EL NINO/SOUTHERN OSCILLATION BASED ADVERSE SELECTION IN THE U.S. CROP INSURANCE PROGRAM

by

John Patrick McGowan

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STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

______________________ 08/11/99

Alan P. Ker
Assistant Professor of
Agricultural and Resource Economics

Date

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ABSTRACT

Research has shown that an indication of forthcoming weather conditions may be seen through the ocean and atmospheric anomalies associated with El Nino/Southern Oscillation (ENSO). This thesis undertakes an empirical analysis to determine the extent to which ENSO based adverse selection by private insurance companies may inflate government losses in federally supported crop insurance programs. An empirical case study of Texas wheat indicated that a statistically significant portion of interannual yield variability could be explained by fluctuations in ENSO-related sea surface temperatures. Simulations of reinsurance decisions over the period of 1978-1997 indicate that insurance companies can gain excess profit at the expense of excess government loss through ENSO-based adverse selection activities.

CHAPTER 1

INTRODUCTION

As early as 1922 the U.S. Department of Agriculture had published data citing drought as the largest factor inflicting crop losses throughout the decade of 1909 to 1918 (Kramer 1983a). Frost and excessive moisture were listed as other major contributors so not surprisingly the impact of weather on agriculture in the United States has long been documented. Concern following the economic hardships brought on by the droughts of the 1930's eventually lead to the formation of the Federal Crop Insurance Corporation (FCIC) with the objective of ensuring farmers a safety net in the event of widespread crop failure.

As the crop insurance program evolved, its history became marked by low participation and persistent economic deficiency. By the late 1990's crop insurance cost the Federal Government an average of 1.1 billion dollars annually in payments to farmers and insurance companies (United States General Accounting Office 1998). The exorbitant expenses however, have not discouraged policy planners from making a firm commitment to the crop insurance program for the future. For example consider the words of U.S. Agriculture Secretary Dan Glickman in his radio address of December 28, 1998. He stated: "It's no secret that I want 1999 to be the 'year of the safety net' ... a year in which we build a strong risk management system anchored in a strengthened crop insurance program." (United States Department of Agriculture 1998) The commitment to crop insurance was reiterated by President Clinton in his 1999 State of the Union

Address. The President stated: "Last year, the Congress provided substantial assistance to help stave off a disaster in American agriculture. And I am ready to work with lawmakers of both parties to create a farm safety net that will include crop insurance reform and farm income assistance. I ask you to join with me and do this." (White House 1999)

If federally funded crop insurance programs are going to serve as a central element to U.S. farm policy, as the President and Secretary have indicated, they will require an actuarially sound foundation. This has been an elusive element in the past and will require an equitable partnership between FCIC and the private insurance industry. This thesis will attempt to evaluate one aspect of this partnership.

In recent years, research has shown that forthcoming weather and climate conditions may often be seen many months in advance through the ocean and atmospheric anomalies associated with the phenomenon known as El Nino/Southern Oscillation (ENSO). This is of critical interest to the crop insurance industry since weather conditions are the primary cause of interannual crop yield variability. The objective of this thesis is to determine the extent, if any, to which private insurance companies may inflate government losses through adverse selection activities based on El Nino/Southern Oscillation. If the opportunity for ENSO-based adverse selection by insurance companies were to exist, it may imperil the integrity of the crop insurance program.

1.1 Federal Crop Insurance

Until 1980 the federal crop insurance program was available to only a few major crops and covered about 10% of the land in production. However in an attempt to encourage higher participation and to promote crop insurance as an alternative to federal disaster aid, Congress began to subsidize the farmers premiums and eventually shifted the primary marketing and administration of insurance contracts to the private insurance industry. There results a three-party economic arrangement involving the U.S. federal government, private insurance companies, and the farmers who purchase insurance contracts.

In addition to marketing and servicing crop policies, private insurance companies enter into a risk-sharing contract with the government known as the Standard Reinsurance Agreement (SRA). Upon selling a contract the SRA allows insurance companies to place it in one of three funds: the commercial, developmental, or assigned risk. In all cases insurance companies retain a minimum portion of the underwriting gains or losses, however their share varies from very little in the assigned risk fund to substantial in the commercial fund. Presenting these options in reinsurance allows companies some liberty as to whether they wish to heavily guarantee a contract themselves or cede its risk to the federal government. This creates a potential problem when information asymmetries exist between the two parties.

Consider that FCIC has at their disposal a set of information with which they will evaluate the risk in production for a forthcoming crop season. Using this information they estimate an insurance premium which ideally would accurately reflect the risk in production. However suppose that an insurance company had at their disposal additional information which would allow them to more accurately assess the production risk in a forthcoming crop season. Insurance companies could then incorporate the additional information into their decision strategy regarding reinsurance with the federal government. If information were to indicate that a contract would likely be profitable, they may prefer to retain a large share of the underwriting gains or losses and place it in the commercial fund. Likewise if information were to indicate that a contract would likely not be profitable, they may wish to minimize their liability and place it in the assigned risk fund. These actions are termed adverse selection and could leave the government with an abundance of liability in which the true risk were higher than reflected in the insurance premium. In time the government would likely suffer excessive losses on these contracts, thus imperiling the integrity of the crop insurance program.

Past empirical studies have considered adverse selection in the U.S. crop insurance program (Coble, Knight, Pope, and Williams 1996; Luo, Skees, and Merchant 1994; Goodwin 1994; Quiggin, Karagiannis, and Stanton 1993). However the focus of these studies has been limited to the activities of producers themselves. Considering the three-way economic arrangement under which the crop insurance program is administered, it becomes appropriate to explore the potential for adverse selection activities by insurance companies as well.

Crop yield at a point in time can be thought of as a function of two processes: the technology employed and weather. Insurance premiums are established more than a year in advance. Information regarding the expected weather during the growing season is not yet available so it is assumed that production risk is the same in any given year. However as stated, it has been found in recent years that an indication of forthcoming weather and climate patterns may often be seen months in advance through oceanic and atmospheric anomalies. The most preeminent indicator is the widely publicized phenomenon known as El Nino.

El Nino/Southern Oscillation (ENSO) refers to a fluctuating ocean-atmospheric interaction observed around the equatorial Pacific Ocean. Every few years it reaches an extreme state, El Nino [or La Nina], that is characterized by abnormally warm [cold] surface waters and low [high] overlying surface air pressure in the eastern and central equatorial region of the Pacific Ocean. An El Nino peaking in the winter of 1982/83, at the time the strongest of the century, was blamed for droughts, wildfires, floods and other catastrophic natural disasters that caused billions of dollars in damages in the U.S. and throughout the world. Following a more moderate El Nino in 1986-1987 conditions rapidly developed by the late spring of 1988 into the most severe La Nina (the equivalent cold phase of ENSO) in 20 years. As reported by Trenberth and Branstrator (1992) this coincided with a very hot and dry spring that led off a drought and heat wave the Associated Press called the worst natural disaster in United States history; causing $30 billion in agricultural losses, record damage from forest fires, and contributing to 10,000 deaths from heat stress. Trenberth and Branstrator showed that the strong La Nina was responsible for conditions contributing to the drought.

Prompted by such catastrophes, the last decade or so has led to great advances in understanding ENSO and the role it plays in seasonal and interannual climate variability throughout the world (Trenberth 1997a). ENSO has now been linked strongly to weather patterns in the U.S. and throughout the world, so it is a powerful aid in forecasting seasonal weather and climate. The interest in this to agriculture and the crop insurance industry is considerable. If insurance companies are able to monitor ENSO to gain insight into the production risk for an upcoming crop season, they may incorporate this information into their decision strategy regarding reinsurance with the federal government.

1.2 ENSO and Adverse Selection in Crop Insurance

An abundance of studies have outlined regions of the U.S. which exhibit ENSO-related climatic anomalies (e.g. Ropelewski and Halpert 1986, 1989; Kiladis and Diaz 1989). An area consistently identified is the state of Texas, where ENSO effects winter and springtime precipitation and temperature. In Texas, wheat is planted in the fall so that it can get an early start in growing the following spring. Thus wheat yield is heavily influenced by winter and springtime weather conditions. Not surprisingly, analysis and previous research has shown that Texas wheat yield can be impacted by ENSO as well (Mjelde and Keplinger 1998). Therefore if insurance companies were to engage in ENSO-based adverse selection activities, the crop insurance market for Texas wheat would be a likely starting point.

Since information regarding ENSO is freely available, it raises the question as to why producers themselves would not use it to adverse select. There are three reasons why this is not likely to occur. First, insurance premiums are subsidized by the government. A risk-neutral producer will purchase a contract if they estimate their expected loss to be greater than reflected in the price of the premium. Since premiums are heavily subsidized by the government (40% on average) this is likely be the case regardless of ENSO conditions. Unlike producers, insurance companies are not explicitly subsidized so they are not presented this disincentive to adverse select. Second, a risk-averse producer may purchase a contract even if they estimate their expected loss to be less than reflected in the price of the premium. Simply put they are not likely to literally "bet the farm on the weather". Insurance companies however have the capability of spreading their risk so they will engage in weather-based adverse selection. Finally, although information regarding ENSO is freely available, producers may lack the means of incorporating it into decision making. With superior resources this is not an obstacle for insurance companies.

Analysis indicates that Texas wheat yields are significantly correlated with ENSO conditions observed prior to the deadline date for insurance companies to reinsure their contracts with the federal government. This creates the potential for ENSO based adverse selection by private insurance companies as depicted on the time line in figure 1.1. First, premiums are established by the government over a year in advance. Information regarding ENSO conditions for the growing season is not yet available. Insurance companies then market the contracts to producers. By monitoring ENSO conditions prior to the deadline, insurance companies may then adverse select when making reinsurance decisions with the Federal Government. They may opt to retain a larger share of the underwriting gains or losses in years of little risk where they will likely profit, while ceding a majority to the federal government in years of high risk. Crops are usually planted shortly after the reinsurance deadline. They are harvested the following spring. Upon harvest, claims are settled on crop contracts and any underwriting gains or losses are divided between private insurance companies and the government. An illustration will help to demonstrate the potential for ENSO based adverse selection by a private insurance company.

To calculate an insurance premium, FCIC will estimate the distribution of yield conditioned on the technology employed. Yield variability due to weather, including the effect of ENSO, is encapsulated in the disturbance term and reflected in the variance of the density. Figure 1.2 presents an example of the yield distribution conditioned on technology. A premium which were to guarantee a minimum yield, say *g* bushels/acre, is based on the likelihood and magnitude of a shortfall. This area is shaded in the figure.

However assume there is a relationship between ENSO and wheat yield. That portion of the disturbance term may be incorporated to estimate the yield distribution conditioned on both the technology employed and ENSO. There may be an alternative expected yield, and because the disturbance attributed to ENSO has been explained, this estimate will have less variance. It will allow the calculation of an alternative insurance premium that will more accurately reflect the risk involved in production.

For example suppose that prior to the decision deadline, ENSO conditions indicate a favorable season for growing wheat and likely a bountiful yield. An insurance company may incorporate this to estimate the yield distribution conditioned on both the technology and ENSO. Notice the distribution conditioned on technology and ENSO, depicted in Figure 1.3, will exhibit a smaller variance and a higher expected yield than was estimated by FCIC. Subsequently, the likelihood of a shortfall and the risk on a contract which were to guarantee *g* bushels/acre (again represented by the shaded area) is lower than estimated by FCIC and reflected in the premium.[1] An insurance company would expect to profit in guaranteeing this contract.

Alternatively suppose that ENSO conditions indicate that there will likely be an unfavorable season for growing wheat, and the yield distribution conditioned on technology and ENSO is as depicted in figure 1.4. The distribution conditioned on technology and ENSO again has a smaller variance, but notice there is a lower expected yield than estimated by FCIC. In this case, likelihood of a shortfall and the true risk in production is higher than reflected in the premium. An insurance company would expect to suffer a loss in guaranteeing this contract.

This illustration is compounded by the terms of the SRA but it demonstrates how ENSO may be incorporated into decision strategy, possibly introducing the opportunity for adverse selection.

1.3 Objectives

The objective of this thesis is to determine the extent, if any, to which private insurance companies may inflate government losses through adverse selection activities based on El Nino/Southern Oscillation. To accomplish this, the study will perform an empirical simulation over the 20 year period of 1978-1997. Assume that insurance premiums are established by the government and are based on an estimate of the yield

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[1] Although reduced variance and higher expected yield will usually translate into less likelihood of a

distribution conditioned on technology. In addition, assume that insurance companies will have at their disposal information regarding ENSO, which they will use to adverse select when reinsuring contracts on Texas wheat. Insurance companies are presumed risk-neutral and will base their decision strategy on an estimate of the yield distribution conditioned on technology and ENSO. The study will then calculate profits, losses, and loss ratios for the government, insurance companies, and the overall program under various scenarios. First, insurance companies are restricted in their reinsurance decisions and underwriting gains and losses are subject to the constraints of the SRA. This is followed by a simulation in which insurance companies are unrestricted in and may either accept themselves or cede to the federal government 100% of a contract's liability as they choose. In addition the study will use randomization procedures to determine the statistical significance of the results.

As individual farm level data is unavailable, county level data will serve as a suitable proxy. The study will use mean yield data for the 55 largest wheat producing counties in Texas. This encompasses over 85% of the wheat acreage harvested throughout the state in 1997. As a in index of ENSO, the study will use sea surface temperatures (SSTs) of the Nino3 region of the Pacific Ocean. This area is critical to the ENSO cycle and is indicative of its year to year variability.

1.4 Methodology

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shortfall, there are exceptions to this case.

Assume that technology and ENSO are independent and additive processes in their relationship to wheat yield. Under this assumption they may be estimated in a generalized additive model. This will allow the estimation of each component separately using appropriate univariate techniques (Buja, Hastie, and Tibshirani 1989).

The technology component of yield is generally marked by a positive trend over time due to technological advancement. As Moss and Shonkwiler (1993) point out, technical innovation may be a stochastic process. Thus technological advancement may be random and sporadic. Under these circumstances it may be difficult or inappropriate to specify a functional form *a priori*. Therefore the study will employ nonparametric techniques, specifically an Isotonic Robust Super Smoother (IRSS) (Ker and Coble 1998), to estimate the technological component of yield. Technological advancement is likely to be a non-decreasing function. Thus estimates are isonotized, or restricted to be non-decreasing. This is imposed using the pool-adjacent-violators (PAV) algorithm in Hanson, Pledger, and Wright (1973).

In analyzing the relationship between ENSO and crop yield, previous studies have frequently considered linear correlation. This was consistent with early studies indicating a linear relationship between ENSO and weather variables such as precipitation and temperature. However recent attention has found that assumptions of linearity do not always hold. For this reason the study will use nonparametric techniques to estimate the effect of ENSO as well. Specifically, the IRSS is well suited to accommodate the unknown underlying functional form.

To maintain the authenticity of the simulation when estimating the technological component to derive insurance premiums the study will adopt the technique currently used by FCIC: a restricted linear spline function. A spline function is estimated with one knot to accommodate a change in the rate of technological advancement, and is restricted to the class of non-decreasing functions. Additionally, outlying yield realizations are windsorized to obtain a robust estimate of the function.

Various methods have been used to estimate conditional yield densities in the past. These are reviewed in Goodwin and Ker (1998). The study will employ non-parametric kernel density estimation (Goodwin and Ker 1998).

1.5 Layout of the Study

The remainder of the study will be laid out in the following manner. Chapter 2 will review the history of crop insurance and the federal crop insurance program. This will introduce some of the past obstacles in employing "all peril" crop insurance, which help to explain some of the difficulties still faced in its administration today. Chapter 3 will provide an overview of climatological topics and previous literature relevant to the study. An understanding of ENSO and its relationship with crop yield is necessary to properly analyze the impact it may have on the crop insurance industry. Chapter 4 will discuss the data employed. This outlines the manner in which SSTs are averaged to index fluctuations in ENSO conditions. Wheat yield data is also introduced. Chapter 5 details the risk-sharing structure of the 1998 SRA. The various risk-sharing options in the SRA provide a vehicle through which private insurance companies may adverse select. Therefore, its specific is critical to the analysis. Chapter 6 discusses the methodology used in the study. Techniques used to estimate the process of technology and the impact of ENSO on wheat yield are outlined. Yield density estimation is also discussed. Chapter 7 will present the empirical results, including analysis and discussion. Finally Chapter 8 will provide conclusions and policy recommendations.

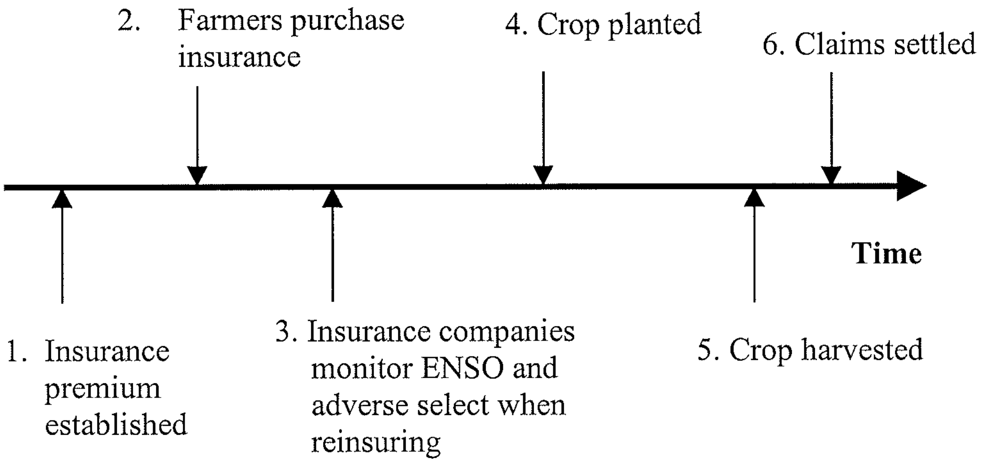

Figure 1.1: Time line of ENSO-based adverse selection.

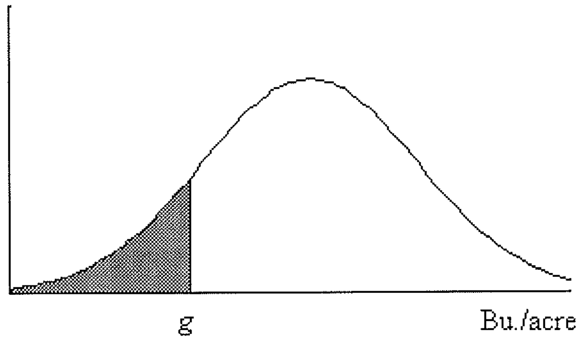

Figure 1.2: Yield density conditioned on

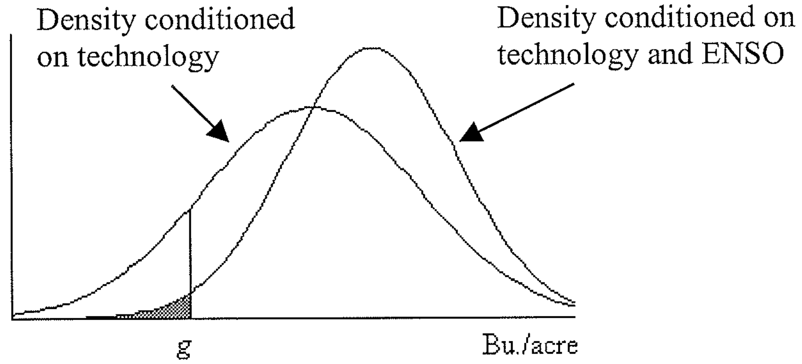

Figure 1.3: Comparison of conditional yield densities.

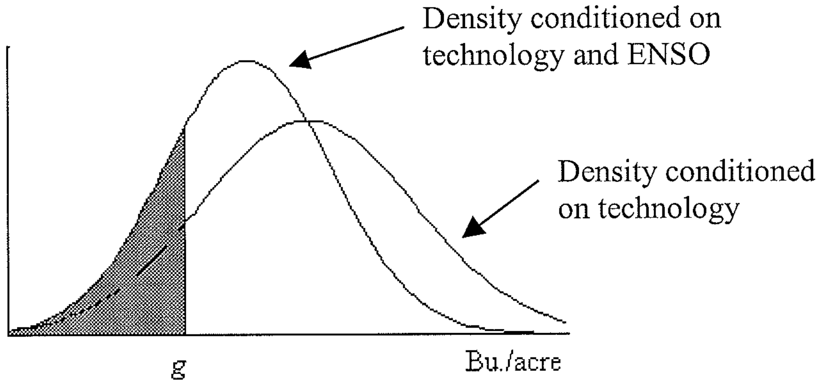

Figure 1.4: Comparison of conditional yield densities.

CHAPTER 2

HISTORY OF THE CROP INSURANCE PROGRAM

By the 1930's several private insurance companies had attempted to administer multiple peril crop insurance (MPCI). However the predominant lack of success eventually lead the federal government to investigate the matter. This resulted in the formation of the FCIC and initiation of the federal crop insurance program. This chapter will review the history of crop insurance and the development of the federal crop insurance program.[2]

A persistent difficulty throughout the history of the crop insurance program has been the inability of FCIC to establish actuarially fair insurance premiums. Most commonly this has been a result of asymmetric information between FCIC and the farmers who purchase contracts. However the introduction of insurance companies to sell and monitor contracts created a new avenue through which this problem could emanate. If the opportunity for ENSO based adverse selection by insurance companies were to exist, it would present another obstacle contributing to the deficiency of the program.

2.1 Early Attempts at Crop Insurance

Insurance coverage guarding crops against fire and hail was commonly available by the end of the 19th century. However all risk policies guarding against non-specific

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[2] For a more complete review of the history of the crop insurance program, from which much of this information was attained, see Kramer (1983a). For an historical review with a detailed discussion of the economics of crop insurance, see Goodwin and Smith (1995).

events were not offered until 1899 when the Realty Revenue Guarantee Co. from Minneapolis Minnesota offered to buy an insuree's entire wheat crop for $5 per acre. The success of the program was not noted but the offer was discontinued the following year. Three companies in the Dakotas and Montana then wrote policies in 1917, however they did not cover a large enough area to adequately spread their risks and suffered heavy losses due to a drought. In yet another attempt, the Hartford Fire Insurance Co. offered a policy guaranteeing both price and yield risk, however sharp declines in crop prices resulted in net losses of over $1.7 million (Kramer 1983a). With such high correlation among producers and little history to work with, early experiments at MPCI had been for the most part unsuccessful. As we will see these common problems still persist today. For example there is minimal information available to establish insurance premiums. The incorporation of information such as ENSO, which is unavailable when premiums are established, allows private insurance companies to better determine production risk than the government.

2.2 Early Discussions at the Federal Level

Motivated by low commodity prices for agricultural products in 1921 and 1922 Senator Charles McNary of Oregon put forth a resolution which led to the appointment of a committee to investigate certain aspects of crop insurance. Particular reference was made to the costs and adequacy of private insurance and the sufficiency of available data on yields, but at the time there was little desire for direct government sponsorship. As Senator McNary stated the committee did not propose to project the Federal Government into the business of writing crop insurance, calling it a field of risk little known to the insurance experts or companies doing an insurance business. Secretary of Agriculture Henry C. Wallace and representatives of the Grange and Farm Bureau agreed, but spokespeople from the farmers National Council declared that the Federal Government ought to pay a large part of the cost of insuring these crops (Kramer 1983a). R. M. Bissell, whose company had tried unsuccessfully to provide crop insurance, argued that the government could help by collecting data but that its more important role would be to allow private companies to form a syndicate to provide the insurance. In these debates we see that from the very outset, questions loomed as to the feasibility of a government run program. Though the need for crop insurance was recognized, officials were hesitant to become actively committed.

By the time McNary's committee reconvened in the fall of 1923 even worse economic conditions in the agricultural sector redirected the interest of Congress to the more immediate measure of relief. No further hearings on crop insurance had been held but within a short time higher yields and exports had alleviated conditions.

Throughout the remainder of the 1920's other initiatives of farm support were discussed. One such proposal outlined by Harvard agricultural economist John D. Black was the domestic allotment plan, which contained an element of crop insurance (Kramer 1983a). All producers were required to purchase an allotment right to the amount they could mill and sell domestically. Farmers whose production fell short of their allotment could then sell the remainder of their rights to another whose allotment had been exceeded, thereby receiving a modest compensation for the shortfall. The domestic allotment plan was promoted and supported by President Franklin D. Roosevelt and Henry A. Wallace (son of the aforementioned Henry C. Wallace) who would later be his Secretary of Agriculture. Several elements of the plan made it into the First Agricultural Act of 1933, but the crop insurance aspect was not one of them.

A popular commodity loan program for cotton and corn also began in 1933, which following the drought of 1934 Secretary Wallace wished to extend to form the basis of an ever normal granary (Kramer 1983a). Under this proposal insurance premiums would be paid and indemnity payments collected in the form of grain rather than cash.

By 1936 a substantial amount of data on cotton and wheat yield had been collected and the USDA's research on crop insurance was renewed. Following the droughts of 1934 and 1936 there was great public interest in crop insurance and not surprisingly it became a campaign issue in the 1936 presidential election. President Roosevelt appointed an interagency committee with representatives from the departments of Treasury, Agriculture, and Commerce to study the possibility of government sponsored crop insurance. Governor Alfred M. Landon of Kansas, a chief campaign opponent of Roosevelt, differed in that he felt a private approach was more appropriate. Many questions were raised about the feasibility of such a plan along with the hope that it would not turn out to be a concealed subsidy to the politically important agricultural industry. Another concern, expressed by the Christian Science Monitor was that it may "become in effect an underwriting of high risk farming areas which in fact ought to be retired from farming and put to grazing, forests or other use instead of burdening steadier farms with cutthroat competition in good years and demand upon them for assistance in bad years." (Kramer 1983b, p.186) These concerns were proven to be justly warranted.

2.3 Federal Crop Insurance Implemented

Despite the skepticism, the President's committee in 1937 recommended the establishment of a federal crop insurance program pertaining only to wheat and to be administered by the USDA. They recommended that policies be sold locally with minimum levels of participation required for a given county or region, and premiums and indemnities to be collected in kind or cash. Furthermore they suggested that rates be calculated on an actuarial basis to cover losses in the long run. A weighted average of the loss experience of the individual farm and that of the county or region was also recommended. Assigning weight to individual farm losses was done to prevent the transfer of losses of incompetent farmers and those on less productive lands, to others in areas of high and regular production. The government would also subsidize the storage and administrative costs.

Senator James Pope of Idaho wrote these recommendations into a bill, and its provisions were part of the Agricultural Adjustment Act of 1938. As Kramer states (1983a), this marked a bold experiment as private attempts to provide crop insurance had largely failed and no previous government programs such as this existed in the U.S. or abroad. Prior to 1930 the federal government had taken an indirect role in its assistance to the agricultural sector. It had provided research and methods of improving marketing and production, such as the establishment of land-grant colleges and experiment stations.

However the establishment of a federal crop insurance program was a big step of direct assistance.

Under the plan farmers could insure between 50 and 75% of their recorded or appraised average yield, against the various losses covered. For a given farm with a yield history, premiums were determined first by calculating the average indemnity had the farm insured at the 50% (75%) level for each year recorded. From this an average loss cost for the farm was determined, which was then averaged with the loss experience of the county to determine the premium.

2.4 Evolution and Performance of the Crop Insurance Program

Early results did not bode well for the program, as nearly 1/3 of the insured farmers collected indemnities resulting in a loss ratio of 1.52. And although there had been a drought in several states, nationally yields had been slightly above average. The shortcomings of the first year led to modifications in determining yields and premium calculations, and participation rose steadily in the next couple of years. Loss ratios were no better at 1.51 and 1.68 in 1940 and 1941 respectively, despite yields 14% and 32% higher than the 15-year average.

In the spring of 1940 Congress passed a bill to include cotton in the program but President Roosevelt vetoed it saying "It seems evident, therefore, that we do not have as yet the essential back log of experience required for the establishment of a sound actuarial basis for crop insurance, i.e. for a crop insurance plan that would be fully self supporting, with premium rates sufficient to cover costs of administration as well as indemnities."

(Rosenman 1940, p.182) Like the early ventures into crop insurance that were discussed in section 2.1, we again see that the lack of information or "back log of experience" was an obstacle in administering a financially sound crop insurance program. This is essentially the same problem introduced by the advances in understanding the relationships between ENSO, weather, and crop yields.

Although the words of President Roosevelt seemed an accurate assessment of the program, he approved a bill that expanded crop insurance to include cotton in 1942. Over the next two years the program was just as unsuccessful. The poor performance and low participation rates prompted Congress to suspend the program in the Agricultural Appropriation Act for 1944, but an amendment to the 1938 Agricultural Adjustment Act brought it back for good by 1945. The program was again expanded to include coverage for more crops and experimental programs on several others, but it allowed the FCIC to not offer insurance in areas of low participation or high risk.

In 1946 FCIC made two significant changes. First, they added in 3-year contracts for wheat. Second, a switch was made to using countywide rates because they believed that the limited data for individual farms was not enough to accurately establish yield variability. Loss ratios however, continued to exceed 1.

In 1947 the loss ratio fell below 1 for the first time, but the program was cut back some and the success was short lived as droughts in the early '50s again inflicted heavy losses. Fourteen counties from Colorado, New Mexico, and Texas which were recognized as high risk and unsuitable for insurance became ineligible as of the 1956 growing season and the program began to level off. Through experimentation with additional crops it grew slowly and continued to remain stable, but the total amount of coverage remained below the level at the time of the cutback in 1947.

The program remained limited and experimental until 1980 when Congress began to subsidize farmer's premiums in an effort to increase participation. The intention was to encourage the use of crop insurance as an alternative to Federal disaster aid, which itself had been a costly burden over the years. In order to handle the anticipated increase in participation, private insurance companies were brought into the industry to sell and monitor contracts.

Participation has ballooned as the Federal Crop Insurance Reform and Department of Agriculture Reorganization Act of 1994 required farmers participating in other USDA Farm programs to purchase a minimum amount of crop insurance (see premium subsidies in table 2.1). This was followed by the 1996 Farm Bill which featured an end to traditional disaster aid. The government's supporting role in MPCI however, remains four-fold. They are responsible for the establishment of premiums, subsidize the farmers payment of premiums, pay the private insurance companies to market the contracts and process the claims, and pay a large portion of underwriting losses as specified in the SRA.

2.5 Conclusions

With the aforementioned changes of farm policy in 1994 and 1996, participation in crop insurance has risen so that 70% of the land in production was covered in 1998. By these actions the Federal Government has fully committed itself to the crop insurance program despite its historic lack of success. Unfortunately, many of the obstacles that contributed to the previous difficulties continue to persist today. The scarcity of data upon which to establish premiums is one example. This leads to information asymmetries which have contributed to the programs persisted deficiencies.

Table 2.1 lists the total expenses incurred by the government in maintaining the crop insurance program throughout the 1990's. On top of premium subsidies, fees to insurance companies, and operating expenses of the FCIC, an additional $1.4 billion was attributed to indemnities paid in excess of premiums (United States General Accounting Office 1998). Adverse selection based on ENSO could threaten to inflate this figure even further. Having made significant strides in the early goal of increasing participation, the challenge ahead in crop insurance lie in managing the program so as to be actuarially sound.

Fiscal year	Claims paid in excess of premiums and other income	Premium subsidy	Administrative expense reimbursements	FCIC operating costs	Government total cost
1990	$279	$255	$325	$104	$963
1991	285	226	282	97	890
1992	261	221	277	99	858
1993	822	217	274	115	1,428
1994	-136	264	312	83	524
1995	196	807	389	109	1,501
1996	90	996	499	65	1,650
1997 (estimated)	-373	945	450	74	1,096
Total	**$1,423**	**$3,931**	**$2,808**	**$747**	**$8,909**

Table 2.1: Government's cost of federal crop insurance.
Constant 1997 dollars in millions. Totals may not add because of rounding.
Source: US-GAO (1998) (p. 25).

CHAPTER THREE

ENSO, CLIMATE, AND CROP YIELD

The Southern Oscillation (Walker 1924) refers to a pendulous swaying of atmospheric pressure over the southern Pacific Ocean. Low barometric pressure in the area of Australia is usually accompanied by higher pressure towards South America, and vice versa. Bjerknes (1969) eventually linked the Southern Oscillation to the warm waters of El Nino and proposed that changes in atmospheric heating due to anomalous sea surface temperatures (SSTs) could actually change mid-latitude circulation and weather patterns.

A full understanding of ENSO and the role it plays in global circulation and weather is necessary to properly incorporate it into any planning or decision strategy. To begin, this chapter will discuss the typical circulation in the Equatorial Pacific and how it is altered by the fluctuations of ENSO.[3] This is followed by an overview of the important characteristics of ENSO-related anomalies and the manner in which they may affect weather and climate patterns throughout the globe. Finally a review of the literature relevant to the study is provided.

3.1 The Pacific Ocean and Atmospheric Dynamics

Normal circulation in the equatorial Pacific region is depicted in figure 3.1. Surface winds typically blow from East to West across the ocean, carrying with them

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[3] For a more thorough discussion of global circulation and the role of ENSO, see Philander (1990), Glantz

warm ocean surface waters which then pile up in the Western Pacific. These East to West winds are known as the Walker Circulation. As the warm waters are carried west, colder water will upwell from the depths below, creating a temperature gradient in the ocean surface waters from East to West. Air over the warm pool will become warm and moist; and because warm air is less dense than cold air it will rise up in the atmosphere. This is known as convection. As the moist air ascends through the atmosphere it will cool and condense to form storm clouds. These convective zones, known as the Intertropical Convergence Zone (ITCZ), are characterized by increased cloudiness and heavy precipitation. The rising air creates permanent low pressure at the surface below, which results in the convergence of surface air to the area. Thus a feedback is created that works to maintain the Walker Circulation.

Along with creating increased cloudiness and precipitation in the immediate area of the ITCZ, the air diverges in the upper atmosphere and will migrate. It will eventually be drained of its moisture and subside over another location creating high pressure and giving off heat. Areas that lie under the descending air are usually characterized by clear dry conditions. These continuous transfers of energy and moisture from the tropics to the mid-latitudes make the ITCZ a critical component of global circulation and energy balance, which has a major impact on climate worldwide.

3.2 El Nino/La Nina and Circulation

During an El Nino event, air pressure in the central Pacific is lower then usual,

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(1996), or Trenberth (1996).

reducing the East-West pressure gradient and weakening the easterly winds. This will prevent the transport of warm water to the West and subsequently the upwelling of cold water from the depths below, resulting in anomalously warm surface water in the Central and Eastern Pacific. Figure 3.2 demonstrates conditions during an El Nino.

As the pool of warm water has shifted to the East, convection and precipitation will intensify and become more concentrated over the Central and Eastern Pacific. Convection and increased air temperatures over the warm water will allow air pressure to become even lower, which further lowers the East-West pressure gradient, and further weakens the easterly winds. Thus a feedback is created allowing the event to intensify. On occasion the air pressure to the East has become so low that the trade winds have not only died but actually reversed direction.

Comparatively, during the cold phase, or La Nina, convection will intensify farther to the West than as usual and subsidence will increase to the East. Conditions become hypernormal. As air pressure becomes even lower in the West relative to the East, the easterly winds strengthen, and the event intensifies. Interestingly the cold phase seems to occur with less frequency than the warm phase.

The geographically displaced zones of convection during an El Nino or La Nina event alter the typical transfer of energy and moisture in the atmosphere. This sets the stage for widespread circulation and climatic anomalies that extend well beyond the tropical Pacific through linked processes known as teleconnections. It is through teleconnections, which are discussed in section 3.5, that ENSO may ultimately impact weather in the U.S. including the state of Texas.

3.3 Life Cycle of an ENSO Event

The life cycle of an ENSO event will usually follow closely with the annual cycle. Figure 3.3 depicts the life cycle of an El Nino/La Nina as measured by SST anomalies in the Nino3 region of the Central Pacific. This is based on a composite of 6 El Nino/La Nina events occurring in the last quarter-century.[4] Notice that SST anomalies will first appear early in the calendar year, and then increase in magnitude. The anomalies will typically peak during the Northern Hemisphere winter, after which temperatures usually return to normal.

Not all events develop in the same manner however. For instance the six major El Nino events prior to 1982 were noted first by an increase in sea temperatures along the South American coast early in the calendar year, with the extent of the warm water covering the entire equatorial region by July. The El Nino of 1982/83 in contrast, saw no increase of sea temperatures off of South America until September and October (Rasmusson and Wallace 1983) where they rose sharply and eventually peaked as one of the most extreme events of the century. Figure 3.4 depicts the same 6 events individually where the somewhat unique development and deterioration of each can be seen. Though most events only last for one year, they will occasionally linger for two or three with multiple peaks.

3.4 The Quantitative Definition El Nino/La Nina

To this point we have yet to define El Nino or La Nina beyond stating that they

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[4] La Nina events included in the composite were of opposite sign.

are two opposing extremes of ENSO. One of the earliest attempts to establish quantitative criteria defining El Nino was offered by Rasmusson and Carpenter (1983).[5] Using the criteria they designated years as either "El Nino" or non-"El Nino", thus enabling a comparison of weather observations from the two subsets. The designation was determined as follows.

During periods of adequate surface marine data (1921-1938, 1948-1979) they considered the average SST between 4-12°South, along a ship track which paralleled the South American coast. Warm events were identified as years that exhibited a maximum positive anomaly > 1.0°C and an anomaly change > 2.5°C between the largest negative anomaly of the previous year to the largest positive anomaly the year of the warm episode. For periods of inadequate ship observations (1875-1920, 1939-1947), Rasmusson and Carpenter based their designation on those years recorded as moderate and strong events as given by Quinn et al. (1978).[6] In cases where the anomalies persisted for multiple years, only the first year of the event was designated.

This particular criteria is somewhat arbitrary but gained acceptance in the scientific community, largely because it quantitatively identified those years which were previously acknowledged to have experienced El Nino events. The index was adequate in identifying anomalies associated with the typical one-year El Nino cycle, but provided no insight into factors that may be significant in non-El Nino years.

Despite having traditionally been thought of in terms of discrete El Nino and La Nina events, the temperature and pressure anomalies that are associated with ENSO

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[5] This article will be hereafter referred to as RC83.

actually fluctuate along a continuum. The familiar terms El Nino and La Nina have merely been adopted to describe conditions as they persist near either of the extremes. Because the deviations associated with ENSO are continuous and not discrete, there is a lack of homogeneity to what may be considered an El Nino or La Nina event. Though the anomalies commonly peak around the end of the calendar year, there is much diversity as to their magnitude and duration. Any implications of these unique characteristics are lost when ENSO conditions are discretely categorized.

Other recent definitions of El Nino or La Nina are delineated somewhat similarly to RC83, but generally suffer the same shortcomings. The shared characteristics of many events render this technique useful, but it is essential to note its limitations. For these reasons we will condition not on the occurrence of an El Nino or La Nina event, but the actual SSTs associated with the yearly fluctuations in ENSO.

3.5 Teleconnections

The weather ultimately observed in a region influenced by ENSO is a combination of both the ENSO signal, and other atmospheric noise (Hoerling and Kumar 1997). The signal is the effect or climatic anomaly attributed to ENSO, while noise represents other climatic processes which may negate, enhance, over-ride, or just interfere with the ENSO signal. As a result the weather observed in an area influenced by ENSO can vary greatly from one event to another. A stronger ENSO signal relative to the noise will allow for more accurate and consistent prediction of subsequent climate and weather.

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[6] Quinn et al. had chronicled El Nino back to the early 1500's using historical and archeological evidence.

It will also provide greater opportunity for ENSO-based adverse selection. Early studies linked ENSO to climatic anomalies in the tropics (e.g. RC83). Although its influence on the U.S. including Texas is not as direct as is seen in the tropics, there exist some patterns common to most events.

3.6 The Role of ENSO on Weather in the U.S.

ENSO has received much attention for its impact on weather in the U.S. over the last two decades. This was largely motivated by the catastrophic consequences associated with past extreme events. As a result, an abundance of studies have outlined regions of the U.S. which exhibit ENSO-related climatic anomalies. Its effect on the state of Texas, in particular, has been well documented.

Many of the earliest studies into ENSO-related climatic anomalies focused exclusively on the impact of El Nino. With greater understanding of ENSO the scope eventually broadened to include La Nina. Ropelewski and Halpert (1986) performed a comprehensive analysis that would become a cornerstone to research in the U.S.[7] Using harmonic vector analysis they identified 4 regions in the U.S. which exhibited a coherent seasonal response to a "typical" El Nino event (Fig. 3.5).[8] Within each region they then looked at time series of data to determine the consistency of the ENSO signal over the period of record. Defining El Nino years as those identified in RC83, they found that in 18 of 22 cases the Gulf of Mexico (GM) region, including much of Texas, experienced

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[7] Ropelewski and Halpert will be referred to as RH.

[8] Temperature or precipitation anomalies associated with ENSO at a given location are plotted as vectors on a map. The direction of the vector indicates the season of the weather anomaly while its length representatives the magnitude. Those areas in which vectors exhibit a similar length and direction are

above normal precipitation in the season from October of the ENSO year through the following March.[9] They also identified an area in the Southeastern United States virtually coinciding with the GM region that experienced abnormally cool temperatures in the winter and spring following an El Nino.

Continuing their work Ropelewski and Halpert (1989) examined 19 regions of the globe with documented El Nino-precipitation relationships, for analogies that may exist during La Nina. They found that 15 of the 19 exhibited a relationship during the cold phase as well, but of the opposite sign. In 13 of these the season of the signal coincided almost exactly as the season of the warm signal, which lead them to conclude that ENSO exhibited a largely linear response. The Gulf of Mexico region in the U.S. again exhibited a relationship, with reduced precipitation during October through April. This is particularly relevant since an expectation of low precipitation or drought would motivate a private insurance company to cede crop contracts to the federal government.

Following the studies of RH, Kiladis and Diaz (1989) again looked at global climatic anomalies associated with the extremes of ENSO. Using a slightly altered definition of El Nino/La Nina, they identified large regions that exhibit a response to both extremes. Warm event signals were again typically opposite those of cold events, supporting the conclusion that it was a largely linear phenomenon. In addition they identified temperature and precipitation anomalies around the U.S. Gulf Coast and inland Texas which were consistent with the findings of RH.

Once a link between ENSO and weather phenomena in the U.S. was clearly

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identified as regions exhibiting a "coherent response" to ENSO.

established, researchers set out to further understand its spatial and seasonal effects. In a study similar to RH86, Piechota and Dracup (1996) applied harmonic vector analysis to Palmer Drought Severity Index (PDSI) data to examine the relationship between the extreme phases of the southern oscillation and drought in the U.S. The PDSI is calculated from time series of temperature and precipitation data and is considered a general measure of drought (Soule 1992). Piechota and Dracup designated El Nino years based on RC83 while cold phase years were defined in the same manner given in RH89; mapping the results they identified four regions showing a coherent response (Fig. 3.6). Upon analyzing the 1900-1993 time series, they concluded that the GM1 region, which consisted mainly of Texas, registered significantly wetter on the PDSI throughout the spring and early summer following the warm phase. In addition the region showed a tendency to be dry following the cold phase. Interestingly the effect of ENSO on drought in Texas extended later into the year than its effect on precipitation and temperature. Therefore it may have a residual influence on wheat growing conditions even after weather has returned to normal.

As an alternative to defining El Nino/La Nina years, Montroy (1997) analyzed the linear relationship between SSTs and monthly North American precipitation anomalies. This study again confirmed many of the well-known teleconnective patterns including those in the area of Texas. Additionally they identified weaker signals yet undetected. More recently however, studies have shown that the assumption of linearity does not always hold. For example Hoerling, Kumar, and Zhong (1997) reported a large non-

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[9] Recall the ENSO year is defined as the year at the onset of the event.

linear component to North American climate anomalies associated with the extreme phases of ENSO. Other non-linearities have been reported by Gershunov and Barnett (1998), Gershunov (1998), and Montroy, Richman, and Lamb (1998). These studies have shown that climatic anomalies observed at one extreme of ENSO are not always reflected at the other.

3.7 ENSO and Crop Yield

As research began to uncover the links between ENSO and weather throughout the world, a logical extension was to consider a similar correspondence with crop yields. Handler and Handler (1983) performed one of the first analyses of this type when they compared deviation in U.S. corn yield with the occurrence of El Nino. They observed that during an El Nino event, there was higher probability of an above average corn crop in the United States. Unfortunately they did not yet attempt to quantify the relationship.

An established link between ENSO and weather in Australia prompted Nicholls (1985) to explore the possibility of a relationship with major agricultural crops. Comparing yield anomalies with both the Southern Oscillation Index (SOI) and SSTs around Northern Australia, he found that many of the large year to year deviations in yield were associated with large changes in the two ENSO variables.[10] He then calculated the correlation between yield deviation and seasonal pressure and SST anomalies (averaged over a three-month season) and found that significant correlation (explaining 20-40% of the variation) existed between ENSO indicators observed prior to planting,

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[10] The SOI was the method first used to quantify the Southern Oscillation. It is calculated as the difference

and the yields of wheat, barley, oats, and sugar cane. In later studies, Nicholls (1986) and Rimmington and Nicholls (1993) showed that sorghum and wheat yields were significantly correlated with the Southern Oscillation as much as six months prior to planting.

These studies in Australia demonstrate that yield may not only be altered by ENSO, but that an indication of this may be offered well ahead of time. Initial inferences of expected yield can be made well in advance and then updated with more certainty as lead-time decreases. If this information were not available to all parties involved in an insurance contract on the crop, there would be a significant opportunity for adverse selection.

Examining the correlation between crop yield and ENSO is a different approach to analysis than RH and most methods previously discussed. This offers an advantage in that it is more informative than simply categorizing years as El Nino, La Nina, or neutral. By utilizing SSTs or the SOI directly, one may consider the actual magnitude of the anomaly. In addition this recognizes that ENSO fluctuates along a continuum and conditions may lie anywhere between the extremes of El Nino and La Nina. This may be valuable information that is retained in the analysis.

Because of its importance as a commercial crop and its vulnerability to weather stress, studies have focused on the relationship between ENSO and corn in the U.S. Building on his earlier work, Handler (1990) looked at the correlation between corn yield and SSTs on a ship track along the South American coast. Although at the time studies

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of surface air pressure at Tahiti minus the surface air pressure at Darwin, Australia.

such as RH86 had not shown a relationship between ENSO and precipitation in the Corn Belt, there had been much discussion of this following the drought of 1988. Using data from 1867-1988 for 41 states, Handler found that in general correlation was strongest during the early and late part of the record, and weak to non existent from about 1910 to 1950. Looking more closely at the period of 1961-1988, he found that correlation was significant in only Florida and the Corn Belt.

The literature has shown that the region of the U.S. most consistently influenced by ENSO is the Gulf coast including much of the state of Texas. RH86 indicated that this area experience increased precipitation and cooler temperatures during the winter at the peak of an El Nino. Piechota and Dracup (1996) agreed with this showing a negative tendency towards drought in the spring and early summer following the peak of an El Nino. Likewise they demonstrate negative precipitation anomalies and a tendency toward drought are associated with the peak of the cold phase.

In areas such as Texas that experience a mild winter, wheat is planted in the fall so that it may get an early start in growing before the hot summer arrives. Above normal soil moisture conditions after planting and during the winter are extremely beneficial to this crop (Ash and Lin 1987). Conversely, hot weather during March, April, and May can noticeably reduce crop prospects. In this regard El Nino may provide the optimum conditions for growing winter wheat in Texas. Similarly the dry conditions associated with La Nina would provide less than optimum conditions for growing winter wheat.

Mjelde and Keplinger (1998) undertook a study to evaluate the potential to use ENSO in predicting Texas wheat yield. Using a time series of statewide yields (1876-

1993) and 0-1 dummy variables noting warm and cold events, they found that both ENSO variables were significant at the 0.05 level for the full-time series as well as for a subset beginning in 1953. Prior to 1953 however, they found El Nino to be statistically significant but not La Nina. They then conducted a simulation where the model was repeatedly used to forecast yield one year in advance and then updated. Although inclusion of the ENSO variables reduced mean squared error, it did not translate into significantly better out of sample predictive power. Predictive power may be improved however, by retaining the actual SST values rather than using the less informative dummy variables. In addition, smaller scale county data rather than state level may be more appropriate since the impact of ENSO may vary spatially across an area as large as Texas.

3. 8 Conclusions

The oceanic and atmospheric anomalies associated with ENSO typically appear early in the calendar year and peak the following winter before returning to normal. Though most events only last for one year, they will occasionally linger for two or three with multiple peaks. The geographically displaced zones of convection during an El Nino or La Nina will then lead to widespread circulation and climatic anomalies through linked processes known as teleconnections. The state of Texas in particular has experienced winters that were typically colder and wetter during El Nino, while dryer during La Nina.

Difficulty arises because the definition of an event is not universal in the literature, and is somewhat subjective to the author. This is discussed in more depth by Trenberth (1997b). Furthermore, the rigid defining of an event fails to recognize that ENSO is not a discrete phenomenon but fluctuates along a continuum. To circumvent these problems, this study will condition not on the occurrence of an event but on actual sea surface temperatures. This will recognize the continuous nature of ENSO.

As we improve our understanding of ENSO and its role in global circulation and climate, it will become an increasingly valuable tool for long range planning and decision making. In Peru ENSO forecasts are incorporated into the National Planning policy for agriculture (Lagos and Butler 1992). In Australia the Queensland Department of Primary Industries as well as the Australian Bureau of Meteorology has encouraged producers to use Southern Oscillation based forecasts as a management tool (Patridge 1994).

Here in the U.S. Mjelde et al. (1997) showed that ENSO information could be used to increase the value of corn production by $1-2 per acre in East Central Texas. They demonstrate that ENSO-based forecasts of precipitation in the pre-planting season can help determine profit-maximizing levels of inputs. By knowing how much preseason rainfall to expect, producers who apply fertilizer in the fall or before the end of the preseason can adjust their input levels accordingly. Furthermore this information can help input dealers in their planning and provide insight into expected yields, aggregate supply, and ultimately market prices.

An understanding and assessment of the role ENSO and forecasting will take in the crop insurance industry is necessary to efficiently exploit any benefits this forthcoming science may provide. We focus this analysis on the insurance market for

Texas winter wheat to for two reasons. First, ENSO exhibits a much publicized impact on the weather in Texas. This makes Texas wheat a good likely starting point for insurance companies to engage in ENSO-based adverse selection activities. Second, as outlined in the following chapter, data for this analysis is readily available. In actuality, insurance companies are not likely to base adverse selection activities on a global phenomenon such as ENSO-related SSTs, but local predictors such as regional long-term weather forecasts which would consider SSTs. In the broader context of weather based adverse selection, conditioning solely on SSTs can be viewed as a case utilizing the least information available.

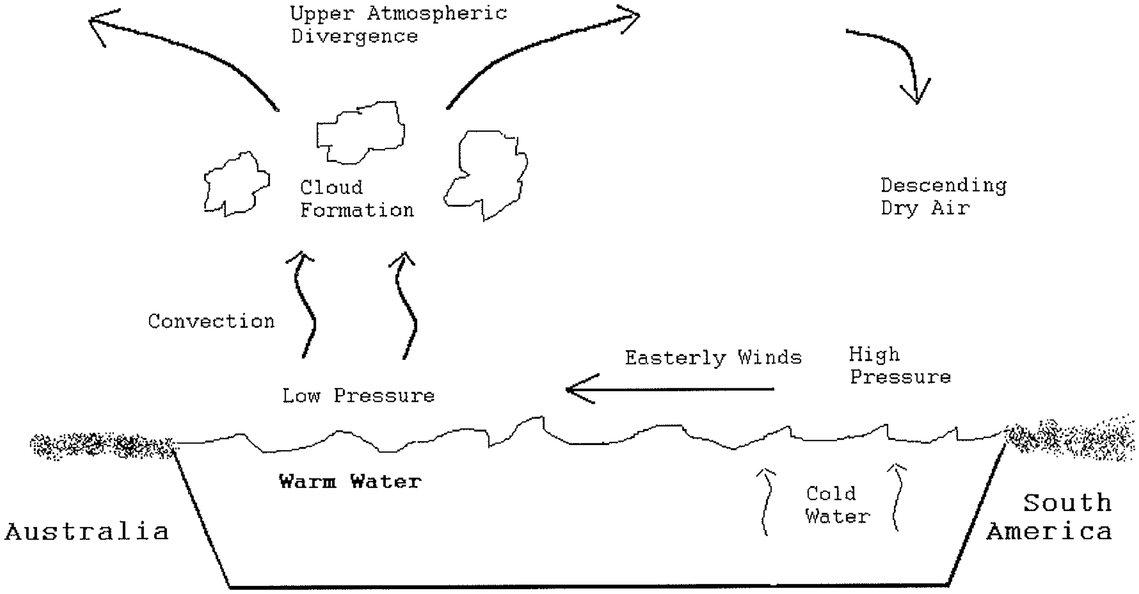

Figure 3.1: Normal circulation in the equatorial Pacific

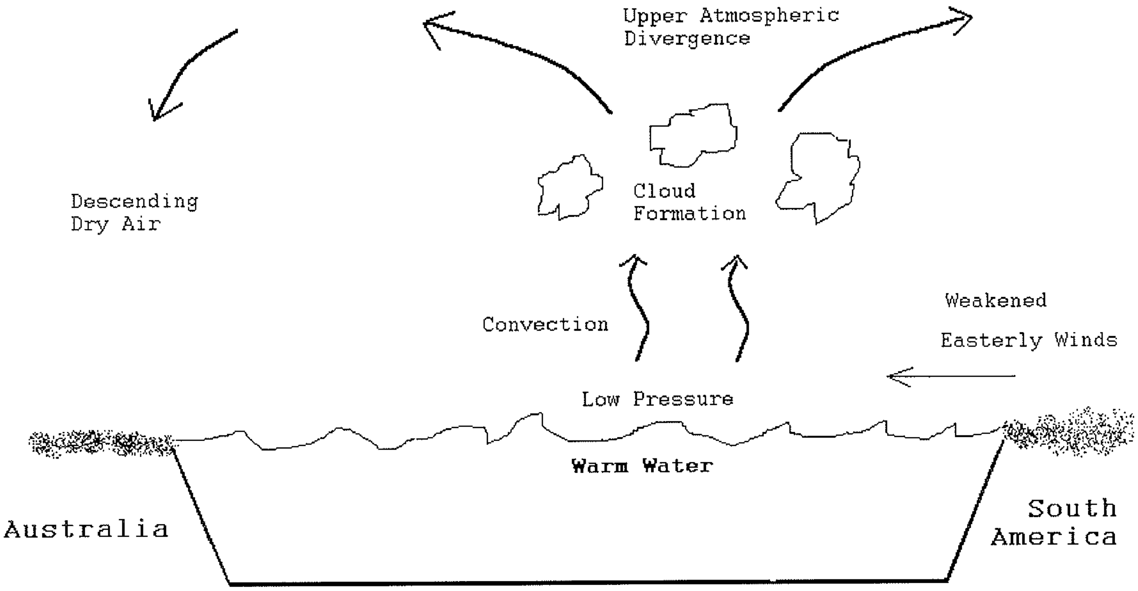

Figure 3.2: Circulation during El Nino.

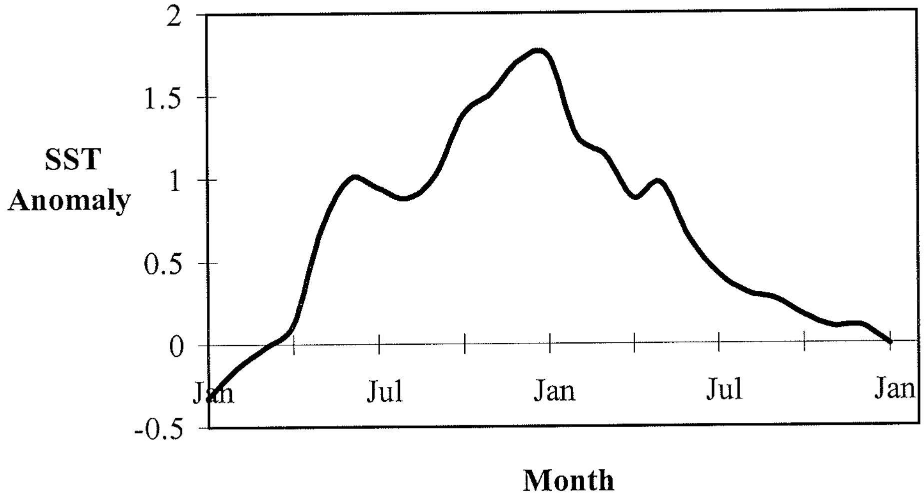

Figure 3.3: ENSO composite cycle. Life cycle of ENSO-related SST anomalies composited from six recent El Nino/La Nina events.
La Nina events were of opposite sign.

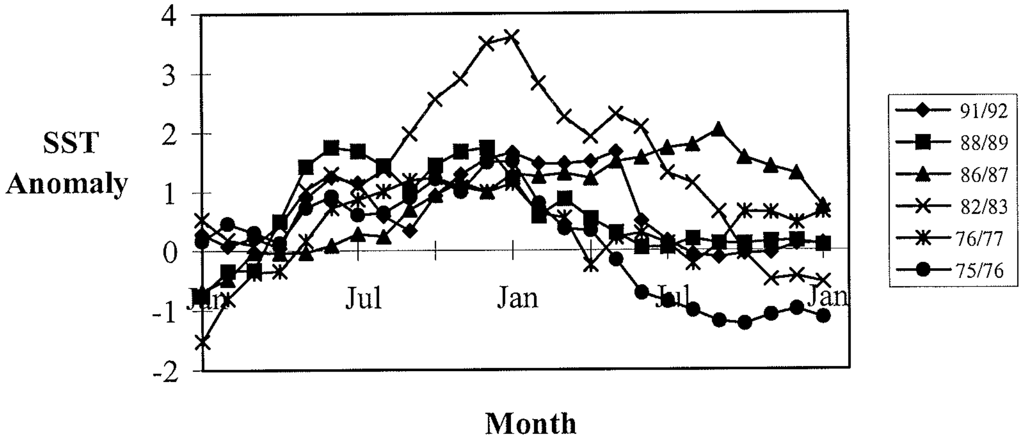

Figure 3.3: ENSO cycle. SST anomalies associated with six recent ENSO events.
La Nina events (1975/76 and 1988/89) were of opposite sign.

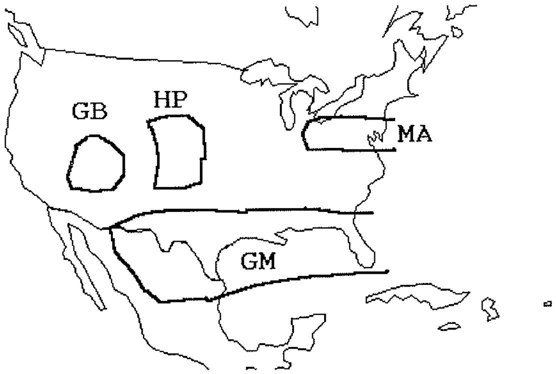

Figure 3.5: Regions exhibiting a coherent response to El Nino.
Source: Ropelewski and Halbert (1986)(p. 2364).

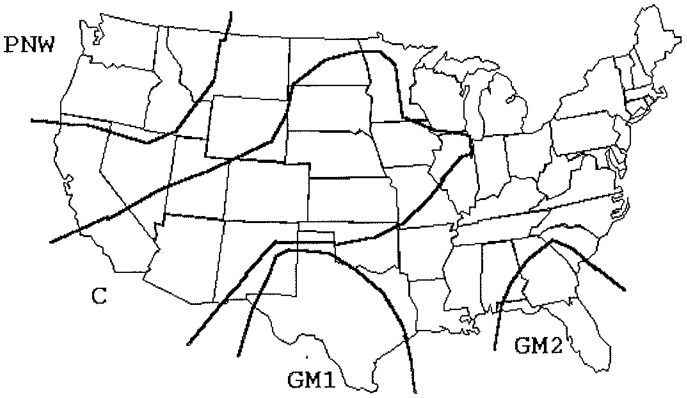

Figure 3.6: Regions exhibiting a coherent response of the PDSI.
Source: Piechota and Dracup (1996)(p. 1361).

CHAPTER 4

DATA

In the state of Texas, El Nino is associated with above normal precipitation throughout the winter and spring with a reduced likelihood of drought continuing into the early summer. These conditions are very beneficial to the production of winter wheat. Conversely La Nina is associated with below normal winter and spring rainfall with an increased likelihood of drought continuing into the early summer. These conditions are not beneficial to the production of winter wheat. Not surprisingly, research has shown that there is a statistically significant relationship between ENSO and wheat yield. This makes Texas wheat a likely starting point for insurance companies to engage in ENSO-based adverse selection activist. This chapter will discuss the data to be employed in the study. Specifically, the process by which sea surface temperatures are spatially averaged to serve as an indicator of ENSO is explained. In addition, the wheat yield data is discussed.

4.1 Sea Surface Temperatures

The Southern Oscillation was first quantified using the SOI. Since it has been linked to El Nino, ENSO has also been measured by changes in SSTs, which show less sporadic variability. Research has outlined four regions (named Nino1-Nino4) of the Pacific Ocean that are considered critical to ENSO and they are pictured in Figure 4.1.[11]

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[11] Another region commonly discussed in the literature is the Nino3.4 region, which simply encompasses a

The region considered for analysis in this study is the Nino3.

The Nino3 region of the Pacific is defined specifically as the area lying between 5°North - 5°South latitude and 150°West-90°West longitude. This is the region of the Pacific most strongly affected by the cold water upwelling discussed in sections 3.1 and 3.2 so its surface temperatures vary greatly with the changing phases of ENSO. During an El Nino the upwelling is inhibited so the Nino3 region will exhibit positive temperature anomalies; while in the event of La Nina the upwelling is enhanced, so the temperature anomalies will be negative. For this reason it is a commonly used index of ENSO.

Following previous work such as Handler (1990), and Rimmington and Nicholls (1993), sea surface temperature values used in the study will be averaged over a 3-month season. The closing date for wheat contracts in Texas is September 30th and insurance companies are afforded an additional 30 days to make decisions regarding reinsurance (White 1998). Thus July-August-September SSTs will be the most current available information for insurance companies to incorporate into their decision strategy.

Recall the El Nino composite in Fig. 4.3. Sea surface temperature anomalies typically peak in the season of November-December-January, so it is often the best indicator of year to year variation in ENSO. Note however that anomalies typically first appear earlier in the calendar year. Thus July-August-September anomalies serve as a good indication of forthcoming ENSO conditions in the critical winter months. Though yield is not as highly correlated with SSTs in July-August-September as it is with SSTs in

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portion of the Nino3 region and an adjacent portion of the Nino4 region.

November-December- January, the difference is only moderate as temperatures in the two seasons are themselves highly correlated (Pearson correlation coefficient = 0.85). As the interest of this study concerns the opportunity for adverse selection in the insurance market, analysis is best served to focus on the relationship between wheat yield and SSTs observed in July-August-September prior to planting.

Sea surface temperature data was obtained from the U.S. Department of Commerce, NOAA, Climate Prediction Center. Temperatures are reported in degrees centigrade as monthly averages for the Nino3 region. These monthly values are calculated in two ways.

Since November 1981, sea surface temperatures have been analyzed on the entire ocean surface using a method of optimum interpolating (OI) as described in Reynolds and Smith (1994). The analysis is done weekly and combines in situ (ship or buoy) SST data, satellite SST retrievals, and sea ice coverage to calculate global SSTs on a 1° grid. These grid points are known as OI fields. The weekly OI fields are then linearly interpolated to produce daily values, which are then averaged over the appropriate number of days to produce monthly OI fields. Monthly temperatures for the Nino3 region as a whole are then obtained by taking an average of the monthly OI fields within the region.

SST's prior to November 1981 have been reconstructed using a method detailed in Smith et al. (1996). The more accurate OI analysis from 1982-1993 is used to fit empirical orthogonal functions (EOFs) to historic in situ SST data in a least squares sense. These functions are then used to construct the complete SST field from in situ data for the years 1950-1981.

SST anomalies are then calculated on a base period of 1950-1979 as described in Reynolds and Smith (1995). Finally anomalies for the months of July-August-September are averaged for each year included in the analysis to obtain the seasonal value for the region.

4.2 Wheat Data

In 1997 the state of Texas planted 6,300,000 acres of wheat ranking it 4th nationally with about 9% of the total wheat producing land area in the United States. Essentially all of the wheat grown in Texas is winter wheat. In this region grains are often planted for grazing and ultimately go unharvested. To avoid contamination from this practice, the study will consider yield averaged as bushels per acre harvested. This measure differs from convention, as it will overlook crops that may be planted and abandoned do to failure. However it will provide a suitable representation of the impact of ENSO while avoiding the more serious contamination introduced by grazed lands.

Mean wheat yield at the county level from 1956 to 1997 was obtained from the National Agricultural Statistical Services (NASS). The study will consider the 55 largest wheat producing counties in Texas. This encompasses over 85% of the wheat acreage harvested throughout the state in 1997. Individual farm rather than county data would be ideal, as the majority of crop policies are sold at the farm or sub-farm level. However given the periodicity of ENSO fluctuations there is insufficient farm level data to conduct a credible analysis of ENSO based adverse selection. In addition, private crop insurance companies will often base reinsurance decisions at the county level, rather than the farm level. Thus county level data is suitable for the study.

4.3 Conclusions

Research has shown that ENSO exhibits a significant influence on weather and wheat yield in Texas. Therefore Texas wheat is a likely starting point for private insurance companies to engage in ENSO based adverse selection activities. To determine the extent to which private insurance companies may inflate government losses through ENSO based adverse selection, this study will perform an analysis on the 55 largest wheat-producing counties in Texas. The final date for reinsurance decisions on Texas wheat is in October, so Nino3 SSTs are average over the three month span of July-August-September to index the annual variation in ENSO conditions. In practice it is more likely that an insurance company would condition reinsurance decisions on variables such as local weather forecasts. Local forecasts would consider ENSO conditions so conditioning on SSTs can be viewed as a lower bound on the opportunity for weather based adverse selection.

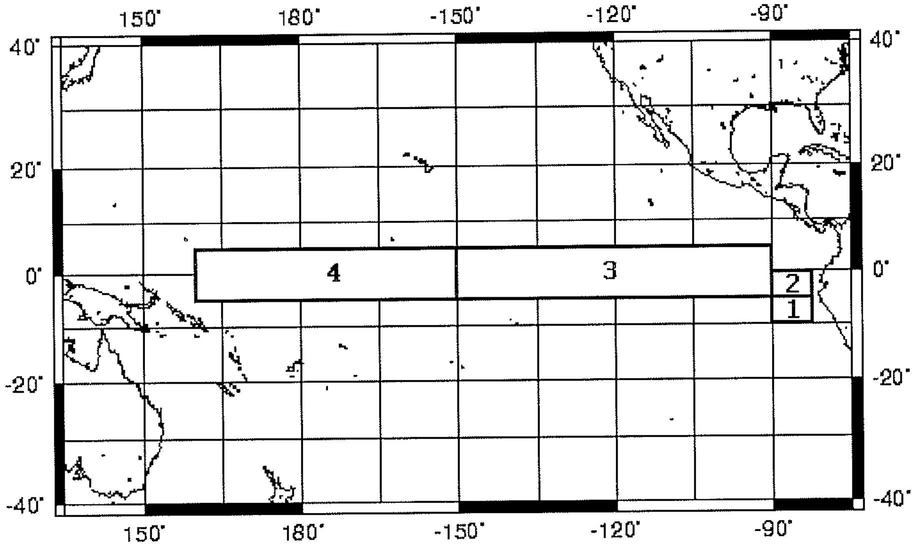

Figure 4.1: Regions of the Pacific critical to ENSO. Nino1-4.

CHAPTER 5

THE STANDARD REINSURANCE AGREEMENT

Although the SRA is renegotiated annually, substantive changes are generally not made every year. The 1998 SRA designates three separate funds to which an MPCI contract may be assigned: the commercial, developmental, or assigned risk. Reinsured companies are required to retain a minimum portion of underwriting gains or losses, however their share varies in each fund. The different options in reinsurance allow companies some liberty as to whether they wish to heavily guarantee a contract themselves or cede it to the federal government. Thus, the SRA provides a vehicle through which reinsured companies may engage in adverse selection activities.

Section 5.1 of this chapter will outline the specific risk-sharing structure of the 1998 SRA. Numerical examples are used to illustrate the manner in which underwriting gains and losses are divided between the federal government and private insurance companies. Section 5.2 presents an example of ENSO-based adverse selection. Through estimation of the yield distribution conditioned on technology and SSTs, insurance companies can estimate their expected profit from each of the three reinsurance funds. This will allow them to strategically assigned contracts to the various funds in an attempt to maximize profit,

5.1 Risk Sharing Structure of the 1998 SRA

Under the 1998 SRA there is a two-tiered risk sharing structure for each fund in the program. In the first tier, private insurance companies retain a pre-selected share of the funds underwriting gains/losses while FCIC will accept the remainder (table 5.1). In the assigned risk fund, the private insurance company (PIC) share is bounded on the bottom at 20%, and they may select to retain up to 100%. In the developmental and commercial funds, they may select to retain 35-100% and 50-100% respectively. A PIC must select the share they wish to retain at the first-tier by July 1 of the preceding crop year.

In the second-tier of the SRA, underwriting gains/losses are divided according to the loss ratio of the fund. The second tier shares for each fund are illustrated in table 5.2. Note that the second tier shares are applied marginally. For example, if the loss ratio in the commercial fund were 2, a PIC would retain 50% of the losses that inflated the loss ratio to 1.65, and 40% of the losses that inflated the loss ratio from 1.65 to 2. This structure is made clearer in an example below. Note that the assigned risk fund requires companies to retain only a negligible amount of the underwriting gains/losses relative to the developmental and commercial funds, in which they retain a moderate and large share respectively. The share of the gains or losses retained by a PIC at the second tier, is then multiplied by the share they retain at the first tier, to determine their final underwriting gains or losses from each fund.

A maximum limit is placed on the amount of premiums that may be placed in the assigned risk fund. In Texas, for example, companies may place no more than 75% of their statewide premiums to the assigned risk fund. There is no limit to the amount of premiums that may be placed in the developmental or commercial funds. A numerical example will help illustrate the risk sharing structure of the SRA.

Assume that a PIC were to designate contracts to the assigned risk fund with premiums that total \$1 million. Assume also that claims for those policies were \$3 million. Therefore, the total loss for the fund is \$2 million. At the first tier the company would retain 20%, and thus \$400, 000 of the loss ($0.2 \times \$1.0 - 0.2 \times \$3.0 = -0.4$). At the second-tier however, the PIC would retain a share of those losses based on the loss ratio of the fund. Given the loss ratio is 3.0, the PIC would accept 5% of the losses that inflate the loss ratio for 1.0 to 1.6, 4% of the additional losses which inflate the loss ratio up to 2.2, and 2% of any remaining losses. Therefore, the PIC would accept a total loss of only \$14,000 ($(1.6 - 1.0) \times \$1m \times .2 \times .05 + (2.2 - 1.6) \times \$1m \times .2 \times .04 + (3.0 - 2.2) \times \$1m \times .2 \times .02 = \$6,000 + \$4,800 + \$3,200 = \$14,000$). This would be a relatively negligible portion (<1%) of the overall loss for the fund.

Consider a second example of the risk sharing structure. Assume that a PICwere to assign policies to the commercial fund with premiums that total \$3 million, and that claims for these policies were \$1 million. Therefore, the total profit for the fund is \$2 million. In addition, assume that the company had agreed to retain 100% of the profit/losses at the first tier. At the second-tier however, the PIC must share those profits with FCIC. Given the loss ratio of 0.33, the PIC would retain 94% of the profits that bring the loss ratio down to 0.65, 70% of the additional profits which bring the loss ratio down to 0.5, and 11% of the additional profits which bring the loss ratio down to 0.33.

Therefore, the insurance company would retain a profit of \$1, 357, 600 ((1.0 – 0.65) × \$3m × 1 × 0.94 + (0.65 – 0.5) × \$3m × 1 × .7 + (0.5 – 0.33) × \$3m × 1 × 0.11 = \$987, 000 + \$315, 000 + \$55, 000 equals \$1, 357, 600). This represents a substantial portion (approximately 68%) of the total profits.

It becomes readily apparent that the different options in reinsurance provide a vehicle for private insurance companies to engage in adverse selection activities. If PICs can use ENSO to evaluate the risk in a forthcoming crop year, they can use this information in deciding how to allocate the contracts that they sell. If conditions indicate there will be little risk on a contract, they may allocate it to the commercial fund and retain a majority of the liability. Conversely if conditions indicate that forthcoming risk is likely high, they may prefer to retain minimal liability and place it in the Developmental and/or Assigned Risk fund. An example will demonstrate the calculation of insurance premiums and the incorporation of SSTs into the reinsurance decision.

5.2 An Example of Adverse Selection in the Insurance Market for Wheat

The Risk Management Agency (RMA) is the branch of USDA responsible for the establishment of insurance premiums. To calculate an insurance premium, the RMA will use historic yield data to estimate the conditional yield distribution $\hat{f}_{RMA}(y_t|t)$. This is done over a year in advance so information is not yet available as to the weather expected during the growing season for the insured crop. Historic data are modeled as some function of the technology employed, while weather variability including the effect of SSTs is encapsulated in a disturbance term. However assume that a PIC may incorporate the relationship between wheat yield and SSTs into the model, which will allow estimation of the conditional yield distribution $\hat{f}_{PIC}(y_t|t, SST)$. This distribution will have an alternative expected yield, and because the disturbance attributed to SSTs has been explained, it will have less variance. An insurance premium based on $\hat{f}_{PIC}(y_t|t, SST)$ will differ from a premium based on $\hat{f}_{RMA}(y_t|t)$, and will more accurately reflect the risk involved in production. The opportunity for adverse selection created by these differing distributions will be demonstrated numerically.

The risk portion of an insurance premium is calculated as

$$\text{premium rate} = \frac{\text{expected loss}}{\text{total liability}}$$

$$= \frac{P(y < \lambda y^e)(\lambda y^e - \mathrm{E}[y \mid y < \lambda y^e])}{\lambda y^e} \tag{1}$$

where y is yield, y^e is expected yield, and λ ($0 < \lambda < 1$) is the percentage of y^e that the contract will guarantee. Thus in the event that yield falls short of the guarantee level ($y < \lambda y^e$), the contract will pay an indemnity equal to the shortfall ($\lambda y^e - y$).

For simplicity in this example, assume that yields are Gaussian in distribution. The expected loss or shortfall based on a Gaussian distribution and a chosen coverage level λ is given by

$$\text{Expected loss}_\lambda = \Phi\left(\frac{\lambda y^e - y^e}{\sigma}\right)(\lambda y^e - y) + \phi\left(\frac{\lambda y^e - y^e}{\sigma}\right)\sigma \tag{2}$$

where Φ is the standard Gaussian c.d.f., ϕ is the standard Gaussian p.d.f., and σ is the standard deviation of yield y. This is based on the expected value of a truncated Gaussian distribution. If $Ƶ \sim N(\mu,\sigma^2)$ and δ is a constant and the truncation is $x < \delta$, then $E[Ƶ|\delta] = \mu - \sigma\,\phi(\alpha)/\Phi(\alpha)$ where $\alpha = (\delta-\mu)/\sigma$.

Unable to condition on SSTs, the RMA would gather data and estimate the yield distribution $\hat{f}_{RMA}(y_t|t)$. Assume that $\hat{f}_{RMA}(y_t|t)$ is represented by a Gaussian distribution such that $y^e = 25$ and $\sigma = 9$. Note that the standard deviation, σ, represents the variability in crop yield including the effect of SSTs. Assume that the contract is to guarantee 80% of the expected yield ($\lambda = 0.8$). Substituting these values into equation (2) the RMA would recover the corresponding premium rate

$$P_g = \Phi\left(\frac{20-25}{9}\right)(20-25) + \phi\left(\frac{20-25}{9}\right)9 = 1.63 \qquad (3).$$

Thus for a contract that were to guarantee 20 bushels per acre of wheat ($\lambda y^e = 0.8 \times 25 = 20$), RMA would charge a price that reflected an expected shortfall of 1.63 bushels/acre.

However, assume that a PIC were aware that there is a relationship between yield and SSTs. By monitoring SSTs prior to the reinsurance deadline, they observe an indication of forthcoming growing conditions and hence wheat yields. This will allow them to estimate $\hat{f}_{PIC}(y_t|t,SST)$ which may indicate an alternative expected yield (y^e). In addition $\hat{f}_{PIC}(y_t|t,SST)$ will have a smaller variance since they have explained the variability due to SSTs. This alternative distribution will more accurately reflect the true risk in production.

To continue the numerical example, suppose that SSTs indicate that conditions likely will not be favorable for growing wheat. Assume that $\hat{f}_{PIC}(y_t|t, SST)$ were represented by a Gaussian distribution such that $y^e = 18$ and $\sigma = 7$. This is depicted in figure 5.1. Substituting this information into equation (2), we can more accurately calculate the shortfall expected on a contract that were to guarantee a yield of 20 bushels per acre:

$$\Phi\left(\frac{20-18}{7}\right)(20-18)+\phi\left(\frac{20-18}{7}\right)7 = 3.89 \qquad (4).$$

Notice the expected shortfall conditioned on SSTs is higher than that calculated by RMA and charged to producers. For every \$1.63 collected in premium there is an expected loss of \$3.89. An insurance company would likely suffer a loss if they were to guarantee this contract and accept 100% of the underwriting gains or losses.

However in accordance with the 1998 SRA, the underwriting gains and losses are shared between PICs and the government. Companies may designate a contract to one of the three reinsurance funds, with their share of the gains/losses varying in each. Assume that PICs are risk-neutral with an objective of maximizing profit. Given a choice of three funds to which a contract may be assigned, a logical decision criteria would be to select the fund which offered the highest expected expected profit. Thus we require the expected profit from each of the three funds.

The profit on an insurance contract is equal to the price of the premium less the indemnity. For demonstration purposes, assume that the true distribution of yield were given by the conditional yield distribution $f_{PIC}(y_t|t, SST)$. The domain of f_{PIC} will then represent the set of all possible yield outcomes. At a given yield outcome y, we can then define the indemnity as:

$$\text{indemnity} = max\ (0,\ \lambda y^e - y) \quad (5).$$

Continuing the numerical example, if the yield distribution were given by $\hat{f}_{PIC}(y_t|t, SST)$ ~ Gaussian (18, 7), then the corresponding distribution of indemnity on a contract that were to guarantee 20 bushels is depicted in Fig. 5.2. Notice it is a mixed distribution consisting of a continuous portion coinciding with the event of a shortfall $(y < 20)$, and a discrete portion otherwise. Subsequently the pure profit on a contract is defined:

$$\pi(y) = \begin{cases} P_g & \text{if } y \geq \lambda y^e \\ P_g - (\lambda y^e - y) & \text{if } y < \lambda y^e \end{cases} \quad (6)$$

where P_g is the price of the premium as calculated by RMA and charged to producers. Thus if harvested yield were to meet or exceed the level of guarantee ($y \geq \lambda y^e$) then profit will equal the price of the premium, P_g. In the event of a shortfall ($y < \lambda y^e$) profit will equal the price of the premium less the shortfall, or $P_g - (\lambda y^e - y)$. The distribution of profit for this example is depicted in Figure 5.3.

This is not the profit or loss retained by the insurance company, but rather the total profit/loss for the contract. The total is shared between the insurance company and the government in accordance with the SRA. The profit retained by an insurance company at yield y can be defined as:

$$s = \pi(y)\rho(y) \quad (7)$$

where ρ is the share of total profit retained by the insurance company. As outlined in section 5.1, ρ is determined by the loss ratio of the fund and varies in each of the three. We can then define the distribution of PIC profit as f_s which will likewise differ for each of the three funds. Subsequently the expected PIC profit for a fund is given by:

$$\pi_{PIC}^{e} = E[s] = \int s f_s dy \tag{8}$$

where E is the expectation operator.

Figure 5.4 compares the cumulative distribution of PIC profit for the numerical example in both the commercial and assigned risk funds.[12] It is evident from the diagram that reinsured companies retain a negligible share in the assigned risk fund relative to the commercial. Their share in the developmental fund (not pictured) lies between the two.

If we calculate the PIC expected profit for each fund, we find it is negative in all three cases (Table 5.4). This is not surprising since $\hat{f}_{PIC}(y_t|t, SST)$ had indicated unfavorable growing conditions. Therefore, a risk-neutral insurance company would place the contract in the assigned risk fund in an attempt to minimize their loss.

It is important to note that in actuality the loss ratio for each fund will depend on every contract that is placed in it. This would require an immense number of possible yield combinations and the knowledge of which contracts were to be in each fund. By calculating expected profit on each contract individually, we are assuming that it is the only in each fund. Thus the loss ratio of the fund, which determines the second tier shares, is assumed equal to the loss ratio of the contract.

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[12] It is assumed that the insurance company would accept 100% of the liability at the first tier.

For demonstration purposes consider another example. Suppose that SSTs indicate favorable conditions for growing wheat. Assume that an insurance company were to estimate that $\hat{f}_{PIC}(y_t|t, SST)$ is represented by a Gaussian distribution such that $y^e = 30$ and $\sigma = 7$. This is depicted in figure 5.5. Substituting this information into equation (2), we can calculate the shortfall expected on a contract that were to guarantee a yield of 20 bushels per acre:

$$\Phi\left(\frac{20-30}{7}\right)(20-30) + \phi\left(\frac{20-30}{7}\right)7 = 0.24 \qquad (9).$$

Notice the expected shortfall conditioned on SSTs is lower than that calculated by RMA and charged to producers. For every \$1.63 in premium there is an expected loss of only \$0.24. It would likely profit an insurance company to guarantee this contract if they were to retain 100% of the underwriting gains or losses.

Taking the SRA into consideration, figure 5.6 compares the cumulative distribution of PIC profit for the commercial and assigned risk funds. Again the relatively negligible share in the assigned risk fund is evident. If we calculate the PIC expected profit for each of the three funds (Table 5.4), we find it highest for the commercial in which they retain the largest share of the underwriting gains or losses. This is expected considering $\hat{f}_{PIC}(y_t|t, SST)$ had indicated favorable conditions. Thus in this example the insurance company would assign the contract to the commercial fund.

5.3 Conclusions

The two-tiered risk sharing structure of the SRA allows insurance companies to accept varying portions of the underwriting gains or losses in each of the three available reinsurance funds. Their share varies from substantial in the commercial fund to relatively negligible in the assigned risk fund.

Insurance premiums are established by the RMA a year in advance using the conditional yield distributing $\hat{f}_{RMA}(y_t|t)$. However, by monitoring SSTs prior to the reinsurance deadline, a PIC can estimate the conditional yield distribution $\hat{f}_{PIC}(y_t|t, SST)$. This will provide a more accurate estimation of the production risk than $\hat{f}_{RMA}(y_t|t)$ as used by the RMA. Insurance companies may use $\hat{f}_{PIC}(y_t|t, SST)$ to estimate the expected profit of a contract from each of the three reinsurance funds, and assign it accordingly. This practice will allow them to keep a large portion of the underwriting gains/losses when conditions are favorable, while ceding a majority to the government when conditions are unfavorable. In time this practice may inflate government losses and threaten the integrity of the crop insurance program.

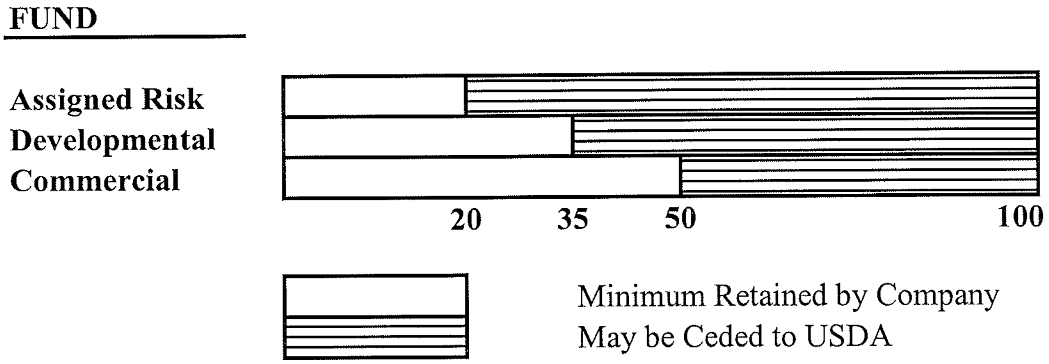

Table 5.1: Proportion of underwriting gains/losses retained by insurance company and proportion ceded to USDA at the first tier.

Loss Ratio	Assigned Risk	Developmental	Commercial
0.00 - 0.50	2.0%	6.0%	11.0%
0.50 - 0.65	9.0%	50.0%	70.0%
0.65 - 1.00	15.0%	60.0%	94.0%
1.00 - 1.60	5.0%	25.0%	50.0%
1.60 - 2.20	4.0%	20.0%	40.0%
2.20 +	2.0%	10.0%	17.0%

Table 5.2: Percentage of underwriting gains/losses retained by insurance company at the second tier.

	Commercial	Developmental	Assigned Risk
Expected Profit	-0.46	-0.23	-0.01

Table 5.3: Expected profit/loss by fund.

	Commercial	Developmental	Assigned Risk
Expected Profit	0.70	0.46	0.02

Table 5.4: Expected profit/loss by fund.

Figure 5.1: Density of yield

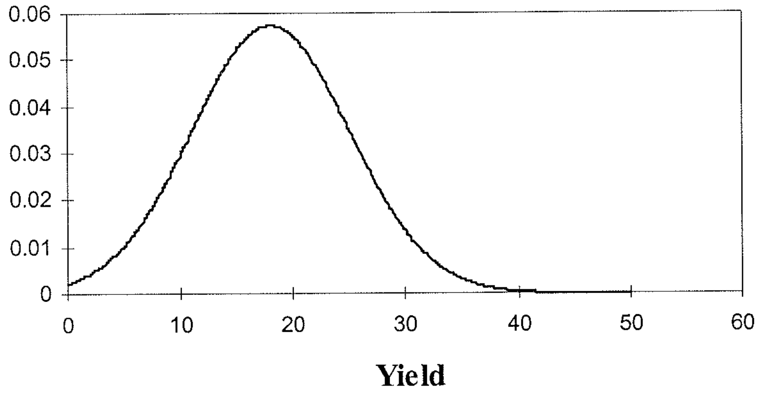

Figure 5.2: Distribution of total indemnity

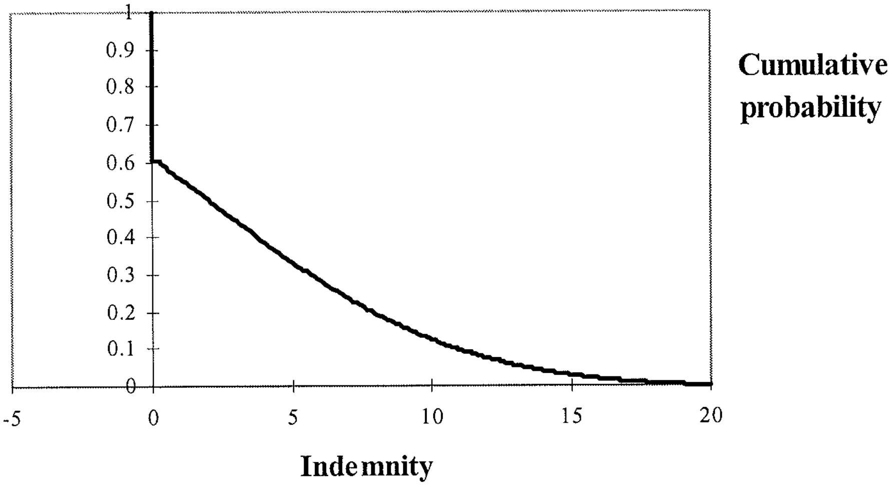

Figure 5.3: Distribution of total profit

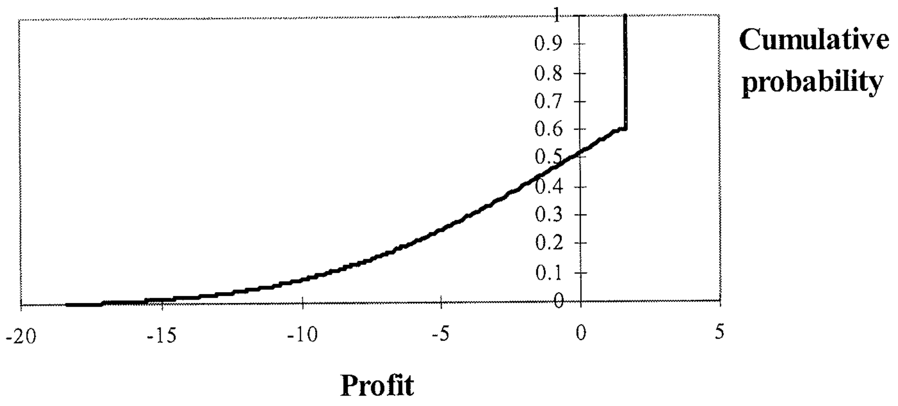

Figure 5.4: PIC profit by fund

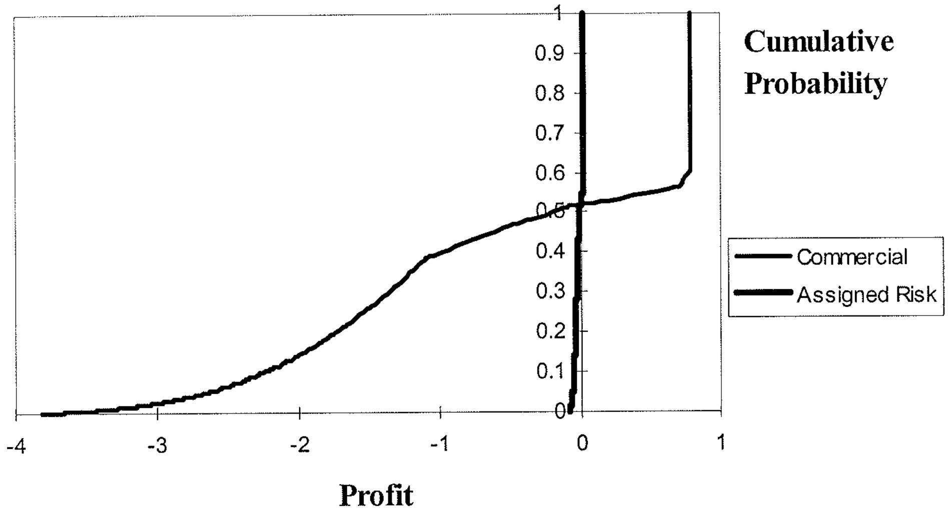

Figure 5.5: Density of yield

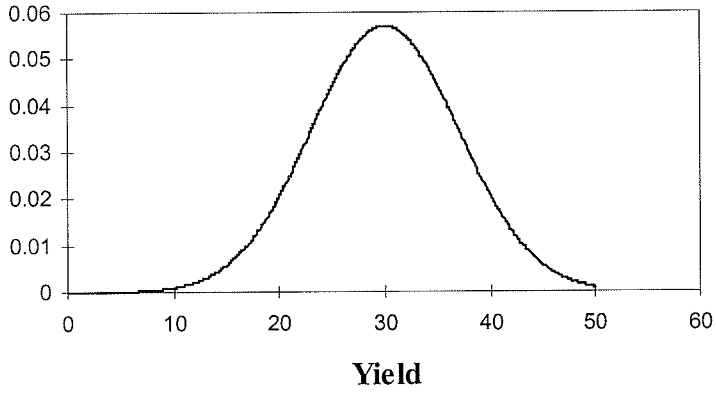

Figure 5.6: PIC profit by fund