reinsurance program meets the stated objectives of the government. The design embodies the FCIC setting major policy variables, such as pricing and coverage levels, while the competitive firms sell and adjust the policies sold. The competitive firms bear some risk on the policies they sell and transfer the rest to the FCIC through proportional and stop-loss reinsurance.

IV. Competitive firms deliver all crop insurance with the government providing reinsurance. Unlike Design III, all primary insurance decisions are now made by the competitive insurance firms who also decide whether or not to buy FCIC reinsurance. Since multi-peril private crop insurance does not exist, this design evaluates under what conditions such a market breaks down. This information helps to investigate whether alternative federal reinsurance programs would facilitate such a market to evolve and, if it does, whether this market would meet the stated crop insurance goals of the government.

Designs I and II are polar cases designed to identify the performance of the two main alternative institutions for meeting the government's objectives for crop insurance. Designs III and IV are alternative formulations to investigate the effects of combining the two insurance institutions to deliver crop insurance in the presence of non-diversifiable risk.

## 1.3 Working Hypotheses for the Study

Several working hypotheses are employed in the models of this study. These working hypotheses simplify the models but they do so in a way that allows important insights to be gained into the role of private firms and the government in delivering crop insurance. These working hypotheses are:

(i) *Competitive firms can deliver crop insurance at a lower cost than the FCIC.*

This hypothesis is supported by the arguments of Hazell, who suggests that government agencies have little incentive to be cost-effective when the insurer has a government guarantee. There is no direct evidence to compare the delivery cost of the government to that of a competitive firm since a competitive crop insurance market does not exist. However, if the health industry is to be used as a proxy for competitive firms, administrative costs (as a ratio of total premiums) is placed at about 5 percent (Diamond) compared to the FCIC's 51 percent (Hazell).

(ii) *When farmers belong to different risk classes then competitive firms have perfect information regarding each farm's risk classification but the FCIC cannot distinguish between risk classes.*

This working hypothesis is a simple stylized way of incorporating the general idea that competitive firms have more information on farmer risk types than the government. The idea comes from Hazell's assertions that government agencies have little incentive to be cost-effective when the insurer has a government guarantee. Hazell's arguments suggest that the government would have higher costs of getting the same information on farmer characteristics as competitive firms, which implies that they have less incentive to collect such information compared to firms. An extreme case would be when the competitive firms collect full information on farmer risk types but the FCIC collects no information. Furthermore, there is evidence to suggest that political factors constrain the government from collecting information that would help better classify farmer risk types. For example, attempts to include farm size in premium calculations have been seen as government discrimination against small farmers[2]. This would not be a factor in the case of competitive firms.

(iii) *Competitive firms delivering crop insurance are risk averse while the FCIC is risk neutral.*

Competitive insurance firms are often hypothesized to be driven by safety designed to avoid bankruptcy. This is empirically supported by the fact that private insurance firms purchase reinsurance on their portfolio. This aversion to risk is modeled using a mean-variance framework in this study. The government, on the other hand, is backed by the federal treasury and following arguments forwarded by Arrow and Lind (that the government is able to spread risk across a large number of taxpayers and diversify over a large portfolio), the government's preferences are portrayed as risk neutral.

(iv) *Competitive firms are assumed to operate at reservation utility levels in long-run equilibrium.*

This concept was first introduced by Appelbaum and Katz whereby a competitive firm enters or exits an industry depending on whether their expected utility from participating in the industry is higher or lower than a reservation utility level. The reservation utility indicates preferences for alternative investments opportunities available to the firm. By defining long run equilibrium in this manner, the risk aversion of competitive firms is modeled to investigate the effects of systematic risk on coverage to farmers. This approach differs from the usual

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[2] Personal communication with Roy Black, Michigan State University.

assumptions of risk neutrality and zero profits as conditions for long-run equilibrium and is an important innovation in this study.

(v) *Agricultural yield risks are highly correlated across farms (systematic risk).*

Systematic risks occur in the agricultural sector mainly because the sector is prone to unpredictable, widespread natural disasters. Empirical support for this assumption is provided by Miranda, Hazell, and Hara.

(vi) *Yield risk is the only source of risk to farm income.*

Other risks, such as price risk, are assumed away so as to concentrate on risks that are purely a result of the technical production process. This also facilitates isolation of the effects of systematic risks on coverage levels of farmers.

## 1.4 Outline of the Dissertation

The rest of the study is organized as follows. Chapter 2 provides an historical overview of the U.S. Federal Crop Insurance Program. Chapter 3 presents a basic model and studies competitive firms and FCIC delivery of crop insurance in the presence of high positive correlation between farm risks (but with only one farmer risk class). Chapter 4 extends the analysis of Chapter 3 by including multiple farmer risk classes and assuming that the FCIC cannot distinguish which farmer belongs to which class. Chapter 5 studies a stylized version of the current FCIC reinsurance program where the FCIC makes all of the primary insurance decisions, while Chapter 6 investigates reinsurance programs where the FCIC provides reinsurance only and does not make all primary insurance decisions. Chapter 7 provides a summary and conclusions and highlights the main implications of the study.

# 2. An Overview of Crop Insurance in the U.S.

The congress created federal crop insurance in 1938 after private insurance companies were unable to establish a financially viable multi-peril crop insurance business. The 1980 Crop Insurance Act extended the federal crop insurance program to be the primary disaster assistance provider in the United States. However, since its inception in 1938, and throughout the period after the 1980 Crop Insurance Act, critics have rated the performance of the program as poor. This section gives a brief historical overview of the program before 1980 and elaborates on the workings and performance of the program since 1980. The primary source of information in compiling this information has been various General Accounting Office (GAO) reports while the historical overview has been heavily drawn from Gardner and Kramer.

## 2.1 Historical Overview

Crop insurance was offered on a limited basis for hail and fire before the 20th century (Gardner and Kramer). The first multiple peril crop insurance sold was recorded in 1899 by Realty Revenue Guaranty of Minneapolis but none of the programs were sustained over time. In 1922 crop insurance was approached as a national problem for the first time when the U.S. Senate passed a resolution calling for the investigation of crop insurance (U.S. Congress 1923). The resolution of 1922 provided for the appointment of a select Senate Committee to investigate (i) the kinds and costs of insurance available; (ii) the adequacy of protection; (iii) the desirability of any practical methods for extending the scope of such insurance; and (iv) the availability and sufficiency of statistics to properly and safely issue additional insurance. However, by the summer of 1924 no action on crop insurance was undertaken by Congress.

In 1936, President Roosevelt appointed a committee to make recommendations for legislation providing for government sponsored crop insurance. The legislation established the Federal Crop Insurance Corporation (FCIC), an agency within the United States Department of Agriculture (The Federal Crop Insurance Act of 1938). The management of the corporation was vested in a board of directors appointed by the secretary of Agriculture and the FCIC was backed by the resources of the treasury. The initial insurance was only for wheat and then it was extended to cotton. Local committees of the Agriculture Adjustment Administration administered the crop insurance program.

The initial experience of the crop insurance program was not very encouraging as the program's indemnities exceeded premiums. The program was hampered by high costs, low participation, and the inability to accumulate adequate reserves for catastrophic losses. It seems that inexperienced estimators relied too heavily on county averages for setting premiums (Gardner and Kramer). Added to these problems, many states had also experienced drought during this time (Clendenin). Private companies continued to provide coverage for hail and fire damage, which generally are not prone to systematic risk.

After the 1939 experience of appraising yields too high, the FCIC established a key farm system for future years (FCIC Annual Report 1939). Under this system, fifty to a hundred farms with good yield data were selected from each county. To appraise yields, a comparable farm from the key farms was appraised to calculate premiums. Participation in the program increased steadily with the number of farms insured increasing from 165,775 in 1939 to 371,392 in 1941. Despite the growth in participation, the FCIC continued to pay indemnities in excess of premiums received (FCIC Annual Report, 1943). The program for wheat and cotton was highly criticized in the 1943 congressional hearings because of large underwriting losses and the low level of participation. The congress expected to subsidize administrative costs but not cover indemnities for normal years (Agriculture Finance Review, 1943). It became clear that the program would not be self supporting and the annual underwriting loss of $4 million each year was troublesome because losses occurred even during relatively good crop years.

In 1946 several new features were added to the program. A three year contract for wheat was introduced to overcome adverse selection (as many wheat farmers bought insurance after soil moisture indicated a poor crop). The three year contract was designed to eliminate adverse selection, at least for the second and third year of the program (Gardner and Kramer). Also, since there was not enough data available to determine individual farm yield variability, all crops were insured under countywide rates. Further, partial coverage was offered for the first time (i.e., receive a lower level of protection for a lower premium) but this did not prove popular with farmers.

In 1947, the FCIC collected premiums in excess of its indemnities for the first time in its history. However, the legislation passed that year severely curtailed the operations of the corporation. Although the scope of the program was reduced, the FCIC was given greater latitude in experimenting with alternate forms of insurance (FCIC Annual Report 1948). Over the experimental phase (1948-52) the surplus of premiums over indemnities was $2.25 million. Beginning in 1956, FCIC announced that it would no longer be selling insurance to counties in Colorado, New Mexico, and Texas (these counties were considered high risk farming areas and not selling insurance to these areas was expected to result in a surplus for the national program). Other factors, such as improved operation methods and advancement of closing date for application to reduce adverse selection, also contributed to the improved performance.

During the 1960s the FCIC concentrated on increasing its coverage reaching $920 million in 1969 (versus $470 million in 1947 and $271 million in 1959). However, this rapid increase came at a cost - in the last three years of the 1960s the corporation paid 29% of the total indemnities paid during the entire 1948-69 period (Gardner and Kramer). The secretary of agriculture appointed new management who concluded that, for many crops, risks had been miscalculated and premium rates set too low. The cotton program was identified as one of the corporations major problems. At this time, premiums for cotton were increased and potatoes were dropped from the program altogether.

In 1970, the secretary of agriculture appointed a new task force on non-governmental insurance to study the FCIC. The task force criticized the practice of establishing premiums on a county-wide basis, and concluded that the most urgent needed change was to base the program on individual farm risks (FCIC Task Force, 1970). It was concluded that low participation prevented FCIC from operating an effective protection program. To increase farmers participation in the crop insurance program, individualized farm protection was proposed.

The federal government also offers disaster assistance programs and various emergency loan programs to cover gaps left by crop insurance. For example, beginning in the mid 1970s the disaster assistance program paid an average of $436 million annually (mainly cash) to farmers between 1974 and 1980. USDA made an average of $965 million in emergency loans between 1970 and 1979.

## 2.2 The 1980 Crop Insurance Act

By 1980, direct cash payments and emergency loans were being criticized for being too expensive and allowing farmers carry too little of their production risks. This encouraged farmers to plant crops in marginal lands susceptible to natural disasters (GAO/RCED-92-25). These programs were also considered inequitable since they only provided payments to farmers of the six primary crops (wheat, corn, sorghum, barley, upland cotton and rice). The crop insurance program was seen as an alternative way to deliver disaster assistance to farmers. It was considered the best disaster assistance method because (GAO/RECD-88-211BR): (i) insurance rates are based on actuarial data and such a system provides for more stable funding of disaster losses; and (ii) with crop insurance there is only one value judgment to be made - the level of subsidization of the insurance premium (while with loans and direct payments several value judgments, such as the terms and the timing of assistance, which are not related to actual severity of the disaster have to be made). To make crop insurance the primary disaster assistance provider the congress enacted the Crop Insurance Act of 1980 (PL 96-365, September 26, 1980) and greatly expanded the FCIC program. Specifically, the objectives of the 1980 Crop Insurance Act for the FCIC may be summarized as:

(i) The program is to work on an actuarially sound basis;

(ii) The program is to provide maximum coverage feasible to all farmers such that the program serves as the primary provider of disaster assistance;

(iii) The program is to include the private sector to make it more efficient and avoid undue burden on taxpayers.

## 2.3 Design of the FCIC Program

The crop insurance delivered by the FCIC is designed to protect participating farmers against unavoidable risks, such as droughts, floods, insect infestations, and other natural disasters. All farmers are eligible to participate if FCIC offers an insurance program in their county. Participants can elect coverage of 50, 65, or 75 percent of their normal yield which also includes damage on quality for most crops. This normal yield is calculated as Average Production History (APH) using the farmer's own records for yields in the years available, and county averages for the years when yield records are not available. The farmers can choose any price selection ranging from 30 percent to 100 percent of the crop's expected market price and, accordingly, the insurance premium rates depend on the dollar amount of insurance protection that one chooses to purchase. FCIC subsidizes 30 percent of the premium costs for all policies up to the 65 percent coverage level, and pays for the program's administrative costs. The rates that the farmer faces are net rates after government subsidies and all crop insurance premiums are tax deductible. If the farmer's individual yields are above county yields, and records are available, then premiums for that farmer may be reduced. The premium is also reduced if the farmer buys separate hail and fire insurance.

The deadline for purchasing insurance is one month prior to usual planting. The bill for the premium is not sent out until harvest time, which implies that premiums do not add to input cost at planting time. In a year of loss, the premium is deducted and the indemnity is based on an estimate of actual production by an independent loss adjuster. The farmer can choose the mix of crops to insure but the farmer must insure all planted acreage owned in the county.

To satisfy the legislative mandate of the 1980 crop insurance act for greater private sector involvement, FCIC developed two systems of delivering crop insurance -- Masters Marketers and reinsured companies. Master Marketers are private insurance companies that sell crop insurance as agents for the FCIC. These private companies bear no risk on the policies they sell and do not adjust claims. The federal government retains all premiums and pays all indemnities. The Master Marketers get approximately 15% of the premiums as fees.

Reinsured companies sell, service and settle claims on their own crop insurance policies, although the premium and other policies are determined by FCIC. Unlike Master Marketers, reinsured companies bear risk on the policies they sell but obtain reinsurance from the FCIC. Consequently, reinsured companies and the FCIC share gains and losses from policies. In addition, the FCIC reimburses reinsured companies for administrative costs amounting to 32-33 percent of the premiums (premiums include government subsidy at the 50 and 65 percent coverage level). By 1990, reinsured companies accounted for 89% of total crop insurance policies sold to farmers.

## 2.4 Performance of Crop Insurance since the 1980 Crop Insurance Act

Various GAO reports have indicated that FCIC performance has fallen far short of that envisioned by Congress in the 1980 Crop Insurance Act. Despite federal payments for all administrative expenses, and federal subsidies on crop insurance premiums, federal crop insurance has continuously borne losses every year in the 1980-90 decade, without any establishment of reserves against catastrophic losses. Participation rates (gross insured area/planted area) has been less than the 50 percent hoped for and has stayed below 25 percent of the eligible acres for most of the decade (GAO/RCED-92-25). Moreover after a decade of operation, there is no indication that crop insurance has replaced other disaster assistance programs. This is, in part, because of the government's provision of ad hoc disaster payments and emergency loans. In 1980-90, the USDA spent $25 billion on insurance loans and direct payments, 76 percent or $19 billion of which was spent for disaster payments and emergency loan programs. Government outlays over 1980-90 for the three major disaster assistance programs are given in Table 2-1.

Table 2-1: Government Agricultural Disaster Assistance ('000 $), 1980-90.

| Program | Crop Insurance | Disas. Payment | Emergency Loan | Total |
|---|---|---|---|---|
| 1980 | 28,015 | 303,352 | 245,261 | 576,628 |
| 1981 | 426,923 | 1,422,363 | 402,171 | 2,251,459 |
| 1982 | 480,724 | 337,390 | 440,681 | 1,258,795 |
| 1983 | 345,865 | 127,897 | 436,225 | 909,987 |
| 1984 | 325,956 | 26,979 | 438,673 | 791,608 |
| 1985 | 462,696 | 17,795 | 730,337 | 1,210,828 |
| 1986 | 733,136 | 16,610 | 865,598 | 1,615,344 |
| 1987 | 562,470 | 824,193 | 1,180,047 | 2,566,710 |
| 1988 | 1,223,054 | 114,203 | 1,647,491 | 2,984,748 |
| 1989 | 811,292 | 4,012,104 | 2,242,010 | 7,065,406 |
| 1990 | 751,864 | 1,659,607 | 1,461,491 | 3,872,962 |
| Total | 6,151,997 | 8,862,493 | 10,089,985 | 25,104,475 |

Source. GAO/RCED-92-25 (GAO analysis of USDA data).

One of the reasons given by the congress for continuing support for all three forms of disaster assistance programs is that the participation rates in the FCIC program has been too low. The question of participation rates in the FCIC program was important enough to warrant a General Accounting Office investigation which is documented in GAO/RCED-88-171BR. The study indicates that of ten states surveyed in 1987, participation rates varied from 2.9 percent to 44.9 percent against a national average of 24.9 percent (since then the figure has been revised to

20.1 percent). Some crops were not insured at all while others had over 60 percent participation rates. Table 2-2 reports the FCIC participation trends for the years 1980-91.

Table 2-2: Participation Rates in the FCIC Program, 1980-90.

| Category | # of County programs | # of Crops Insured | Acres Eligible[a] | Acres Insured[a] | Participation Rate (%) |
|---|---|---|---|---|---|
| 1980 | 4,632 | 30 | 273,889 | 26,272 | 9.6 |
| 1981 | 5,969 | 30 | 282,333 | 44,996 | 15.9 |
| 1982 | 14,498 | 29 | 280,046 | 42,721 | 15.3 |
| 1983 | 15,415 | 32 | 240,103 | 27,935 | 11.6 |
| 1984 | 17,868 | 37 | 276,073 | 42,668 | 15.5 |
| 1985 | 18,892 | 39 | 265,967 | 48,537 | 18.2 |
| 1986 | 19,053 | 41 | 247,987 | 48,632 | 19.6 |
| 1987 | 19,263 | 42 | 244,807 | 49,134 | 20.1 |
| 1988 | 19,611 | 44 | 243,114 | 55,589 | 22.9 |
| 1989 | 20,507 | 49 | 253,795 | 101,502 | 40[c] |
| 1990 | 21,354 | 51 | 254,047 | 101,126 | 39.8[c] |
| 1991 | 21,373 | 51 | b | b | b |

Source: GAO/RCED-92-25 (GAO analysis of FCIC data).
[a]in thousands.
[b]data not available at report time.
[c]many producers who participated in the 1988 or 1989 disaster assistance programs were required to purchase crop insurance the following year.

According to the GAO/RCED-88-171BR report, reasons for low participation rates are: (i) Climate conditions - some areas are less prone to adverse climatic conditions than others; (ii) Complex record keeping - farmers feel that the complex record keeping is more trouble than it is worth; (iii) Condition of the farm economy - with decreasing profits in the farming sector, farmers see insurance as an additional cost in operations; (iv) Costly premiums - premium rates are considered actuarially out of line and the costs outweigh the benefits from insurance; (v) Crop diversification - crop diversification is seen as adequate insurance by many farmers; (vi) Crop tolerance - corn is more tolerant to hail than soybeans, but soybeans are more tolerant to drought and this affects insurance purchasing; (vii) Delivery system - many farmers believe that crop insurance is becoming more concerned with higher commissions to agents and less concerned with servicing farmers; (viii) Distrust of federal programs - conflicts about insurance claims have created negative attitudes towards FCIC and the Federal Program; (ix) Farmer optimism - many farmers have an optimistic outlook for a good crop and, hence, a decreased demand for insurance; (x) Other federal programs - other farm programs provide income and price support with direct cash payments at no cost; (xi) Frequent program changes - frequent program changes gives insurance agents little time to develop effective marketing plans to sell crop insurance; (xii) Education - the FCIC is seen to give insufficient education to farmers on the benefits of purchasing insurance; (xiii) Insurance agent's knowledge - many insurance agents do not have the knowledge to explain the program accurately to farmers; (xiv) Limited coverage - the insurance program is seen to have limited coverage, so that buying this insurance is not beneficial; (xv) No guaranteed payments - unlike other government programs, the crop insurance does not guarantee annual payments to farmers; and (xvi) Actuarial fairness - the FCIC's rates may not reflect the actual risk level of farmers and price elections may not always reflect the current year's crop prices.

The report also gives the following reasons for different participation rates among states: (i) Agent incentives - high risk areas have high premiums implying agent commissions are high and therefore agents are more active in selling insurance. In the North East farms are small and there are fewer crops, therefore less profitability; (ii) Crop diversification - reduces the expected return from crop insurance; (iii) Crop value - high value crops, such as peanuts, sugar beets, and tobacco, are more likely to be insured; (iv) Insurance education - the way in which the FCIC promote insurance education is not adequate; and (v) Weather patterns -stable weather patterns, such as in Arizona, cause farmers to be less likely to buy insurance.

## 2.5 Problems of the FCIC Program

GAO reports identify some key problem areas for the FCIC program. These areas are actuarial soundness of the program, crop price forecasts, and inadequate risk sharing by the insurance delivering private sector.

### 2.5.1 Actuarial Soundness

The Comptroller General's report (GAO/AFMD-87-36) says that the premiums rates set by the FCIC are not adequate to cover losses on insured crops and establishment of reasonable reserves against unforeseen losses. The FCIC's response to this allegation is that higher premiums rates would further aggravate producer participation in the program (one of the goals of the 1980 crop insurance act). Some of the specific reasons for this lack of actuarial soundness are documented below:

#### 2.5.1.1 Lack of Farm Level Data

One clear problem is the lack of individual farm level data. This lack of data has resulted in classification problems which has led to adverse selection, compromising the actuarial soundness of the program.

#### 2.5.1.2 Political Pressure

Political pressure also compromises the actuarial soundness of the program. The GAO report notes "we advised the FCIC manager that rapid expansion of the program might result in increased exposure to loss because insurance rates might be based on questionable actuarial assumptions and methodologies" (p.24, GAO/RECD-92-25). An example of expansion of the program at the cost of actuarial soundness is given by the sale of insurance for non-irrigated safflower in California counties that had suffered four straight years of drought. The policies offered had too high a yield guarantee to work on an actuarially sound basis. FCIC staff involved in the California program said losses occurred for two reasons: (i) weak internal controls for expansion of county programs and (ii) inability to establish an actuarially sound program because of political pressure (GAO/PEMD-91-27).

### 2.5.2 Crop Price Forecasts

Crop price forecasts have been the other major influence on the actuarial soundness of the program. FCIC's forecast are intended to reflect actual seasonal average market prices for the crop year, and provide the basis for the different program price options. Price elections are important because they directly affect the amount of the premium a farmer pays and the amount of indemnity the FCIC pays. Price elections also affect private companies selling insurance because it alters commissions. If prices are low, participation rates fall and if prices are high, indemnities are high and moral hazard problems increase.

Some of the problems identified with price forecasts are: (i) forecasts being made earlier in the crop year than necessary; (ii) lack of an effective management process to evaluate accuracy and methods; and (iii) the failure to deduct harvest costs when total crop losses occur.

The GAO/PEMD-92-4 report indicates that FCIC's corn, wheat, and soybean price forecasts exhibit large bias errors. For example, in 1983-89 the FCIC would have spent $194 million less if it had used the World Agriculture Outlook Board (WAOB) price forecast for crops. For the same period, if the A&US (Actuarial and Underwriting Service) forecasts had been used it would have paid $167 million less. However, the WAOB is restricted by administration regulations from publicly releasing supply and demand forecasts before the President's annual budget submission.

FCIC's forecasts are intended to reflect actual seasonal average market prices for the crop year, and provide the basis for the different program price options. Currently FCIC makes price forecasts nine months prior to the closing date on insurance sales, while farmers generally delay insurance purchases as long as possible. This puts inflexibility into the system. Also, the FCIC forecasts national average prices rather than for regions. The Agricultural Stabilization and Conservation Service (ASCS) has established differentials for many of the program crops on account of local differences in grain prices. ASCS data show that regional differences may vary above or below average by as much as 20 percent. The GAO/PEMD-92-4 report suggests that FCIC could improve forecasting accuracy by using the available price differentials. FCIC started using the commodity futures market to forecast the price for soybeans in crop year 1989 and added wheat and corn in crop year 1990. Otherwise actuarial staff prepares forecasts by discussion with, and input from, USDA analysts and non government commodity analysts.

### 2.5.3 Lack of Risk Sharing by Reinsurance Companies

Under the reinsurance program of the FCIC, private insurance companies sell policies whose premiums and yield loss adjustment policies are set by the FCIC. The private firms service and adjust the losses on FCIC policies sold under their names. The reinsurance companies are compensated for administrative, operating and claim adjustment expenses. Through the reinsurance agreements, the FCIC shares any gains or losses that are incurred with reinsurance companies. The details of the reinsurance agreement are given in Chapter 5 of this study.

During the 1980s, the government has borne most of the risk for excess program losses to ensure that companies would participate in the program, "In fact, the reinsured companies collectively realized small profits in the years when the policies they sold had large losses" (p.3 GAO/PEMD-92-4). The report also indicates that in 1981-90 FCIC sustained over $2.3 billion in excess losses while reinsurance companies made $101 million of profits.

# 3. Systematic Risk and the Delivery of Crop Insurance

This chapter compares the effects of crop insurance when insurance is delivered by a competitive firm and when it is delivered by the federal government (also referred to as the FCIC). Both the institutions are modeled in a highly stylized fashion that incorporates two of the basic features outlined in the working hypotheses (see Chapter 1): (i) that competitive firms have a lower cost of delivery than the government; and (ii) that competitive firms are risk averse while the government is risk neutral. The analysis is done in a full information setting by assuming only one risk type of farmers. The long-run competitive and FCIC equilibria are both developed assuming positively correlated agricultural risks.

The rest of the chapter is organized as follows: section 3.1 describes the stylized risk market model and the framework for analysis in this study; section 3.2 develops the model for crop insurance demand by farmers; section 3.3 presents the competitive equilibrium for crop insurance; section 3.4 presents the FCIC equilibrium of crop insurance; and section 3.5 compares the two equilibria.

## 3.1 Stylized Risk Market Model and a Framework for Analysis

### 3.1.1 The Risk Market

The agricultural risk market is modeled in a simple binary loss/no-loss framework as it provides a straightforward way to generate useful results. There is one risk class of farmers producing the same crop. The maximum yield for each farmer is M and the yield loss when disaster occurs is $l$. The loss $l$ is binary and takes the value L with probability P and zero otherwise. The marginal distribution of loss is identical for all farmers. The correlation of loss between any two farmers is identical and indicated by the correlation coefficient $\rho$. This correlation coefficient is taken to be a measure of systematic risk in the system since an increase in $\rho$ would increase correlation of loss between all farmers in the group. To understand the probability distribution and the correlation of loss between farmers, consider the loss distributions of any two farmers, say 1 and 2, in the bivariate distribution below:

| | Loss Farm 2 | No Loss Farm 2 | Mar. Dist. Farm 1 |
|---|---|---|---|
| Loss Farm 1 | $P_{11}$ | $P_{10}$ | P |
| No Loss Farm 1 | $P_{01}$ | $P_{00}$ | (1-P) |
| Mar. Dist. Farm 2 | P | (1-P) | 1 |

The bivariate distribution is for crop losses on two farms. It indicates that the probability that farm 1 suffers loss L is P (given as the marginal distribution in column 4). There are two scenarios when farm 1 makes a loss: (i) farm 1 loses L and farm 2 loses L (given by probability $P_{11}$) or (ii) farm 1 loses L and farm 2 makes no loss (given by probability $P_{10}$). The marginal distribution of both the farms are equal since they are from a single risk group. Although the marginal distributions are identical, the degree of covariance between the farm losses is determined by the probabilities of the bivariate distribution. The correlation coefficient for the two losses is

larger for higher values of $P_{11}$ and $P_{00}$. The expected value, variance[3], and correlation[4] of loss are denoted respectively by

$$E(l) = \overline{L} = PL;$$

$$Var(l) = \sigma_L^2 = P(1-P)L^2;$$

$$Corr(l_i, l_j) = \rho = 1 - \frac{P_{10}}{P(1-P)}$$

In the crop insurance market only zero or positive correlation between the losses are assumed since the agricultural market displays high levels of positive co-variability.

### 3.1.2 The Mean-Variance Framework

The framework selected to analyze the agricultural insurance market is the mean-variance (MV) decision rule for farmers and insurance firms. This approach is chosen because the analysis involves insurance firms making coverage decisions on more than one source of risk in their portfolios. For such an analysis, approaches such as the Expected Utility (EU) framework soon become very complicated to analyze, even for simple models.

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[3] It should be noted that in such a bivariate loss distribution while the expected value of loss increases with higher disaster probability, the variance reaches its maximum at probability of loss at P=0.5 and then decreases. If the probability of loss remains below 0.5 (this should be the case for all practical purposes), any increase in probability of disaster would also increase the variance of output.

[4] The Correlation coefficient is calculated from the expression

$$Corr(l_i, l_j) = \rho = \frac{Cov(l_i, l_j)}{\sqrt{Var(l_i)\,Var(l_j)}} \qquad i \neq j$$

where $Cov(l_i, l_j) = E(l_i, l_j) - E(l_i)E(l_j)$

Although choosing the MV framework may at first appear restrictive, Meyer has shown that if there is only one source of risk then location scale transformation of the risk would result in the MV analysis being consistent with the EU framework. For example, consider output of a firm selected so as to maximize expected utility from profits which are given by $\pi$=px-c(x) (where p is the random output price and c(x) is the non-random variable cost). Then, since all profit alternatives are a linear transformation of the random price p and hence related to each other only by location and scale parameters, the expected utility-maximizing choice of x can instead be represented as one which maximizes preferences over only mean and variance of profits. This is the case for farmers in the model of this study because profits from farming is a linear transformation of random crop yield. However, similar arguments cannot be extended to competitive insurance firms since the portfolio of these agents consist of more than one source of risk.

Empirically there is very little work showing preference of the EU framework over MV framework. Of the little work there is, Meyer and Rasche have analyzed common stocks and shown that, within measurement errors, "one cannot reject the hypothesis that the EU efficient set of portfolios for risk averse investors are contained in the MS [MV] efficient set" (p. 92). If consistency with the EU framework is desired, the MV analysis may be thought of as a two moment approximation of the EU framework. Robison and Barry write that "we justify the use of the [MV] model even when it is not consistent with the EU models because it is interesting in its own right. Moreover the proper test of the [MV] model is not its absolute consistency with the EU models but its ability to describe and predict decision maker behavior under risk." (p.84).

In this study the linear functional form

$$\text{Utility}(\tilde{y}) = \text{Mean}(\tilde{y}) - \frac{\lambda}{2}\text{variance}(\tilde{y})$$

is used where the expected value and variance are the objects of utility. Such a function allows for relative ease in deriving optimal solutions and conducting equilibrium analysis. Holding $\lambda$ constant and maximizing the utility function gives a solution on the MV frontier that is consistent with arriving at the frontier with any other criteria. For comparative statics analysis, holding $\lambda$ constant approximates substitution effects but not income effects (Robison). A drawback of the MV approach is that if the loss distributions are highly skewed, the decision rule does not explicitly account for moments above the second.

For the remainder of the study the linear MV objective function is referred to as utility of the agents since it provides a consistent ranking for the preferences of the agents.

## 3.2 The Demand for Crop Insurance

Let there be N farmers in the risk group where the probability of disaster P is known to each of the farmers. The farmers are assumed to be risk averse agents who maximize their end of the period utility of profits. If an insurance market exists, it is fully described by the pair ($w(\phi)$, $\phi$), where $w(\phi)$ is the premium as a function of coverage $\phi$. The decision problem of the farmer is to maximize his or her utility of profits by choosing the optimal coverage level. For example, let a farmer's maximum average yield per acre be M=140 bushels. If disaster strikes the loss in yield is L=70 bushels. The farmer may decide to purchase 50 percent coverage at w(50)=5 bushels. If disaster strikes, the farmer has (140-70+35-5)= 100 bushels of corn per acre; and if disaster does not strike, the farmer has (140-5)= 135 bushels of corn rather than in the uninsured state of 70 and 140 bushels per acre respectively.

To determine the demand for crop insurance let profits from farming be the only argument entering the utility of the farmer. Let the premium be quoted on a per acre basis and it is assumed that $w(\phi)=w\phi$, so that the premium is linear in coverage. Further the coverage is restricted to be positive and not exceed the total loss, i.e., $\phi\in[0,1]$. The profits[5] of a farmer are:

(3-1) $$\pi_F = M - w\phi - (1-\phi)l$$

where $l$ takes the values L or 0 with probabilities P and (1-P) respectively. If positive coverage is chosen, the associated premium $w\phi$ is paid irrespective of the state of nature. If there is a disaster, the farmer loses $(1-\phi)L$ of his output, the rest is covered by insurance.

The relevant moments needed for the MV model are

$$\overline{\pi}_F = M - w\phi - (1-\phi)\overline{L}$$

and

$$\sigma^2_{\pi_F} = (1-\phi)^2\sigma^2_L$$

It is assumed that the farmer's preferences are a positive function of expected end-of-period profits and a negative function of the variance of end-of-period profits from farming. The farmer's insurance problem is to choose coverage to maximize his or her preference function.

To obtain a specific crop insurance demand for the farmer the linear preference function

$$U(.) = \overline{\pi}_F - \frac{\lambda}{2}\sigma^2_{\pi_F}$$

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[5] This satisfies Meyer's location scale conditions since it is linear in $l$

is assumed where $\frac{\lambda}{2}$ equals the equilibrium slope at the tangency between an iso-expected utility line and the mean-variance set (Robison and Barry). The slope reflects the degree of risk aversion of the agent with higher values indicating higher degrees of risk aversion. The first-order condition[6] (FOC) to the maximization problem of the farmer then becomes

$$\left( -w + \overline{L}\right) + \lambda(1-\phi)\sigma_L^2 = 0$$

and the demand for insurance at premium w is

$$\phi = 1 - \left(\frac{w - \overline{L}}{\lambda\sigma_L^2}\right). \quad (3\text{-}2)$$

Equation (3-2) helps to identify constraints on the premium (w) that must hold if an interior solution to the problem exists. Firstly, for positive co-insurance it must be the case that

$$1 - \left(\frac{w - \overline{L}}{\lambda\sigma_L^2}\right) > 0 \text{ or } \left(w - \overline{L}\right) < \lambda\sigma_L^2.$$

In words, the difference between the premiums and expected indemnities cannot exceed the product of the farmer's risk preferences and the variance of the loss. The possibility of an interior solution increases if a farmer is highly risk averse (indicated by larger values of λ) or the loss displays high variability.

Secondly an interior solution also requires that the coinsurance be less than 100 percent. For this to hold

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[6] The second order condition is $-\lambda\sigma^2 < 0$ and therefore the solution gives a maximum.

$$1-\left(\frac{w-\bar{L}}{\lambda\sigma_L^2}\right)<1 \text{ or } w-\bar{L}>0.$$

This implies that the premium must exceed the expected loss for the farmer. Further implications of farmers purchasing insurance are summarized in the following propositions (the results of these propositions are common knowledge and may be found in various text books[7]).

*Proposition (3-1): If the insurance premium is actuarially fair, a risk averse farmer will always seek full coverage*

*Proof.*

If the insurance is actuarially fair, i.e., premium equals indemnity then $w=\bar{L}$ in which case Equation (3-2) indicate that $\phi=1$.

*Proposition (3-2): A more risk averse farmer will seek higher coverage than a less risk averse farmer, provided the premium is above actuarially fair.*

*Proof.*

From Equation (3-2), increases in $\lambda$ will increase $\phi$ given that $w-\bar{L}>0$.

*Proposition (3-3): A risk averse farmer will buy less coverage if the premium per acre increases.*

*Proof.*

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[7] All these results also hold for an Expected Utility model with general distribution for *l*.

From Equation (3-2) any increase in premium (w) will lead to a decrease in coverage.

*Proposition (3-4): For probabilities of loss below 0.5, a farmer with greater probability of loss will seek to buy more coverage than a farmer with a lower probability of loss.*

*Proof.*

Note that the probability of loss affects both the mean and the variance. Consider the relevant "primal-dual"[8] element to study the response of $\phi$ to changes in P

$$\left[1+2n\lambda L(1-\phi)P(1-P)(1-2P)\right]\frac{\partial\phi}{\partial P}>0$$

This if $P \leq 0.5$ the $\frac{\partial\phi}{\partial P}>0$.

## 3.3 Competitive Equilibrium in the Market for Crop Insurance

### 3.3.1 Competitive Supply of Crop Insurance

The competitive crop insurance industry is assumed to be comprised of risk averse[9] firms selling only crop insurance because the primary business of many of these firms actually engaged in the industry is selling crop insurance. Since there is only one risk group there are no farmer

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[8] see Silberberg

[9] Although Rothschild and Stiglitz assume risk neutral behavior for private firms they indicate that justification for such an assumption cannot be supported from the literature of firm behavior under uncertainty since it is one of the more unsettled areas of economics. This study appeals to the empirical evidence that insurance firms buy reinsurance on the portfolio they insure and therefore this reflects risk averse behavior.

classification problems and all the properties discussed in Section 3.2 about the farmer are assumed to hold. For convenience the firms are assumed to incur administrative costs of c per acre, which is assumed to be linear in coverage, and there are no fixed costs.

The end of period profit of a firm from selling crop insurance to n farmers is

$$\pi_S = n(w_S\phi_S - \phi_S c) - \phi_S \sum_{i=1}^{n} l_i$$

The subscript s refers to the competitive insurance firm. The profits are a function of premiums less administrative costs and indemnities paid to the n farmers. The mean and the variance[10] of the portfolio of the competitive firm are

$$\overline{\pi}_S = n\phi_S(w_S - \overline{L} - c)$$

and

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[10] The variance of a sum of random variables is

$$Var(\sum_{i=1}^{n} X_i) = \sum_{i=1}^{n} Var(X_i) + \sum_{i=1}^{n}\sum_{\substack{j=1 \\ j\neq i}}^{n} Cov(X_i, X_j).$$

Since in this study, all the random variables (yield losses) have the same marginal distribution and the covariance between any two random variable (yield losses) is positive and identical, the correlation coefficient between any two of the random variable is

$$\rho = \frac{Cov(X_i, X_j)}{\sigma^2}.$$

Substituting the identical variance and correlation coefficient values in the variance expression

$$Var(\sum_{i=1}^{n} X_i) = \sum_{i=1}^{n} \sigma^2 + \sum_{i=1}^{n}\sum_{\substack{j=1 \\ j\neq i}}^{n} \rho\sigma^2$$

or

$$Var(\sum_{i=1}^{n} X_i) = \sigma^2 n[1 + (n-1)\rho].$$

$$\sigma^2_{\pi_s} = n\phi_S^2\sigma_L^2[1+(n-1)\rho]$$

where ρ is the correlation coefficient between any two farms. Recall that ρ is assumed to be non-negative. The higher the value of ρ, the higher the co-variability of yield loss between farms. As the value of ρ increases the correlation between all the farmers increases, and therefore ρ also indicates the level of non-diversifiable risk in the portfolio of the insurance firms. Therefore, with each increase in risk, the degree of increase in the variance of the portfolio is also a function of the degree of correlation between the risks. If the risks are independent (ρ=0) then the portfolio variance does not increase as much as if there is some degree of positive correlation between the risks (ρ>0).

As in the case of the farmer, it is assumed that the preferences of the insurance firm are a positive function of the end-of-period profits and a negative function of the variance of the end-of-period profits, i.e.,

$$V(\bar{\pi}_S, \sigma^2_{\pi_s}).$$

The insurance firm's problem is to maximize its preferences by choosing the coverage it would provide to farmers given the premium per acre. The number of policies is determined by competition in the insurance market and at this point it is assumed to be exogenously given. To determine the supply of insurance, as in the case of the farmer, a specific utility form of the type

$$V(.) = \bar{\pi}_S - \frac{\psi}{2}\sigma^2_{\pi_s}$$

is assumed where $\psi$ reflects the degree of risk aversion of the competitive firm. The FOC[11] to the firm's maximization problem is

(3-3) $$n(w_S - \bar{L} - c) - \psi n \phi_S \sigma_L^2 [1 + (n-1)\rho] = 0$$

The coverage that would be offered by the insurance firm is

$$\phi_S = \frac{(w_S - \bar{L} - c)}{\psi \sigma_L^2 [1 + (n-1)\rho]}.$$

This indicates that, given a premium, the coverage level decreases if either the variance or the degree of correlation between the risks increases. Similarly if the firm becomes more risk averse. Since the coverage must lie between 0 and 1, there are some restrictions put on the insurance premium. Firstly, the coverage must be positive. This implies that

$$(w_S - \bar{L} - c) > 0.$$

Since the right hand side (RHS) is always positive, for the competitive firm to offer coverage, the premium must exceed expected indemnities plus cost. In other words, the competitive firm needs a positive "risk premium" to insure the farmer risk. However, by requiring the coverage to be less than one, an interior solution also requires the restriction that

$$(w_S - \bar{L} - c) < \psi \sigma_L^2 [1 + (n-1)\rho]$$

or the "risk premium" must not exceed the RHS. We know that the value of the RHS is positive by definition. Higher values of any parameters in the RHS would decrease the likelihood of coverage exceeding unity.

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[11] Second order condition: $-\psi n \sigma_L^2 [1 + (n-1)\rho] < 0$ therefore the solution gives a maximum.

### 3.3.2 A Definition of Equilibrium

In a competitive equilibrium without risk, the long-run equilibrium is characterized by zero profit brought about by entry and exit of firms. When risk is introduced, the competitive equilibrium is described by zero expected profit if the producers are risk neutral (Rothschild and Stiglitz). If the producers are risk averse then Sandmo's work provides the beginnings of a framework to analyze such a problem. The basic model of the firm in Sandmo's paper is

(3-4) $$\underset{q}{Max} \quad E[U(\pi)] = E[U(pq - c(q) - B]$$

where p is the random output price, q is the quantity to be produced, c(q) is the variable cost and B is the fixed cost. The maximization process involves solving the FOC

(3-5) $$E[U'(\pi)(p - c'(q)] = 0.$$

Given that the second order condition is satisfied, comparative statics are drawn from this framework.

The equilibrium described above is considered to be a short run analysis because output prices are treated as exogenously given with a known distribution. Appelbaum and Katz extend Sandmo's article to incorporate the behavior of expected utility maximizing firms in long-run equilibrium. This is achieved by (i) letting stochastic output price be a function of industry output; and (ii) letting the expected utility of the firm be equal to a reservation utility b of some benchmark activity. Entry and exit of firms require that the expected utility of profits equal this benchmark utility level, i.e.,

(3-6) $$E\left[U[pq - c(q) - B]\right] - b = 0$$

Thus the industry equilibrium is determined by the intersections of equations (3-5) and (3-6) and the number of firms in the industry are determined endogenously. In this model firm output adjusts with free entry and exit of firms, which in turn effects output price and keeps the expected utility of the firm at the reservation utility level b. Appelbaum and Katz find that comparative statics for the firm are altered in the industry equilibrium as opposed to the short run equilibrium studied in Sandmo's framework. An application of the principle of reservation utility is found in Meyer and Robison which look at land (an input) prices adjusting (affecting profitability through cost of production) to maintain industry equilibrium in the agricultural land market.

A long-run equilibrium concept similar to that suggested by Appelbaum and Katz is adopted here to study the competitive equilibrium in crop insurance. Appelbaum and Katz's framework is modified such that, in the long-run, competition adjusts the number of insurance policies sold to maintain a reservation utility level. The number of firms in the industry is determined endogenously and is given by N/n where N is the total number of farmers. All information is assumed to be common knowledge. All the firms in the industry are identical in all respects and therefore it is sufficient to determine the equilibrium by analyzing one firm. For convenience, it is assumed that when the value of n is not a positive integer, the firms collude to provide insurance on the fraction such that the farmer is provided insurance as if he were receiving it from one firm.

### 3.3.3 The Competitive Equilibrium

*Definition (3-1): A competitive equilibrium in this model of crop insurance delivery is a premium level $w^0$, coverage level $\phi^0$ and number of policies $n^0$ for each firm such that:*

(3-7) $$\left(-w^0 + \bar{L}\right) + \lambda(1-\phi^0)\sigma_L^2 = 0$$

(3-8) $$n^0(w^0 - \bar{L} - c) - \psi n^0 \phi^0 \sigma_L^2 [1 + (n^0 - 1)\rho] = 0$$

(3-9) $$n^0\phi^0(w^0 - \bar{L} - c) - \frac{\psi}{2} n^0 (\phi^0)^2 \sigma_L^2 [1 + (n^0 - 1)\rho] - b = 0\,.$$

The first expression is the demand for insurance by the farmer, the second expression is the short-run supply of insurance by a competitive firm, and the third expression is the long-run equilibrium condition that the utility of the firm is at the reservation level b. The simultaneous solution of the three non-linear system of equations determines the long-run equilibrium premium $w^0$, coverage $\phi^0$ and the number of policies sold $n^0$ by each insurance firm.

### 3.3.4 Properties of the Competitive Equilibrium

The properties of the equilibrium are discussed in a series of propositions below. In stating the propositions it is assumed that a solution exists (the alternative being no insurance bought or sold at equilibrium).

*Proposition (3-5): With independent risks ($\rho$=0) the equilibrium coverage ($\phi^0$) to the farmer is determined independently of the reservation utility (b) of the firm.*

*Proof.*

At equilibrium, the FOC of the firm may be re-written as

$$\phi^0 = \frac{w^0 - \overline{L} - c}{\psi\sigma_L^2[1+(n^0-1)\rho]};$$

with ρ = 0, the FOC reduces to

$$\phi^0 = \frac{w^0 - \overline{L} - c}{\psi\sigma_L^2}$$

and therefore premium and coverage are determined by equations (3-7) and (3-8) which are independent of $n^0$.

*Proposition (3-6): With independent risks (ρ=0) reservation utility (b) determines the number of policies held by the firm at equilibrium, and it is increasing in b.*

*Proof:*

Substituting equilibrium coverage from Equation (3-8) into (3-9) to solve for $n^0$

(3-10) $$\frac{n^0}{[1+(n^0-1)\rho]} = \frac{2b\psi\sigma_L^2}{(w^0 - \overline{L} - c)^2};$$

with ρ = 0 this expression reduces to

$$n^0 = \frac{2b\psi\sigma_L^2}{(w^0 - \overline{L} - c)^2}.$$

Since w is determined independently of this equation (see proposition (3-5)), and given that all the parameters are known, any increase in b will increase $n^0$.

*Proposition (3-7): With identical risks ($\rho=1$), reservation utility (b) determines the premium over and above expected indemnities and cost charged to farmers at equilibrium, and it is increasing in b.*

*Proof:*

with $\rho=1$, expression (3-10) reduces to

$$(w^0 - \overline{L} - c) = \sqrt{2b\psi\sigma_L^2}\ .$$

Any increase in b will increase the equilibrium premium charged to farmers.

*Proposition (3-8): With independent risks ($\rho=0$), the equilibrium coverage decreases with increases in cost of delivery (c) and/or increases in risk aversion of the insurance provider ($\psi$); and the equilibrium coverage increases with increase in variance ($\sigma_L^2$) and/or increases in the risk aversion ($\lambda$) of the farmer.*

Proof:

Equilibrium coverage is $\phi^0 = \dfrac{\lambda\sigma_L^2 - c}{\sigma_L^2(\lambda + \psi)}$.

From this equation it is clear that an increase in c or $\psi$ would decrease equilibrium coverage.

Further

$$\frac{\partial\phi^0}{\partial\sigma_L^2} = \frac{c}{(\sigma_L^2)^2(\psi + \lambda)} > 0$$

$$\frac{\partial\phi^0}{\partial\lambda} = \frac{\sigma_L^2\psi + c}{\sigma_L^2(\psi + \lambda)^2} > 0$$

Both the derivatives are positive indicating increases in variance and risk aversion of the farmer would both increase equilibrium coverage.

*Proposition (3-9): With identical risks ($\rho$=1), the equilibrium coverage decreases with increases in cost of delivery (c) and/or increases in risk aversion of the insurance provider ($\psi$) and/or increases in the reservation utility of the firm (b); and the equilibrium coverage increases with increases in variance ($\sigma_L^2$) and/or increases in the risk aversion of the farmer ($\lambda$).*

*Proof.*

With ($\rho$=1) equilibrium coverage is $\phi^0 = 1 - \frac{\sqrt{2b\psi\sigma_L^2} + c}{\lambda\sigma_L^2}$ and it is clear from this equation that increases in b, $\psi$, or c would decrease coverage and increase in $\lambda$ would increase coverage. Also, since

$$\frac{\partial\phi^0}{\partial\sigma_L^2} = \frac{\lambda\left(\sqrt{2b\psi\sigma_L^2} + c\right)}{2(\lambda\sigma_L^2)^2} > 0$$

increases in variance will increase coverage.

So far, the comparative statics in the propositions above were limited to polar cases of $\rho$=0 and $\rho$=1. This is because when positive but less than perfect correlation exists, obtaining equilibrium values requires solving a system of non-linear equations in three unknowns. Because of this difficulty numerical examples are explored and results are reported in Table 3-1 through Table 3-3. The parameters chosen for the numerical example are P=0.3 and 0.4; c=5 bushels; M=140 bushels; L=70 bushels; $\psi$=0.01 and 0.001;$\lambda$=0.01; and b=10 or 20. The parameters chosen do not reflect any real world application and are only for expository purposes.

Table 3-1: Competitive Equilibrium Coverage Levels: $\psi$=0.01, $\lambda$=0.01, b=10.

| | P=0.30 | | | | P=0.40 | | | |
|---|---|---|---|---|---|---|---|---|
| ρ | w1 | ϕ1 | u1 | n1 | w2 | ϕ2 | u2 | n2 |
| | 0 | 0 | 113.855 | 0 | 0 | 0 | 106.120 | 0 |
| 0.0 | 27.645 | 0.354 | 114.501 | 15.490 | 35.380 | 0.372 | 106.936 | 12.260 |
| 0.1 | 29.443 | 0.179 | 114.021 | 20.472 | 37.159 | 0.221 | 106.408 | 14.683 |
| 0.2 | 30.669 | 0.060 | 113.874 | 49.683 | 38.417 | 0.114 | 106.197 | 23.610 |
| 0.3 | a | a | a | a | 39.494 | 0.023 | 103.846 | 103.846 |
| 0.4 | a | a | a | a | a | a | a | a |

a = interior solution did not exist.

Table 3-2: Competitive Equilibrium Coverage Levels: $\psi$=0.01, $\lambda$=0.01, b=20.

| | P=0.30 | | | | P=0.40 | | | |
|---|---|---|---|---|---|---|---|---|
| ρ | w1 | ϕ1 | u1 | n1 | w2 | ϕ2 | u2 | n2 |
| 0.0 | 27.645 | 0.354 | 114.501 | 30.980 | 35.380 | 0.372 | 106.936 | 24.520 |
| 0.1 | 30.691 | 0.058 | 113.872 | 102.677 | 38.466 | 0.110 | 106.191 | 48.681 |
| 0.14 | a | a | a | a | 39.311 | 0.038 | 106.129 | 125.972 |
| 0.15 | a | a | a | a | a | a | a | a |

a = interior solution did not exist.

Table 3-3: Competitive Equilibrium Coverage Levels: $\psi$=0.001, $\lambda$=0.01, b=10.

| | P=0.30 | | | | P=0.40 | | | |
|---|---|---|---|---|---|---|---|---|
| $\rho$ | w1 | $\phi$1 | u1 | n1 | w2 | $\phi$2 | u2 | n2 |
| 0.0 | 24.663 | 0.644 | 115.989 | 46.857 | 31.796 | 0.677 | 108.816 | 37.086 |
| 0.1 | 25.708 | 0.543 | 115.369 | 21.589 | 32.874 | 0.586 | 108.136 | 18.223 |
| 0.2 | 26.241 | 0.491 | 115.094 | 18.190 | 33.437 | 0.538 | 107.820 | 15.266 |
| 0.3 | 26.652 | 0.451 | 114.900 | 16.731 | 33.870 | 0.501 | 107.596 | 13.913 |
| 0.4 | 27.001 | 0.417 | 114.749 | 15.990 | 34.237 | 0.470 | 107.417 | 13.155 |
| 0.5 | 27.309 | 0.387 | 114.625 | 15.623 | 34.562 | 0.442 | 107.269 | 12.703 |
| 0.6 | 27.589 | 0.360 | 114.521 | 15.494 | 34.856 | 0.417 | 107.143 | 12.438 |
| 0.7 | 27.848 | 0.335 | 114.431 | 15.538 | 35.128 | 0.394 | 107.032 | 12.301 |
| 0.8 | 28.090 | 0.311 | 114.353 | 15.724 | 35.382 | 0.372 | 106.935 | 12.260 |
| 0.9 | 28.319 | 0.289 | 114.284 | 16.038 | 35.622 | 0.352 | 106.848 | 12.297 |
| 1.0 | 28.537 | 0.268 | 114.223 | 16.476 | 35.850 | 0.333 | 106.770 | 12.403 |

In all of the tables, results are presented for two probabilities of disaster (P=0.3 and P=0.4). This is done to see how the results are affected by an increase in the probability of disaster. Table 3-1 and Table 3-2 are presented to illustrate the effects of increases in reservation utility of the firm from b=10 to b=20. And Table 3-1 and Table 3-3 are presented to see the effects of decreasing the degree of risk aversion of the firm from $\psi = 0.01$ to $\psi = 0.001$ (the degree of risk aversion of the farmer $\lambda$ is kept constant in all the examples) and u1 and u2 are the equilibrium utility levels of the farmers when P=0.3 and P=0.4 respectively. Similarly n1 and n2 are equilibrium number of policies held by the insurance firms when P=0.3 and P=0.4 respectively.

The first row of Table 3-1 shows the utility of the farmer when no insurance is bought. As expected, if positive levels of coverage are bought in equilibrium, the utility of the farmer is greater than without insurance. Also as expected, the coverage to farmers increases as the degree of risk aversion of the firm decreases (compare Table 3-1 and Table 3-3).

## Equilibrium Effects of Correlation (ρ) Between Losses

The numerical results show that, in all cases, as the degree of correlation among risks increases, the insurance premium increases and the coverage decreases in equilibrium. The equilibrium utility of the farmers is always at its highest when risks are independent ($\rho$=0). Results in Table 3-1 and Table 3-2 indicate that, as risks become more non-diversifiable, competitive equilibrium coverage decreases. Given a set of parameters and a cost structure, correlation between farm losses could reach a point such that no competitive crop insurance market exists.

There appears to be no pattern to the number of policies the firm would hold as the correlation between losses increases. The results indicate that the number of policies held by a firm may increase or decrease as $\rho$ increases, depending on the parameters of the system.

## Equilibrium Effects of Reservation Utility (b)

As indicated by proposition (3-6) the reservation utility of the firm has no effect on the equilibrium coverage if risks are un-correlated (see results in Table 3-1 and Table 3-2 for $\rho = 0$). For all other cases the equilibrium premium increases and the coverage decreases with increases in reservation utility of the firm. Therefore, with correlated risks the competitive equilibrium coverage depends on the reservation utility of the firm. As stated earlier the only exception to this rule is when the degree of correlation among the farms is zero and the level of reservation utility decides only the number of policies (n) the firm holds at equilibrium. Theoretically, there is a possibility of only one firm supplying crop insurance in a competitive equilibrium, depending on the level of reservation utility.

## 3.4 FCIC Delivery of Crop Insurance

Now we turn to an alternate institutional arrangement, the FCIC, for delivering crop insurance to the same farmers. The FCIC crop insurance delivery system is modeled in a stylized way according to the mandates of the 1980 Crop Insurance Act, i.e., provide crop insurance to all farmers at actuarially fair premiums plus delivery cost. Such a program would be self sustaining in the long-run (as desired by Congress) and therefore the current program's subsidies are not included in the design. Since there is only one risk type, there are no farmer classification problems faced by the FCIC and all information is assumed to be common knowledge.

Delivery cost is g which is assumed to be linear in coverage and there are no fixed costs. The FCIC premium per acre is

$$w_g = \overline{L} + g$$

where g is the cost of delivery of the FCIC. Farmer behavior remains exactly the same as in the competitive equilibrium developed earlier. The FCIC equilibrium may now be introduced.

### 3.4.1 The FCIC equilibrium

*Definition (3-2): An FCIC equilibrium in this model of crop insurance delivery is a premium* $w^*$ *and a coverage level* $\phi^*$ *such that:*

(3-11) $w^{*} = \overline{L} + g$

(3-12) $\phi^{*} = 1 - \frac{w^{*} - \overline{L}}{\lambda \sigma_L^2}$

Since there are no informational problems the FCIC breaks even in the long-run. Given the premiums, the farmers choose coverage $\phi^{*}$ at equilibrium. Note that for an interior solution to exists premiums must exceed expected indemnities in this model.

### 3.4.2 Properties of the Equilibrium

The equilibrium coverage under the FCIC program is

$$\phi^{*} = 1 - \frac{g}{\lambda \sigma_L^2}$$

Depending on the delivery cost (g), the coverage to the farmer could be minimal (for high values of g) or close to unity (for very low values of g). This equilibrium coverage is an increasing function of the degree of risk aversion of the farmer and the variance of the risk.

Note that because the FCIC sets premiums at actuarially fair levels plus delivery costs, the degree of correlation between the farm losses does not enter the FCIC decision making in crop insurance delivery. This suggests risk neutral behavior of the FCIC for reasons such as the government's ability to spread risk among a large number of taxpayers and also diversify its portfolio over a large number of activities (Arrow and Lind).

## 3.5 Comparison of the Competitive Equilibrium and FCIC Delivery

It has been a working hypothesis in this study that the cost of delivery associated with the FCIC is higher than the competitive firms. However, whether the farmer benefits more from the FCIC or the competitive equilibrium is also a function of risk preferences of the competitive firms, the level of non-diversifiable risk in the system and the level of reservation utility of the competitive firms.

*Proposition (3-10): If premium and coverage of both the FCIC and the competitive equilibrium are identical ($w^0=w^*$, $q^0=q^*$) then it must be the case that delivery cost associated with the FCIC is higher than that of the competitive firm (g>c).*

*Proof:*

If equilibrium coverage levels are identical then

$$\phi^0 = \phi^* \Rightarrow \frac{\lambda\sigma_L^2 - c}{\lambda\sigma_L^2 + \sigma_L^2\psi(1+(n^0-1)\rho)} = \frac{\lambda\sigma_L^2 - g}{\lambda\sigma_L^2}$$

From the expression above, it can be seen that the denominator associated with the competitive firm coverage is larger than that of the FCIC coverage because $0 \leq \rho \leq 1$ and given that the firm holds at least one policy ($n \geq 1$). Therefore, for equality to hold $c<g$.

*Proposition (3-11): The farmer has greater (equal or less) coverage in an FCIC equilibrium than in a competitive equilibrium if the cost of delivery (g) associated with the FCIC is*

$$g < (\geq) \lambda\sigma_L^2 - \frac{\lambda\sigma_L^2 - c}{1 + \frac{\psi}{\lambda}(1 + (n^0 - 1)\rho)} .$$

*Proof:*

Follows directly from proposition (3-10) above.

The propositions indicate that the cost of delivery of the FCIC can always be made high enough such that competitive equilibrium could be made more desirable to farmers. Proposition (3-11) indicates the relationship between FCIC cost of delivery and the parameters of the competitive firm under which the farmer is indifferent between the two institutions delivering crop insurance. This relationship shows that cost of delivery alone does not drive the equilibrium coverage to farmers. As can be seen from the results of Section 3.3.4, the amount of non-diversifiable risk in the system and the reservation utility of the competitive firm are important factors in determining the competitive equilibrium coverage along with degree of risk aversion of the firm.

Depending on the value of the parameters, increases in the level of non-diversifiable risk in the system could substantially reduce equilibrium coverage to the extent that no competitive equilibrium exits. Since the level of non-diversifiable risk is high in the agricultural sector, these results indicate that competitive equilibrium coverage could be substantially reduced in this market. In practice one observes private insurance for hail and fire (which are fairly independent across farms) but no private insurance for multi-peril disasters as floods, pests, etc. which are highly correlated across farms (for further discussion on systematic risk and equilibrium, see Chapter 6).

Furthermore, whether the competitive or the FCIC equilibrium provides higher coverage to farmers is a function of the reservation utility of the firms. The analysis indicates that if risks are independent then the reservation utility does not affect the coverage to farmers and equilibrium is determined by the degrees of risk aversion of the insurance seller and buyer, as well as the cost of delivery. This is the general scenario of most studies that assume independent risks. However with non-diversifiable risks, the reservation utility affects the coverage to farmers such that coverage decreases with increases in the reservation utility. If the reservation utility is very high then equilibrium coverage to farmers could be minimal or even non-existent. The non-independence of risk, therefore, affects coverage indirectly through reservation utility.

The results in this chapter suggest that if there are high levels of systematic risks in the crop insurance market the only recourse may be for the government to deliver crop insurance directly if it is politically desirable to do so. However, the effectiveness of federal crop insurance delivery may be reduced if the FCIC faces high information costs such that classification of farmers into risk groups is a problem. This could compromise the actuarial soundness of the program and pose serious budgetary outlays to the taxpayers. The next chapter studies this aspect of the problem in more detail.

# 4. Crop Insurance Delivery Under Multiple Farmer Risk Classes

The purpose of this chapter is to build on the stylized model of the previous chapter by including multiple farmer risk types. It is assumed that there are heterogeneous farm risk types and, as discussed in the working hypotheses (see Chapter 1), the government (or the FCIC) is assumed to be unable to obtain information to distinguish farmers into risk classes for insurance selling purposes. On the other hand competitive firms providing crop insurance are assumed to be able to obtain this information costlessly. These polar cases are used to highlight the issues resulting from information differences between the government and competitive firms. All of the other assumptions outlined in Chapter 3 for the crop insurance model also hold in this chapter.

The initial sections of this chapter are devoted to developing an FCIC equilibrium while imposing the assumptions that (i) the program is actuarially sound[12]; and (ii) the program provides maximum coverage to all farmers. Conditions under which the inability to classify farmers into risk classes becomes a problem are developed. The later sections of the chapter develop a competitive model of insurance delivery with more than one risk type in the market (and positive correlation between farm risks). The chapter states the conditions under which a competitive insurance firm would prefer to hold contracts for both risk types in its portfolio, and the resulting implications for farmer coverage. The chapter then compares the FCIC equilibrium to the competitive equilibrium.

[12] Actuarially sound is taken to mean that the program is self sustaining.

## 4.1 The Risk Market

To introduce imperfect information into the FCIC equilibrium, farmers of two risk types, 1 and 2, are assumed. Type 2 farmers are the high risk group. The maximum yield for each farmer in each risk class is M and the random yield loss is $l_i$ for type i=1,2. The loss $l_i$ is binary and takes the value L with probability $P_i$ for risk type i and zero otherwise. There are $N_1$ of type 1 farmers and $N_2$ of type 2 farmers. The ratio of type 1 to type 2 farmers is R. For example, R=1 implies that there are equal numbers of both types of farmers and R=2 implies that there are twice as many type 1 than type 2.

To understand the joint probability distribution of any two farms, consider the loss distributions of the farms, say A and B, in the bivariate distribution below:

| | Loss Farm B | No Loss Farm B | Mar. Dist. Farm A |
|---|---:|---:|---:|
| Loss Farm A | $P_{AB}$ | $P_{A0}$ | $P_A$ |
| No Loss Farm A | $P_{0B}$ | $P_{00}$ | $(1-P_A)$ |
| Mar. Dist. Farm B | $P_B$ | $(1-P_B)$ | 1 |

The bivariate distribution is for crop losses on two farms. It indicates that the probability that farm A suffers loss L is $P_A$ (given as the marginal distribution in column 4). There are two scenarios when farm A makes a loss: (i) farm A loses L and farm B loses L (given by probability $P_{AB}$) or (ii) farm A loses L and farm B has no loss (given by probability $P_{A0}$). Similarly for farm

B's marginal probability distribution. If the two farmers are of the same risk type then $P_A = P_B$ and the marginal distributions of the two farms are equal.

The expected value, variance and correlation coefficient of loss for the two farms are:

$$E(l_i) = \overline{L}_i = P_i L \qquad i = A, B$$

$$Var(l_i) = \sigma_i^2 = P_i(1-P_i)L^2 \qquad i = A, B$$

$$Corr(l_i, l_j) = \rho_{ij} = \frac{P_{ij} - P_i P_j}{\sqrt{P_i(1-P_i)\,P_j(1-P_j)}} \qquad i = A, B$$

Since the study refers to risk types as type 1 and type 2, for notational purposes correlation of losses between two farmers within a risk type are $\rho_1$ and $\rho_2$ for types 1 and 2 respectively and correlation of losses between a type 1 farmer and a type 2 farmer is $\rho_{12}$.

## 4.2 The FCIC Equilibrium

### 4.2.1 Definition of an FCIC equilibrium

The FCIC equilibrium is modeled to be consistent with the mandates of the 1980 Crop Insurance Act, i.e., (i) the program should operate on an actuarially sound basis with premium income sufficient to cover losses; and (ii) the program must make maximum crop insurance coverage available to all farmers such that the FCIC program serves as the primary provider of disaster assistance.

Unlike the previous chapter, the FCIC is now assumed to operate with imperfect information about farmer risk types. The informational problem of the FCIC is such that it lacks information to classify farmers into risk types. It is assumed that the FCIC has knowledge about the amount of loss, the probability of loss of high and low risk types, the ratio of low to high risk farmers, and the preferences of the farmers. In other words the only information that is lacking is whether a particular farmer is of type 1 or 2.

Given that the FCIC is mandated to operate with zero expected profits and maximum coverage to all farmers, an ideal program with full information would operate by selling insurance to each farm at an actuarially fair price for that farm, plus cost of delivery, and the farmers would choose their optimum coverage. However, with the information problems described this may not be feasible since a high risk farmer cannot be distinguished from a low risk farmer and the high risk farmer does not have an incentive to reveal that he is high risk, thereby paying higher premiums. Therefore if type 2 farmers have an incentive to buy type 1 contracts, the contracts must be designed to correct for the classification problems.

To arrive at an FCIC equilibrium it is assumed that the FCIC is the sole provider of crop insurance, and that it can offer contracts that specify both premium and coverage levels. Since the second mandate requires that maximum coverage be provided to all risk types, the FCIC provides only those contracts that are efficient. In other words, if the coverage (and utility) of a farmer can be increased while keeping the other farmers unaffected , such a contract will be offered. Because there are two risk types (and given all have identical preferences), more than two contracts are not considered since a third contract would be redundant.

Ideally, in this model the FCIC would like to classify farmers into two risk pools: a high risk pool which has all the high risk farmers and a low risk pool that has all the low risk farmers.

With two risk pools there are three situations envisioned where an FCIC equilibrium can occur under farmer classification problems: (i) a separating equilibrium with no cross subsidies[13] across risk pools; (ii) a separating equilibrium with cross subsidies across risk pools; and (iii) a pooling equilibrium with average pricing of the premium. Equilibrium in situations (i) and (ii) require that when two contracts, high and low, are offered by the FCIC the high risk types have no incentive to buy the low risk contracts and vice versa (there is self selection of contracts). In situation (iii) everyone that buys insurance buys the same contract since only one premium and coverage is offered by the FCIC to all farmers irrespective of risk type. It is self evident that in a pooling equilibrium there are cross subsidies across risk types. The three situations are discussed in detail in the sections below.

### 4.2.2 Separating Equilibrium With No Cross-Subsidization Across Risk Pools

As mentioned earlier, a separating equilibrium requires that the high risk types buy the high risk policies and the low risk types buy the low risk policies offered by the FCIC. The premium and coverage must be such the one risk type has no incentive to buy the contract meant for the other risk type. The other requirement in this equilibrium is that there are to be no cross subsidies across risk types. Therefore the FCIC makes zero expected profits from each risk pool. In other words the premiums in each risk pool must be such that they equal expected indemnities plus cost of delivery or

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[13] Subsidies or taxes are referred to in the context of subsidizing or taxing a coverage that would be offered in full information. For example if 50 percent coverage is priced at 2 bushels in a full information environment then selling the same coverage for 3 bushels implies that there is a tax of 1 bushel. Similarly for subsidies.

(4-1) $\phi_i^* w_i^{FI} = \phi_i^* (\overline{L}_i + g) \qquad i = 1,2$

where $\phi_i^*$ is the separating equilibrium coverage to risk types 1 and 2 and $w_i^{FI}$ is the full information premium per acre (which equals expected loss $\overline{L}_i$ and cost of delivery g). Note that as in Chapter 3 the premium and cost of delivery are assumed to be linear in coverage. Given that this coverage leads to a separating equilibrium, the following conditions hold

(4-2) $N_1(w_1^{FI} - \overline{L}_1 - g)\phi_i^* = 0$ and $N_2(w_2^{FI} - \overline{L}_2 - g)\phi_2^* = 0$.

The separating equilibrium without cross subsidies is identical in most respects the model developed by Rothschild and Stiglitz (R-S) for a risk neutral competitive insurance firm. The only difference is that, while in the R-S model the zero profit condition on each risk pool is arrived at by competition, here it is arrived at by the mandates of the FCIC and the assumption of no cross subsidies across risk types. The other major difference to be noted is that here farm risks are allowed to be positively correlated while R-S assume no correlation. However, this has no effect because both the R-S model and the FCIC model assume insurance providers are risk neutral so higher moments do not come into play.

Most of the results arrived at by the R-S model hold for the current FCIC separating equilibrium without cross subsidies. While the R-S model is mainly a graphical exposition of the separating equilibrium, the FCIC equilibrium is developed here with a more mathematical approach using the mean-variance framework. Certain specific results which are more relevant to the study of crop insurance are highlighted in the ensuing paragraphs.

4.2.2.1 The Model

Since the FCIC is unable to distinguish between high and low risk farmers, and premiums must satisfy expression (4-1), there must be restrictions on coverage to achieve a separating equilibrium. The restrictions on coverage must be such that the high risk farmers are indifferent to or less prefer the coverage associated with the premium for the low risk types and vice versa[14]. To arrive at the restrictions on coverage in this equilibrium, the second mandate of providing maximum coverage to all risk types is used. The FCIC offers only two contracts specifying both coverage level and premium for both the contracts. Coverage levels are obtained by providing full information coverage to the high risk type and, keeping the utility of the high risk types constant at this level, determining the maximum coverage to the lower risk group such that the high risk types are indifferent between the two contracts[15]. It is shown later in this chapter that the separating equilibrium arrived at in this fashion leads to the greatest utility for both risk types under FCIC classification problems.

As in Chapter 3 assume the preference function

$$U(\overline{\pi},\sigma^2) = \overline{\pi} - \frac{\lambda}{2}\sigma^2$$

---

[14] There is an important implicit restriction in the separating equilibrium without cross subsidies regarding the number of high risk farmers. It is obvious from the equation above that if there were a low proportion of high risk types, then premiums set at the actuarially fair level plus cost is not a preferred equilibrium. For example if there was only one high risk farmer and all the others were low risk types, then by making a loss on the one high risk farmer and spreading this loss across all low risk farmers potentially could increase the utility of the low risk farmers as they would be paying only slightly higher prices for coverage than the case when there is full information. Such an equilibrium that allows losses on some risk types and profits on other risk types, but overall zero profits can be superior to the equilibrium studied here. Such situations are studied later in the chapter.

[15] The probability of disaster of the risk types and preferences of farmers are assumed known by the FCIC.

for both types of farmers, so that the preference function is increasing in expected value and decreasing in the variance of profits from farming. The value of λ indicates the risk preferences of the farmer, with higher values indicating greater degrees of risk aversion. Let the optimum coverage associated with the high risk type at full information be $\phi_2^{FI}$; superscript *FI* indicates full information.

In this separating equilibrium the contract offered to type 2 farmers is the same contract as in the full information situation, i.e., $(\phi_2^{FI} w_2^{FI}, \phi_2^{FI})$. The preference function of a type 2 farmer when he buys this contract is[16]

$$U^H(.|w_2^{FI}, \phi_2^{FI}) = M - \phi_2^{FI} w_2^{FI} - (1-\phi_2^{FI})\overline{L}_2 - \frac{\lambda}{2}(1-\phi_2^{FI})^2 \sigma_2^2$$

where $U^H$ is the value of the preference function of the higher risk type. Now let the FCIC offer a contract for the low risk type given by $(\phi_1 w_1^{FI}, \phi_1)$, where $\phi_1$ is some positive coverage level meant for a farmer from risk type 1. The high risk farmer may opt to buy this since the FCIC cannot distinguish him from a type 1 farmer. If the farmer buys the low risk contract, the utility of the farmer is

$$U^H(.|w_1^{FI}, \phi_1) = M - \phi_1 w_1^{FI} - (1-\phi_1)\overline{L}_2 - \frac{\lambda}{2}(1-\phi_1)^2 \sigma_2^2.$$

If $U^H(.|w_1^{FI}, \phi_1) > U^H(.|w_2^{FI}, \phi_2^{FI})$ then the coverage and premium meant for the type 1 farmer is preferred by the high risk farmer. A pooling situation occurs if both groups buy the same contract and the program would lose money on the high risk farmers. Therefore, for a separating

[16] See the previous chapter for a derivation of the expected value and variance of farm profits.

equilibrium to exist, it must be the case that $U^H(.|w_1^{FI},\phi_1) \leq U^H(.|w_2^{FI},\phi_2^{FI})$; it is assumed that when the preferences from the two contracts are equal the farmer purchases the contract meant for the high risk type. However, contracts of the form $U^H(.|w_1^{FI},\phi_1) < U^H(.|w_2^{FI},\phi_2^{FI})$ would imply decreasing coverage of the lower risk group, without any apparent gain to the higher risk group (goes against the FCIC mandate of maximum coverage feasible to all risk types) and as such these contracts are not considered. The coverage to the lower risk type at which the higher risk type is indifferent between buying the two FCIC contracts is the equilibrium coverage for the lower risk type.

*Definition (4-1): AN FCIC separating equilibrium without cross subsidies between risk pools in this model of crop insurance delivery is a premium $w_i^{FI}$ and coverages $\phi_1^*$ and $\phi_2^{FI}$ such that:*

(4-3) $w_i^{FI} = \bar{L}_i + g \qquad i = 1,2$

(4-4) $\phi_2^{FI} = 1 - \dfrac{g}{\lambda\sigma_2^2}$

(4-5) $\phi_1^*(-w_1^{FI} + \bar{L}_2) - \dfrac{\lambda}{2}(\phi_1^* - 1)^2\sigma_2^2 = \phi_2^{FI}(-w_2^{FI} + \bar{L}_2) - \dfrac{\lambda}{2}(\phi_2^{FI} - 1)^2\sigma_2^2.$

The equilibrium values are obtained by solving the four equations sequentially. With known probability of disasters, the premiums to the two risk types are set at expected indemnity plus cost (full information premiums). Only two coverage levels are marketed by the FCIC: (i) the full information coverage for the high risk types arrived at by the second expression above; and (ii) separating equilibrium coverage for the low risk types determined by the point where the high risk type is indifferent between the two contracts.

At equilibrium with positive g, an interior solution would be ensured for risk type 2 as long as $g < \lambda\sigma_2^2$. All the conditions discussed for an interior solution in Chapter 3 hold for both types of farmers. However, with classification problems there are some additional concerns associated with this equilibrium that must be addressed. Most of these concerns effect only risk type 1 since the higher risk type enjoys the same conditions as a full information situation. For risk type 1 there is a possibility that the coverage ($\phi_1^*$) arrived at from expression (4-5) is higher than what it would be under full information, i.e., the parameters of the model are such that

$$\phi_1^* > \phi_1^{FI} = 1 - \frac{g}{\lambda\sigma_1^2}$$

In such a case the utility of type 1 farmers could be increased by setting the coverage less than ($\phi_1^*$)at the full information level ($\phi_1^{FI}$) with premium $\phi_1^{FI} w_1^{FI}$. If such a situation exists, then the FCIC difficulty with farmer classification is not a problem. The FCIC could simply restrict coverage with each premium at the optimum level and each group would buy contracts meant for them.

Consider the following discussion to see the conditions under which information asymmetry is always a problem with positive delivery cost. Start with a situation in which full information coverage is dictated by the FCIC for both risk pools. The two contracts offered are (i) coverage $\phi_1^{FI}$ and premium $\phi_1^{FI} w_1^{FI}$ and (ii) coverage $\phi_2^{FI}$ with premium $\phi_2^{FI} w_2^{FI}$. Note that both premium and coverage are restricted to the ones specified in the contracts. Given that both the contracts are marketed by the FCIC, the farmer may buy any contract he chooses. Also note that $\phi_1^{FI} < \phi_2^{FI}$ always for positive g.

*Proposition (4-1): If* $g \le \dfrac{2\sigma_1^2}{(\sigma_2^2+\sigma_1^2)}$ *then FCIC premium and coverage to farmers cannot be delivered at full information levels if the program is to remain actuarially sound.*

*Proof.*

The situation where the low risk contract is more attractive (>), indifferent (=), or less attractive (<) to the high risk contract for a type 2 farmer is given by the condition

$$\phi_1^{FI}(-w_1^{FI}+\bar{L}_2)-\frac{\lambda}{2}(\phi_1^{FI}-1)^2\sigma_2^2 \quad (>,=,<) \quad \phi_2^{FI}(-w_2^{FI}+\bar{L}_2)-\frac{\lambda}{2}(\phi_2^{FI}-1)^2\sigma_2^2$$

where the left hand side (LHS) is the utility of the farmer buying low risk contract and the right hand side (RHS) is the utility of the farmer buying high risk contracts (the common terms are canceled out). By substituting in the premium and the full information values for ϕ, the above expressions reduces to

$$\text{(4-6)} \quad (\bar{L}_2-\bar{L}_1)*\frac{(\lambda\sigma_1^2-g)}{\lambda\sigma_1^2} \quad (>,=,<) \quad \frac{g}{\lambda\sigma_1^2\sigma_2^2}\left(\frac{g((\sigma_2^2)^2-(\sigma_1^2)^2)}{2\sigma_1^2}-(\sigma_2^2-\sigma_1^2)\right).$$

As indicated earlier, as long as the LHS < RHS, the high risk farmer would always prefer the contracts written for the high risk types and farmer classification is not a problem in this model. If LHS > RHS then lack of information on farmer classification is a problem and the coverage to the low risk types is determined in a separating equilibrium stated above (coverage to type 1 farmers will be always less than coverage at full information). For lack of information on farmer classification to be always a problem in this model (with positive cost of delivery insurance), it is sufficient that the terms in the brackets in the RHS is non-positive or

$$\frac{g((\sigma_2^2)^2-(\sigma_1^2)^2)}{2\sigma_1^2}-(\sigma_2^2-\sigma_1^2)\le 0$$

or

(4-7) $$g \le \frac{2\sigma_1^2}{(\sigma_2^2 + \sigma_1^2)}.$$

It must be remembered that imperfect information may still cause a problem even if g does not satisfies the condition. This would depend on expression (4-6). Also, as can be seen from the above proposition at g=0, imperfect information would never allow FCIC equilibrium to deliver crop insurance at full information levels. For the remainder of the study it is assumed that (4-1) holds such that the separating equilibrium coverage to type 1 farmers is less than full information coverage ($\phi_1^* < \phi_1^{FI}$).

So far in the discussion it has been implicitly assumed that when a separating equilibrium exists, the low risk types will always purchase the contract meant for the low risk farmer. Here it is shown that this is always true in equilibrium.

*Proposition (4-2): In a separating equilibrium, the low risk type always prefers the low risk contract to the high risk contract.*

*Proof:*

Suppose that both the risk types buy the high risk contract and preferences are $U^H(.|w_2^{FI}, \phi_2^{FI})$ and $U^L(.|w_2^{FI}, \phi_2^{FI})$ respectively for risk types 2 and 1. Now decrease the premium to $w_1^{FI}$ and adjust coverage such that the high risk type is indifferent between the contracts. This is the separating equilibrium point $U^H(.|w_1^{FI}, \phi_1^*) = U^H(.|w_2^{FI}, \phi_2^{FI})$. Recall from

Chapter 3 that for the same premium a high risk farmer would always seek higher coverage than a low risk farmer. Thus for the low risk farmer to be indifferent to $U^L(.|w_2^{FI},\phi_2^{FI})$, the coverage will be lower than $\phi_1^*$. Since it is assumed that Proposition (4-1) holds then

$U^L(.|w_1^{FI},\phi_1^*) > U^L(.|w_2^{FI},\phi_2^{FI})$.

Having established the conditions under which the separating equilibrium is feasible, the properties of the equilibrium with no cross subsidies are now discussed.

*Proposition (4-3): Any increase in the cost of delivery (g) will decrease coverage to both the high and low risk farmers.*

*Proof:*

Increase in cost of delivery would increase premiums by the same amount to both risk groups, i.e.,

$$w_1^{new} = \overline{L}_1 + g + \Delta g$$
$$w_2^{new} = \overline{L}_2 + g + \Delta g$$

Without an adjustment in equilibrium coverage, then the utility associated with the low risk contract will be higher, since there will be a greater decrease in the expected value of loss associated with the high risk type, i.e.,

$$\Delta g \phi_2^{FI} > \Delta g \phi_1^*.$$

After the equilibrium coverage to the high risk group adjusts to a lower level, the contract of the lower risk type gets even more attractive if no adjustment in coverage to this contract takes place. To restore separating equilibrium, the coverage to the lower risk group must decrease.

*Proposition (4-4): With a decrease in the probability of disaster for the low risk types ($P_1$), coverage provided to the low risk types must decrease if a new separating equilibrium is to exist. The level of decrease in the coverage is moderated by the cost of delivery (g) -- the higher the cost the lower the decrease.*

*Proof:*

Rewrite equilibrium expression (4-5) as

$$\phi_1^*(P_2L - P_1L) + (\phi_2^{FI} - \phi_1^*)g = \frac{\lambda}{2}\left((\phi_1^* - 1)^2 - (\phi_2^{FI} - 1)^2\right)\sigma_2^2$$

Assume that equilibrium exists and at equilibrium there is a decrease in $P_1$; this implies LHS > RHS. Since $\phi_2^{FI}$ is fixed (there is no change in $P_2$), the only variable that can change is $\phi_1^*$. Consider the case where there is no cost of delivery (g=0). Then any decrease in $P_1$ would lead a to decrease in $\phi_1^*$. However with positive cost of delivery there must still be a decrease in $\phi_1^*$ for the equilibrium to hold, but the decrease in coverage must be less since any drop in $\phi_1^*$ would tend to increase the LHS via the effect of g — the higher the value of g the less the coverage to type 1 falls.

*Proposition (4-5): The coverage (and utility) to the low risk type is at a maximum in this model of FCIC separating equilibrium if the coverage to the higher risk type equals the coverage at full information ($\phi_2^{FI}$).*

*Proof:*

Let the initial equilibrium be at the unconstrained optimum for the higher risk type at $\phi_2^z$ and the corresponding separating equilibrium for the lower risk type at $\phi_1^z$, such that the higher risk group is indifferent between the two contracts. Now if the coverage level for type 2 is varied above or below $\phi_2^z$ the utility of the farmer would decrease and for any such situation the contract of the lower risk type is now more attractive and a pooling situation occurs. To regain separating equilibrium, the coverage to the lower risk type must be lowered thus decreasing the utility of these farmers. In other words the highest level of utility to the lowest risk type is attained when the higher risk type is given the optimum coverage, which is the same as coverage under full information ($\phi_2^z = \phi_2^{FI}$).

### 4.2.3 FCIC Separating Equilibrium With Cross-Subsidization Across Risk Pools

The equilibrium with no cross subsidies across risk pools may not be the most desirable one to all farmers. Cross subsidies across risk pools would imply that the FCIC makes expected positive profits on one risk pool and expected losses on other risk pool but overall it make zero expected profits. Such a situation does not violate the mandates of the FCIC stated earlier as it keeps the program at actuarially sound levels. This section develops a separating equilibrium with cross subsidies across risk pools and states the conditions under which the separating equilibrium with cross subsidies provides higher utility to both types of farmers who buy insurance.

4.2.3.1 The Model

In a separating equilibrium with cross subsidies[17] the premiums need no longer be at expected indemnity plus costs. If $w_i^+$ and $\phi_i^+$ are the cross subsidy premiums and coverage offered by the FCIC in a separating equilibrium to type i farms, the expected profits of the FCIC are

(4-8) $$N_1(w_1^+ - \overline{L}_1 - g)\phi_1^+ + N_2(w_2^+ - \overline{L}_2 - g)\phi_2^+ = 0$$

where overall there are zero expected profits, but there may be expected profits and losses in each risk pool.

As before, the sole provider position of the FCIC allows it to offer only two contracts such that both premium and coverage are specified for each contract. It is assumed that the conditions specified in Proposition (4-1) hold and full information premium and coverage cannot be offered to farmers when there are classification problems.

Results from the previous section illustrate that taxing high risk types would further reduce the coverage to the low risk types to maintain a separating equilibrium. Thus, if there is to be any cross subsidization it must be in the form of taxing the low risk premiums, subsidizing the high risk premiums, and adjusting coverage such that a separating equilibrium is achieved.

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[17] A separating equilibrium with cross subsidization is not feasible in a competitive market as described by the Rothschild and Stiglitz model. The only reason it is feasible here is because the FCIC is assumed be the sole provider of crop insurance in the model and as such does not face competitive forces.

*Definition (4-2): AN FCIC separating equilibrium with cross subsidization in this model are the premiums $w_i^+$ and coverage $\phi_i^+$ for risk types i (i=1, 2) such that:*

(4-9) $$w_1^+ = w_1^{FI} + d$$

(4-10) $$w_2^+ = w_2^{FI} - Rd$$

(4-11) $$\phi_2^+ = 1 - \frac{w_2^+ - \overline{L}_2}{\lambda\sigma_2^2}$$

(4-12) $$\phi_1^+(-w_1^+ + \overline{L}_2) - \frac{\lambda}{2}(\phi_1^+ - 1)^2\sigma_2^2 = \phi_2^+(-w_2^+ + \overline{L}_2) - \frac{\lambda}{2}(\phi_2^+ - 1)^2\sigma_2^2$$

The first expression in the equilibrium conditions is the premium per acre for the low risk types and it is arrived at by adding a tax d to the full information premium[18] for the low risk types. The second expression is the premium for the low risk types and it is arrived at by subsidizing the full information premium by subtracting Rd from the full information premium per acre. R reflects the ratio of type 1 to type 2 farmers. The expression Rd indicates that if R=1 then the tax on the low risk farmer premium equals the subsidy on the high risk premium. If R=2, indicating that twice as many low risk types to high risk types, then the subsidies go the higher risk type goes even further. The third expression is the optimal coverage that the high risk type would receive at $w_2^+$ (the choice of this coverage follows from a similar proof to that of Proposition (4-5)). And finally, the last expression determines the coverage to the low risk types required to generate a separating equilibrium at the given premium levels.

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[18] Recall that premium is linear in coverage and therefore tax also enters as linear in coverage.

The equilibrium above shows that the a high risk type always enjoys higher preference level from the separating equilibrium with cross subsidies than the separating equilibrium without cross subsidies. This is because the premium per acre with cross subsidy to the type 2 farmer is lower that the with no cross subsidy ($w_2^+ < w_2^{FI}$) and coverage is higher ($\phi_2^+ > \phi_2^{FI}$). On the other hand, the type 2 farmer faces higher premiums ($w_1^+ > w_1^{FI}$) but also higher coverage ($\phi_2^+ > \phi_2^*$). Whether the preferences of type 1 farmers is higher or lower is yet to be seen.

With tax d on the premium per acre, the coverage $\phi_1^d$ at which the low risk farmer is indifferent to a no tax situation is $U^L(.|w_1^{FI}, \phi_1^*) = U^L(.|w_1^{FI} + d, \phi_1^d)$; $\phi_1^d$ is the critical coverage that a separating equilibrium must ensure for the cross subsidies equilibrium to be more desirable than the equilibrium with no cross subsidies, i.e., $U^L(.|w_1^+, \phi_1^+) \geq U^L(.|w_1^+, \phi_1^d)$.

*Proposition (4-6): A separating equilibrium with cross subsidies ($\phi_1^+ w_1^+, \phi_1^+$) is superior to an equilibrium without cross subsidies if the tax d on the lower risk type satisfies:*

$$d < \frac{g(\phi_1^+ - \phi_1^*)}{\phi_1^+} + \frac{\lambda}{2\phi_1^+}\sigma_1^2\left((\phi_1^* - 1)^2 - (\phi_1^+ - 1)^2\right)$$

*Proof.*

Consider the utility of the low risk type in a separating equilibrium with no cross subsidies

$$\text{(4-13)} \quad M - \overline{L}_1 + \phi_1^*(-w_1^{FI} + \overline{L}_1) - \frac{\lambda}{2}(\phi_1^* - 1)^2 \sigma_1^2 = \Delta$$

where $\Delta$ is the utility level of the farmer. Now if coverage is allowed to increase to $\phi_1^+$, the utility of the farmer would increase and the farmer would desire this new contract. This increase in utility of the farmer would be less if the premium is allowed to increase simultaneously since increases in premium decrease utility. Let the increase in premium per acre be d (the tax level) such that it is at $w_1^+ (= w_1^{FI} + d)$. The utility of the farmer is reduced but it is still higher than the level Δ. Then subtracting expression (4-13) from the utility with coverage $\phi_1^+$ and premium $\phi_1^+ w_1^+$ will yield a positive value or

$$\phi_1^+(-w_1^+ + \overline{L}_1) - \frac{\lambda}{2}(\phi_1^+ - 1)^2 \sigma_1^2 - \left(\phi_1^\bullet(-w_1^{FI} + \overline{L}_1) - \frac{\lambda}{2}(\phi_1^\bullet - 1)^2 \sigma_1^2\right) > 0$$

Rewriting this expression to isolate w gives

$$\phi_1^+ w_1^+ - \phi_1^\bullet w_1^{FI} < (\phi_1^+ - \phi_1^\bullet)\overline{L}_1 + \frac{\lambda}{2}\sigma_1^2\left((\phi_1^\bullet - 1)^2 - (\phi_1^+ - 1)^2\right)$$

The RHS of this expression is positive. Since $w_1^+ = w_1^{FI} + d$ (where $w_1^{FI} = \overline{L}_1 + g$). Rewriting the expression above and isolating d gives

$$d < \frac{g(\phi_1^+ - \phi_1^\bullet)}{\phi_1^+} + \frac{\lambda}{2\phi_1^+}\sigma_1^2\left((\phi_1^\bullet - 1)^2 - (\phi_1^+ - 1)^2\right).$$

The condition in Proposition (4-6),is more likely to hold if the tax d on the low risk type goes further in subsidizing the high risk types. From the equilibrium condition it is evident that this happens as the value of R (the ratio of low to high risk farmers) increases. Therefore, if the market has higher ratios of low to high risk farmers, then a cross subsidizing separating equilibrium would increase utility (and coverage) to all farmers than in a separating equilibrium with no cross subsidies.

To highlight discussions of this section further consider a simple numerical example below. The same parameters as in Chapter 3 are used i.e., $P_1$=0.3; $P_2$=0.4; g=3 bushels; M=140 bushels; L=70 bushels; λ=0.01; R=ratio of low to high risk types. The reader is reminded that the parameters chosen do not reflect any real world application and are only for expository purposes. The results of the numerical analysis is reported in the Table 4-1 through Table 4-1 below.

Table 4-1 FCIC Equilibrium Coverage Levels With Taxes and Subsidies: R=1

| | P=0.30 | | | P=0.40 | | |
|---|---|---|---|---|---|---|
| Tax (d) | $w_1^*$ | $\phi_1^*$ | u1 | $w_2^*$ | $\phi_2^*$ | u2 |
| 0 | 26.0 | 0.151 | 114.530 | 33.0 | 0.575 | 108.060 |
| 0.1 | 26.1 | 0.157 | 114.540 | 32.9 | 0.583 | 108.120 |
| 0.7 | 26.7 | 0.199 | 114.565 | 32.3 | 0.634 | 108.486 |
| 0.9 | 26.9 | 0.215 | 114.561 | 32.1 | 0.651 | 108.615 |

Table 4-2 FCIC Equilibrium Coverage Levels With Taxes and Subsidies: R=2

| | P=0.30 | | | P=0.40 | | |
|---|---|---|---|---|---|---|
| Tax (d) | $w_1^*$ | $\phi_1^*$ | u1 | $w_2^*$ | $\phi_2^*$ | u2 |
| 0.1 | 26.1 | 0.162 | 114.561 | 32.8 | 0.592 | 108.180 |
| 0.7 | 26.7 | 0.243 | 114.668 | 31.6 | 0.694 | 108.951 |
| 0.9 | 26.9 | 0.277 | 114.677 | 31.2 | 0.728 | 109.235 |
| 1.0 | 27.0 | 0.296 | 114.674 | 31.0 | 0.745 | 109.382 |

Table 4-3 FCIC Equilibrium Coverage Levels With Taxes and Subsidies: R=0.5

| | P=0.30 | | | P=0.40 | | |
|---|---|---|---|---|---|---|
| Tax (d) | $w_1^*$ | $\phi_1^*$ | u1 | $w_2^*$ | $\phi_2^*$ | u2 |
| 0.04 | 26.04 | 0.152 | 114.536 | 32.98 | 0.577 | 108.074 |
| 0.1 | 26.10 | 0.155 | 114.535 | 32.95 | 0.579 | 108.092 |

The first column of each table indicates the tax imposed on the lower risk group and the remaining columns indicate premium (w), coverage ($\phi$) and utility (u) for risk type 1 and 2 respectively. Table 4-1 shows the results where there are equal numbers of low to high risk farmers; Table 4-2 shows the results when the number of low risk types are twice as many as the high risk types; and Table 4-3 indicates the case when there are twice as many high risk types to low risk types. The results are reported for selective tax levels.

Results in Table 4-1 show that subsidizing the high risk type (type 2) leads to decreased premium and increased coverage (and higher utility to risk type 2). Since in this equilibrium the subsidies to the higher risk type is financed by taxing low risk farms, the premiums for these farms increase. However, increases in premium to the lower risk type (by taxation) does not lead to lowering of the preference value of the lower risk type in a separating equilibrium. As the higher risk class is made increasingly better off with subsidies the separating equilibrium allows an increase in the coverage offered to the lower risk class. In this example both the equilibrium premium and coverage to the lower risk type increases in the separating equilibrium. The preferences of the lower risk group (indicated by u1 in Table 4-1) increases as the tax increases and reaches a maximum at an approximate tax of 0.7 bushels, after which it starts to decline. This implies that given a choice of insurance contracts, the low risk group would choose a contract at which the premium is higher than in an FCIC separating equilibrium contract (premium at 26.7 bushels) with a higher coverage (0.199 percent) as opposed to a premium of 26 bushels and coverage of 0.151 percent, without any taxes. Taxing of the low risk types also makes it possible to increase the coverage (and utility) of the high risk types from 0.575 percent 0.651 percent.

However, not all situations permit taxing and subsidizing to increase the preferences of all farmers. The results depend on the proportion of low to high risk farmers in the market. Table 4-2 and Table 4-3 report the results for the same example but with the proportion of high to low risk farmers changed. Results of Table 4-2 indicate that, when there are twice as many low to high risk farmers, the same level of tax to the low risk type increases the preferences of both risk groups compared to the case when there was an equal number of high and low risk groups. For example, a tax of 0.1 bushels now has coverage of 0.162 bushels (u1=114.561) compared to 0.157 bushels (u1=114.540) in Table 4-1. While earlier the preferences of the low risk farmers were maximized at a tax of 0.7 bushels, it is now maximized at 0.9 bushels, indicating that as the ratio of low to high risk types increase, higher levels of tax are preferred. Furthermore, the high risk types are increasingly better off (compare u2 of Table 4-2 to that of Table 4-1 for each level of tax) with the tax and subsidy plan as the proportion of low to high risk farms increased. This result is driven by the fact that the taxes go a lot further as there are more type 1 farmers than type 2 farmers.

A situation where tax and subsidy schemes are less effective is indicated in Table 4-3 where there are twice as many high risk types as low risk types. These results show that at taxes any higher than 0.04 bushels the utility of the low risk types decreases (at 3 decimal places the utility does not change from the case when there are no taxes). With this amount of tax the preference function of the high risk types is increased only slightly.

### 4.2.4 The FCIC Pooling Equilibrium

The third and final possibility considered in this chapter is a pooling equilibrium. In this case, only one contract is offered by the FCIC and every farmer buys the same coverage and pays the same premium irrespective of their risk classes. In this section it is also assumed that proposition (4-1) holds and that the FCIC cannot classify farmers into risk classes.

#### 4.2.4.1 The Model

A pooling equilibrium occurs where the premium per acre $(w^P)$ is an average premium, i.e.,

$$w^P = \frac{N_1 w_1^A + N_2 w_2^A}{N_1 + N_2} + g \tag{4-14}$$

where $w_i^A$ is the actuarially fair premium for risk class i and g is the cost of delivery per acre. As before, the premium is assumed to be linear in coverage. The FCIC is able to calculate this premium because all the information in the expression is known. The pooling premium depends on the number of high to low risk types. If there are no high risk types ($N_2$=0) than the premium reduces to the premium for the low risk types with full information and vice versa.

*Proposition (4-7): If the premium to all risk types is* $w^P = \frac{N_1 w_1^A + N_2 w_2^A}{N_1 + N_2} + g$ *there can be only one coverage level in equilibrium.*

*Proof:*

Let the coverage level to low and high risk types be $\phi_1$ and $\phi_2$ respectively. The expected profits of the FCIC is

$$E(\pi_g) = N_1\phi_1(w^p - \bar{L}_1 - g) + N_2\phi_2(w^p - \bar{L}_2 - g)$$

The first term in the RHS is the expected profits on the low risk pool and the second term is the expected profits on the high risk pool. Substituting the value $w^p$ from expression (4-14) and simplifying gives

$$E(\pi_g) = \frac{N_1 N_2}{N_1 + N_2}(\bar{L}_2 - \bar{L}_1)(\phi_1 - \phi_2)$$

It is clear from the expression above that for the FCIC to break even, $E(\pi_g) = 0$, the coverage offered to both farmer types must be the same ($\phi_2 = \phi_1$).

From Proposition (4-7) it appears that there are no limits to the coverage for equilibrium as long as the coverage to all farmers is the same. However, from the demand side there are boundaries to the coverage that the FCIC can sell.

*Proposition (4-8): In the pooling equilibrium of this model, the pooling coverage $\phi^p$ must be such that $\phi^p \leq 2\left(1 - \frac{(w^p - \bar{L}_1)}{\lambda\sigma_1^2}\right)$.*

*Proof:*

For the given premium $w^p$, the farmer would not buy FCIC insurance if the utility of buying insurance is lower than the utility from no insurance, i.e. $U(.|w^p, \phi^p) > U(.|0,0)$. For the specific utility function in this study the condition to buy insurance is

$$M-\bar{L}+\phi(-w+\bar{L})-\frac{\lambda}{2}(\phi-1)^2\sigma_L^2 \geq M-\bar{L}-\frac{\lambda}{2}\sigma_L^2 .$$

Simplifying and rearranging the expression gives

$$\phi \leq 2\left(1-\frac{(w^p-\bar{L})}{\lambda\sigma_L^2}\right).$$

The expression in the brackets in the RHS is the expression for optimum coverage that the farmer would choose given the premium $w^p$. Therefore, in this linear mean-variance framework, coverage above twice the optimum level would not be bought by the farmer. Since the FCIC program is to serve as the primary disaster provider, it must ensure that both risk types buy insurance or the pooling coverage must satisfy

$$\text{(4-15)} \quad \phi^p \leq 2\left(1-\frac{(w^p-\bar{L}_1)}{\lambda\sigma_1^2}\right).$$

For the rest of the analysis, it is assumed that FCIC sets coverage such that both risk types buy insurance. Since coverage could essentially be set anywhere within the stated bounds, selection of the coverage level becomes difficult without further information. To see how different coverage levels effect the utility of the farmers let $\phi_1^p$ and $\phi_2^p$ be the optimum coverage for risk types 1 and 2 with premiums at $w^p\phi_1^p$ and $w^p\phi_2^p$ respectively. Also note that $\phi_2^p > \phi_1^p$ Let $\phi^p$ be the pooling equilibrium coverage chosen by the FCIC. If $\phi^p = \phi_1^p$ then the utility of the low risk type is maximized while that of the high risk type is minimized under the pooling premium. Note that the full information utility cannot be achieved for the low risk types because $w^p > w_1^{FI}$ and $\phi_1^{FI} > \phi_1^p$. If coverage is set such that $\phi^p = \phi_2^p$, then the coverage of the high risk type is at a maximum (and that of the low risk type is minimized). Here the high risk type is better off than in the case of full information because both coverage $\phi_1^{FI} < \phi_2^{p}$ and premium $w^{p} < w_2^{FI}$ are better.

To compare the pooling equilibrium with the separating equilibrium, consider setting the pooling coverage at level $\phi^{p*}$, such that the utility of the high risk type is maintained at a separating equilibrium level with some tax d. To facilitate the comparison, consider a separating equilibrium with tax $d^{p}$ such that $w_1^{+} = w^{p} = w_2^{+}$. The level at which $d^{p}$ must be set is

$$(4\text{-}16) \quad d^{p} = \frac{1}{1+R}(w_2^{FI} - w_1^{FI}).$$

At this level of tax a separating equilibrium breaks down and a pooling equilibrium occurs because if taxes are at Equation (4-16), then Proposition (4-7) shows that there can only be one coverage for both risk types. This is because the premium is the same and there can no longer be a separating effect through coverage, and the FCIC still maintain zero profits. From Proposition (4-6) we know that the separating equilibrium provides higher utility to the low risk type only if

$$d < \frac{g(\phi_1^{+} - \phi_1^{*})}{\phi_1^{+}} + \frac{\lambda}{2\phi_1^{+}}\sigma_1^2\left((\phi_1^{*} - 1)^2 - (\phi_1^{+} - 1)^2\right).$$

So in a pooling equilibrium this condition is more likely to hold if R is as large as possible so that $d^{p}$ is as small as possible, or a pooling equilibrium is approached by a separating equilibrium when the ratio of R is very high.

We have seen in this section that a separating equilibrium with cross subsidies can lead to a pooling equilibrium with the right amount of tax on the low risk types. Calculations in the numerical examples (presented in the previous section) support a separating equilibrium with cross subsidies rather than a pooling equilibrium where the utility of the low risk types are maximized.

This is because, in these examples the ratio of low to high farmers is not large enough to justify a pooling equilibrium. Since a pooling equilibrium can always be approached from a separating equilibrium with cross subsidies, for the remainder of this study, only separating equilibria are considered.

### 4.2.5 Implications for Current FCIC Policies

So far the study has shown what an FCIC equilibrium might look like with lack of information to classifying farmers into risk types. This section briefly connects the results of this model with the current FCIC program policies.

The current FCIC program operates as if it has full information on farmer risk types since measures to addresses classification problems are not present. All the farmers have a choice of 50, 65 or 75 percent coverage level with rates based on their past 10 years average yield. Skees and Reed have indicated that using only average yield is not adequate for proper farmer classification. The federal crop insurance figures available for the 1980-90 decade indicate that close to a billion dollars have been transferred from the FCIC to the farmers — this has been over and above any predetermined subsidies. Therefore, among other problems such as moral hazard, timing of sales, etc., the classification issue appears to be a problem to the crop insurance program.

Results from this study indicate that if the FCIC is to operate on an actuarially sound basis, attempts must be made to price policies such that high risk farmers self select high risk policies (if information on classification cannot be obtained inexpensively). One way to do this is subsidize high coverage levels and tax low coverage levels. Results show that a pooling equilibrium may severely penalize the low risk types unless the proportion of low to high risk farmers is large.

The results of the separating equilibrium gives an idea of how the contracts would look. The implications of some of the current government practice of providing subsidies is summarized below.

*Proposition (4-9): The current FCIC practice of providing subsidies to lower coverages and not to the higher coverage will either (i) lower the coverage to the lower risk type in a separating equilibrium or (ii) further increase budgetary outlays through adverse selection*

*Proof:*

Starting in a separating equilibrium, provision of subsidies to the lower risk group makes these policies more attractive to the higher risk group then they otherwise would be. To restore a separating equilibrium expression (4-12) indicates that there must be a decrease in the coverage of the low risk group or the government will face losses due to adverse selection.

*Proposition (4-10): If the maximum coverage to the high risk types is limited to below the full information optimum, then either (i) the coverage to the lower risk type is reduced in a separating equilibrium or (ii) there are further increases in budgetary outlays through adverse selection. .*

*Proof:*

Follows from Proposition (4-5).

*Proposition (4-11): Subsidization of administrative costs (g) is beneficial to all risk groups in an FCIC separating equilibrium and in an FCIC pooling equilibrium.*

*Proof:*

From Proposition (4-3) it follows that lowering administrative costs would increase the utility of both the high and low risk types while still maintaining a separating equilibrium. For a pooling equilibrium, given the same coverage, lower premiums would be faced by both risk types.

For a separating equilibrium with or without cross subsidies, policies that subsidize all risk types will increase the utility of both risk types (the current program pays all administrative costs). Even policies that only subsidize the higher risk types are desirable in a separating equilibrium but policies that subsidize only the lower risk types have the effect of reducing coverage (and utility) to these risk types in equilibrium.

## 4.3 The Competitive Delivery of Crop Insurance with Two Risk Types

Recall the working hypothesis that competitive firms are risk averse with very low cost of gathering information such that they are assumed to operate with full information. This, of course is a very strong assumption, but it is used here to highlight the differences between the FCIC and private competitive firms. Also recall that these firms are also assumed to face insurance delivery costs lower than the FCIC. This section of the chapter investigates how the competitive equilibrium will behave when there are two risk types in the market, and under what conditions a firm would hold only one risk type in its portfolio.

### 4.3.1 The Competitive Equilibrium

All the characteristics of the competitive firm specified in Chapter 3 hold. This implies that, in the long-run, the competitive firm is operating at reservation utility b such that no entry occurs. Competition determines the number of policies held by each firm. As before, assume the specific preference function for the firm

$$V(.) = \bar{\pi}_S - \frac{\psi}{2}\sigma^2_{\pi_S}.$$

*Definition (4-3): A competitive equilibrium in this model of crop insurance delivery with two risk types is a premium level* $w_i^0$*, coverage level* $\phi_i^0$ *and number of policies* $n_i^0$ *for each firm such that:*

(4-17) $$-w_1^0 + \bar{L}_1 + \lambda(1-\phi_1^0)\sigma_1^2 = 0$$

(4-18) $$-w_2^0 + \bar{L}_2 + \lambda(1-\phi_2^0)\sigma_2^2 = 0$$

(4-19) $$n_1^0(w_1^0 - \bar{L}_1 - c) - \psi\left[\phi_1^0 n_1^0[1+(n_1^0 - 1\rho_1)]\sigma_1^2 + n_1^0 n_2^0 \phi_2 \sigma_{12}\right] = 0$$

(4-20) $$n_2^0(w_2^0 - \bar{L}_2 - c) - \psi\left[\phi_2^0 n_2^0[1+(n_2^0 - 1)\rho_2]\sigma_2^2 + n_1^0 n_2^0 \phi_1^0 \sigma_{12}\right] = 0$$

(4-21) $$\begin{aligned} &n_1^0(w_1^0 - \bar{L}_1 - c) + n_2^0(w_2^0 - \bar{L}_2 - c) \\ &-\frac{\psi}{2}\left[(\phi_1^0)^2 n_1^0[1+(n_1^0-1)\rho_1]\sigma_1^2 + (\phi_2^0)^2 n_2^0[1+(n_2^0-1)\rho_2]\sigma_2^2\right] \\ &-\frac{\psi}{2} n_1^0 n_2^0 \phi_1^0 \phi_2^0 \sigma_{12} - b = 0 \end{aligned}$$

(4-22) $$n_1^0 = R n_2^0$$

The first two equations are the first-order conditions (FOC) for maximizing the preference functions of the two risk type farmers as they choose coverage given the insurance premiums. The next two equations are the FOC for maximizing the preference of the competitive by choosing the coverage it would provide to risk type 1 and 2 respectively. The fifth equation states the long-run condition whereby the preferences of the competitive firm is at reservation level b and the final equation gives the proportion of low risk to high risk farmers. The equilibrium values are attained by solving the non-linear system of equations for the six unknowns.

Although it appears that in equilibrium firms hold both types of policies in their portfolio, this is not necessarily the case. A competitive firm will only hold both risk types in its portfolio if it can offer better coverage to a farmer than a firm which is holding only that farmer risk type in its portfolio. If this were not the case, then some firms would hold only one risk type in its portfolio and these firms would be able to take business away from the firms that hold both risk types. The condition under which the company would hold both risk groups in its portfolio is outlined below.

Consider the coverage to farmer type 1 (type 1 is chosen arbitrarily) and let this be $\phi_{1b}$ when the firm is holding both farmer types in its portfolio and $\phi_{1a}$ when it is holding only that farmer type in its portfolio. The respective coverages at a competitive equilibrium are

$$\phi_{1b} = \frac{\lambda\sigma_1^2 - c - \psi R n_{1b}\phi_2\sigma_{12}}{\sigma_1^2(\lambda + \psi N_{1b})} \quad \phi_{1a} = \frac{\lambda\sigma_1^2 - c}{\sigma_1^2(\lambda + \psi N_{1a})}$$

where $N_i=[1+(n_i-1)\rho]$ and $\sigma_{12} = \rho_{12}\sigma_1\sigma_2$.

For the firm to hold both risk groups in its portfolio, it must be the case that $\phi_b \geq \phi_a$ otherwise the farmers would not buy insurance from a firm that has both farmer types in its portfolio. After some algebraic manipulation it is seen that the company will hold both types in its portfolio if

$$\sigma_{12} \le \rho_1 \frac{(\lambda\sigma_1^2 - c)(n_{1a} - n_{1b})}{Rn_{1b}\phi_2}.$$

Although this condition is alone sufficient, a similar argument may be developed for the high risk farmer types, i.e.,

$$\sigma_{12} \le \rho_2 \frac{(\lambda\sigma_2^2 - c)(n_{2a} - n_{2b})}{Rn_{2b}\phi_1}$$

again this alone is sufficient. Note: $n_{ia}$-$n_{ib}$ (i=1,2) is positive[19] since negative covariance between any two farmers is not permitted in this model.

*Proposition (4-12): A competitive firm would hold only one risk type of farmers in its portfolio if either* $\sigma_{12} \le \rho_1 \frac{(\lambda\sigma_1^2 - c)(n_{1a} - n_{1b})}{Rn_{1b}\phi_2}$ *or* $\sigma_{12} \le \rho_2 \frac{(\lambda\sigma_2^2 - c)(n_{2a} - n_{2b})}{Rn_{2b}\phi_1}$ *is satisfied.*

It is then clear that if risks between two farmers in any risk class are independent but not independent across risk classes ($\rho_i = 0, \quad \rho_{12} \ne 0$), the firms in this model will hold only one risk

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[19] Alternatively it may be proved as follows: consider the case when the company is holding only one risk type in its portfolio. Now with the addition of the second risk type the number of policies it holds of the first risk type will not change if

$$n_2\phi_2(w_2 - \bar{L}_2 - c) - \frac{\psi}{2}\left[\phi_2^2 n_2[1 + (n_2 - 1)]\sigma_2^2\rho_2 + n_1 n_2\phi_1\phi_2\sigma_{12}\right] = 0$$

This is not feasible if the firm's FOC is to hold (this expression is positive). Since the reservation utility remains at b an addition of a positive value is tantamount to reducing the reservation utility to a lower level than b. Results from Chapter 3 show that with reduction of reservation utility, the number of policies must decrease.

type in its portfolio. On the other hand if $\rho_i > 0$ and $\rho_{12} = 0$, they will hold both risk types in their portfolio. More generally, the intuitive reasoning of the proposition is that firms would hold both risk types whenever there are opportunities for diversification.

## 4.4 Comparison of the Competitive Equilibrium and FCIC Delivery

Chapter 3 highlighted the differences between an FCIC equilibrium and a competitive equilibrium under full information for both agents. The results on coverage to farmers were driven by the working hypothesis that the FCIC has a high cost of delivery but behaves as risk neutral while competitive firms have lower cost of delivery but are risk averse and operate at reservation utility. While the cost of delivery reduces the FCIC coverage, high levels of positive systematic risk reduce the competitive coverage. The comparison between the two equilibria in this chapter complement the results of chapter 3 by adding classification problems to the FCIC equilibrium, and adding higher diversification possibilities for the competitive firm.

For reasons mentioned earlier, only the separating FCIC equilibrium is considered and for exposition purposes the FCIC separating equilibrium with no cross subsidies is discussed first followed by the separating equilibrium with cross subsidies. The competitive firm may have one or more risk types in its portfolio, depending on the correlation of loss between farms.

### 4.4.1 The Case of a Separating Equilibrium With No Cross Subsidies

High Risk Farmers

The comparison of results between the FCIC and the competitive equilibrium for the high risk farmers does not change from those presented in Chapter 3 if Proposition (4-12) holds and only one risk type is held by a competitive firm. The conditions assumed are such that the competitive firms supplying insurance to the high risk types hold only high risk policies in their portfolios while in an FCIC separating equilibrium the coverage offered to the farmers is the same as in the FCIC full information case. It may be concluded that classification problems do not change the position of the high risk farmer away from a full information FCIC equilibrium. If Proposition (4-12) does not hold then the competitive firm is able to provide higher coverage to high risk types because of diversification possibilities. This implies that if we start at a situation where the high risk type is indifferent between the FCIC and competitive coverage at full information, the farmer now prefers to buy insurance from a competitive firm.

Low Risk Farmers

The coverage under a competitive equilibrium is as described in Chapter 3 if Proposition (4-12) holds. If it does not hold, then diversification possibilities ensure that higher coverage is attained now under the competitive equilibrium. If, in the full information FCIC equilibrium, the farmer preferred purchasing insurance from a competitive firm, the situation now is more in favor for doing so from a competitive firm because FCIC coverage is now lower because of classification problems and competitive coverage is higher because of diversification. A situation which makes the FCIC separating equilibrium coverage decrease compared to an FCIC full information equilibrium is if there are large difference in the probabilities of disaster of the two risk types. Proposition (4-4) shows that as the difference in the probability of disaster increases, the coverage to the lower risk group is reduced.

### 4.4.2 The Case of a Separating Equilibrium With Cross Subsidies

High Risk Farmers

With positive cross subsidies from the low risk types, the higher risk farmers are made better off in this separating equilibrium than under the FCIC equilibrium with full information. Similarly if there are diversification possibilities under the competitive equilibrium. An additional factor that affects the coverage level in the FCIC equilibrium is the proportion of low to high risk farmers — as the proportion increases the subsidies increase and the high risk types are increasingly better off. Whether this coverage is higher than the competitive equilibrium still remains a function of cost of delivery of the FCIC and the degree of risk aversion of a competitive firm and the degree of correlation between farm risks.

Low Risk Farmers

The low risk farmers' utility still remain below the full information level although the utility is higher than in the case of no cross subsidies. How much higher is a function of the ratio of low to high risk farmers. As the proportion of low to high risk increases, then farmers have higher coverage (and utility) under the separating equilibrium. Thus with classification problems, a separating equilibrium is able to achieve more for both risk types as the proportion of low to high risk farmers increases.

## 4.5 Conclusions

The FCIC equilibrium was characterized by informational problems in differentiating between farmer risk classes. Conditions were developed and stated when this lack of information on farmer risk classification was a problem in the FCIC equilibrium. Three specific FCIC equilibria with classification problems were considered (i) a separating equilibrium with no cross subsidies between risk pools; (ii) a separating equilibrium with cross subsidies across risk pools; and (iii) a pooling equilibrium. Conditions were developed under which each of these equilibria were preferable to farmers. Of the three equilibria, it is seen that (i) and (iii) are special cases of equilibrium (ii). To low risk farmers, a separating equilibrium with no cross subsidies provides the lowest coverage when there is a large proportion of low to high risk types and the pooling equilibrium provides the lowest coverage when there is small proportion of low to high risk farmers.

When lack of information on farmer classification is a problem, contracts require that high risk farmers self select high risk contracts. The basic nature of the separating equilibrium implies that low risk farmers are penalized in the presence of high risk farmers. If cross subsidization between risk classes is allowed, then the penalty on the low risk type is reduced as the ratio of low to high risk farmers increases.

FCIC separating equilibrium has implications for government practices. If there are to be any subsidies from taxpayers, then subsidization of all risk types is desirable to better meet the mandates of the FCIC. The practice of subsidizing lower coverage levels has adverse effects on the coverage of the lower risk types and, in the long-run, such subsidies penalize these risk types instead of helping in a separating equilibrium.

When there is more than one risk type, there are also implications for the coverage offered by competitive firms. Conditions are stated on correlation between risks under which a competitive firm would sell both types of policies and diversify to provide higher coverage to all farmers. The presence of two risk classes of farmers impacts the comparisons made in Chapter 3 between a full information FCIC equilibrium and a competitive equilibrium. In all cases, in an FCIC equilibrium, the high risk types stand to gain and the low risk types lose to a varying degree. Which equilibrium provides higher coverage to the low risk farmers is a function of the difference in the probability of disaster between low and high risk farmers, the ratio of low to high farmers, the cost of delivery of the FCIC and the competitive firm, the degree of correlation between farm losses, and the degree of risk aversion of competitive firms.

# 5. FCIC Reinsurance Under the 1980 Crop Insurance Act

One of the mandates of the 1980 Crop Insurance Act was to include the private sector in the federal crop insurance program to make it “more efficient”. The purpose of this chapter is to introduce the private sector into the FCIC model through a reinsurance contract in which competitive firms administer contracts and bear some risks but the FCIC sets insurance contract characteristics and provides reinsurance to these firms. The expected performance of such a program is evaluated in terms of its ability to meet two main objectives of the 1980 Crop Insurance Act: (i) the program should work on an actuarially sound basis and (ii) the program should provide maximum coverage feasible to all farmers, such that the program serves as the primary provider of disaster assistance.

According to the working hypothesis of the study and the results from Chapters 3 and 4, the FCIC could increase coverage to all farmers and still function on an actuarially sound basis, if it had more information on classifying farmers into risk types and lower costs of delivering insurance.. However, unlike the FCIC, private insurance firms are risk averse profit making agents that would presumably charge a premium to compensate for bearing risk. This premium is likely to be high in a market where the losses are highly correlated, as in the agricultural sector. This chapter develops a model to incorporate competitive private firms into the FCIC model provided earlier in the study. The competitive firms participate in the program as long as the utility from participating is higher than a reservation utility.

This chapter's proceeds as follows. First the current FCIC reinsurance program is outlined in detail. Then the program is studied when there is only one farmer risk type. Most of the major results are derived in this section. Next the reinsurance program is examined under multiple farmer risk types and classification problems by the FCIC. The chapter concludes by looking at the implications of the model for the current objectives of the FCIC program.

## 5.1 The Federal Crop Insurance Program

Under the current program the FCIC determines the premiums and coverage for all policies sold to farmers including loss adjustment standards and procedures. The FCIC is mandated by the 1980 Crop Insurance Act to set premiums at actuarially sound levels and offer coverage at 50, 65 and 75 percent of 10 year average yields of the farm. To encourage widespread adoption of FCIC crop insurance, the FCIC decided to subsidize all delivery costs of the program. The private firm delivering FCIC crop insurance is obligated to sell insurance to any farmer that seeks insurance if federal crop insurance is offered in that county for the particular crop. For expenses incurred in selling and servicing the FCIC policies, the FCIC pays between 32-33 percent of the premium of every policy sold to the participating private firm. This percentage is decided annually by the Standard Reinsurance Act[20] between the FCIC and the private firms.

### 5.1.1 The FCIC Reinsurance Program

Reinsurance is insurance for firms selling insurance. In the private sector reinsurance is generally sold by companies that specialize in this business, such as Lloyds of London. In most cases the decisions of pricing, coverage, etc. are made by the primary insuring firm and if

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[20] This is the reinsurance agreement between the FCIC and the private firms and it is revised annually. The contracts reported here are taken from 1991 and 1993 Standard Reinsurance Agreements.

reinsurance is sought, the reinsurer and the insurance company decide on the premium paid for the portion of policies to be reinsured.

The FCIC chose to use reinsurance of private insurance firms as the primary means to deliver federal crop insurance to farmers. Unlike traditional private reinsurance agreements, the FCIC, who is also the reinsurer, sets the premiums and coverage on the policies and the private firms are passive deliverers. Once the policies are delivered, the private firms determine how much they will retain under the FCIC reinsurance contracts available to them. Reinsurance contracts between the FCIC and the private companies take two forms: (i) proportional reinsurance; and (ii) stop-loss (or non-proportional) reinsurance.

#### 5.1.1.1 Proportional Reinsurance

In proportional reinsurance, FCIC and the private insurance companies share specified portions of both the policy premiums collected and the indemnities paid. Under the Standard Reinsurance Agreement between the FCIC and private firms, the firms categorize their business into three risk pools: (a) Assigned Risk Fund, (b) Developmental Fund, and (c) Commercial Fund. The Assigned risk pool contains the high risk policies where the FCIC assumes responsibility for 80 percent of the of the liabilities in exchange for 80 percent of the premium. The amount of business that a company may put in this pool is limited by states and is determined by the FCIC[21]. The firm may choose to place some or all of its crop insurance business in it the Developmental risk pool but the firm must retain a minimum 35 percent of premium and associated liabilities. The company may place any business not included in the above two pools in the Commercial pool.

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[21] It ranges from 20 percent in some states to 75 percent in others.

Here the private company must retain at least 50 percent of the premium and the associated liabilities.

### 5.1.1.2 Stop-Loss Reinsurance

That part of business that the reinsured companies do not cede to FCIC through proportional reinsurance is then eligible for stop-loss reinsurance. For example if 60 percent of the business was reinsured through proportional reinsurance the retained business (40 percent) is then eligible for stop-loss reinsurance. In stop-loss reinsurance the FCIC agrees to reimburse the firms for losses over a certain predetermined loss ratio of the crop insurance portfolio (loss ratio expresses the amount of indemnities as a percentage of premiums which include government subsidies). In other words there is a cap on the losses a firm can incur by participating in the program. To pay for this stop-loss protection, the private firms enters into a gain sharing rule with the FCIC such that if positive profits are made by the firm, the FCIC takes a percentage of these profits. The gain sharing rule is exogenously given to the firms through the Standard Reinsurance Agreement (revised annually). In the period 1986 through 1990, FCIC bore 100 percent of all losses above a 156.5 loss ratio.

## 5.2 FCIC use of the Information and Delivery Cost Position of Private Firms

There are two characteristics of private firms that are desirable to incorporate into the model: (i) information to classify farmers into risk pools; and (ii) lower delivery cost structure. The question therefore is whether the current FCIC program described above is able to do this and what are the implications for the program?

In the current program the FCIC sets all premiums and coverages to farmers. Risk classes are determined according to the average production history (APH) of the last 10 years of yield data. If data are not available, then county level data are substituted to calculate the premium for the particular farmer and no additional information is used to classify the farmer[22]. The information available to private firms is not used at this stage of the program. Where the information position of the private firms is used is at the time when the firms make reinsurance decisions since they are able to assign policies to different risk pools for proportional reinsurance purposes. However, this information is not used by the FCIC in subsequent years to classify farmers. Thus, it is concluded that the current program does not use the information available to private firms to classify farmers into risk pools. There is no advantage gained to improve the information position of the FCIC by involving private firms under the current FCIC reinsurance program.

Under the reinsurance agreement, FCIC reimburses delivery (or administrative) costs to the private firms for each policy sold irrespective of the amount of business retained by the private firms. Whether the current FCIC program is more efficient in paying for delivery costs in such a manner as opposed to using its own delivery cost remains to be studied.

Since the information position of the private firms are not used to classify farmers, much of the analysis in this chapter is done with only one risk type and the focus is more on the delivery cost aspect of the FCIC program and the implication of using risk averse competitive firms. The effects of information problems are discussed in later sections.

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[22] The study by Skees and Reed has shown that although the use of APH is better than no information at all there are still adverse selection problems.

## 5.3 FCIC Reinsurance of Private Firms With One Risk Class of Farmers

This section develops a model with farmers of one risk type to study the private firm's responses to the FCIC reinsurance program. The model has three agents, the farmer, the FCIC and the competitive firm; each of which are discussed in turn. Since the decision making of the farmer and FCIC are in line with the analyses in Chapter 3, only brief comments are made and the main results are stated. Much of the discussion focuses on the competitive firm's decision to reinsure in this program.

### 5.3.1 FCIC Supply of Insurance to Farmers

The model for the agricultural risk market is identical in most respects to the one described in chapter 3. To recapitulate, there are a total of N farmers and each farmer owns one acre of land that yields M bushels of output. Loss L occurs with probability P and zero otherwise. The mean and the variance of this loss are identical for all farmers and given by

$$Mean = \overline{L}$$

$$Var = \sigma_L^2.$$

The correlation of losses between two farms is ρ and it is the same for any two farms in the area. As in chapter 3, the utility function

$$U(.) = \overline{\pi}_F - \frac{\lambda}{2}\sigma_{\pi_F}^2$$

is assumed for all farmers and utility it is increasing in the mean and decreasing in the variance of profits. The mean and the variance of profits of a farmer with coverage ϕ and premium ϕw are

$$\bar{\pi}_F = M - w\,\phi - (1-\phi)\bar{L}$$

and

$$\sigma^2_{\pi_F} = (1-\phi)^2 \sigma^2_L .$$

Since there is only one risk type, there are no classification problems and premiums are set at actuarially fair levels ($w=w^A$) as all delivery costs are subsidized by the FCIC. The competitive firms deliver these policies to the farmers at coverage levels set by the FCIC. Results from Chapter 3 indicate that at actuarially fair premiums, a risk averse farmer would seek full coverage ($\phi=1$). However, the FCIC limits the maximum coverage to levels below one ($\phi=0.75$ is the maximum coverage under the current FCIC program) and therefore the risk averse farmer would prefer this coverage to any coverage below this at actuarially fair premiums.

### 5.3.2 The Reinsurance Decisions of Private Firms

Now that we have established the premium and coverage to the farmer at the FCIC equilibrium, we turn to the competitive firm reinsurance decisions once the policies are sold. Since everything else is determined by the FCIC the only aspect that the competitive firm has control over is the amount of reinsurance it would seek from the FCIC. For the sake of clarity the reinsurance decisions of the firm are first developed with only FCIC proportional reinsurance, and then stop-loss reinsurance is introduced.

#### 5.3.2.1 Proportional Reinsurance

With only one risk type of farmers, only one risk pool is considered for proportional reinsurance purposes. If the firm participates in the FCIC program, then it is required that it maintain a minimum proportion of each of the policies sold. The firm keeps the corresponding premium and is responsible for indemnifying that portion of the policies. Let $t=t^c$ be this minimum percent retention required of the competitive firm on each policy sold. The upper limit is t=1 where the full policy is retained by the firm. The profits of a competitive firm from selling FCIC insurance is

$$(5\text{-}1) \quad \pi_s = t\phi(nw^A - \sum_{i=1}^{n} l_i) + \theta n w^A \phi \qquad t^c \leq t \leq 1.$$

The first term on the right hand side (RHS) is the net profits from selling crop insurance to n farmers. Since the firm must sell policies to any farmer that seeks insurance, n is beyond the control of the firm. At this point assume n to be exogenously given. $\phi w^A$ is the actuarially fair premium collected from the farmer and $\phi l_i$ is the indemnity paid to farmer i from the FCIC insurance. The indemnity payment to farmer i takes the values $\phi$L or 0 with probability P and 1-P respectively. It has already been established that $\phi$ will be the maximum coverage allowed by the FCIC.

The second term on the RHS is an expression to capture any transfer that might take place from the FCIC to a competitive firm over and above any delivery cost. Since premiums are assumed to be at actuarially fair levels, the only way this transfer can take place in the model is through administrative cost remuneration. Let $\theta$ be the percent of premiums transferred to competitive firms for each policy sold. For example, the current reinsurance agreement pays approximately 33 percent of premiums as administrative costs. If the actual cost for delivering crop insurance is only 30 percent then 3 percent of premiums is a direct transfer from the FCIC to the competitive firm. If the administrative costs equals the actual cost incurred then $\theta$=0 and there are no positive transfers from the FCIC to the competitive firm. Negative transfers are not considered. Since the firm receives this transfer irrespective of the percent of policies it retains through proportional reinsurance, it is not a function of reinsurance (1-t) bought by the firm.

The mean and the variance of the portfolio of the competitive firm are

$$\bar{\pi}_s = \theta n w^A \phi$$

and

$$\sigma^2_{\pi_s} = t^2\phi^2 n[1+(n-1)\rho]\sigma^2_L$$

Note that the expected value is not a function of the reinsurance bought by the firm since policies are actuarially fair.

As in Chapter 3, assume that the utility of the firm is given by

$$V(.) = \bar{\pi}_S - \frac{\psi}{2}\sigma^2_{\pi_s}$$

which is increasing in the mean and decreasing in the variance. The problem of the competitive firm is to maximize its utility by choosing the proportion (t) of the policies it would retain under the current FCIC program. The first-order condition (FOC) to this maximization problem is[23]

$$(5\text{-}2) \qquad -\psi t\phi^2 n[1+(n-1)\rho]\sigma^2_L = 0\,.$$

This expression is solved only at t=0 (all the other parameters are positive by assumption) and it is independent of positive transfers from the FCIC.

[23] The second-order condition $-\psi\phi^2 n[1+(n-1)\rho]\sigma^2_L < 0$ for maximum is satisfied.

*Proposition (5-1): In this model of FCIC reinsurance with one risk type and actuarially fair premiums, the risk averse competitive firm prefers not to hold any of the FCIC policies it sells, even with positive transfers from the FCIC.*

The proposition above does not mean that the competitive firm will not participate in the program, only that it prefers not to hold any of the actuarially fair premiums. If there are no positive transfers from the FCIC, it is not likely that a risk averse firm would participate in the program since the firm's utility from participating in the program is lower than doing nothing (in this particular utility function, utility of doing nothing is normalized at zero).

*Proposition (5-2): In this model, a participating competitive firm would never hold more than the minimum portion of policies $t^c$ required of it by the FCIC.*

*Proof:*

Any increase in t would decrease utility since it does not effect the mean and it increases the variance.

Now introduce competition among firms participating in the FCIC program and as in Chapter 3 assume that there is a reservation utility b such that the firm would only participate if the utility of participation exceeds this reservation utility, i.e.,

$$\theta n\phi w^A - \frac{\psi}{2}(t^*)^2\phi^2 n[1+(n-1)\rho]\sigma_L^2 \geq b\,.$$

With competition among firms, the only factor that can adjust is the number of policies (n) held by each firm (everything else is kept fixed by the FCIC). If the transfers from the FCIC are such that by participating in the FCIC program, the reservation utility of the firm is above b, then in a competitive market there would be entry or exit of firms as n adjusts to regain reservation utility. Equilibrium is reached when the utility of participating in the FCIC program is at b

$$(5\text{-}3) \qquad \theta n w^A \phi - \frac{\psi}{2}(t^*)^2 \phi^2 n[1+(n-1)\rho]\sigma_L^2 = b\,.$$

The changes in n with respect to other parameters is not clear because it appears as a quadratic term in the expression. Another way to look at this problem is to see how utility changes with changes in n.

Increases in n would increase utility if the expression

$$(5\text{-}4) \qquad \frac{\partial V(.)}{\partial n} = \theta w^A \phi - \frac{\psi}{2}(t^*)^2 \phi^2 [1+(n-1)\rho]\sigma_L^2 - \frac{\psi}{2}(t^*)^2 \phi^2 \sigma_L^2 n \rho$$

is positive and vice versa for decreases in n. To simplify the expression, multiply throughout by n (it is positive and this will not change the sign of the expression). Note that the first two terms when multiplied by n gives the expression b in equilibrium or at equilibrium signing the expression is equivalent to determining the sign of

$$(5\text{-}5) \qquad b - \frac{\psi}{2}(t^c)^2 \phi^2 \sigma_L^2 n^2 \rho$$

This expression can take positive or negative values depending on the values of the other parameters and the initial value of n. For example consider a small increase in t at equilibrium such that there is a decrease in utility. If expression (5-5) is positive, the number of policies n held by each firm would increase to bring the reservation utility back to equilibrium. This would mean that there would be exit of some firms.

This suggests that within each transfer level θ, the FCIC has some flexibility to adjust t as changes in t will simply reshuffle the number of policies held by a competitive firm. Another way to state this is that there is a minimum transfer $\theta_c$ such that it would ensure $t^c$ is being held by a competitive firm. Any higher transfer level would not result in the competitive firms holding more of the policies but rather entry and exit of firms.

Consider the transfer level $\theta_c$ such that for transfer levels below this competition cannot adjust n and bring the firms utility back to reservation levels. This then is the minimum transfer required for competitive firms to participate in the FCIC program and retain $t^c$ of the policies it sells[24]. Let the number of policies associated with $\theta_c$ and $t^c$ be $n_c$. Now lets say that FCIC decreases its transfer level below $\theta_c$ such that there is a decrease in utility of the firm (the mean of profits drop). To increase utility, the number of policies held by each firm would decrease or increase depending on the sign of expression (5-5). If the expression is positive then n would increase to restore equilibrium and firms would exit the industry. This contradicts the fact that $\theta_c$ is the minimum transfer level for $t^c$. Similarly if the expression (5-5) is negative then n would decrease, or firms would enter to bring utility back to reservation levels. This too contradicts the fact that $\theta_c$ is the minimum transfer level. Therefore it must be the case that the expression (5-5) equals zero, or at minimum transfer

(5-6) $$\theta_c n_c w^A \phi - \frac{\psi}{2}(t^c)^2 \phi^2 n_c [1+(n_c-1)\rho]\sigma_L^2 = b$$

and $b - \frac{\psi}{2}(t^c)^2 \phi^2 \sigma_L^2 \rho n_c^2 = 0$ must hold.

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[24] Note that minimum transfer level would change with the minimum t value.

*Proposition (5-3): The minimum transfer ($\theta_c$) required for the competitive firms to participate in the FCIC program increases with minimum retention ($t^c$) required of the firms.*

*Proof:*

Follows from expression (5-6) above as any increase in t must be followed by increase in θ such that reservation utility b is maintained.

In other words the proposition states that if the FCIC writes reinsurance contracts such that competitive firms retain higher levels of the policies, then the minimum transfer to the firms must increase to compensate for the firms holding larger portions of actuarially fair policies.

*Proposition (5-4): If the correlation between farm losses is zero, then the number of firms in the program increases directly with increases in transfer level θ.*

*Proof:*

The equilibrium expression with ρ=0 is

$$\text{(5-7)} \quad \theta n w^A \phi - \frac{\psi}{2}(t^*)^2 \phi^2 n \sigma_L^2 = b$$

and n is exactly solved by

$$n = \frac{b}{\theta w^A \phi - \frac{\psi}{2}(t^*)^2 \phi^2 \sigma_L^2}.$$

The higher the level of transfers the smaller the number of policies held by each firm at equilibrium, and the larger the number of firms participating in the FCIC program.

5.3.2.2 Stop-Loss Reinsurance

So far the discussion has concentrated only on proportional reinsurance to the competitive firms. This section introduces stop-loss reinsurance provided by the FCIC. The stop-loss reinsurance covers indemnity payments of a firm if the loss ratio is over a certain predetermined level on the total retained business of the company. Stop-loss reinsurance is not on a policy by policy basis as in proportional reinsurance, rather it is on the whole portfolio of the competitive firm delivering FCIC crop insurance (the firms are assumed to hold only FCIC crop insurance in their portfolio).

Assume that n is exogenously given to simplify the discussion. Stop-loss is introduced in the model such that if the total loss of the farmers appearing in the portfolio of the insurance firm exceeds k, the FCIC is responsible for paying for all the excessive indemnity of the firm (i.e., losses exceeding $t\phi k$). Note that the FCIC is already responsible for all such losses in the portion of the policies that it holds through proportional reinsurance, i.e., $(1-t)\phi k$, which makes the FCIC responsible for all losses exceeding $\phi k$. In return for providing stop-loss reinsurance to the firms, the FCIC engages in gain sharing with these firms. This gain sharing is such that if the competitive firm delivering FCIC insurance makes positive profits on its crop insurance portfolio, the competitive firm keeps $\gamma(k)$ percent of the profits and the FCIC takes the rest. The gain sharing rule is portrayed as a function of k since it would vary according to how much stop-loss coverage k is provided. The higher the coverage, the higher the premium collected through the gain sharing rule. Both the stop-loss level k and gain sharing are exogenously given to the firm participating in the FCIC program.

With the availability of stop-loss the profits of the competitive company are the same as expression (5-1), but now stop-loss is introduced.

$$(5\text{-}8)\qquad \pi_s = \theta n w^A \phi + \begin{cases} \gamma(k)t\phi\sum_{i=1}^{n}(w^A - l_i) & if \quad \sum_{i=1}^{n}(w^A - l_i) > 0 \\ \max(t\phi\sum_{i=1}^{n}(w^A - l_i), -t\phi k) & if \quad \sum_{i=1}^{n}(w^A - l_i) \le 0 \end{cases}$$

As before the first term on the RHS is the direct transfer of funds from the FCIC to the competitive firm. The second term now includes both the proportional and stop-loss reinsurance. If there are positive profits $(\sum(w^A - l_i) > 0)$, the firm gets to keep γ(k) percent of the profits of the retained business and if there are non-positive profits $(\sum(w^A - l_i) \le 0)$, the maximum loss the firm bears is $t\phi k$, the rest being covered by stop-loss reinsurance[25].

Recall that stop-loss reinsurance is given exogenously to the firm and the only decision the firm makes is the amount of business it will retain through proportional reinsurance. To see how stop-loss reinsurance effects the competitive firm's decisions on proportional reinsurance define $\tau = \sum_{i=1}^{n}(w^A - l_i)$ to be the random profits with distribution $F(\tau)$ and supports [$nw^A$,-nL]. Without stop-loss, the maximum loss the policies can make is nϕL (all the farmers in the portfolio collect indemnity for that period), and the maximum gain the policies can make is $n\phi w^A$ (no farmers collect indemnity for that period). For the moment let the direct transfers from the government to the competitive firm be zero (θ=0). Since the premiums are actuarially fair the expected value of profits is

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[25] Note that k is actually a function of n but since n is assumed to be exogenously given, we simply state k which makes the notation and the discussion much clearer.

$$E(\tau)=\int_{-nL}^{nw^A}\tau F(\tau)=0$$

which may be re-written as

$$t\phi\left(\int_{-nL}^{-k}\tau F(\tau)+\int_{-k}^{0}\tau F(\tau)+\int_{0}^{nw^A}\tau F(\tau)\right)=0.$$

Now if the gain sharing rule is actuarially fair such that the expected value of stop-loss payments to the competitive firm equals the expected value of gain collected by the FCIC then

$$-t\phi\int_{-nL}^{-k}\tau F(\tau)=t\phi(1-\gamma^A(k))\int_{0}^{nw^A}\tau F(\tau)$$

or

$$\gamma^A(k)=1-\frac{-\int_{-nL}^{-k}\tau F(\tau)}{\int_{0}^{nw^A}\tau F(\tau)}.$$

Where $\gamma^A(k)$ is the value of gain sharing rule which is actuarially fair at stop-loss reinsurance k. At this value the government would break even in the long-run by providing stop-loss reinsurance. If the gain sharing rule is such that $\gamma>\gamma^A$, the stop-loss premium is priced above actuarially fair and the FCIC would make profits from providing stop-loss and if $\gamma<\gamma^A$, the stop-loss is below actuarially fair and the FCIC would makes losses.

*Proposition (5-5): The minimum transfer ($\theta_c$) required for competitive firms to participate in the FCIC program is reduced with the introduction of actuarially fair stop-loss reinsurance.*

*Proof:*

Assume that the stop-loss is provided at an actuarially fair gain sharing rule ($\gamma^A$) such that the expected profits of the competitive firm is zero. The variance of loss is now decreased compared to the case of only proportional reinsurance because the loss is truncated at k and $\gamma<1$. Now reintroduce a positive transfer level ($\theta > 0$) such that the competitive firm participating in the program retains t percent of the policies (for reasons cited in the previous section). Unlike the case where no stop-loss was available, now with stop-loss the variance is lower. Expression (5-6) shows that the reduction in variance could mean that the minimum transfer required of the competitive firms to participate in the program is reduced.

Therefore stop-loss reinsurance provides another avenue for the government to transfer risk from the competitive firms to the FCIC. If the gain sharing rule is actuarially fair, then it reduces the variance of the portfolio by keeping expected profits (excluding positive transfers) at zero while reducing the variance of the portfolio. At the extreme when k=0, all losses are paid by the FCIC and the gain sharing rule is $\gamma^A(0)=0$, or all the gain is taken by the FCIC.

Thus proportional and stop-loss reinsurance both serve very similar purposes and one can be substituted for the other to transfer risk from the competitive firm to the FCIC. For example with the addition of stop-loss reinsurance there is a further reduction in variance and now the FCIC can increase the minimum proportion of policies (t) to be retained by the competitive firms. One example could be that the increase in t can be such that it compensates for the decrease in variance and the reservation utility of the firms is maintained in b.

However, unlike proportional reinsurance where the premium charged and indemnities paid are clearly defined by t, it is more difficult to come up with actuarially fair gain sharing rule in stop-loss reinsurance. This is because the probability distribution of profits is required which may not be known with high degree of certainty[26]. There is the possibility that the premium collected through gain sharing for stop-loss is not actuarially fair. Consider the case where the gain sharing rule is below actuarially fair (premium does not cover expected payments). For the discussion here let the direct transfers be zero ($\theta=0$) so that if stop-loss is actuarially fair, firms will not participate in the program. If stop-loss is provided at below actuarially fair prices then the premiums $w^A$ collected from the farmer become above actuarially fair for the firm. This is because the probability of making positive profits is now greater than making losses. Results from Chapter 3 show that the firm would now voluntarily opt to retain some of the policies ($t > 0$) through proportional reinsurance (recall that in the case of proportional reinsurance, given the choice, the firms would always prefer to hold $t=0$). Depending on how much the stop-loss premiums are below actuarially fair, the firms may even opt to retain more than the minimum amount required of them or we now may observe $t>t^*$. In such a case the competitive firms would hold higher portions of the policies it sells. The FCIC would lose money in such a stop-loss reinsurance program.

## 5.4 FCIC Reinsurance With More than One Risk Class of Farmers

As indicated earlier in this chapter, the current FCIC program does not use the informational position of the competitive firms to classify farmers for insurance delivery. This

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[26] The same may be said about arriving at actuarially fair premiums but with only one risk type, this problem is assumed away at present.

implies that all the informational problems of the FCIC discussed in Chapter 4 are retained in the program. The only difference in this chapter is that now all administrative costs are subsidized by the FCIC and the FCIC insures indirectly through reinsurance.

If the farmer classifications problems are not addressed by the FCIC and attempts are made to price premiums at actuarially fair levels, then all farmers would signal that they are low risk farmers and pay the same premium to buy the same maximum coverage in this model. Clearly, there are adverse selection problems as the high risk types are paying premiums less than expected indemnities. It is not difficult to extend the analyses of the previous section to see that increasing amounts of positive transfers would be required for the competitive firms to participate with adverse selection problems. The FCIC would be facing additional expenditures in two areas: (i) paying indemnities greater than premiums directly to the farmers on the portion of the business they hold and (ii) paying higher transfer levels to competitive firms in order for these firms to hold policies priced at below actuarially fair levels. The program would not operate at an actuarially sound basis and would lose money.

The purpose of this section is not to study a situation as described above but to look at a situation described in the previous chapter; a separating equilibrium such that the program is actuarially sound on the portion of the business directly associated with farmers. In other words, this section studies scenarios where the program's expected indemnities to farmers equal premiums collected from farmers. Given such a situation, the effects of the current reinsurance agreements on such a program is studied.

### 5.4.1 FCIC Reinsurance in a Separating Equilibrium

The section first presents a modified version of the separating equilibrium with cross subsidies between farmer risk types as presented in Chapter 4. The modification from the model in Chapter 4 is that all delivery cost is removed. Recall that the FCIC is a dictator who follows the FCIC mandates and is able to provide and sustain any contract it desires. The separating equilibrium model of chapter 4 is reproduced below (minus delivery cost).

(5-9) $w_1^+ = w_1^A + d$

(5-10) $w_2^+ = w_2^A - Rd$

(5-11) $\phi_2^+ = \phi_2^{\max} \qquad \phi_2^{\max} < 1$

(5-12) $\phi_1^+(-w_1^+ + \overline{L}_2) - \dfrac{\lambda}{2}(\phi_1^+ - 1)^2\sigma_2^2 = \phi_2^{\max}(-w_2^+ + \overline{L}_2) - \dfrac{\lambda}{2}(\phi_2^{\max} - 1)^2\sigma_2^2$

The first two expressions are the premiums to risk type 1 and 2 respectively. The premiums are at actuarially fair levels plus there is a tax d on risk type 1 and a subsidy Rd on risk type 2. Recall that R is the ratio of low to high risk farmers. Subsidy on risk type 2 implies that premiums are below actuarially fair and this means that risk type 2 would seek coverage above 100 percent (farmers seek 100 percent coverage at actuarially fair premiums). Following the current FCIC program it is assumed that the maximum coverage is less than 100 percent ($\phi_2^{\max} < 1$). This is represented in the third expression. The fourth and final expression presents the coverage restrictions on type 1 farmers such that a separating equilibrium is achieved. This coverage is determined at the point where the high risk type is indifferent between the low and high risk contracts. The two contracts offered by the FCIC are ($\phi_1^+, \phi_1^+ w_1^+$) and ($\phi_2^{max}, \phi_2^{max} w_2^+$) for low and high risk types respectively.

The basic features of the equilibrium are that type 1 farmers face premiums higher than actuarially fair and type 2 farmers face premiums below actuarially fair levels. Results from the previous chapter show that when delivery costs are subsidized, as in the present model, farmer classification is always a problem. The other result to note is that truncating maximum coverage to below the level desired by risk type 2 also lowers the coverage feasible to the low risk type. This is because the coverage to low risk types can be increased if the utility of the high risk type is increased. All the results regarding the tax d and the ratio of low to high risk farmers R discussed in the previous chapter also hold here.

The reinsurance decisions of the competitive firms are now discussed. It is assumed that parameters are such that positive coverage is feasible within the separating equilibrium to both risk types (otherwise the problem reduces to the case of only one risk type — i.e., insurance to only type 2 farmers). All reinsurance considered is proportional reinsurance. Stop-loss reinsurance is removed to keep the analyses simple and, as shown in the previous section, the effects of stop-loss is very similar to proportional reinsurance.

A competitive firm participating in the FCIC program must sell policies to any farmer that seeks it. In a separating equilibrium, the high risk farmer would buy the high risk policies and the low risk farmer would buy the low risk policies. Once the policies are sold, the competitive firm has to make decisions on how much of the policies would be retained under the proportional reinsurance agreement and how much will be passed on to the FCIC. Assume that the FCIC provides two risk pools for reinsurance purposes. For the high risk pool minimum retention rate is

$t_2^c$ and for the low risk pool the minimum retention rate is $t_1^c$ such that $t_1^c > t_2^c$. As in the FCIC program there is a maximum amount of business that may be put in the high risk pool. To simplify the analysis it is assumed that the companies do not have a higher percent of type 2 farmers than the maximum allowed in the high risk pool. For example, if 70 percent is the maximum of the portfolio allowed in the high risk pool, the competitive firms have less than 70 percent high risk types in their portfolio.

By design of the separating equilibrium, the total portfolio that a competitive firm holds (before reinsurance) has zero expected value. Consider the high risk types for reinsurance purposes. It has be established earlier in the chapter that positive transfers to the competitive firms must take place for the firms to retain a proportion of these policies (since these policies are below actuarially fair prices). The positive transfer would now be greater for the same minimum retention level than the case when there is only one risk type in the portfolio of the firm. The case is the opposite for reinsurance of the low risk types. In the separating equilibrium, the low risk types are paying above actuarially fair prices for the coverage they receive. The competitive firms would now voluntarily choose to hold positive proportions of these policies. Whether the fraction chosen is above or below the minimum retention required for these policies is a function of how much higher or lower the premium is from actuarially fair levels.

Thus we see that a proportion of risk type 1 policies are desirable (given tax $d>0$) to a competitive firm while no proportion of risk type 2 are desirable. Let $n_1$ be the number of policies of risk type 1 and $n_2$ be the number of policies of risk type 2 in the portfolio of a firm. These numbers are assumed to be exogenously given for simplicity. The profits of the firm from participating in the FCIC program are

(5-13)
$$\pi_s = \theta n_1 w_1^+ \phi_1^+ + \theta n w_2^+ \phi_2^{\max} + t_1 \phi_1^+ (n_1 w_1^+ - \sum_{i=1}^{n_1} l_i) + t_2 \phi_2^{\max} (n_2 w_2^+ - \sum_{i=1}^{n_2} l_i)$$
$$t_2^* \le t_2 \quad t_1^* \le t_1 \quad t_2^* \le t_1^*$$

The first two terms on the RHS are the direct transfers from the FCIC to the competitive firms. θ remains the same for both types of policies since the cost of delivery is assumed to be identical for both policies. The third and the fourth terms are the premiums collected and indemnities paid to risk type 1 and 2 respectively for the retained business of the firm.

The mean and variance of the portfolio of the firm are

$$\bar{\pi}_s = \theta n_1 w_1^+ \phi_1^+ + \theta n w_2^+ \phi_2^{\max} + t_1 \phi_1^+ n_1 (w_1^+ - \bar{L}_1) + t_2 \phi_2^{\max} n_2 (w_2^+ - \bar{L}_2)$$

$$\sigma_{\pi_s}^2 = t_1^2 (\phi_1^+)^2 n_1 [1 + (n_1 - 1)\rho_1]\sigma_1^2 + t_2^2 (\phi_2^{\max})^2 n_2 [1 + (n_2 - 1)\rho_2]\sigma_2^2$$
$$+ t_1 t_2 n_1 n_2 \phi_1^+ \phi_2^{\max} \rho_{12} \sigma_1^2 \sigma_2^2$$

where $\rho_1$ is correlation between two type 1 losses, $\rho_2$ is correlation between two type 2 losses, and $\rho_{12}$ is the correlation between a type 1 and a type 2 loss. All correlations are assumed to be positive.

Unlike the case with only one risk type, the mean of the portfolio is now affected by the retention levels $t_1$ and $t_2$. The mean is increased by higher retention levels of type 1 farmers and decreased by higher retention levels of type 2 farmers. The variance is increased by higher retention levels of any type farmer. Also note that the variance is a function of correlation between risks. Since only positive correlation is considered, the higher the number of policies in its portfolio the greater would be the increase in variance.

Notice that given the right demand conditions, correlation coefficients, and coverage restrictions, there is a combination of $t_1$ and $t_2$ such that competitive firms would hold both types of policies without needing any subsidy from the FCIC. This is possible because the gains from risk type 1 could compensates for the losses from risk type 2 and still maintain reservation utility. Since positive expected profits must be made for this to happen, it is the case that the expected value of the portion of the policies transferred to the FCIC has expected negative value. The FCIC program is then no longer sound. The situation is further aggravated if direct transfers are required to ensure that the competitive firms participate.

Therefore the effects of FCIC reinsurance with classification problems is that now the low risk farmers also bear the burden for classification problems. While in the one risk case, FCIC was bearing all the burden of transfer to the competitive firms, now this transfer to the competitive firms plus transfer to the type 2 farmers are borne by the low risk farmers and the FCIC. In the separating equilibrium, the program falls short of providing maximum coverage to all farmers to serving as the primary provider of disaster assistance.

## 5.5 Implications for the FCIC Reinsurance Programs

The model in this chapter suggests that without farmer classification problems (only one risk type), the government is able to meet its objective of providing the maximum possible coverage under the federal crop insurance program. Whether this objective is met with minimum cost to the taxpayer under the current FCIC reinsurance program is not clear. If stop-loss reinsurance is at actuarially fair premiums then the short answer to this question is yes, if the FCIC cannot deliver crop insurance at costs below 33-34 percent of premium. The answer is no if its delivery costs are higher.

Stop-loss reinsurance is essentially a substitute for proportional reinsurance and it is a similar means of transferring risk from the competitive firms to the FCIC. However, unlike proportional reinsurance the pricing of stop-loss reinsurance is not easily verified to be at actuarially fair levels via the gain sharing rule. If stop-loss reinsurance has very favorable terms (i.e., it is priced at below actuarially fair levels), then it is another way to transfer funds from the FCIC to private competitive firms. Unlike the transfer of funds through administrative costs, this transfer directly effects the retention of policies by the private competitive firms. If the stop-loss is at very favorable terms then the competitive firms could hold more than the minimum proportion of policies required through proportional reinsurance. If the stop-loss reinsurance is priced at below actuarially fair (as various GAO reports indicate), then the delivery cost of the program is above the 33-34 percent of premium. However, this does not suggest that FCIC can deliver it at a cheaper rate if its own cost of delivery is very high.

The long-run effects of competition among private firms suggest that associated with every t (retention level) there is a minimum transfer such that competitive firms participate in the FCIC program. Among other things this minimum transfer is a function of the level of reservation utility and the degree of correlation between farm losses. If the current transfer level of the FCIC is above this level then higher levels of transfer are being dissipated by entry of firms through competition. The implication of this model then is that the transfer can be reduced without adversely affecting farmers while ensuring that competitive firms still participate in the program.

With the introduction of classification problems, the inclusion of private competitive firms with reinsurance would further aggravate the problem since these firms would now demand a higher "risk premium" to hold policies that are priced below actuarially fair. If no differentiation between the high and the low risk farmers is made, and the premiums are priced at actuarially fair prices, then the program succeeds in providing maximum coverage to all farmers but would face severe expenditures. This may partially explain why the program has paid close to $2 billion to farmers in the 1980-90 decade over and above predetermined subsidies. If private competitive firms are required to hold these policies, then high transfer rates, via administrative costs and very favorable stop-loss features has to be in place.

If reinsurance is applied to a separating equilibrium situation then the program may no longer be able to provide maximum coverage desired to all farmers, as the low risk farmers are now taxed. Since private firms are still required to hold a minimum of high risk policies then transfer of funds, either from low risk farms and/or the FCIC, will still be required.

The findings of the study on the stylized FCIC reinsurance program explaining the idea that reinsurance to private firms is provided on better terms than commercial reinsurance companies would provide. The basic reasons given by the FCIC are that: (i) the farming sector is more prone to widespread natural hazards as droughts that affect a large number of farmers; and (ii) the private companies are obligated to sell FCIC crop insurance to all farmers (at FCIC set premiums) who demand it if crop insurance is offered for the particular crop (unless specifically excluded by the FCIC). The results of this chapter provide explanations why generous reinsurance agreements are needed.

The overall conclusion from this chapter is that the information position of private firms are not used to classify farmers. Rather, it is used for reinsurance purposes. Whether the cost of involving the private firms to deliver FCIC insurance is lower than the FCIC delivering insurance itself is not clear. The model suggests that the current reinsurance program of requiring private firms to retain a part of the policies it sells is not the most cost effective way of delivering crop insurance. If the cost structure of the private firms is to be used then it is best not to require private firms to retain any of the business they deliver, as this appears to serve no purpose in achieving the FCIC's objectives. Under the current FCIC program, the model suggests that the most efficient way is to hire these private firms to simply deliver and adjust the policies sold for a fee while the FCIC bears all the risks. This finding is consistent with the recommendations of various General Accounting Office reports.

# 6. Reinsurance for a Competitive Crop Insurance Market.

This chapter focuses on the FCIC's ability to involve the private sector through reinsurance. The reinsurance schemes investigated are self sustaining and therefore preclude negative expected profits. Historically, private multi-peril crop insurance has not existed in the United States for any sustained period of time[27]. Therefore the primary question here is: if no private crop insurance market existed without FCIC reinsurance then could the availability of FCIC reinsurance facilitate such markets? This question gains further importance because one of the goals of the FCIC is to involve the private sector primarily through reinsurance. The second question here is: under what conditions can FCIC reinsurance increase coverage to farmers buying private competitive crop insurance?

The main difference between the stylized model of this chapter and that of Chapter 5 is that here the FCIC involves itself only by making reinsurance available to competitive firms. Unlike the reinsurance program discussed in chapter 5 (and the existing FCIC program) where all premium, coverage, loss adjustments, etc. decisions were made by the FCIC; such decisions are now made by competitive insurance firms. The purchase of reinsurance is not mandatory and if a firm buys FCIC reinsurance it is only because reinsurance benefits the firm.

This chapter is organized as follows: First, the competitive insurance market model of chapter 3 is used to investigate the conditions under which equilibrium breaks down in the competitive market. Both a mathematical and a graphical approach are used. This is done to help answer the first question of this chapter and study reasons why private multi-peril crop insurance does not exist in the agricultural sector. The chapter then introduces FCIC proportional reinsurance

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[27] The only time such insurance existed was around the turn of the Century (see chapter 2).

where the FCIC pays a proportion of indemnities for a share of the same proportion of premiums (see below for details). This section analyzes how this reinsurance scheme might bring about insurance markets where none existed before, and its ability to increase coverage to farmers. The chapter then looks to answer the same questions in a reinsurance scheme where the premiums for reinsurance are actuarially fair. Next is a discussion which summarizes results on the ability of FCIC to provide conventional reinsurance schemes when it lacks information on farmer risk classes. The final section provides discussion on an alternative "reinsurance" scheme of using an Area-Yield Insurance Plan (explained below) to overcome some of the problems faced in the more conventional reinsurance schemes.

## 6.1 Constraints on Existence of Competitive Insurance Markets

Let there be one risk type of farmer with properties as described in Chapter 3. To recapitulate, each acre yields M bushels of output. If disaster occurs on a farm, output $L$ is lost with probability P and 0 otherwise. The correlation of loss between any two farms is the same and it is denoted by $\rho$ which is assumed to be non-negative for agricultural markets. The competitive market is such that the portfolio of the insurance firms consists of only crop insurance policies and, in the long-run, competition ensures that firms operate at reservation utility levels. All the assumptions described in Chapter 3 regarding agent's preferences, functional forms, etc. hold here. The notation also remains identical unless otherwise stated.

To analyze the conditions under which equilibrium breaks down, the definition of a competitive equilibrium from Chapter 3 is reproduced below.

*Definition (3-1): A competitive equilibrium in this model of crop insurance delivery is a premium level $w^0$, coverage level $\phi^0$ and number of policies $n^0$ for each firm such that:*

(3-8) $$\left(-w^0 + \bar{L}\right) + \lambda(1-\phi^0)\sigma^2 = 0$$

(3-9) $$n^0(w^0 - \bar{L} - c) - \psi n^0\phi^0\sigma^2[1+(n^0-1)\rho] = 0$$

(3-10) $$n^0\phi^0(w^0 - \bar{L} - c) - \frac{\psi}{2}n^0(\phi^0)^2\sigma^2[1+(n^0-1)\rho] - b = 0.$$

The simultaneous solution of the three non-linear equations in coverage, premium, and number of policies, gives the equilibrium values. To study the equilibrium analytically the first two equilibrium expressions are solved first and then the third expression is included.

Solving the first two equations gives the equilibrium coverage

(6-1) $$\phi^0 = \frac{\lambda\sigma_L^2 - c}{(\lambda + \psi(1+(n^0-1)\rho))\sigma_L^2}$$

This equilibrium coverage is a function of degrees of risk aversion of farmers and firms, the variance of the loss, the degree of correlation between losses, the number of policies held by the firm, and the cost of insurance delivery. This expression shows an obvious case where equilibrium does not exist; when cost of delivery is high enough that the numerator is non-positive. Alternatively, one may think of the numerator being non-positive if either the degree of risk aversion of the farmer is low (tending towards risk neutrality) or the variance of the loss is low. In these situations an insurance market will not exist because benefits from insurance do not justify the cost. For the rest of this chapter it is assumed that the numerator takes positive values. This allows us to concentrate on the less obvious aspects of when equilibrium breaks down in this model.

Exactly what coverage level would transpire (if an equilibrium exists) is a function of $n^0$ which is to be determined at equilibrium. This is done by including the third expression for equilibrium that states that the firm must operate at reservation utility levels[28]. Therefore, expression (3-10) maps the equilibrium relation between reservation utility b and number of policies $n^0$. Theoretically the values of $n^0$ can range from 0 to infinity. At $n^0=0$ the utility of the firm is zero[29] (equivalent to the utility from the firm doing nothing). As $n \to \infty$, the equilibrium utility (V) of the firm approaches

$$\lim_{n\to\infty} V \to \frac{\left(\lambda\sigma_L^2 - c\right)^2}{2\psi\rho\sigma_L^2}.$$

These limits give us two reference points between which reservation utility takes values. If it can be shown that the limit at which n tends to infinity is the upper limit then we can determine the values of b which are not in the equilibrium set. One way to do this is to show that in expression (3-10), b is monotonic for positive values of n. To check whether this expression is monotonic, differentiate the preference function with respect to n using the envelope theorem to obtain

$$\frac{\partial V}{\partial n} = \phi(w - \bar{L} - c) - \frac{\psi}{2}\phi^2\sigma_L^2\left(1 + (2n-1)\rho\right).$$

If this expression is monotonic in n then there should be no turning points. Let us assume that there exists a turning point, in which case the expression takes the value

$$\phi(w - \bar{L} - c) - \frac{\psi}{2}\phi^2\sigma_L^2\left(1 + (2n-1)\rho\right) = 0.$$

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[28] One must note that when $\rho=0$, the number of policies does not appear in the coverage level and therefore appear to be independent of it or reservation utility. As seen in chapter 3, this is not the case and reservation utility still affects the premium and coverage to farmers.

[29] This is a result of M-V preference function normalization.

At this point the coverage to farmers is solved as

$$\phi = \frac{\lambda\sigma_L^2 - c}{(\lambda + \frac{\psi}{2}(1+(2n-1)\rho))\sigma_L^2}.$$

If this is an equilibrium expression it must satisfy Equation (6-1). The only point where the two expressions are identical are at ρ=1 or perfect correlation between all risks. One is not likely to find this extreme case in an insurance market and it may be safe to assume that the reservation utility is monotonic in the range stated for n.

Equilibrium reservation utility is therefore bounded by

$$b \in \left[0, \frac{\left(\lambda\sigma_L^2 - c\right)^2}{2\psi\rho\sigma_L^2}\right]$$

and it can be represented graphically as

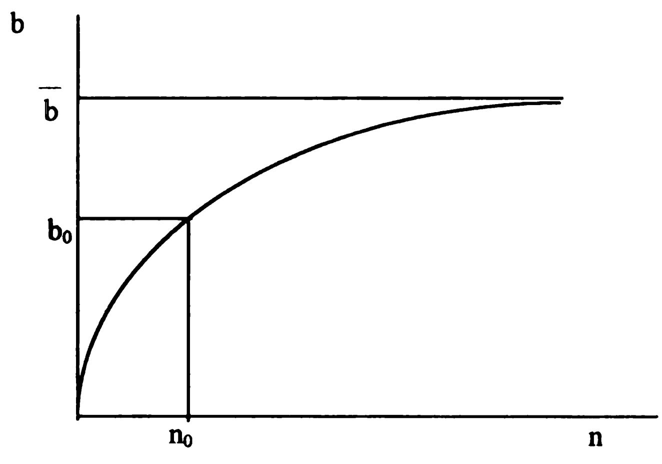


Figure 6-1: Reservation Utility and Competitive Equilibrium

Equilibrium utility varies in the range $[0, \bar{b}]$ where $\bar{b}$ is the upper limit. Figure 6-1 contains all the information necessary to solve for equilibrium coverage and premium. For example given a reservation utility, say $b_0$, the corresponding equilibrium number of policies is $n_0$. This value of $n_0$ can then be used to obtain coverage in Equation (6-1), and then the premium can be determined from the first-order condition (FOC) of the farmer (Equation 3-1).

Figure 6-1 may now be used to gain insights into how equilibrium breaks down in a crop insurance market with positive correlation between risks. The equilibrium relation between n and b shows that values of n cannot be determined for reservation utility values above $\bar{b}$ (no equilibrium is achieved for such utility levels). The reasons why equilibrium breaks down are therefore contained in the upper limit expression for reservation utility b, i.e.,

$$\bar{b} = \frac{\left(\lambda\sigma_L^2 - c\right)^2}{2\psi\rho\sigma_L^2}.$$

To ensure a large range of reservation utility for equilibrium points this expression must be made as large as possible. The factor that affects this range the most is the value of ρ, or the degree of the correlation between risks (also a measure of systematic risk in this study). If the correlation ρ between farm losses tends to zero, the upper limit to equilibrium increases to infinity. This means that as the risks gets closer to being independent, equilibrium points are almost always ensured (although high reservation utility would provide minimal coverage to farmers). However, as ρ moves away from zero towards unity, the upper limit to equilibrium reservation utility is brought down very sharply. This shows that even with low levels of correlation between farm losses, there could be breakdown of competitive equilibrium. This breakdown in equilibrium is further aggravated if the competitive firms are highly risk averse (high values of ψ).

The findings of this model provide an explanation for the observed non-existence of multi-peril crop insurance in the private sector because of the catastrophic nature of many disasters. Also note that private insurance markets for fire and hail exist and these risks are fairly across farms. Further for some perils, insurance markets may not exist (even if risks are independent) because, as indicated earlier, the benefits from insurance may not justify the costs or because of moral hazard and adverse selection.

## 6.2 Proportional Reinsurance

Following the mandates of the 1980 Crop Insurance Act, the FCIC chose to use reinsurance of private insurance firms as the primary mode of delivering crop insurance to farmers. This was done to make the program more "efficient" by increasing coverage to farmers and running it on a self sustaining basis (although still eligible for some pre-determined subsidies). The working hypotheses in Chapter 1 provides reasons why private competitive firms were more suited than FCIC to gain this "efficiency", viz., (i) a higher level of information for farmer risk classification and (ii) a lower delivery cost. Chapter 5 explained reasons why the current FCIC program has fallen short of using the information position of the private firms to classify farmer risk types. One of the primary reasons for this assertion is that the private firms participate in a very passive framework where all coverage, premium, adjustment, etc. decisions are made by the FCIC while the private firms only deliver crop insurance and then decide how much of the policies to retain through reinsurance. The focus of this section is to introduce FCIC proportional reinsurance, but let the private competitive firms make all the insurance decisions. This is to overcome the major criticism of the current program which is that it does not use the information position of the private competitive firms. In doing so the study analyzes the effectiveness of such a reinsurance scheme in opening markets where none existed before, and in increasing the coverage to farmers.

### 6.2.1 Proportional Reinsurance Described

Proportional reinsurance contracts are where a firm reinsures a proportion of its portfolio and the FCIC is responsible for indemnities on that proportion of every policy. In exchange, the FCIC receives the same proportion of premiums charged by the competitive firms to farmers. This proportional reinsurance structure is similar to the one existing in the current FCIC program, with one major difference; the competitive firms now make all the coverage, premium, adjustment, etc. decisions while the FCIC only makes reinsurance available to competitive firms.

The reinsurance structure described above makes positive expected profits for the FCIC since it shares in the premiums set by the competitive firms. This is because the competitive firms are risk averse and the premiums set by such firms would be priced above expected indemnity plus cost of delivery. According to the working hypothesis of this study (the FCIC being assumed to be risk neutral) the FCIC would be willing to sell the same reinsurance to firms at premiums that make zero expected profits. However the proportional reinsurance described is extremely easy to operate since it requires no actuarial calculations on the part of the FCIC. Actuarial calculations would be difficult for the FCIC because it is assumed to lack information on farmer risk classification. For this reason the FCIC is assumed to sell reinsurance in the manner described and make positive profits. The profits generated from such a program may be placed back into the program by subsidizing the cost of obtaining reinsurance to firms, or transferring it to farmers purchasing crop insurance (through tax breaks, etc.). These issues are abstracted from in this study and it is assumed that the FCIC provides proportional reinsurance which generates positive expected profits.

### 6.2.2 The Model

Since the firms are assumed to have full information, only one risk type of farmers is assumed (this also simplifies the analyses considerably). Further, it is assumed that the insurance firms sell crop insurance, and if a firm buys reinsurance, it must buy reinsurance for its entire crop insurance portfolio. The profits of a competitive firm with FCIC reinsurance is

$$\pi_S = tn\phi(w-c) - t\phi\sum_{i=1}^{n} l_i - n\phi(1-t)k$$

The first term in the right hand side (RHS) is the premium w less cost c (both quoted in per acre terms) collected from n farmers for $\phi$ percent coverage. With proportional reinsurance, the firm retains t percent of this net premium and passes on 1-t percent to the FCIC as premium (for 1-t percent proportional reinsurance). The second term indicates the total losses incurred by farmers, which $\phi$ percent is covered through crop insurance. Of this $\phi$ percent paid to farmers the FCIC pays 1-t percent through a reinsurance contract and t percent is borne by the competitive firm. The last term is the transaction cost incurred by the competitive firm to obtain FCIC proportional reinsurance. This transaction cost k is assumed to be linear in the amount of reinsurance bought. If (1-t) is the amount of reinsurance bought, then the total indemnity reinsured is $n\phi(1-t)$. The total fee that must be paid for this reinsurance is $n\phi(1-t)k$.

The mean and the variance of profits for the competitive firm are

$$\overline{\pi}_S = tn\phi(w - \overline{L} - c) - n\phi(1-t)k$$

$$\sigma^2_{\pi_S} = t^2\phi^2 n[1+(n-1)\rho]\sigma^2_L .$$

Reinsurance has the effect of reducing both the mean (by reducing retained premiums and transaction costs) and the variance (by transferring a portion of the indemnity to the FCIC).

As in previous chapters, the competitive firm is assumed to have a preference function that is increasing in the expected value of profits and decreasing in variance of profits of its portfolio. The specific functional form

$$V(.) = \overline{\pi}_S - \frac{\psi}{2}\sigma^2_{\pi_S}$$

is used to represent the utility of the firm.

The decision problem of a competitive firm is to maximize its preference function by deciding on the amount of insurance it would provide to farmers given that federal reinsurance is available in the market. The utility of the firm selling insurance is

(6-2) $$V = tn\phi(w - \overline{L} - c) - \frac{\psi}{2}\phi^2 t^2 n[1+(n-1)\rho]\sigma^2_L - n\phi(1-t)k$$

The FOC[30] to maximize this function with respect to $\phi$ is

(6-3) $$tn(w - \overline{L} - c) - n(1-t)k - \psi\phi t^2 n[1+(n-1)\rho]\sigma^2_L = 0$$

Solving for coverage yields

[30] The Second Order Condition is satisfied ($-\psi t^2 n[1+(n-1)\rho]\sigma^2_L < 0$)

$$(6\text{-}4) \qquad \phi = \frac{(w - \overline{L} - c) - \frac{(1-t)}{t}k}{\psi t[1 + (n-1)\rho]\sigma_L^2}.$$

To attain equilibrium values the farmer must be introduced. The decision problem of farmers is exactly identical to that given in Chapter 3, since FCIC reinsurance does not effect the farmer directly. Recapitulating, the farmer maximizes his preference function

$$U = M - \phi w - \overline{L} + \phi \overline{L} - \frac{\lambda}{2}(\phi - 1)^2 \sigma_L^2.$$

The FOC to this problem is

$$(6\text{-}5) \qquad -w + \overline{L} - \lambda(\phi - 1)\sigma_L^2 = 0$$

and the coverage sought is

$$(6\text{-}6) \qquad \phi = 1 - \frac{w - \overline{L}}{\lambda \sigma_L^2}.$$

The equilibrium conditions may now be expressed in the presence of FCIC proportional reinsurance.

*Definition (6-1): A competitive equilibrium in this model of crop insurance delivery with FCIC proportional reinsurance $t^r$ is a premium level $w^r$, coverage level $\phi^r$, number of policies $n^r$ for each firm such that:*

$$(6\text{-}7) \qquad (-w^r + \overline{L}) - \lambda(\phi^r - 1)\sigma^2 = 0$$

$$(6\text{-}8) \qquad t^r n^r (w^r - \overline{L} - c) - \psi \phi^r {t^r}^2 n^r [1 + (n^r - 1)\rho]\sigma_L^2 - n^r(1 - t^r)k = 0$$

$$(6\text{-}9)\quad t^r n^r \phi^r (w^r - \overline{L} - c) - \frac{\psi}{2}\phi^{r^2}\sigma_L^2 t^{r^2} n^r [1 + (n^r - 1)\rho] - n^r (1 - t^r)\phi k - b = 0$$

$$(6\text{-}10)\quad -\phi^r w^r + \phi^r \overline{L} - \frac{\lambda}{2}(\phi^r - 1)^2 \sigma_L^2 \geq -\phi^0 w^0 + \phi^0 \overline{L} - \frac{\lambda}{2}(\phi^0 - 1)^2 \sigma_L^2$$

The first two expressions in the definition of a competitive equilibrium are the first-order conditions for maximize the preferences of the farmer and the competitive firm, respectively. The third expression is the condition that the utility of the competitive firm is at reservation level b. The fourth expression is the condition that the utility of the farmer must be higher when the firm buys reinsurance than without it. This last expression assures that reinsurance level $t^r$ is in the equilibrium set since if the firm buying reinsurance cannot provide higher coverage (and utility) to farmers, then a firm not buying this insurance would be able to take policies away from the firm buying insurance. If this expression does not hold then 1-t proportional reinsurance is not in the equilibrium set and such reinsurance offered by the FCIC would not be bought by a competitive firm.

The proportional reinsurance model may now be explored to see if (i) it brings about equilibrium points where non existed before; and (ii) it increases coverage to farmers. Each of these aspects are studied in turn.

### 6.2.3 Can Proportional Reinsurance Facilitate Equilibrium?

Suppose the reservation utility is set such that equilibrium does not exist without reinsurance. Then the question is: can proportional reinsurance bring about equilibrium? To study this one needs to analyze only the first three expressions for equilibrium in Definition (6-1). If equilibrium exists, then expression (6-10) may be used to check if such reinsurance levels would actually be bought by competitive firms. This line of argument is clearer in the discussion below.

The presence of FCIC reinsurance (t<1) would bring new equilibrium points if it is able to shift the upper equilibrium limit to above t=1. To solve for the equilibrium relation between reservation utility b and number of policies n, steps identical to those in section 6.1 are followed. First the equilibrium coverage is solved for from expressions (6-3) and (6-5) to arrive at

$$(6\text{-}11)\quad \phi = \frac{\lambda\sigma_L^2 - c - \frac{(1-t)k}{t}}{(\lambda + t\psi(1+(n-1)\rho))\sigma_L^2}.$$

As before, this coverage is a function of exogenous parameters, n but now also t. Assume that t is exogenously given by the FCIC. The value of n is determined at equilibrium as the utility of the firm settles to reservation utility level b. As before, n takes ranging from 0 to infinity. At n=0 the utility remains at zero, while the limit as n tends to infinity is

$$\lim_{n\to\infty} V \to \frac{\left(\lambda\sigma_L^2 - c - \frac{(1-t)}{t}k\right)^2}{2\psi\rho\sigma_L^2}.$$

Further it can be proved that equilibrium reservation utility is monotonic in n (the proof is identical to the previous section) such that reservation utility lies in the range

$$b \in \left[0, \frac{\left(\lambda\sigma_L^2 - c - \frac{(1-t)}{t}k\right)^2}{2\psi\rho\sigma_L^2}\right]$$

for values of $\rho<1$.

In the limits of b, we see that as t increases, the upper limit decreases (with positive k) because

$$\lim_{t \to 0} \frac{(1-t)}{t} \to \infty .$$

In other words, if equilibrium did not exist when t=1 (i.e., because reservation utility was above $\bar{b}$ ) then for values of t<1, the reservation utility levels in the equilibrium set cannot be increased. This may be illustrated graphically as

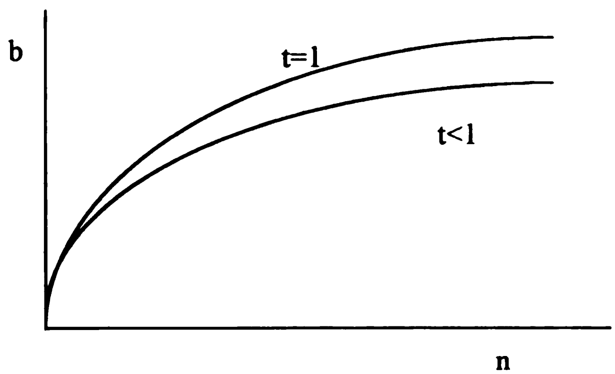


Figure 6-2: Competitive Equilibrium and Proportional Reinsurance

If equilibrium did not exist at t=1, the presence of proportional reinsurance cannot facilitate equilibrium. Making proportional reinsurance available to competitive firms will not entice competitive firms to offer crop insurance to farmers where none existed before.

This result is occurs because, at the limit, with or without reinsurance the firms hold very small portions of each risk in equilibrium. These two limits are equivalent if transaction costs are zero. However, even though a very small portion of each risk is held by the firm, the presence of correlation between risks caps the upper limit. The higher the correlation the lower the limit. In the presence of positive transaction costs, this limit is lowered as shown in Figure 6-2.

### 6.2.4 Can Proportional Reinsurance Increase Coverage to Farmers?

This second question of whether proportional reinsurance would increase coverage to farmers becomes irrelevant if, in the first place, a private insurance market did not exist. Asking such a question is more appropriate for private insurance markets, such as hail or fire which already exist.

Recall from the preceding analysis (and from Figure 6-2 above) that with proportional reinsurance there is a clockwise shift of the equilibrium curve. This implies that for a given reservation utility level, the number of policies held by each firm at equilibrium is increased with proportional reinsurance. If we look at expression (6-11), we see that there is a simultaneous but opposite movement of n and t in the denominator of the expression. Further increases in t would also decrease the numerator for positive k.

Assume that k=0 for the moment and concentrate on the denominator of expression (6-11). If the net effect (of movements in n and t) on the denominator is to increase its value then such movements cannot be consistent with equilibrium since a firm without reinsurance can provide higher coverage to farmers. For coverage to increase under reinsurance the expression $t\psi(1+(n-1)\rho)\sigma_L^2$ must decrease. Let there be two reinsurance levels $t_1$ and $t_2$, such that $t_1>t_2$. This means that $t_2$ is the higher reinsurance level. Now coverage would increase with the higher reinsurance level only if

$$t_2\psi(1+(n_2-1)\rho)\sigma_L^2 < t_1\psi(1+(n_1-1)\rho)\sigma_L^2$$

To determine if reinsurance increases coverage consider expression (6-11) reproduced below with k=0.

$$\phi = \frac{\lambda\sigma_L^2 - c}{(\lambda + t\psi(1+(n-1)\rho))\sigma_L^2}$$

This expression shows that coverage can be increased by increasing reinsurance (decrease in t) as it has the effect of reducing the variance of the portfolio. At the extreme as $t \to 0$, the coverage tends to

$$\phi = 1 - \frac{c}{\lambda\sigma_L^2}$$

which is the expression for coverage provided by a risk neutral insurance provider. If the government constrains the lower limit on the amount of reinsurance that may be bought by a competitive firm, then this lower limit would determine the coverage to farmers.

In the presence of transaction cost, higher values of k results in lower benefits (as increased coverage) to farmers from FCIC proportional reinsurance. Consider the numerical examples below to illustrate this. The parameters for the example are P=0.3; b=10; λ=0.01; ψ=0.01; c=3.

Table 6-1: Competitive Coverage Levels With FCIC Proportional Reinsurance: k=1; ρ=0.05.

| t | w | ϕ | U | n |
|---|---|---|---|---|
| 1.0 | 28.679 | 0.253 | 114.186 | 16.846 |
| 0.9 | 28.643 | 0.257 | 114.195 | 19.064 |
| 0.8 | 28.626 | 0.258 | 114.199 | 22.067 |
| 0.7 | 28.637 | 0.257 | 114.196 | 26.333 |
| 0.6 | 28.697 | 0.251 | 114.181 | 32.822 |

Table 6-2: Competitive Coverage Levels With FCIC Proportional Reinsurance: k=1; ρ=0.1.

| t | w | ϕ | U | n |
|---|---|---|---|---|
| 1.00 | 29.443 | 0.179 | 114.020 | 20.471 |
| 0.95 | 29.445 | 0.179 | 114.020 | 20.779 |
| 0.90 | 29.452 | 0.178 | 114.019 | 23.297 |

Table 6-3: Competitive Coverage Levels With FCIC Proportional Reinsurance: k=0.5; ρ=0.1.

| t | w | ϕ | U | n |
|---|---|---|---|---|
| 1.0 | 29.443 | 0.179 | 114.020 | 20.471 |
| 0.9 | 29.429 | 0.180 | 114.023 | 22.968 |
| 0.8 | 29.430 | 0.180 | 114.023 | 26.320 |
| 0.7 | 29.452 | 0.176 | 114.019 | 31.049 |

Table 6-4: Competitive Coverage Levels With FCIC Proportional Reinsurance: k=0; ρ=0.1.

| t | w | ϕ | U | n |
|---|---|---|---|---|
| 1.00 | 29.443 | 0.179 | 114.020 | 20.471 |
| 0.90 | 29.376 | 0.185 | 114.032 | 22.230 |
| 0.50 | 29.064 | 0.216 | 114.095 | 36.520 |

Table 1 shows that, with proportional reinsurance, the coverage to farmers initially increases, reaches a maximum at approximately t=0.8 and then starts to decline. Note that at t=0.7 coverage to farmers is still better than t=1 although higher coverage is achieved nearer t=0.8. The coverage to farmers is less at t=0.6 than when there is no proportional reinsurance. In this example, if reinsurance is made available to competitive firms it will increase coverage to farmers because of competition among insurance selling firms. As expected, the presence of reinsurance has increased the number of policies held by each firm, or with reinsurance there are fewer firms in the crop insurance market.

However, reinsurance does not increase coverage to farmers in all cases. Consider Table 6-2, where all the parameters are identical except that the correlation between farms is increased from ρ=0.05 to ρ=0.1. This has the effect of rotating the equilibrium curve clockwise in Figure 6-2 above. As expected, the increase in correlation decreases coverage to farmers in the absence of proportional reinsurance. Now if FCIC proportional reinsurance is made available, the results show that even at very low levels of reinsurance t=0.95, there is no increase in coverage to farmers. In such situations, the presence of high correlation between farms results in even proportional reinsurance having no effect on the coverage to farmers.

The situation where proportional reinsurance has no effect can be partially remedied if the transaction cost of procuring proportional reinsurance is reduced. Table 6-3 shows the case where k is reduced from k=1 to k=0.5. In this case proportional reinsurance does increase the coverage to farmers at t values above t=0.7. The optimum coverage is achieved at approximately t=0.9. Thus, as expected, a reduction in k has the effect of increasing coverage to farmers.

Table 6-4 is presented to show how coverage increases if transaction cost is totally subsidized by the FCIC such that k=0. In this case the coverage to farmers is constrained by where the FCIC sets a reinsurance upper limit. For example, if the upper limit on reinsurance is 10 percent (t=90), then the coverage to farmers is at 0.185. Note that this is higher than when there was no reinsurance and, as expected, the number of policies held by each firm increases. If the FCIC had set the upper limit to reinsurance 0.5 (t=0.5), then the coverage to farmers would increase to 0.216 and so on.

## 6.3 Proportional Reinsurance with Government Subsidies

The previous section showed that proportional reinsurance cannot bring about equilibrium where none existed previously. The major reason is that proportional reinsurance takes the same proportion of the premium as the proportion of indemnities it covers. Since the FCIC is risk neutral, it could settle for less premium than those associated with proportional reinsurance.

This section looks at a situation where the government subsidizes the premiums charged for the proportional reinsurance. To highlight the results, it is assumed that the amount of subsidies provided by the government are such that the premiums paid by the firms are actuarially fair plus transaction costs. This means that if the FCIC provides 1-t percent reinsurance it does not charge

1-t percent of the premium collected from farmers. Rather, the FCIC provides the reinsurance at expected indemnities plus cost, i.e.,

$$\overline{L} + c$$

quoted in per acre terms. If the competitive firm sells ϕ percent coverage to farmers and decides to reinsure t percent of the portfolio it holds, the premium charged by the FCIC would be

$$n(1-t)\phi(\overline{L}+c),$$

i.e., the premium quoted at per acre terms is $w = \overline{L} + c$ for n farms with the FCIC covering tϕ of the loss. In such a reinsurance program, the end of the period profits of the competitive firm are

$$\pi_S = n\phi(w-c) - t\phi\sum_{i=1}^{n} l_i - n(1-t)\phi(\overline{L}+c) - n\phi(1-t)k$$

The first term in the RHS is the premium collected from n farms to provide ϕ coverage per acre. The second term is the indemnities paid after having bought (1-t) percent FCIC reinsurance. The third term is the actuarially fair premium paid by the competitive firm to the FCIC to obtain 1-t percent reinsurance. The last term, as before, is the transaction cost faced by the competitive firm for reinsurance on its portfolio. The mean and the variance of profits are

$$\pi_S = n\phi(w-c-t\overline{L}) - n(1-t)\phi(\overline{L}+c) - n\phi(1-t)k$$

$$\sigma^2_{\pi_S} = t^2\phi^2 n(1+(n-1)\rho)\sigma^2_L.$$

The utility of the firm from selling crop insurance is

$$V(.) = n\phi(w-c-t\overline{L}) - n(1-t)\phi(\overline{L}+c) - n\phi(1-t)k - \frac{\psi}{2}t^2\phi^2 n(1+(n-1)\rho)\sigma^2_L$$

The FOC to maximize this utility function with respect to coverage is

$$(w-c-t\overline{L})-(1-t)(\overline{L}+c+k)-\psi t^{2}\phi(1+(n-1)\rho)\sigma_{L}^{2}=0$$

which solves to give coverage

$$\phi=\frac{(w-c-t\overline{L})-(1-t)(\overline{L}+c+k)}{\psi t^{2}(1+(n-1)\rho)\sigma_{L}^{2}}$$

Substituting in the value for w from expression (6-5), the equilibrium coverage is solved to obtain

(6-12) $$\phi=\frac{\lambda\sigma_{L}^{2}-c-(1-t)(c+k)}{(\lambda+\psi t^{2}(1+(n-1)\rho))\sigma_{L}^{2}}.$$

The exact coverage level is determined by equilibrium values of n determined via reservation utility b. As in the previous analysis, equilibrium relationship between b and n is mapped. To do this first obtain the upper limit of the utility of the firm in equilibrium as $n\rightarrow\infty$ which is

$$\overline{b}=\left(\frac{\lambda\sigma_{L}^{2}-c-(1-t)(c+k)}{2\psi t^{2}\rho\sigma_{L}^{2}}\right)$$

Note that here again, the constraint to non-existence of equilibrium (for a given t) is the presence of correlation between farms. However, unlike the case in proportional reinsurance, the denominator can be reduced with increases in reinsurance (1-t). At the limit

$$\underset{t\rightarrow0}{Lim}\quad\overline{b}\rightarrow\infty.$$

The upper limit is constrained by how much reinsurance is being made available by the FCIC to competitive firms. Graphically, this may be represented as an anti-clockwise shift in the equilibrium relationship between b and n

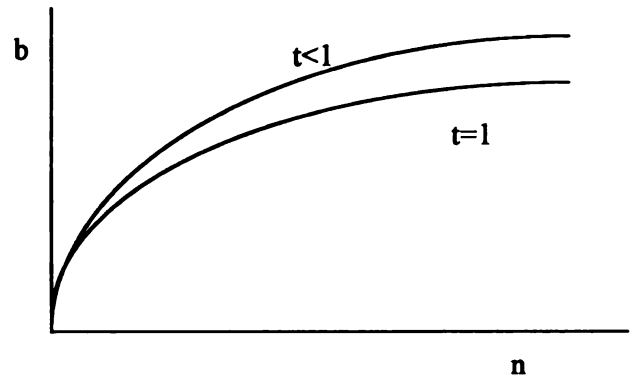


Figure 6-3: Competitive Equilibrium and Subsidized Proportional Reinsurance.

As the reinsurance level increases, the upper limit moves upward. This implies that if there was no feasible solution previously (because of too high reservation utility or too high a degree of correlation between risks), some additional points would now be in the feasible set with the appropriate reinsurance level. This is because the upper limit is constrained only by the reinsurance level 1-t (provided that delivery costs and transaction costs are such that there is positive coverage to start with). Moreover, since for each level of reservation utility n drops (see Figure 6-3) as 1-t increases, it means that coverage to farmers increases (seen through expression (6-12)).

## 6.4 Implications for Conventional Reinsurance Schemes

The analysis in this chapter shows that the presence of correlation between farm losses can be a major reason for the non-existence of competitive insurance for such risks. Proportional reinsurance cannot bring about equilibrium if none existed before (even if all transaction costs were subsidized by the FCIC). Therefore FCIC proportional reinsurance will not create a competitive market for insurance if there was no such market to begin with. A primary reason for this is that proportional reinsurance charges the same premium as the competitive firm for the coverage it provides to farmers. If the FCIC is able to price reinsurance such that it charges actuarially fair premiums, then the results show that such reinsurance schemes may bring about insurance markets where none existed before. This is a situation where the risk neutral position of the FCIC is combined with the higher information and lower cost position of the competitive private sector.

The main drawback of pricing reinsurance at actuarially fair levels would be the lack of information for the FCIC to classify farmers into risk classes. In the model of this section it was easy for the FCIC to calculate actuarially fair premiums given that there was only one risk type considered. If there were more than one risk type, then the FCIC would not be able to calculate actuarially fair premiums for each risk class because it would not have the information to do so. It is highly unlikely that the competitive firms would divulge this information to the FCIC if they could obtain reinsurance for all risk types they hold at the lower reinsurance premiums. Therefore, the same reasons that make it difficult for the FCIC to provide insurance directly to farmers also make it difficult to provide reinsurance to competitive firms, such that private competitive insurance markets emerge. Because the information problems of the FCIC are retained in providing conventional reinsurance, a non-conventional "reinsurance" scheme is proposed below to incorporate the risk neutral position of the FCIC with competitive risk averse firms.

## 6.5 Area-Yield Crop Insurance as "Reinsurance"

One of the crop insurance plans offered by the FCIC on a pilot scale to farmers is the Area-Yield Crop Insurance first suggested by Halcrow in 1949. Miranda has analyzed some of the benefits of such a scheme when offered directly to farmers. In this crop insurance scheme, both indemnities and premiums are not based on a producer's individual yield but rather on the aggregate yield of the area. In any given year every participant would receive the same indemnity irrespective of his own yield. This scheme is attractive because the information on area yield is easily available and there are no delivery costs (except administrative) incurred by the FCIC because monitoring etc. is at its minimum.

It is of interest to explore if such a program could generate equilibrium where none existed before if it was offered to insurance firms as well as farmers. To see how such a plan would work, consider the simplest possible case of a firm insuring $\phi$ percent of random loss $x_1$ for premium $w_1$ (quoted in per acre terms) and incurring cost c. The end of period profit of the insurance firm is

$$\pi_A = \phi(w_1 - c) - \phi x_1 .$$

Let mean and the variance of this random loss be $\bar{x}_1$ and $\sigma_1^2$ respectively. The mean and the variance of profits are

$$\bar{\pi}_A = \phi(w_1 - c - \bar{x}_1)$$

$$\sigma_A^2 = \phi^2 \sigma_1^2 .$$

Now let this firm have access to purchasing t percent of an actuarially fair insurance contract from the FCIC on a random loss $x_2$ with mean $\bar{x}_2$ and variance $\sigma_2^2$. Let the actuarially fair premium quoted in per acre term be $w_2$. If the firm buys into this contract the end of the period profit of the firm is

$$\pi_B = \phi(w_1 - c) - \phi x_1 - t w_2 + t x_2 .$$

The mean and the variance of this profit is now

$$\overline{\pi}_B = \phi(w_1 - c - \overline{x}_1)$$

$$\sigma_B^2 = \phi^2\sigma_1^2 + t^2\sigma_2^2 - 2t\phi\rho\sqrt{\sigma_1^2\sigma_2^2}$$

where ρ is the degree of correlation between loss $x_1$ and loss $x_2$. Because the insurance that the firm buys into is actuarially fair, the mean of end of period profits do not change. What does change is the variance of profits. Since the preference function of a risk averse firm is increasing in mean and decreasing in variance of profits, a decrease in the variance of the portfolio would increase utility of the firm. Or in other words, a firm would choose to buy such an actuarially fair contract only if

$$\sigma_B^2 < \sigma_A^2 .$$

The condition under which this holds is

$$\phi^2\sigma_1^2 + t^2\sigma_2^2 - 2t\phi\rho\sqrt{\sigma_1^2\sigma_2^2} < \phi^2\sigma_1^2$$

or

$$\rho > \frac{t}{2\phi}\sqrt{\frac{\sigma_2^2}{\sigma_1^2}} .$$

The RHS of the above expression is positive, so as long ρ is positive, there can be found a t where this inequality holds. In fact the higher the value of ρ, the more the decrease in variance for a given t and ϕ.

### 6.5.1 Implications of Area-Yield Insurance as "Reinsurance"

The Area-Yield Insurance Plan may be used by an insurance firm in lieu of conventional reinsurance schemes to arrive at an equilibrium where none existed before (because of high levels of systematic risk in the system). If a firm selling crop insurance is given the option to buy into the plan, then the variance of the portfolio of the competitive firm can be reduced, especially in the agricultural sector where farm losses are highly correlated. The attractiveness of such a plan is that the FCIC, being risk neutral, can provide Area-Yield insurance at actuarially fair premiums (such an scheme would not be forthcoming from the private sector). The information on area yields are readily available and therefore actuarially fair premiums are easier to construct. Moreover the FCIC does not have to deal with any asymmetric information problems in such a scheme (the FCIC does not need to have information on risk classes that a competitive firm may hold) and delivery costs are minimal as it does not have major monitoring activities.

The option of buying into the Area-Yield Insurance Plan would have the effect of shifting the curve in Figure 6-3 counter-clockwise because of the reduction of variance. Since the reduction of variance is a function of correlation between risks, the greatest reduction takes place when this correlation is highest between the portfolio of the firm and the area yield. Such a hedging scheme directly counteracts the breakdown of competitive equilibrium because of high systematic risk in the market. This scheme also overcomes one of the main drawbacks of the Area-Yield Insurance Plan when offered directly to farmers — that this Plan was not an individual insurance scheme. If the Area-Yield Plan when bought directly by a farmer did not adequately cover the farmer, the farmer had to seek out additional insurance to protect himself (and if no such private insurance scheme existed the farmer had no recourse). By making the Area-Yield plan available to private insurance firms, this drawback is removed since private firms offer individual insurance schemes.

The farmer now only has to deal with one insurance seller and potentially cut down on search and transaction costs.

Once competitive equilibrium is established, the FCIC can also make proportional reinsurance (as described in Section 6.2.4) available to competitive firms to increase coverage to farmers. Again, such a reinsurance scheme does not require information on the part of the FCIC and the program would not make expected negative profits. Thus a combination of Area-Yield plan and Proportional Reinsurance provides a "reinsurance" plan to bring into existence competitive insurance where none existed before and use the expertise of the competitive sector to deliver crop insurance to farmers. These plans have minimal expenditure from taxpayers while having the potential to achieve the objectives of the FCIC to make reinsurance the primary mode of crop insurance delivery.

# 7. Summary, Conclusions and Policy Implications

This study was motivated by concerns that the U.S. federal crop insurance program has not served as the primary provider of federal disaster assistance and has not been self sustaining (as was envisioned by the 1980 Crop Insurance Act). The key problem areas identified by various General Accounting Office reports are crop price forecasts, actuarial soundness, and inadequate risk sharing by the private sector. The focus of this study was on the latter two problems.

This study had three broad objectives. The first was to compare competitive and public provision of crop insurance given the working hypotheses that (i) competitive firms can deliver crop insurance at a lower cost than the FCIC; (ii) when farmers belong to different risk classes then competitive firms have perfect information regarding each farm's risk classification but the FCIC cannot distinguish between risk classes; (iii) competitive firms delivering crop insurance are risk averse while the FCIC is risk neutral; (iv) competitive firms are assumed to operate at reservation utility levels in long-run equilibrium; (v) agricultural yield risks are highly correlated across farms (systematic risk); and (vi) yield risk is the only source of risk to farm income. The second objective was to study the performance of the current institutional arrangement where the Federal Crop Insurance Corporation (FCIC) involves private firms in crop insurance delivery through a reinsurance scheme. The third and final objective was to study alternative reinsurance schemes that may be provided by the FCIC to competitive firms, and to assess how such schemes might meet the goals of government policy on crop insurance.

The analytical framework for the basic model was developed in Chapters 3 and 4. In the case of competitive firms, the equilibrium concept of firms operating at reservation utility in the long-run (first introduced by Appelbaum and Katz) was incorporated and developed. This approach differs from the usual assumptions of risk neutrality and zero profits as conditions in the long-run equilibrium. In the case of the FCIC, separating equilibrium concepts (first introduced by Rothschild and Stiglitz) with cross subsidies across risk types to overcome risk classification problems were also incorporated into the models. To highlight information differences (in identifying farmer risk classes) between competitive firms and the FCIC, competitive firms were assumed to have full information while the FCIC was assumed to have no information.

Polar cases of crop insurance delivery by the FCIC only and by competitive firms only were analyzed in Chapter 3. This analysis abstracted from information differences between the two institutions to concentrate on the differences solely due to cost of delivery and the degree of risk aversion. The results of this section show that coverage to farmers is a tradeoff between high cost of delivery by the FCIC versus an additional loading on insurance premiums by risk averse competitive firms. The loading on the insurance premium that a competitive firm seeks is directly proportional to (i) the level of non-diversifiable risk in the portfolio of the firms; and (ii) the level of reservation utility of the competitive firms. This latter factor determines entry and exit of firms from the crop insurance industry because it is an indicator of alternative investment opportunities available to the firms.

Multiple risk classes were added in Chapter 4 and the FCIC was assumed to have no information on farmer risk classes. The results indicate that if the FCIC is to overcome problems due to this lack of information and operate without making expected losses, then it must offer policies such that the program achieves a separating equilibrium. A separating equilibrium is achieved when there is self selection of policies by the different risk types. In a separating equilibrium the premiums to low risk types (identified by low coverage level policy holders) are taxed while the premiums to high risk types (identified by high coverage level policy holders) are subsidized. In other words the low coverage policies subsidize the high coverage policies. The size of the cross subsidies is a function of the ratio of low to high risk farmers. While such a program induces cross-subsidies from the low to the high risk farmers, it still provides higher coverage (and utility) to the low risk types than if there were no such cross-subsidies. The results also show that a pooling situation (where all risk types buy the same premium and coverage) is an equilibrium only if there is a very high ratio of low to high risk farmers.

Chapter 4 has major implications for the current FCIC practice of subsidizing low coverage policies. This practice is detrimental to the FCIC achieving a separating equilibrium when information on farmer risk classes is lacking. In such a case, if federal subsidies are to be given then they should either be given proportionally to all risk types (all coverage levels), or only to high risk types. Subsidizing low risk types hinders separating equilibrium so either the coverage to low risk types must be further reduced to regain equilibrium or the FCIC must absorb excessive losses through adverse selection.

Using the framework developed in Chapters 3 and 4, a stylized model of the current FCIC reinsurance contract with private firms was analyzed in Chapter 5. The main conclusions drawn from this analysis are that (i) the FCIC does not use the improved information position of the private firms; and (ii) the program can save on delivery costs if the private firms are not required to share in the risks. By requiring the private firms to keep a portion of the policies they sell (through proportional reinsurance), there must be a transfer of funds from the FCIC to the private firms to meet the additional premium loading that is required by the risk averse insurance firms to retain these risks. Two areas are identified in the current FCIC program where this transfer can take place: (i) through generous administrative cost compensation; and (ii) through generous stop-loss reinsurance agreements. These findings are consistent with various General Accounting Office allegations concerning the excessive costs of the FCIC program.

Further, for private competitive firms to participate in the FCIC program the minimum transfer required from the FCIC to these firms increases with increases in the level of systematic risk in the system. A higher level of transfer to firms does not convert into higher coverage to farmers. In other words, the model suggests that the FCIC can cut back on this transfer level without affecting the coverage to farmers. This provides a potential area to cut excessive FCIC expenditure on the program. Furthermore, with more than one risk type among farmers, the current practice of letting the private firms hold less of the more risky policies would aggravate the FCIC actuarial position as the FCIC holds higher proportions of the more adversely selected policies.

Regarding delivery costs, the results of the model indicate that the current program could reduce its cost if the FCIC used the private sector to deliver and adjust the policies for a fee, but did not require them to retain any of the policies. This would ensure that the delivery cost position of the private firms was used with no additional transfer by the FCIC to private firms. If the current institutional structure is to be continued, the results suggest that the FCIC should investigate the possibility of delivering all their policies through private firms but not require the firms to share in the risk. This suggestion stands counter to the FCIC's stated objective of delivering 100 percent of policies through partial reinsurance of private firms under the current program.

Since the current FCIC reinsurance program does not appear to use the information position of the private firms, a more conventional proportional reinsurance scheme was studied in Chapter 6. Here the FCIC is responsible for paying a certain percentage of the indemnities in return for the same percentage of premiums. In such a situation, information on farmer risk classes is not required as the FCIC depends on competitive firms to make all insurance decisions including premiums, coverage, adjustment of policies, etc. However, one of the problems of such a scheme is that private multi-peril crop insurance does not exist in the U.S. The results of this model show that a major reason there are no private competitive multi-peril crop insurance markets is the existence of high levels of systematic risk in the agricultural sector. Results also indicate that if no such market exists, then conventional proportional reinsurance would not facilitate new markets without subsidies from the government.

Chapter 6 also presents a non-conventional "reinsurance" scheme by making a simplified model of the Area-Yield Plan available to competitive insurance firms (this plan is currently only available to farmers). The analysis shows that such a scheme has the potential to encourage emergence of private markets for multi-peril crop insurance. This plan offers a hedge against non-diversifiable risk in the portfolio of the private firms. Once a competitive market for multi-peril crop insurance emerges, conventional proportional reinsurance schemes of the FCIC may be used to increase coverage to farmers. This scheme has the potential to provide individualized insurance to farmers by private firms if the scheme is offered to these firms rather than the current practice of offering it only to farmers.

This study has a number of limitations and therefore the results must be taken as preliminary. Firstly, the study portrayed the FCIC and the competitive private firms on polar ends of the information scale to classify farmers. This was done to highlight the differences in information positions of the two institutions and make the analyses more tractable. A study that allows for more complicated informational assumptions may allow us to see a comprehensive tradeoff among information availability, delivery costs and degree of risk aversion on coverage to farmers. Secondly, for ease of analysis, the study used a linear mean-variance model. A study that uses a more generalized mean-variance or expected utility framework would also account for income effects in addition to substitution effects of the linear model.

Future research in this area could incorporate moral hazard issues and uncertain crop prices into the model. This study has totally abstracted from such issues to focus on concepts of systematic risks and farmer classification problems. Also, there was only one source of risk for the farmer and as such the farmer had no diversification opportunities. General Accounting Office studies have identified crop diversification to be an important alternative to buying crop insurance for farmers in certain areas and therefore should be considered in crop insurance designs for such areas. Further, this study ignored other government farm income stabilization programs that exist simultaneously with federal crop insurance. Information on interaction between these programs and crop insurance program would help policy makers coordinate the programs better in their attempts to stabilize farm incomes.

Despite the limitations of the study and suggestions for further research, this study has taken steps to model insurance markets with systematic risk and risk averse competitive firms. The equilibrium concepts and results provide insights into the role of government and competitive firms in such risk markets. It is hoped that the study will lead to more informed government policies as the search for a better institutional design for U.S. crop insurance continues.

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