Effects of Weather Events on Loss Ratios for Crop Insurance Products: A County-Level Panel Data Analysis.

by

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Introduction

Recent interest in weather (rain, heat, drought, irrigation cost, etc…) insurance for agricultural crops (Mafoua and Turvey (2003); Patrick (1988); Sakurai and Reardon (1997); Turvey (2000, 2001)) requires before implementation an investigation into the relationship between loss ratios[1] under existing crop insurance contracts and specific weather events. Rosenzweig et *al.* (2002) found that the climate records shows that both extreme precipitation events and total annual precipitation in the U.S. have increased over the last 100 years, especially the last two decades. The further increase of precipitation expected in a changing climate regime could lead to increases in crop damage. If, as research suggests, crop variability is highly related to weather variability and events, then this would suggest that heat and rainfall insurance products may be of significant value to managing yield or production risks.

There are many fruit and vegetable crops that are highly susceptible to weather events, but are not well represented by the array of crop insurance products offered to most grain and oilseed crops. Despite the importance of these crops to the economies of New Jersey, there is a need to investigate the impact of weather changes on loss ratios for crop insurance products. The purpose of this study is to examine the relationship over time between specific weather events (drought, excessive rainfall, cold weather, etc…) and crop insurance loss ratios. Such information holds significant implications for agricultural producers, insurance companies, state government agencies, and weather-sensitive sectors of the economy. One critical unanswered question faced by the insurance industry in attempting to plan for the future is whether crop loss ratios are part of the natural climatic variability or whether they are potentially related to other causes such as adverse selection or moral hazard. If indemnities are contingent on rare weather event outcomes, the adverse selection can be explained by its frequency. If high loss ratios were

[1] The loss ratio is a common measure of annual operating performance for insurance products. It is measured as dollars of indemnity paid to growers divided by the dollars of premium paid. If the loss ratio is greater than one (e.g. 1.10), the insurance

correlated with weather events, this would offer an alternative explanation to moral hazard.

The North America economy is widely affected by weather risks. The Chicago Mercantile Exchange (CME) stated that weather affects US$2 trillion of the US$9 trillion gross national product (GNP). Insurance is a critical part of the vulnerability and adaptation equation because many of the economic risks and impacts of weather-related events are diversified and ultimately paid through insurance (IPCC, 2001). Insurance companies have demonstrated sensitivity to uncertainties of weather-related events. The trend in recent decades shows increasing adverse impacts such as rising losses, upward pressure on prices, company insolvencies, and increased reliance on government-provided insurance and disaster preparedness and recovery resources.

The following section starts with a review of the literature regarding the impact of weather events on the U.S. agriculture in general and on the crop insurance industry in particular. Thereafter, the federal crop insurance policies available for New Jersey farmers are discussed. The fourth section analyzes the effects of specific weather events on crop yields and insurance loss ratios in New Jersey and Ness County, Kansas. The fifth section discusses the specification and the estimation of crop insurance loss ratio-weather models, and the data used for the regression models. It is followed by the discussion of the empirical results. The final section provides a conclusion to the research.

Previous Studies

Dutton (2002) estimated that nearly one-third (approximately $3.0 trillion in 2000) of all private industry activities were weather sensitive. Weather risk can be defined as financial gain or loss due to a change in climatic conditions over a period of time that can be hours, days, months, or even years.

Rosenzweig et *al.* (2002) reported that the 1993 US Midwest excessive precipitation events caused damages to farmers valued at about $6-8 billion and in 1997, agricultural production was also negatively

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company has lost money on this particular insurance product for that period, since for every dollar paid to insurance companies (from crop producer and government subsidy) $1.10 came back to farmers in the form of indemnities.

impacted by the North Dakota Red River floods, which caused total damage of roughly $1 billion. To buffer themselves from crop losses related to extreme events, U.S. farmers typically turn to crop insurance. They also concluded that increases in extreme precipitation will likely increase payments from government programs.

The 1999 drought in New Jersey was the third worst of the 20th century. The drought condition created significant difficulty for the agricultural industry in general and the fruit and vegetable sectors in particular. Vegetable growers were stretched to the limit and were battling low prices because of competition from other states as well as low production resulting from the drought and extreme heat. By the end of October 1999, New Jersey Governor Christine Whitman signed the Emergency Disaster Relief Act. The bill appropriated $20 million in financial aid to farmers who had agricultural damage or loss due to the drought.

The 2002 drought in Kansas caused crop insurance to become the primary source of income for many farmers since the drought drove U.S. wheat price well above the target levels, thus reducing loan deficiency payments. Farmers in parts of the Mid-West also were hit hard. This drought had also a substantial impact on crop insurance industry such as many farmers relied on support under the Agricultural Assistance Act of 2003, which provided payments to producers for losses due to weather and related conditions in either the 2001 or 2002 crop years, but not both. The U.S. Government paid out more than $4 billion in claims on actual production history insurance for crop year 2002 compared with almost $3 billion in 2001, the first large scale payout since 1994 (Insurance Information Institute Inc, 2003). Still, these payments failed to offset income losses to wheat producers (Henderson and Novack, 2003).

In addition, the 2002 drought impacted negatively many insurance companies profitability. Two of the US largest crop insurance firms, Acceptance Insurance Company and American Growers Insurance Company, both with a major portion of policies in the drought-stricken Great Plains states, were declared technically insolvent at the end of 2002 and were taken over by regulators[2]. The 1988 drought caused Federal Insurance Company and CHUBB a lost of $20 million and $48 million in claims since claims exceeded the amount that the insurance companies had been underwritten (Changnon and Changnon, 1990).

Actual crop insurance policies are greatly subsidized by governments and indemnities or losses paid out by these programs have historically exceeded the premiums paid into the program resulting in high loss ratios. Skees et al. (1999) stated that the financial experience with publicly, multiple-peril crop insurance has been disastrous. They found that the loss ratio was greater than 2 with public crop insurance programs in Brazil (1975-1981: 4.57), Costa Rica (1970-1989: 2.80), Japan (1985-1989: 4.56), Mexico (1980-1989: 3.65), Philippines (1981-1989: 5.74), and USA (1980-1989: 2.42).

Changnon *et al.* (1997) found that hail losses in 1992 were the worst ever for the crop-hail industry, with 17 states experiencing loss ratios above 100%. Vandeveer and Young (2001) examined the entire 1990/91-2000/01 period for U.S. wheat and found total indemnities were $3.044 billion and premiums were $2.591 billion, resulting in a loss ratio of 1.17. Using Risk Management Agency participation data, Mafoua and Turvey (2003) found that indemnity payments from wheat production in Ness County, Kansas, exceeded premium income in 1989-2001 with a loss ratio averaging 1.37. Past studies attribute both the high loss ratios to problems of moral hazard and adverse selection (…………………). When viewed in the context of specific weather event however, there may be a more natural explanation. Reduction of moral hazard has been considered within the context of area yield insurance schemes (Miranda (1991); Smith et al. (1997); Mahul (1999); Ramaswami and Roe (2001)) and weather-based insurance schemes (Quiggin (1994); Turvey (2000; 2001)).

Although these previous studies have investigated the impacts of weather and climate change on insurance industry but none of them has empirically analyzed the effects of weather events on agricultural

[2] In 1980, 55 insurance institutions serviced the federal crop insurance business. Now there are only 17 companies directly selling policies and in 2003 in addition to the two insolvencies, many insurance companies have reduced their participation in

insurance industry.

The Federal Crop Insurance Policies in New Jersey

This section reviews the crop insurance policies in New Jersey. We focus on apple, blueberry, corn, cranberry, peach and soybeans (Table 1). The most common type of yield-based insurance coverage is the Multi-peril Crop insurance (MPCI) [3]. This insurance policy, which is also referred to as Actual Production history (APH), at buy-up or catastrophic (CAT) coverage is available to field, fruit and berry crop producers in New Jersey. MPCI at buy-up coverage allows farmers to guarantee a percentage (50% to 75%) of actual production history (APH) average yield at a percentage (55% to 100%) of the USDA established price or the effected crop. APH yield is the average of four to ten years of production.

CAT coverage is the minimum MPCI available, which guarantees the farmer 50% of his/her APH average yield at 55% of the established price for the effected crop. CAT coverage costs an administrative fee of $100 per crop per county, regardless of the acreage. For APH insurance, indemnity occurs when crop production is less than insurance guarantee. The federal government through the Risk Management Agency (RMA) completely subsidizes the CAT insurance.

Adjusted Gross Revenue (AGR) insurance[4], a whole farm-risk management tool, made available to New Jersey growers in 2001, insures the revenue of the entire farm rather than an individual crop. This policy guarantees a percentage of average gross farm revenue, including a small amount of livestock revenue. It is based on the past consecutive years of a farmer's Schedule F tax forms to calculate the policy revenue guarantee. It provides comprehensive protection against weather and unavoidable price

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the federal crop insurance program.

[3] MPCI insure farmers against losses due to natural causes such as drought, excessive moisture, hail, wind, frost, insects, and disease. Coverage usually begins when the crop is planted and ends at the earliest of total destruction, harvest, or abandonment of the crop or final adjustment of a claim.

[4] Adjusted Gross Revenue Lite (AGR-Lite) is a modified version of AGR that is available in New Jersey for the year 2004. This version of AGR is available for farmers with adjusted gross revenues of less than $250,000. Unlike regular AGR, farmers with more than 35% livestock income are eligible to participate and are not required to get at least CAT level of coverage for crops covered by MPCI in their county. Under this plan, farmers also cover revenue generated from crops that are currently uninsurable (Hayes, 2003). For more about AGR, see Brumfield and Mafoua ( ) case studies

related causes of loss.

In addition to APH and AGR insurance policies, corn and soybean growers in New Jersey can purchase crop revenue coverage (CRC) insurance[5], which is a comprehensive protection, designed to provide revenue protection against a decline in market price as well as a shortfall in production, or a combination of both. CRC allows farmers to guarantee a percentage (50% to 75%) of APH average yield at a percentage (usually 100%) of the higher of the Chicago Board of trade's early futures market price (base price) or near harvest market price[6]. Because the higher of either the base or harvest market price is used, an indemnity can be paid with normal yields if the harvest market price decreases sufficiently.

Table 1 exhibits the crop insurance profile for the selected crops in New Jersey for the period 2000-2000. In 2000, cranberry had the highest percentage of acreage insured[7] (86%), followed by blueberry (65%). In 2003, blueberry[8] had the highest percentage of acreage insured (70.2%), followed by peach crop (63%). From 2000 to 2001, all crops show an increase in percentage of acreage insured. In 2001, cranberry had the highest percentage of acreage insured (99%). After 2001, with the introduction of new insurance policies, CRC in 2000 and AGR in 2001, there has been a decrease in percentage of acreage insured for all crops except blueberry from 2001 to 2003. From 2000 to 2003 the percentage of acreage insured under CRC has increased from 14 percent to 19.6 percent for corn and from 8 percent to 15.8 percent for soybeans.

Specific Weather Events and the New Jersey Crop Insurance Industry

This section uses the graphical approach to analyze historical records of impacts of all form of

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[5] In addition to CRC, the Kansas wheat producer may purchase Revenue Assurance (RA) coverage that provides dollar-denominated coverage by the farmer selecting a dollar amount of target revenue from a range defined by 50-75% of expected revenue.

[6] The revenue guarantee is calculated as the APH times the coverage level chosen times the higher of either the base market price or the harvest market price. An indemnity payment from the insurance company is triggered when the farmer's revenue (actual yield times harvest market price or base market price) falls below the guarantee.

[7] The percentage of acreage insured, as determined by dividing net insured crop acreage by total crop acreage.

[8] The pilot Blueberry Crop Insurance Program, which is an Actual Production History (APH)[8], began in 1995 in New Jersey. This insurance is provided against the standard causes of losses, insufficient chilling hours to effectively break dormancy, and loss of quality.

extreme weather events on crop yields and specific crop insurance policies in New Jersey and Ness County, Kansas. We attempt to determine if there any evidence that high crop insurance loss in New Jersey and Ness County, Kansas can be associated with climatic variability such as drought, excessive rainfall, and frost…. (Figures 1-5). Specifically for crops produced in New Jersey, we were able to detect which crop had the most impact on the occurrence of high loss ratios during a specific year (Tables 12 and 13).

New Jersey and USA

Figure 1 compares New Jersey and U.S. loss ratios experience for all insurance policies. The lowest loss ratio of the crop insurance industry (0.20) occurred in 2001. New Jersey has experienced four years with loss ratios greater than one (1989, 1990, 1993, 1999) during the observed period. Two major weather events: the 1989 excessive rainfall[9] and 1999 drought had a big impact on New Jersey crop insurance industry. Excessive rainfall affected all crop insurance policies in New Jersey[10]. Blueberry and cranberry insurance policies were the only policies, which were not impacted by the 1999 drought. The highest loss of the insurance industry (2.79) occurred in 1990 after the drought of 1988[11] and excessive rainfall of 1989[12]. This is consistent with the Manitoba Crop Insurance Corporation (2003), which found that in 2001 excess moisture, and drought/heat were the two major causes of crop insurance loss. Excess moisture accounted for 66% of total losses whereas drought and heat accounted for 26% of total losses. But from 1996 to 2001, Excess moisture accounted for 36% of total losses whereas drought and heat accounted for 37% of total losses. Smith (   ) reported that the most frequent cause of losses paid by crop

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[9] During the growing season, most of the New Jersey accumulated over 40 inches of rainfall, 12 inches more than the normal state average. Production of apples, peaches, and cranberries dropped significantly from 1988 (NJ/NASS, 1990).
[10] In most orchards, pesticide spraying and other field activity schedules were seriously interrupted by the untimely rains. (NJ/NASS, 1990).
[11] The drought of 1988 was widespread across the United States. Temperatures were below normal in April, which slowed crop development. Precipitation was sparse during the critical growing season, June-September. Rains in the last two weeks of July briefly relieved stressed crops, but dry conditions persisted in August and September (NJ/NASS, 1989).
[12] Rainfall during the critical period of May to September was much above normal and delayed planting schedules (NJ/NASS, 1990).

insurance was the drought/heat that accounts for 47%. This is followed by excess moisture and cold/frost/freeze that account for 22% and 13%, respectively. Waltman and Peake (   ) found that crop insurance losses in Nebraska occurred during the drought years of 1995, 2000 and 2002.

Many perils or causes of loss to which growers are exposed, such as heat and drought, freezing temperatures and excessive rainfall can affect whole regions. That why when these extreme events occur in a given year, all policyholders in a geographical area suffer losses and are likely to file claims, and the insurances cannot spread the risk of loss broadly enough and over a sufficient length of time to make insurance affordable. Results of these specific weather events had varied effects on the field, fruit and berry crops.

Field Crops

Figure 2 compares New Jersey loss ratios for insurance policies for corn and soybean. Soybean insurance program has experienced more years (8 years) with loss ratios greater than one than corn insurance program (4 years) during the observed period. The 1989 excessive rainfall and 1999 drought had a big impact on both field crop insurance policies. The drought of 1990 had caused corn insurance program to incur the highest loss ratio (10.02) of the history of the insurance industry in New Jersey. This is consistent with our findings in Figure 3 for Kansas's wheat where droughts of 1989, 1996 and 1999 were the only causes of excessive loss ratios in Ness County. This can be explained by the fact that from the early vegetative stage to the dough stage, drought can severely affect the development of water-dependent crop such as corn and wheat, and thus the income derived from the crop after harvest. Based on the Ohio agronomy guide of 1998, the negative effects of drought on Ohio corn yield (as a % yield production) are 5-10% during early vegetative, 10-25% during tassel emergence, 40-50% during silk emergence, pollen shedding, 30-40% during blister, and 20-30% during the dough stage of development.

In 1991, a simultaneous decrease in soybean yield (from 37 bushels per acre to 36 bushels per acre) and season average price (from $5.64 bushels per acre to $5.34 bushels per acre) decreased the total revenue per acre. This contributed in a high soybean loss ratio of 6.28 in 1991, since the only crop insurance program available at that time was the APH policy.

In 1992 heavy frosts that occurred the nights of May 19th and 20th, and morning of 21st produced significant damage to crops. For example, soybean yield, at 33 bushels per acre was below 1991's yield of 36 bushels per acre in 1992 and total production was 5 percent below 1991 (NJ/NASS, 1993). In 1993, soybean yield decreased by 4 bushels per acre to 29 bushels per acre, from 1992's 33 bushels per acre. This reduction in productivity contributed in soybean insurance loss ratios of 1.70 and 1.26 in 1992 and 1993, respectively.

Weather during the 1995-growing season was marked by drought with prolonged period of lack of rainfall and elevated temperatures[13] that adversely affected field crops production and insurance programs. Corn and soybean yields were down by 26 bushels per acre and 12.5 bushels per acre, respectively. Corn and soybean productions decreased by 25 per cent and 40 per cent, respectively (NJ/NASS, 1996). These reduction in production resulted in loss ratios for corn and soybean was 2.00 and 4.60, respectively.

The weather during the 1997 growing season was marked by wetter than normal conditions. The month of July produced greater than normal disease problems. Temperatures reached and exceeded 90°F few days during July and precipitation during the period March through October was above long-term normal (NJ/NASS, 1998). This weather caused corn and soybean yields to decrease by 14 percent and 19 percent, respectively. Due to the decrease in both price and yield, total crop values of corn and soybeans decrease by 18 percent and 13 percent, respectively. These facts contributed in a loss in the yield insurance programs for both field crops.

The drought of 1999 had adverse effects on field crops. Corn and soybeans were severely damaged. Corn yield decreased by 60 percent to 37 bushels per acre and total crop value decreased by 76

[13] Temperatures reached and exceeded 90°F many days during the months of July and August (NJ/NASS, 1996).

percent from 1998' s $19,835,000 to $4,773,000 in 1999. Soybean yield was down by 14 percent and total crop value decreased by 35 percent from 1998's $16,453,000 to $10,702,000 in 1999 (NJ/NASS, 2000). These reduction in productivities resulted in loss ratios for corn and soybean was 10.02 and 1.07, respectively.

Fruit Crops

Figure 4 compares New Jersey loss ratios for insurance policies for apple and peach. Apple insurance program has experienced more years (7 years) with loss ratios greater than one that peach insurance program (5 years) during the observed period. The 2000 cooler summer/hail storms had a big impact on the apple insurance program resulting in a loss ratio of 8.64. Both crop insurance programs were affected in 1989 and 1990. During the four years when New Jersey experienced loss ratios greater than one, peach crop had the highest loss ratios among all crops in 1989 and 1990. The peach insurance policy was highly impacted in 1990 after the 1988 drought and the 1989 excessive rainfall. This can be explained by the fact that in 1990, the early warm temperatures advanced the bloom over four weeks ahead of schedule which made the peach trees vulnerable to later freezing temperatures (NJ/NASS, 1991). In 1994, the hot and dry conditions during summer were responsible for apple and peach insurance loss of 5.51 and 4.94 respectively. There was a decrease in apple production of 7 percent from 1993 utilized production of 73 million pounds. The value of utilized production of peach decreased by $2.6 million from the 1993 value of $25.3 million.

In 1999, pollination of apples and peaches was affected due to low temperatures during April and May, which reduce bee activities. Apple production totaled 50 million pounds. This was a decrease of 7 percent from last year's utilized production of 54 million pounds. Droughts during the summer significantly reduce the peach production and amount of marketable peaches. The value of peach production was down 15 percent. These reductions in production resulted in loss ratios for apple and peach of 2.30 and 1.25, respectively.

In 2000, early season hail storms, cooler summer temperatures, and excessive moisture in early fall had a negative impact on the fruit crops. New jersey apple growers faced increased production costs and tough competition domestically and internationally, and found it hard to stay in the business. Value of production of apple and peach was down by 3 percent and 5 percent, respectively. The decrease in production contributed in loss ratios for apple and peach of 8.64 and 1.21, respectively.

Berry Crops

Figure 5 compares New Jersey loss ratios for insurance policies for blueberry and cranberry. Cranberry has experienced five years with loss ratios greater than one. Blueberry insurance program in New Jersey did not experience any losses during the observed period. In 1991, 1993 and 2001 cranberry had all crops highest loss ratio of 6.28, 1.43 and 1.21, respectively. The excessive rainfall provided an ideal environment for some plant diseases and caused cranberry crop to rot. This resulted in a loss ratio of 1.85 in 1989. New Jersey cranberry growers produced a crop of 292,000 barrels in 1989, 21% below the record of 370,000 barrels in 1988 (NJ/NASS, 1990). In 1991, the loss ratio of cranberry was 6.28 mainly caused by the early frost that damaged some of the crop (NJ/NASS, 1992). In 1993, cranberry growers produced a crop of 386,000 barrels, a decrease of 92,000 barrels or 19 percent from 1992 and the value of utilized production was $18.4 million, down 21 percent from $23.3 million in 1992 (NJ/NASS, 1994).

Crop Insurance Loss Ratio–Weather Models

The previous section described the historical impacts of severe weather events on the agricultural industry and the crop insurance industry in New Jersey. This section covers the model specification and estimation, and the data used to estimate the effects of changes in extreme events on specific crop insurance products.

Model Specification and Estimation

We developed crop insurance-weather models that link the loss ratio for a crop produced in county s with coverage c in year t (LR_{cst}) to cumulative daily rainfall (inches) for the month *m* in county s in year *t* (R_{mst}) and cumulative degree-days above x degrees Fahrenheit for the month *m* in county s in year *t* (H_{mt}). Dummy variables are included into the model to capture the effects of various insurance plans: the Actual Production History (APH) at buy-up coverage, the Crop Revenue Coverage (CRC), the Revenue Assurance (RA)[14], and the Actual Production History (APH) at catastrophic (CAT) coverage. The general model is written as follows:

$$(1)\ LR_{cst} = \sum_{s=1}^{n}\alpha_c APH_{ct}D + \sum_{s=1}^{n}\beta_c CRC_{ct}D + \sum_{s=1}^{n}\phi_c RA_{ct}D + \sum_{s=1}^{n}\eta_c CAT_t D + \sum_{m=1}^{n}\gamma_m R_{mst} + \sum_{m=1}^{n}\theta_m H_{mst} + \sum_{m=1}^{n}\delta_m (RH)_{mst} + \varepsilon_t$$

where:
LR_{cst} = Loss ratio for a crop produced in county s with coverage c in year t
$APH_{ct}D$ = Binary variable equal 1 if the policy is the Actual Production History at buy-up for county s with coverage level c in year t
$CRC_{ct}D$ = Binary variable equal 1 if the policy is the Crop Revenue Coverage at buy-up for county s with coverage level c in year t
$RA_{ct}D$ = Binary variable equal 1 if the policy is the Revenue Assurance Coverage at buy-up for county s with coverage level c in year t
CAT_tD = Binary variable equal 1 if the policy is the Actual Production History at catastrophic coverage for county s in year t
R_{mst} = Cumulative rainfall for the month m in county s in year t
H_{mst} = Cumulative degree-days above x degrees Farenheit for the month m In county s in year t
ε_t = Error term

Using equation (1) the marginal responses of the crop insurance loss ratio to a change in weather event (extreme rainfall or heat) in a specific month are given by

$$(2)\qquad \frac{\partial LR_{cst}}{\partial R_{mst}} = \gamma_m + \delta_m H_{mst}$$

and

[14] The revenue assurance (RA) policy is available only in Ness County, Kansas.

(3) $$\frac{\partial LR_{cst}}{\partial H_{mst}} = \theta_m + \delta_m R_{mst}$$

The effectiveness of weather event in a specific month m can be measured by the crop loss ratio elasticity of weather (rainfall or heat), which measures the percentage change in the crop loss ratio given a percentage change in weather in that specific month. If there were a significant relationship between weather events and insurance loss ratios, this would provide evidence that weather insurance may be a useful substitute for conventional insurance products.

The econometric model described by equation (1) is estimated using the least-squares dummy variable (LSDV) estimator. Since county- and policy-specific panel data are used, unobserved heterogeneity among counties and policies is accounted for in the estimation process (Hsiao, 1986). This model captures these differences by allowing the intercept term to vary across counties and insurance policies under the assumption that county- and policy-specific effects are non-stochastic and time-invariant. Using this specification, crop insurance losses attributable to a given increase in mean weather variable will not be over-estimated if the model used for the estimation control for differences in climate policies and counties.

Data Description

This section describes the data used in the estimation of weather events effects on specific crop insurance loss ratios. Samples for our study consist of pooled cross-sectional, time-series (1989-2001) county (Atlantic, Burlington and Ocean) data for field (corn and soybeans), fruit (apple and peach), and berry (blueberry and cranberry) crops in New Jersey. To provide a point of comparison, we used a single county (Ness County) in Kansas over the period 1989-2001. These data were computed using information on insurance policies, indemnities paid, types of coverage, and delivery methods for the four counties obtained from the Risk Management Agency (RMA).

Descriptive statistics for various crop insurance programs are reported in Table 4. The average loss ratio of New Jersey (1.06) is lower than the national average (1.11). Both measures of New Jersey loss ratio variability, the standard deviation (absolute measure of dispersion) and the coefficient of variation (relative measure of dispersion) of New Jersey are higher than the national average. Both distributions are positively skewed. New Jersey and USA loss ratio distributions are, respectively, negatively and positively kurtotic.

Among crops, apple insurance program has the highest average loss ratio with the highest standard deviation. All crop insurance policies are positively skewed and kurtotic. Corn crop insurance policy, which has the most positively skewed and kurtotic distribution, also has the highest coefficient of variation and maximal value during the observed period.

In addition to crop insurance data, county-level panel data on weather (precipitation and temperature) from 1989-2001 for the weather stations in New Jersey and Kansas were obtained from the National Climate Data Center (NCDC) at the National Oceanic and Atmospheric Administration (NOAA). Weather stations report actual rainfall and maximum temperature for the daytime period and rainfall and minimum temperature for the evening period. Weather variables for Burlington County[15], New Jersey are displayed in Tables 5 and 6. There are cumulative daily precipitation in inches and cumulative degree-days[16] (heat units) above 90 degrees Fahrenheit for critical months[17] such as April, May, June, July, August, and September. Six months of weather data are used to capture major climate variations within a year important in agriculture and reflect the planting, growing and harvesting period of each crop produced in New Jersey.

The month of August shows the highest average cumulative rainfall of 5.41 inches, followed by

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[15] We chose Burlington County, New Jersey to illustrate the monthly distributions of rainfall and heat.

[16] Degree days, specifically "cooling degree days or CDD" is essentially a way of measuring how far the temperature deviates from the baseline over a period of time. In our study, we use 90° F as the baseline. $CDD = \sum_{i=1}^{N} \max(0,\ \mathrm{T_i} - 90^\circ F)$, where N is the number of days and T is the daily maximum temperature of the *i*th day. In our study, if maximum daily temperature is 95°F, and the reference temperature is 90°F, then CDD = 95°F - 90°F = 5°F or 5CDD.

[17] From planting to harvest, precipitation and temperature can affect the quality and quantity of a crop. There is a strong correlation between the fluctuation of crop production volumes and the weather.

the month of July (4.96 inches). The variability in rainfall is the highest during the month of August in terms of standard deviation and during the month of September in terms of coefficient of variation.

Table 6 illustrates the statistics of the cumulative degree-days for different months in Burlington County, New Jersey. The month of July is the hottest month with an average cumulative degree-day heat of 40.31°F. The heat distributions of all months are right-skewed positively kurtotic (except for the month June which is negatively kurtotic). Table 7 presents the independent variables used to explain crop insurance loss ratios.

Empirical Model Results

The goal of this study is to establish and quantify the link between weather variables and the crop insurance policies. Without previous econometric study to build upon directly, the initial attempt to describe such a link is necessarily limited. Nevertheless, the importance of weather insurance products and the lack of similar study make a simple approach all the more useful as a guide for future research. Since field crop models have a larger number of coefficients, their estimated parameters are not presented here but are available upon request from the authors. Summary regression staitistics of the first order coefficients of weather variables are presented in Table 8. Most of the models fit the panel data well with the R-squares (R^2) ranging from 0.49 (soybean model) to 0.92 (blueberry model).

Tables 8-10 compare the effects of rainfall and heat on crop insurance programs. Most of crop models identify statistically significant effect of cumulative daily degree-days for the months of July and September on crop insurance policies. For example, increase in the heat units in the months of July and September will, respectively, increase and decrease the loss ratios for corn and soybean policies. The positive effect of heat in July may be explained by the hot and dry conditions in July may reduce corn yield by 1.5 bushels per acre for each day the temperature reaches 95 degree Fahrenheit or higher during pollination and grainfil (Des Garennes, 2004). In addition, increase in the heat units in the month of August will create a loss in the soybean insurance program. This can be explained by the hot and dry temperatures in early August stress the soybean plants, making them vulnerable to diseases (Des Garennes, 2004). In the months of May and June, an increase in rainfall will increase the loss ratios for both programs, but these effects are not statistically significant. But from the months of July to September an increase in rainfall will decrease the corn crop loss ratios since July and late August rains aids the corn crop (Des Garennes, 2004). In the months of September, an increase in rainfall will decrease the loss ratios for both programs, but this effect is not statistically significant.

Conclusions

This study has examined one aspect of the federal crop insurance program of New Jersey. Increasing incidence of losses in the insurance programs could be attributed to increased climatic variability, especially with respect to variability in monthly temperature.

References

Changnon , S.A., D. Changnon, E.R. Fosse, D.C. Hoganson, R.J. Roth Sr., and J.M. Totsch. "Effects of Recent Weather Extremes on the Insurance Industry: Major Implications for the Atmospheric Sciences." *Bulletin of the American Meteorological Society*, 78, 3 (1997): 425-435.

Changnon, S.A. and J.M. Changnon "Use of Climatological Data in Weather Insurance." *Journal of Climate*, 3 vol.2 (1990): 568-576.

Henderson, J. and N. Novack. "Will Rains and National Recovery Bring Rural Prosperity?" *Economic Review*, Federal Reserve Bank of Kansas City, First Quarter 2003: pp. 77-96.

Mafoua, E.K. and C.G. Turvey. "Pricing Irrigation Cost Insurance: An Application of Weather Insurance to Wheat Production". Working Paper, 2003.

Patrick, G.F. "Mallee Wheat Farmers' Demand of Crop and Rainfall Insurance." *Australian Journal of Agricultural Economics*, 32 (1988): 37-49.

Sakurai, T and T. Reardon. "Potential Demand for Drought Insurance in Burkina Faso and Its Determinants." *American Journal of Agricultural Economics*, 79 (1997): 1193-1207.

Turvey, C.G. "The Pricing of Degree-Day Weather Options." Working Paper 02/05. Department of Agricultural Economics and Business, University of Guelph, Ontario, 2000.

Turvey, C.G. "Weather Derivatives for Specific Event Risks in Agriculture." *Review of Agricultural Economics*, 23(2001): 333-351.

Vandeveer, M.L. and C.E. Young. "The Effects of the Federal Crop Insurance Program on Wheat Acreage." Special Article. Economic Research Service, USDA. Wheat Yearbook? WHS-2001/March 2001.

Table 1: New Jersey State Crop Insurance Profile (Selected Crops, 2000-2003)

Insurable Crops	**2000**		**2001**		**2002**		**2003**	
	Total Acres	Percent Insured	Total Acres	Percent Insured	Total Acres	Percent Insured	Total Acres	Percent Insured
Apple	3,200	17%	2,800	27%	2,600	27%	2,600	24.5%
Blueberry	7,500	65%	7,400	66%	7,400	70%	7,400	70.2%
Corn-APH	90,000	56%	80,000	63%	90,000	52%	80,000	54.1%
Corn-CRC	-	14%	-	14%	-	17%	-	19.6%
Cranberry	3,700	86%	3,400	99%	4,000	95%	4,000	51.4%
Peach	8,000	58%	8,000	70%	8,000	69%	8,000	63.0%
Soybeans-APH	100,000	57%	103,000	63%	100,000	61%	90,000	53.0%
Soybeans-CRC	-	8%	-	8%	-	10%	-	15.8%

Source: Risk Management Agency/USDA

Figure 1: Specific Weather Events and New Jersey Crop Insurance Loss Ratios

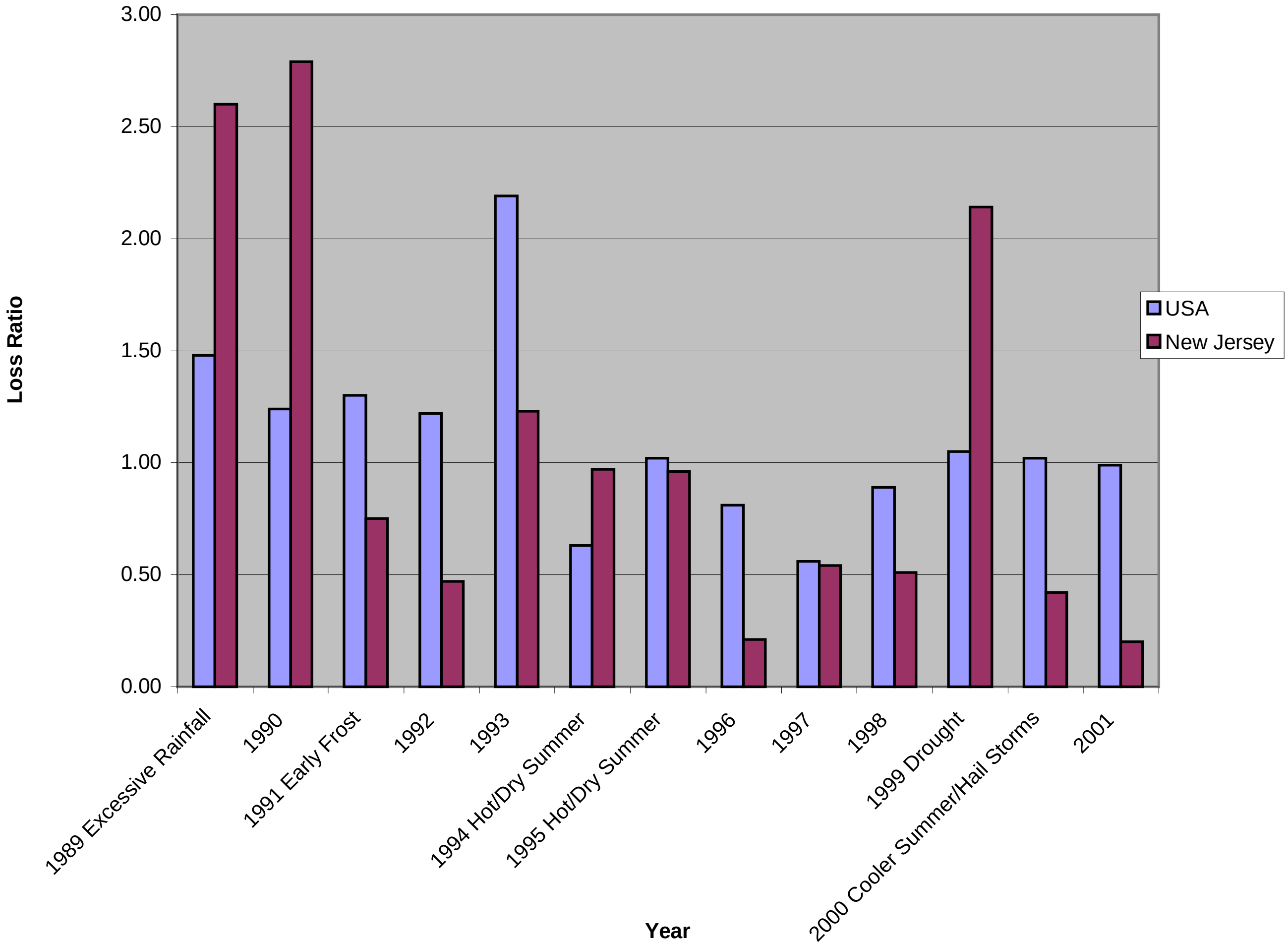

Figure 2: Specific Weather Events and New Jersey Field Crop Insurance Loss Ratios

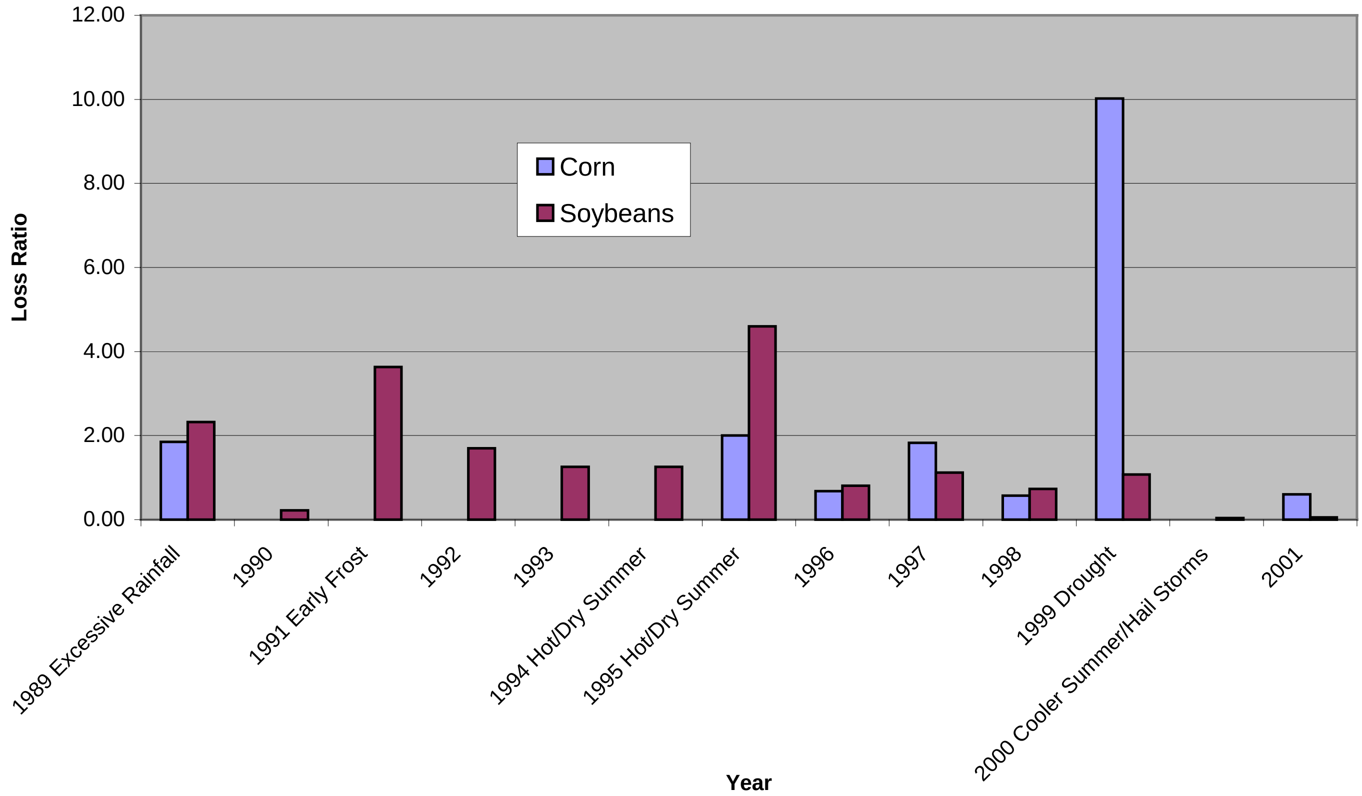

Figure 3: Specific Weather Events and Kansas (Ness County) Wheat Crop Insurance Loss Ratios

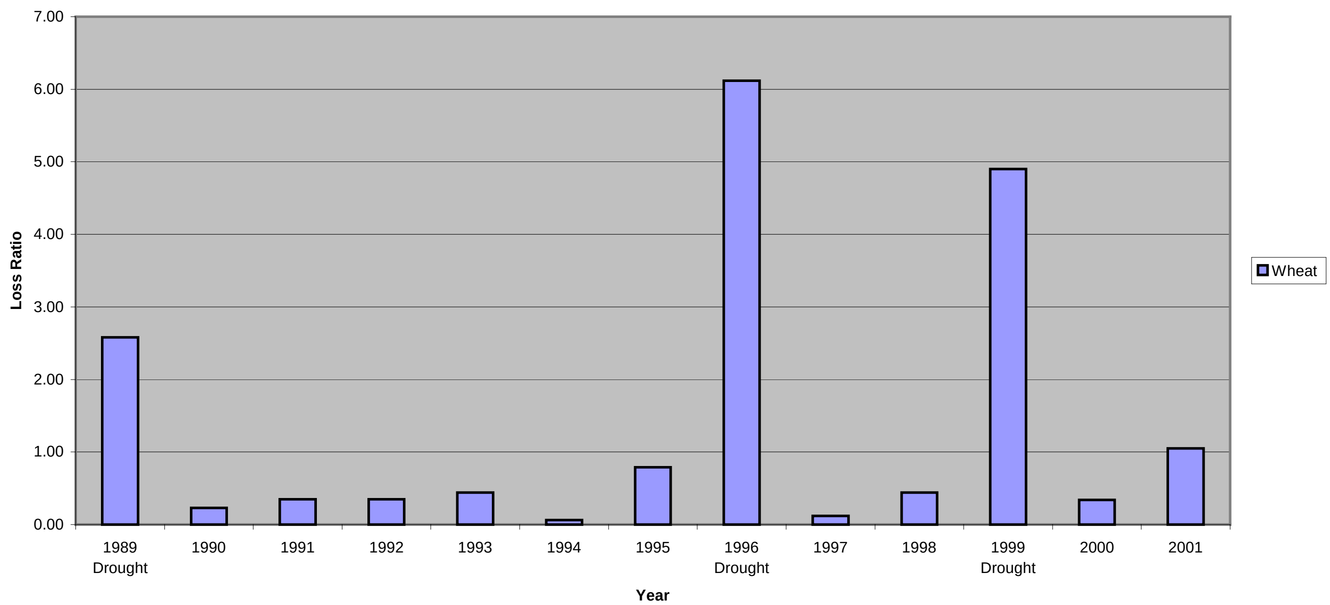

Figure 4: Specific Weather Events and New Jersey Fruit Crop Insurance Loss Ratios

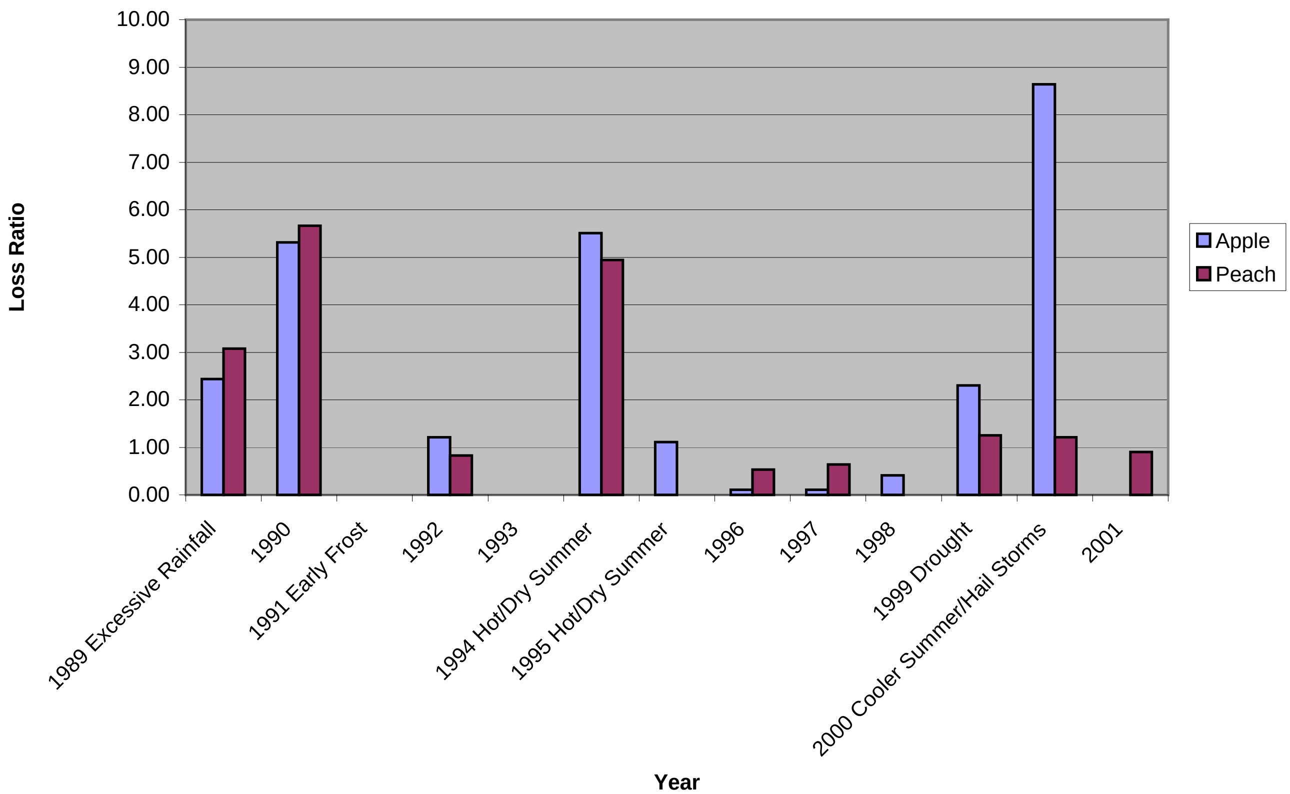

Figure 5: Specific Weather Events and New Jersey Berry Crop Insurance Loss Ratios

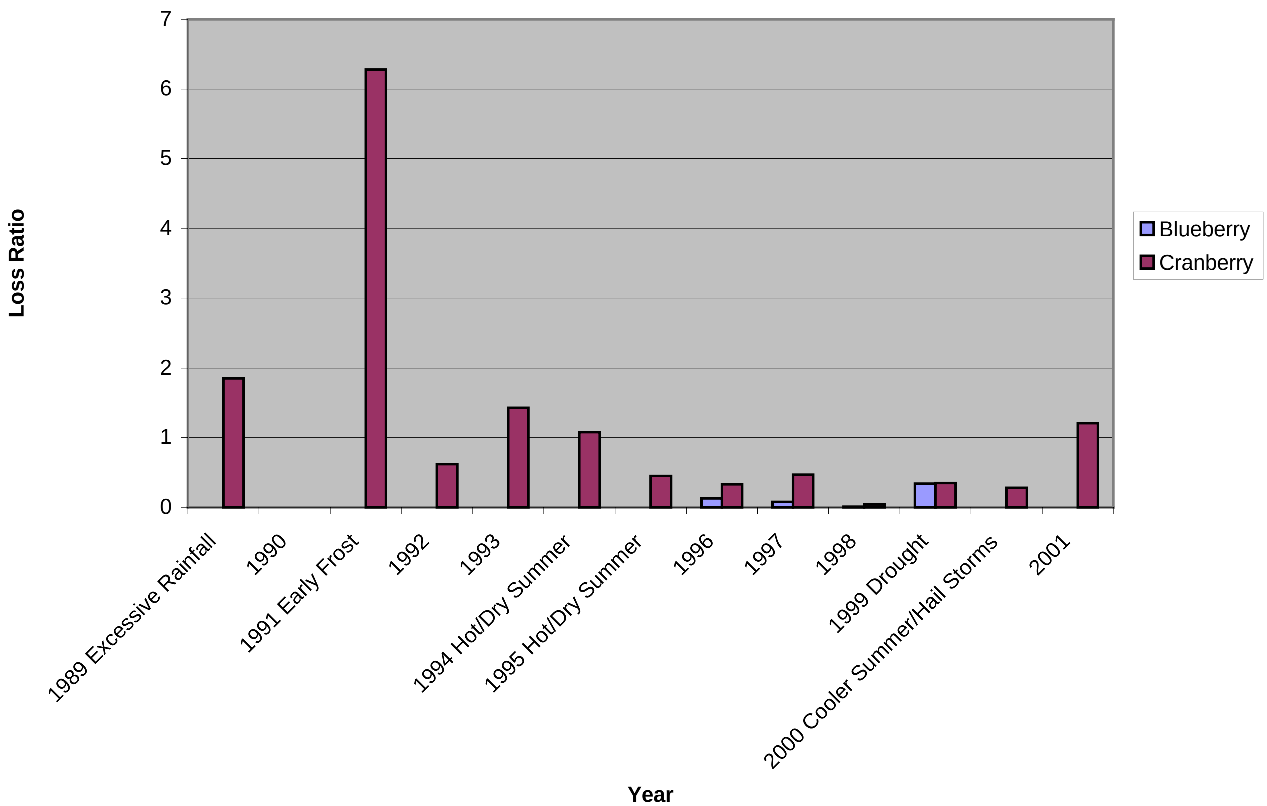

Table 2: Effects of Specific Weather Events on Crop Insurance Programs in New Jersey (1989-1994)

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Weather Events	Drought	Excessive Rain		Early Frost			Hot/Dry Summer
New Jersey	NA	2.60	2.79	0.75	0.47	1.23	0.97
Corn	NA	1.85	0.00	0.00	0.00	0.00	0.00
Soybeans	NA	2.32	0.22	3.63	1.70	1.26	1.26
Apple	NA	2.44	5.31	0.00	1.21	0.00	5.51
Peach	NA	3.08	5.66	0.00	0.83	0.00	4.94
Blueberry	NA	NA	NA	NA	NA	NA	NA
Cranberry	NA	1.85	0.00	6.28	0.62	1.43	1.08

Table 3: Effects of Specific Weather Events on Crop Insurance Programs in New Jersey (1995-2001)

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Weather Events	Hot/Dry Summer				Drought	Cooler Summer/Hail Storms	
New Jersey	0.96	0.21	0.54	0.51	2.14	0.42	0.20
Corn	2.00	0.68	1.83	0.57	10.02	0.00	0.60
Soybeans	4.60	0.81	1.12	0.73	1.07	0.04	0.05
Apple	1.11	0.11	0.11	0.41	2.30	8.64	0.00
Peach	0.00	0.53	0.64	0.00	1.25	1.21	0.90
Blueberry	0.00	0.13	0.08	0.01	0.34	0.00	0.00
Cranberry	0.45	0.33	0.47	0.44	0.35	0.28	1.21

Table 4: Summary Statistics of Crop Loss Insurance Ratios

	USA	NJ	Corn	Soybeans	Apple	Peach	Blueberry	Cranberry	KS-Wheat
Mean	1.11	1.06	1.35	1.45	2.09	1.46	0.08	1.11	1.37
Median	1.02	0.75	0.57	1.12	1.11	0.83	0.01	0.47	0.44
Std Dev.	0.42	0.89	2.72	1.36	2.75	1.90	0.13	1.65	1.97
C.V.	0.38	0.84	2.01	0.94	1.32	1.30	1.57	1.49	1.44
Skewness	1.39	1.13	3.12	1.34	1.45	1.52	1.88	2.93	1.85
Kurtosis	3.21	-0.06	10.41	1.41	1.35	1.19	3.54	9.43	2.35
Minimum	0.56	0.20	0.00	0.04	0.00	0.00	0.00	0.00	0.06
Maximum	2.19	2.79	10.02	4.60	8.64	5.66	0.34	6.28	6.12

Table 5: Summary Statistics of Cumulative Rainfall in Burlington County, New Jersey

	April	May	June	July	August	September

	Rainfall (inches)	Rainfall (inches)	Rainfall (inches)	Rainfall (inches)	Rainfall (inches)	Rainfall (inches)
Mean	2.99	4.16	3.34	4.96	5.41	4.18
Median	2.85	3.70	2.83	4.65	5.13	4.16
Std Dev.	1.17	1.88	1.88	2.44	2.90	2.37
C.V.	0.39	0.45	0.56	0.49	0.54	0.57
Skewness	-0.34	0.88	1.53	0.04	0.17	0.09
Kurtosis	-1.22	0.83	2.63	-0.49	-0.60	-1.32
Minimum	1.09	1.22	1.47	0.51	1.15	0.82
Maximum	4.39	8.32	8.16	9.17	10.69	7.36

Table 6: Summary Statistics of Cumulative Degree-Days in Burlington County, New Jersey

	May D-Days (^oF)	June D-Days (^oF)	July D-Days (^oF)	August D-Days (^oF)	September D-Days (^oF)
Mean	7.31	18.62	40.31	19.38	3.62
Median	3.00	13.00	30.00	14.00	1.00
Std Dev.	10.31	16.35	44.11	21.01	7.12
C.V.	1.41	0.88	1.09	1.08	1.97
Skewness	1.67	0.68	2.43	1.62	2.97
Kurtosis	2.72	-0.06	6.91	2.13	9.57
Minimum	0.00	0.00	4.00	0.00	0.00
Maximum	34.00	54.00	171.00	70.00	26.00

Table 7: Definitions of Independent Variables Used to Explain Crop Insurance Loss Ratios

Variable	Definition
APH35_County	Binary variable=1 if the insurance policy is APH and the coverage level is 35% for a specific county; else=0
APH50_County	Binary variable=1 if the insurance policy is APH and the coverage level is 50% for a specific county; else=0
APH55_County	Binary variable=1 if the insurance policy is APH and the coverage level is 55% for a specific county; else=0
APH60_County	Binary variable=1 if the insurance policy is APH and the coverage level is 60% for a specific county; else=0
APH65_County	Binary variable=1 if the insurance policy is APH and the coverage level is 65% for a specific county; else=0
APH70_County	Binary variable=1 if the insurance policy is APH and the coverage level is 70% for a specific county; else=0
APH75_County	Binary variable=1 if the insurance policy is APH and the coverage level is 75% for a specific county; else=0
APH80_County	Binary variable=1 if the insurance policy is APH and the coverage level is 80% for a specific county; else=0
CRC50_County	Binary variable=1 if the insurance policy is CRC and the coverage level is 50% for a specific county; else=0
CRC55_County	Binary variable=1 if the insurance policy is CRC and the coverage level is 55% for a specific county; else=0
CRC60_County	Binary variable=1 if the insurance policy is CRC and the coverage level is 60% for a specific county; else=0
CRC65_County	Binary variable=1 if the insurance policy is CRC and the coverage level is 65% for a specific county; else=0
CRC70_County	Binary variable=1 if the insurance policy is CRC and the coverage level is 70% for a specific county; else=0
CRC75_County	Binary variable=1 if the insurance policy is CRC and the coverage level is 75% for a specific county; else=0
RA65_County	Binary variable=1 if the insurance policy is RA and the coverage level is 65% for a specific county; else = 0
RA70_County	Binary variable=1 if the insurance policy is RA and the coverage level is 70% for a specific county; else = 0
RA75_County	Binary variable=1 if the insurance policy is RA and the coverage level is 75% for a specific county; else = 0
CAT_County	Binary variable=1 if the insurance policy is the catastrophic coverage; else = 0
Month Rain	Cumulative amount of rainfall during the specific month of the year
Month Heat	Cumulative degree-days units of heat during the specific month of the year
Month Rain*Heat	Cross terms between cumulative rainfall and degree-days units of heat during the specific month of the year

Table 8: Effects of Rainfall and Heat on Field Crop Insurance Programs (Signs of the Estimates)

	Corn Model	Soybean Model	KS-Wheat Model
March Rain	NA	NA	+ (**)
April Rain	NA	NA	_ (***)
May Rain	+	+	_ (***)
June Rain	+	+	_ (***)
July Rain	_	+	NA
August Rain	_	+	NA
September Rain	_ (*)	_	NA
March Heat	NA	NA	NA
April Heat	NA	NA	+ (***)
May Heat	_	_	_ (**)
June Heat	_ (**)	_	_ (***)
July Heat	+ (***)	+ (**)	NA
August Heat	_	+ (**)	NA
September Heat	_ (**)	_ (*)	NA

Table 9: Estimated Regression Equations of Fruit Crop Insurance - Weather Models

Variable	**Apple** (Atlantic & Burlington)		**Peach** (Atlantic & Burlington)	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
APH35_Atlantic	-	-	10.52**	4.14
APH50_Atlantic	-5.04*	2.56	5.86	4.33
APH65_Atlantic	-4.80**	2.33	4.97	4.40
APH75_Atlantic	-3.00	2.46	4.40	5.01
CAT_Atlantic	-5.97**	2.44	2.36	4.49
APH50_Burlington	-	-	9.44	6.47
APH55_Burlington	-	-	-	-
APH65_Burlington	-7.67**	3.24	7.10	6.42
CAT_Burlington	-8.36**	3.68	6.07	7.24
April Rain	2.59	1.99	1.98*	0.99
May Rain	-0.73	0.91	-1.16	0.79
June Rain	0.44	0.51	-0.42	0.55
July Rain	0.52	0.53	-0.59	0.46
August Rain	0.24	0.35	0.23	0.28
September Rain	0.02	0.33	0.18	0.31
May Heat	-0.97	0.65	-0.89**	0.40
June Heat	-0.02	0.17	-0.09	0.17
July Heat	0.07	0.06	-0.16*	0.08
August Heat	0.36**	0.15	0.02	0.13
September Heat	-0.31	0.21	-0.02	0.19
May Rain*Heat	0.15	0.10	0.18**	0.08
June Rain*Heat	0.06	0.09	-0.03	0.07
July Rain*Heat	-0.03	0.03	0.01	0.02
August Rain*Heat	-0.07**	0.03	0.06	0.04
September Rain*Heat	0.02	0.07	0.06	0.11
Number of Observations	45		54	
F-Statistic	2.19		3.32	
RMSE	2.32		2.83	
R-Square	0.68		0.73	
Adj. R-Square	0.37		0.51	

Table 10: Estimated Regression Equations of Berry Crop Insurance - Weather Models

Variable	**Blueberry** (Atlantic & Burlington)		**Cranberry** (Burlington & Ocean)	
	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
APH75_Atlantic	1.372**	0.545	-	-
CAT_Atlantic	0.031	0.504	-	-
APH35_Burlington	-	-	-31.400**	12.651
APH50_Burlington	0.338	1.323	-32.436***	12.453
APH55_Burlington	-	-	-32.181**	12.630
APH65_Burlington	-	-	-31.636***	12.280
APH70_Burlington	-	-	-29.246**	12.878
APH75_Burlington	-	-	-28.388**	12.394
CAT_Burlington	0.333	1.265	0.612	1.984
APH65_Ocean	-	-	-36.702***	13.766
CAT_Ocean	-	-	-23.054*	12.257
April Rain	0.106	0.117	-1.462	1.189
May Rain	-0.044	0.071	0.449	0.706
June Rain	-0.025	0.118	0.585	1.602
July Rain	-0.023	0.032	2.740*	1.545
August Rain	-	-	1.938*	1.087
September Rain	-	-	-0.910	1.125
May Heat	0.024	0.057	-1.320*	0.709
June Heat	0.007	0.046	-0.448	0.298
July Heat	-0.001	0.007	0.162**	0.072
August Heat	-	-	0.383**	0.196
September Heat	-	-	0.118	0.188
May Rain*Heat	-0.004	0.018	0.443**	0.205
June Rain*Heat	-0.004	0.014	0.056	0.055
July Rain*Heat	-0.001	0.004	0.036*	0.022
August Rain*Heat	-	-	-0.046	0.031
September Rain*Heat	-	-	0.097	0.091
Number of Observations	20		58	
F-Statistic	4.89		2.47	
RMSE	0.17		4.12	
R-Square	0.92		0.65	
Adj. R-Square	0.82		0.39	