Estimating Temperature Effects on the Cost of the Federal Crop Insurance Program

Edward D. Perry, Jisang Yu, and Jesse Tack*

Abstract

This paper studies the impacts of temperature variation on U.S. crop insurance. We construct a county-level panel of U.S. crop insurance losses, liabilities, temperature, and precipitation during the period 1989-2014. We find that the ratio of losses to liabilities (LLR) begin to increase significantly at 30 ℃ for corn and 33 ℃ for soybeans. These findings are similar to the estimated impacts of temperature on yield found in previous studies. In a 1 ℃ uniform warming scenario, the LLR, which in the long-run is equal to the actuarially fair premium rate, increases by 24% in corn and 6.5% in soybeans. Using detailed information on the causes associated with insurance losses, we further decompose the impact of temperature on the LLR into heat, drought, excess moisture, and freeze related claims. We find that at extreme temperatures drought is the largest source of insurance losses.

Selected Paper prepared for presentation at the 2017 Agricultural and Applied Economics Association Annual Meeting, Chicago, Illinois, July 30-August 1

*Edward D. Perry (edperry@ksu.edu) is an Assistant Professor, Department of Agricultural Economics, Jisang Yu (jisangyu@ksu.ed) is an Assistant Professor, Department of Agricultural Economics, and Jesse Tack (jtack@ksu.edu) is an Associate Professor, Deparment of Agricultural Economics, all at Kansas State University, Manhattan, KS 66506.

1 Introduction

Both in the United States and elsewhere, government subsidized crop insurance has become increasingly important to crop producers (Miranda and Farrin 2012; Coble and Barnett 2013; Glauber 2013; Goodwin 2015). In 2014, more than 87% of corn and soybean acres were covered by crop insurance, with liabilities totaling in excess of $70 billion, a more than 300% increase from 2000 (RMA 2015). The current political landscape surrounding the upcoming Farm Bill suggests that crop insurance will continue to serve as the cornerstone of public support for agricultural production (Barnaby and Russell 2016).

The probability of triggering insurance indemnity payments, as well as their magnitude, are closely tied to temperature and weather patterns. Extreme heat and drought, for example, lead to lower yields, thereby triggering payments. The magnitude of this relationship, however, is unclear. Many previous studies have investigated the relationship between temperature and crop yields (Schlenker and Roberts 2009), with more recent work focusing on the effect of temperature on yield risk (Lobell et al. 2014). There is little work, however, on the relationship between temperature and insurance losses. The importance of this issue is underscored by the likely prospect of rising temperatures in the future.

The purpose of this paper is to examine how changes in the temperature distribution impact the ratio of crop insurance losses to liabilities (i.e., the loss-liability ratio (LLR)). Changes in the LLR affect actuarially fair premium rates, which in turn lead to changes in farm-paid premiums and mandated government spending, the latter being due to the significant subsidization of crop insurance.

For our analysis, we use a large panel of county-level crop insurance data from the Risk Management Agency (RMA) to estimate regressions in which the LLR is modeled as a function of the temperature distribution and precipitation. In addition, we use detailed information from the RMA cause of loss (COL) data to decompose the impacts of temperature on losses by type of cause. By decomposing the estimates in this way, we gain valuable insights into how temperature interacts with these causes. Based on these estimates we also provide predictions in a uniform 1 ℃ warming scenario.

Our results indicate that, for both corn and soybeans, the LLR begins to increase at 30 ℃, with major increases at 36 ℃ and beyond. We also find that the LLR for heat and for drought start to increase at 30 ℃ for corn and at 33 ℃ for soybeans. A preliminary simulation suggests that a 1 ℃ increase in the average temperature increases the average loss by about $0.029 (24%) per dollar of liability for corn and about $0.01 (6.5%) per dollar of liability for soybeans. Drought LLRs have the largest share in these increases for both corn and soybeans.

The rest of this paper proceeds as follows. Section 1 provides some background information on U.S. Federal Crop Insurance. This is followed by a brief review of the relevant literature in Section 3. Section 4 presents the empirical model and Section 5 discusses the data. Results are presented in Section 6, followed by a set of LLR predictions in a uniform 1 ℃ warming scenario.

2 Background

Federal crop insurance was first developed in the 1930s as a response to the crop losses incurred in the Dust Bowl. Over the years, it has changed significantly, with major expansions and modifications in 1980, 1994, 2000, and 2008. The Federal Crop Insurance Corporation (FCIC), which was founded to carry out the insurance program, is run by the Risk Management Agency (RMA). The RMA develops insurance products and sets the premium rates.[1] In setting the premium rates, the RMA targets actuarially fair levels; that is, levels at which the expected total premiums are equal to the expected total indemnities. Over the years, the rate-setting procedure has been modified to better accomplish this goal (Goodwin

[1] Private companies also can develop insurance products with the approval of FCIC.

1994; Glauber 2013).

The individual policies themselves are sold and administered by sixteen approved private insurance companies. There are essentially two types of policies: (i) yield-based (APH) insurance and (ii) revenue-based insurance.[2] The former consists of insurance against the event that yields fall below a historical based threshold, and the latter protects against yield losses, price fluctuations, or both. Indemnities are paid when yields or revenues fall below the coverage level. For yield insurance, the threshold is with respect to historical yields, whereas with revenue insurance the threshold is based both on historical yields and a projected output price. It is therefore possible in the case of revenue insurance that even in years when yields are quite high that indemnities are paid (if the harvest price is low relative to the projected price).

Crop insurance is heavily subsidized by the government. These subsidies extend to administrative and operating costs, reinsurance, and premium rates (FCIC 2014). As such, the relationship between temperatures and the LLR has direct implications for government outlays. If high temperatures reduce yields enough, then insurance payments kick in and the LLR increases. In equilibrium, the actuarially fair premium rate will adjust to equal this ratio. Assuming that coverage levels and insurance participation rates remain the same or rise, this will in turn increase total government subsidies.

3 Temperature Effects on Crop Yields and Crop Insurance Indemnity Payments

Our work builds on the large and growing literature that examines the impacts of climate change on U.S. agriculture (Mendelsohn et al. 1994 ; Deschenes and Greenstone 2007; Lobell et al. 2014; Burke et al. 2016). Many of these studies

[2] Yield-based and revenue-based insurance are further separated into individual-based and group or area-based insurance.

estimate the effect of temperature variation on crop yields. While disagreement remains, most recent studies find moderate to large reductions in yields across a range of crop under various warming scenarios (Schlenker and Roberts 2009; Tack et al. 2015; Gammans et al. 2017).

As noted, there is relatively little work on the impact of temperature changes on crop insurance. The closest study in nature to this paper is Tack et al. (2017), which investigates how temperature variation impacts crop insurance premium rates and government subsidy outlays. In particular, for each county they estimate the relationship of yield to weather. Based on this relationship, they estimate the mean and variance of yields, which in turn are used to calculate actuarially fair premium rates. Under various plausible uniform warming scenarios, they predict an increase in actuarially fair premium rates of 33.3% (1 ℃ increase) to 87.3% (2 ℃ increase). Government subsidy outlays are predicted to increase by 28% (1 ℃) to 62% (2 ℃).

This study differs from Tack et al. (2017) in a couple of important ways. First, rather than estimate the weather-yield relationship and then construct premium rates, we directly estimate the relationship between temperature variation and the LLR. By doing so, our estimates capture how the RMA actually adjusts premium rates in response to fluctuations in indemnities (and indirectly weather). As such, our analysis may be viewed as complementary to their work. More generally, our work provides an independent source of verification for existing work on the relationship of climate to crop yields.

Second, as noted, we use the COL data to decompose our estimates for the impact of temperatures on crop insurance into heat, cold, drought, and excess moisture. To our knowledge, very few studies have used the COL data. Lobell et al. (2011) use the COL data to summarize the distribution of extreme climate events in California. Among the disasters they consider, excess moisture and cold were found to be the two largest causes of indemnity payments (they do not look at drought). Our study goes one step further by examining how the various causes interact with the temperature distribution. By doing so, we gain unique insights into the channels through which temperature variation reduces yields. The relationship between heat and drought losses are of particular interest, as adaptation to the former is typically viewed as more costly.

4 Estimation Methods

We use a framework similar to the empirical specification in Schlenker and Roberts (2009). Specifically, let i denote a county and t denote a year. We estimate regressions of the following form:

$$y_{it} = x_{it}\delta + c_i + f(\tau_{it}, \beta) + \varepsilon_{it} \quad (1)$$

where y_{it} is the LLR in county i and year t, x_{it} is a vector of controls, which include quadratic total precipitation and state-level quadratic time trends, and c_i is a county level fixed effect. All other unobservables are captured by ε_{it}. The function $f(\tau_{it}, \beta)$ relates county and time specific temperatures, denoted by τ_{it}, to y_{it}. We use two different specifications for f. One specification relates the number of days in each 3 ℃ temperature bin to y_{it}. The second specification is a piecewise linear function: we permit the impact of temperatures on y_{it} to vary over three and four different intervals in a piecewise linear fashion.

In a separate set of regressions we break down the temperature impacts on the LLRs by the cause of loss. Specifically, we can write $y_{it} = \sum_j y_{jit}$, where j denotes a cause that could be cited by the claimant. There are in excess of 30 possible causes, many of which are seldomly invoked. As a result, we focus our attention on some of the main causes, particularly those that relate to temperature. These include heat, drought, excess moisture, and freeze.

5 Data

We use data from several different sources. The crop insurance data were obtained from the Summary of Business (SOB) and Cause of Loss (COL) databases, both publicly available datasets maintained by the RMA. The SOB data contains county-year specific observations of total losses and liabilities by crop. The COL data contains crop-county-year specific observations of losses disaggregated by each of the 44 different possible causes. We restrict our analysis to corn and soybeans from 1989-2014. These are the two most widely grown and insured crops in the United States, and 1989-2014 is the period for which we could obtain the required information on crop insurance.

Data on daily minimum and maximum temperature, as well as total precipitation, were obtained from Wolfram Schlenker's website. These data are based on the PRISM weather data set.[3] Following Schlenker and Roberts (2009), we assume the growing season is from March 1st to August 30th for both corn and soybeans. These data in turn are used to calculate the amount of time spent in each 3 ℃ temperature bin. Figure 1 presents the average amount of daily exposure to each 3 ℃ temperature bin. Overall, there is significant exposure to all bins with the exception of 36 ℃ (exposure to temperatures in excess of 36 ℃ are aggregated into a single bin).

For comparison purposes, we also use data on county-year specific crop yields for corn and soybeans. These data were obtained from the National Agricultural Statistics Service of the United States Department of Agricultural.

Table 1 reports summary statistics for the LLR, cause-specific LLRs, and crop yields. The average LLR in the entire sample is about $0.12 for corn and $0.11 for soybeans. In words, for each dollar of insurance a corn farmer buys, they get indemnity payments of about $0.12, on average. Among the four temperature

[3]We use Wolfram's Stata do file to convert daily temperature data into the amount of time spent at each one degree temperature interval during the growing the season.

and precipitation related causes, drought related losses are the largest, making up about half of the overall LLR. Compared to drought and moisture related losses, heat and freeze related claims comprise a small share of overall losses. We now examine how temperature variation impacts the overall and cause-specific LLRs.

6 Results

Figure 2 presents the estimated impacts for each 3 ℃ temperature bin for both corn and soybeans. These impacts are the net effect of replacing one day at -9 ℃ with one day at the respective 3 ℃ bin. For comparison, we also report the estimated impact of temperature variation on the logarithm of yields. Consistent with previous work, temperatures above 30 ℃ reduce yields significantly. The impact of extreme temperatures on the LLR is highly consistent with the estimated yield impacts. In corn, the LLR increases significantly at 30 ℃ and even more so at 36 ℃. In soybeans, the effect becomes statistically significant at 33 ℃ and increases substantially at 36 ℃. The fact that the LLR only begins to increase at 33 ℃ in soybeans (compared to 30 ℃ for yields) may be due to the fact that indemnity payments only trigger when yields fall below the coverage level. Thus, even though yields may begin declining at 30 ℃ , it may take a *signficant* decline before insurance payments kick in.

Results for the piecewise linear specification are reported in tables 2 and 3. The estimated coefficients for each temperature interval and the corresponding knots were obtained by a search procedure based on fit. For the yield model, both the two-knot and three-knot specifications produce the same knots: 26 ℃ for corn and 27 ℃ for soybeans. These thresholds are slightly lower than in Schlenker and Roberts (2009). We suspect that this is due to our sample excluding years prior to 1989. Indeed, these results are consistent with the estimates obtained by Schlenker and Roberts (2009) in the later temporal subset of their data. Concerning the

LLR, it begins to increase at the same threshold temperature of 26 ℃ in corn, but later in soybeans, at 30 ℃ .

Temperature effects on cause-specific losses are reported in figures 3 and 4 and tables 4 - 7. The results for the 3 ℃ temperature bin specification suggest that the temperature responses for heat-related losses are very similar to the yield and LLR responses. The heat related piecewise linear regressions find higher critical temperatures: 29 ℃ for corn and 33 ℃ for soybeans. These results suggest that losses that are directly due to extreme heat start to occur at higher temperatures.

7 Simulation with warming scenarios

Using the estimated coefficients from the 3 ℃ temperature bin regressions we simulate the impact of a uniform 1 ℃ increase in temperatures during 1989-2014 period. Specifically, we increase the minimum and maximum temperatures by 1 ℃ , recompute the amount of time spent in each 3 ℃ temperature bin, and then calculate the predicted LLR using the estimated coefficients presented in figures 2, 3, and 4. Table 8 contains the overall means for these predictions, as well as the observed mean LLR.

The overall LLR in corn increases by $0.029, or about 24%, and the overall LLR in soybeans increases by $0.007, or about 6%. The cause-specific LLR provide additional information on the drivers of these increases. While freeze and moisture related losses decrease in both corn and soybeans, as would be expected, they are signficantly outweighed by the increase in the LLR for drought and heat. In percentage terms, heat losses increase the most in both corn and soybeans, but in dollar terms, drought losses dominate. In corn, the drought LLR is predicted to increase by $0.035, and in soybeans by $0.018.

References

Barnaby, G. A. and L. Russell (2016). Theme overview: Crop insurance in the 2018/2019 farm bill. *Choices 31*(3).

Burke, M., K. Emerick, et al. (2016). Adaptation to climate change: Evidence from us agriculture. *American Economic Journal: Economic Policy 8*(3), 106–40.

Coble, K. H. and B. J. Barnett (2013). Why do we subsidize crop insurance? *American Journal of Agricultural Economics 95*(2), 498–504.

Deschenes, O. and M. Greenstone (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *The American Economic Review 97*(1), 354–385.

FCIC (2014). 2014 standard reinsurance agreement. http://www.rma.usda.gov/data/ra.

Gammans, M., P. Mérel, and A. Ortiz-Bobea (2017). Negative impacts of climate change on cereal yields: statistical evidence from france. *Environmental Research Letters 12*(5), 054007.

Glauber, J. W. (2013). The growth of the federal crop insurance program, 1990–2011. *American Journal of Agricultural Economics 95*(2), 482–488.

Goodwin, B. K. (1994). Premium rate determination in the federal crop insurance program: What do averages have to say about risk? *Journal of Agricultural and Resource Economics*, 382–395.

Goodwin, B. K. (2015). Agricultural policy analysis: the good, the bad, and the ugly. *American Journal of Agricultural Economics 97*(2), 353–373.

Lobell, D. B., M. J. Roberts, W. Schlenker, N. Braun, B. B. Little, R. M. Rejesus, and G. L. Hammer (2014). Greater sensitivity to drought accompanies maize yield increase in the us midwest. *Science 344*(6183), 516–519.

Lobell, D. B., A. Torney, and C. B. Field (2011). Climate extremes in california agriculture. *Climatic change 109*(1), 355–363.

Mendelsohn, R., W. D. Nordhaus, and D. Shaw (1994). The impact of global warming on agriculture: a ricardian analysis. *The American economic review*, 753–771.

Miranda, M. J. and K. Farrin (2012). Index insurance for developing countries. *Applied Economic Perspectives & Policy 34*(3).

RMA (2015). Summary of business. http://www.rma.usda.gov/data/sob.html.

Schlenker, W. and M. J. Roberts (2009). Nonlinear temperature effects indicate severe damages to us crop yields under climate change. *Proceedings of the National Academy of sciences 106*(37), 15594–15598.

Tack, J., A. Barkley, and L. L. Nalley (2015). Effect of warming temperatures on us wheat yields. *Proceedings of the National Academy of Sciences 112*(22), 6931–6936.

Tack, J., K. H. Coble, and B. Barnett (2017). Warming temperatures will likely induce higher premium rates and government outlays for the us crop insurance program. *Working Paper*.

Figures and Tables

Table 1. Summary Statistics of LLR, Cause-specific LLRs, and Crop Yields)

	(1) Corn		(2) Soybeans	
	Mean	SD	Mean	SD
Summary of Business and Cause of Loss, RMA				
Total Loss/Liability	0.119	0.180	0.107	0.154
Heat Loss/Liability	0.00564	0.0270	0.00437	0.0236
Freeze Loss/Liability	0.00170	0.0168	0.000911	0.0145
Drought Loss/Liability	0.0619	0.140	0.0562	0.121
Moisture Loss/Liability	0.0298	0.0769	0.0291	0.0757
Number of county-year observations	30,261		29,014	
Crop Yields, NASS				
Yield	113.9	36.44	35.43	10.29
Number of county-year observations	44,861		39,775	

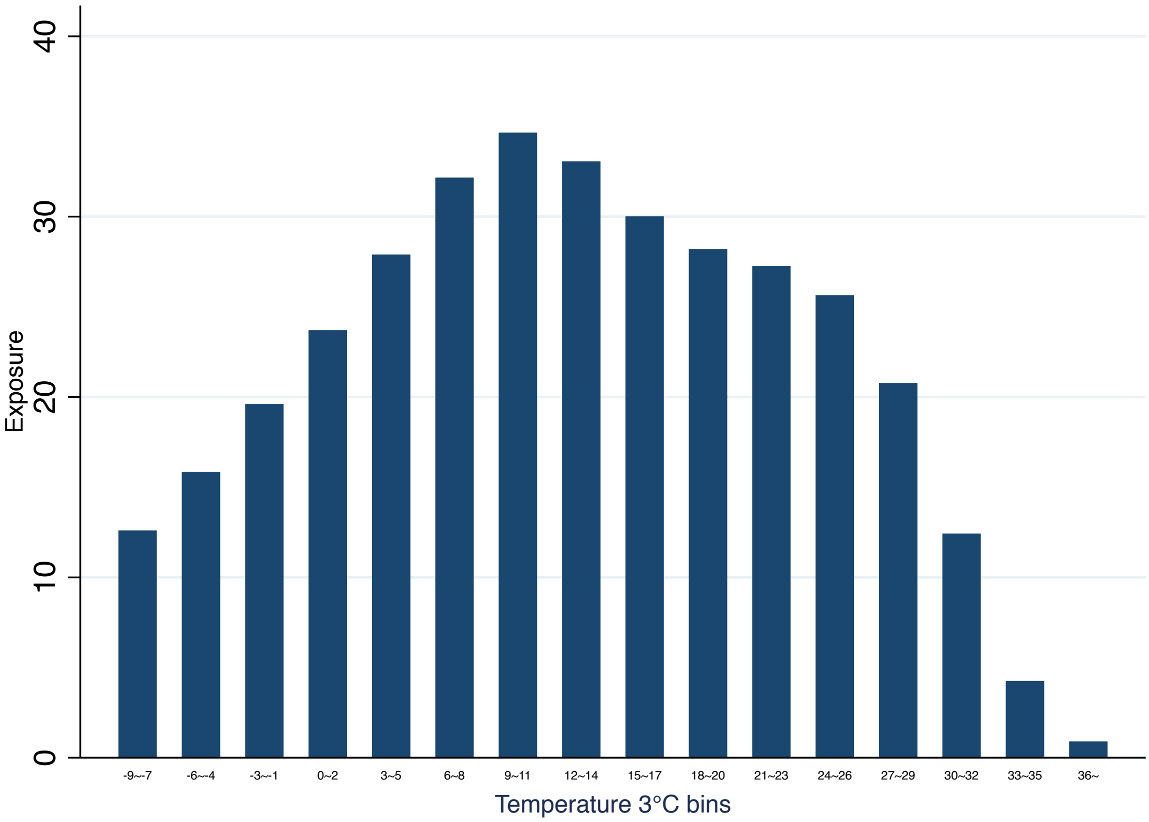

Figure 1. Average Temperature Exposure (1989-2014)

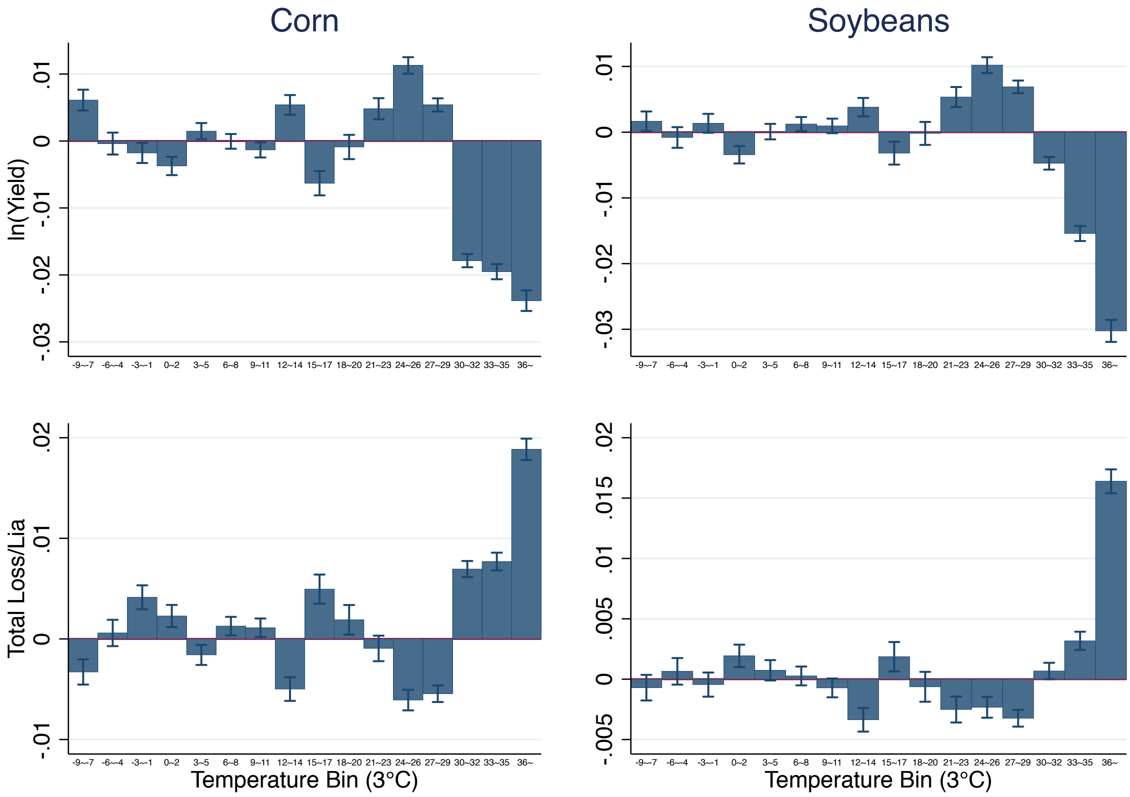

Figure 2. Temperature Effects on Crop Yields and Crop Insurance Indemnity per Dollar of Liability (1989-2014)

Table 2. Piecewise Linear Regression Results (Two Knots): Crop Yields and Crop Insurance Indemnity per Dollar of Liability (1989-2014)

	(1)	(2)	(3)	(4)
	Corn	Corn	Soybeans	Soybeans
VARIABLES	$\ln(Yield)$	$\frac{Total\ Loss}{Lia}$	$\ln(Yield)$	$\frac{Total\ Loss}{Lia}$
-9℃ to Knot 1	-3.16e-05***	7.93e-05***	0.000122***	-5.74e-05***
	(1.15e-05)	(8.57e-06)	(1.05e-05)	(7.01e-06)
Knot 1 to Knot 2	0.00374***	-0.00335***	0.00374***	-0.000458***
	(9.09e-05)	(7.24e-05)	(8.89e-05)	(2.28e-05)
Knot 2 to Inf	-0.00520***	0.00310***	-0.00515***	0.00285***
	(5.24e-05)	(4.18e-05)	(5.75e-05)	(5.43e-05)
Constant	4.236***	0.255***	2.273***	0.638***
	(0.0473)	(0.0350)	(0.0449)	(0.0304)
Knot 1	22℃	22℃	23℃	21℃
Knot 2	26℃	26℃	27℃	30℃
Observations	44,651	30,261	39,775	29,014
R-squared	0.705	0.476	0.711	0.512

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The first knot is searched over the temperatures from 0 to 25 ℃ and the second knot is searched over the temperatures from 26 to 36 ℃.

Table 3. Piecewise Linear Regression Results (Three Knots): Crop Yields and Crop Insurance Indemnity per Dollar of Liability (1989-2014)

VARIABLES	(1) Corn $\ln(Yield)$	(2) Corn $\frac{Total\ Loss}{Lia}$	(3) Soybeans $\ln(Yield)$	(4) Soybeans $\frac{Total\ Loss}{Lia}$
-9℃ to Knot 1	0.00137***	-0.000472***	0.00638***	-0.00186***
	(0.000170)	(5.23e-05)	(0.000727)	(0.000460)
Knot 1 to Knot 2	-0.000118***	0.000189***	3.63e-05***	-3.60e-05***
	(1.56e-05)	(1.33e-05)	(1.36e-05)	(8.88e-06)
Knot 2 to Knot 3	0.00407***	-0.00373***	0.00313***	-0.000488***
	(9.90e-05)	(8.07e-05)	(7.20e-05)	(2.39e-05)
Knot 3 to Inf	-0.00528***	0.00320***	-0.00513***	0.00288***
	(5.34e-05)	(4.27e-05)	(5.64e-05)	(5.47e-05)
Constant	3.499***	0.767***	1.427***	0.882***
	(0.101)	(0.0593)	(0.110)	(0.0691)
Knot 1	-5℃	-1℃	-8℃	-8℃
Knot 2	22℃	22℃	22℃	21℃
Knot 3	26℃	26℃	27℃	30℃
Observations	44,651	30,261	39,775	29,014
R-squared	0.705	0.478	0.712	0.512

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The first knot is searched over the temperatures from -8 to -1 ℃, the second knot is searched over the temperatures 0 to 25 ℃ and the third knot is searched over the temperatures from 26 to 36 ℃.

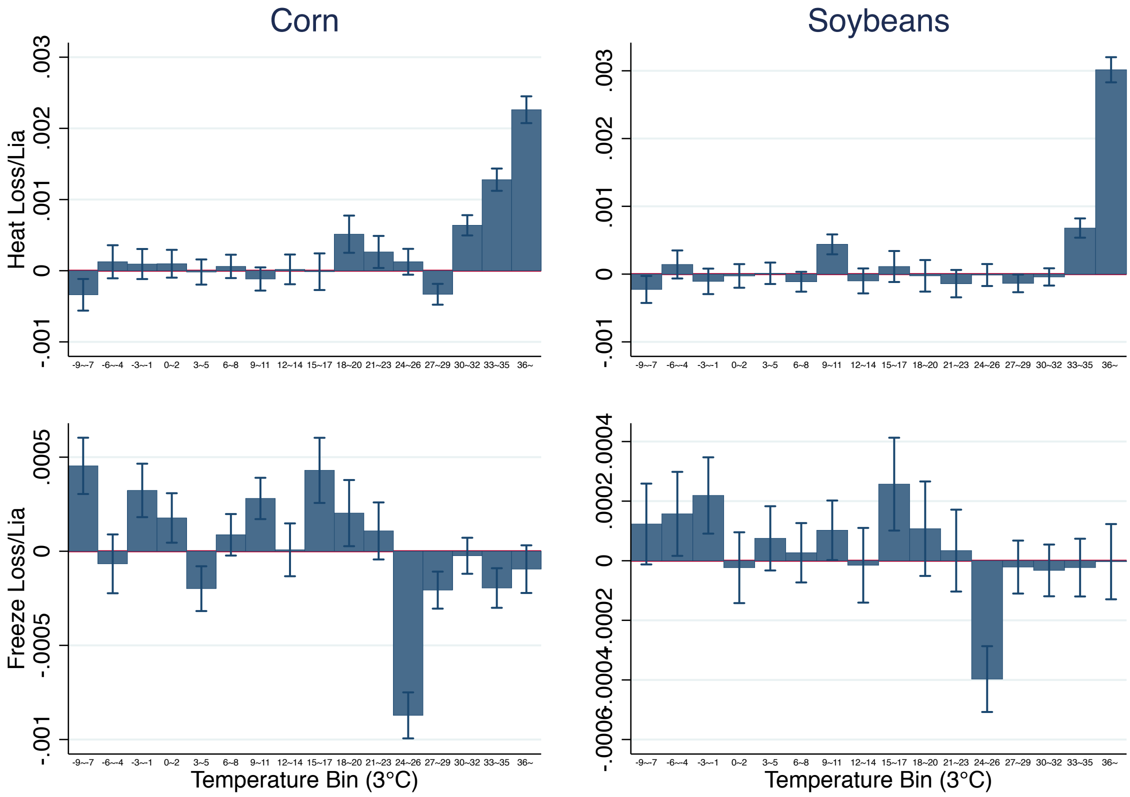

Figure 3. Temperature Effects on Crop Insurance Indemnity Associated with Heat/Freeze per Dollar of Liability (1989-2014)

Table 4. Piecewise Linear Regression Results (Two Knots): Crop Insurance Indemnity Associated with Heat/Freeze per Dollar of Liability (1989-2014)

VARIABLES	(1) Corn $\frac{Heat\ Loss}{Lia}$	(2) Corn $\frac{Freeze\ Loss}{Lia}$	(3) Soybeans $\frac{Heat\ Loss}{Lia}$	(4) Soybeans $\frac{Freeze\ Loss}{Lia}$
-9℃ to Knot 1	1.40e-05***	3.37e-05***	-8.73e-07	1.74e-05***
	(1.40e-06)	(2.01e-06)	(1.14e-06)	(1.81e-06)
Knot 1 to Knot 2	-0.000125***	-4.09e-05***	-7.04e-06	-2.16e-05***
	(1.01e-05)	(1.50e-06)	(5.59e-06)	(1.36e-06)
Knot 2 to Inf	0.000371***	3.44e-05***	0.000757***	2.38e-05***
	(1.04e-05)	(3.50e-06)	(2.08e-05)	(3.18e-06)
Constant	-0.0547***	-0.0209***	0.00298	-0.0109**
	(0.00609)	(0.00504)	(0.00546)	(0.00463)
Knot 1	24℃	8℃	25℃	8℃
Knot 2	29℃	26℃	33℃	26℃
Observations	30,261	30,261	29,014	29,014
R-squared	0.274	0.141	0.276	0.107

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The first knot is searched over the temperatures from 0 to 25 ℃ and the second knot is searched over the temperatures from 26 to 36 ℃.

Table 5. Piecewise Linear Regression Results (Three Knots): Crop Insurance Indemnity Associated with Heat/Freeze per Dollar of Liability (1989-2014)

VARIABLES	(1) Corn $\frac{Heat\ Loss}{Lia}$	(2) Corn $\frac{Freeze\ Loss}{Lia}$	(3) Soybeans $\frac{Heat\ Loss}{Lia}$	(4) Soybeans $\frac{Freeze\ Loss}{Lia}$
-9℃ to Knot 1	-6.26e-05***	0.00113***	-6.11e-05	0.000438***
	(8.93e-06)	(6.53e-05)	(8.24e-05)	(6.97e-05)
Knot 1 to Knot 2	2.72e-05***	-1.16e-05***	-3.04e-07	2.80e-06
	(2.06e-06)	(1.31e-06)	(1.38e-06)	(2.31e-06)
Knot 2 to Knot 3	-0.000166***	-0.000134***	-8.25e-06	-2.08e-05***
	(1.11e-05)	(9.16e-06)	(5.83e-06)	(1.58e-06)
Knot 3 to Inf	0.000389***	6.48e-05***	0.000758***	2.39e-05***
	(1.06e-05)	(5.04e-06)	(2.09e-05)	(3.26e-06)
Constant	0.0183*	-0.128***	0.0115	-0.0556***
	(0.0104)	(0.00972)	(0.0128)	(0.00923)
Knot 1	-1℃	-8℃	-8℃	-8℃
Knot 2	24℃	22℃	25℃	10℃
Knot 3	29℃	26℃	33℃	26℃
Observations	30,261	30,261	29,014	29,014
R-squared	0.276	0.145	0.276	0.108

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: The first knot is searched over the temperatures from -8 to -1 ℃, the second knot is searched over the temperatures 0 to 25 ℃ and the third knot is searched over the temperatures from 26 to 36 ℃.

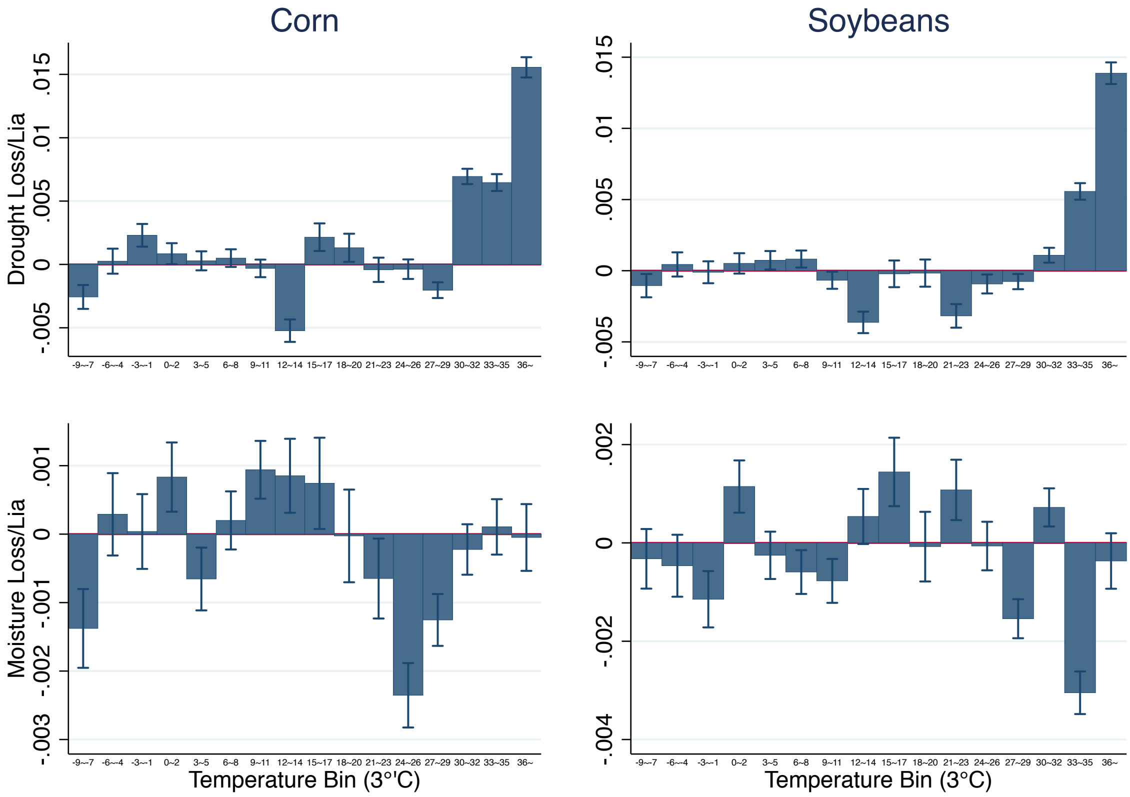

Figure 4. Temperature Effects on Crop Insurance Indemnity Associated with Drought/Excess Moisture per Dollar of Liability (1989-2014)

Table 6. Piecewise Linear Regression Results (Two Knots): Crop Insurance Indemnity Associated with Drought/Excess Moisture per Dollar of Liability (1989-2014)

VARIABLES	(1) Corn $\frac{Drought\ Loss}{Lia}$	(2) Corn $\frac{Moisture\ Loss}{Lia}$	(3) Soybeans $\frac{Drought\ Loss}{Lia}$	(4) Soybeans $\frac{Moisture\ Loss}{Lia}$
-9℃ to Knot 1	9.28e-05***	-1.39e-05***	-3.39e-05***	-0.000176***
	(6.48e-06)	(3.87e-06)	(5.58e-06)	(1.97e-05)
Knot 1 to Knot 2	-0.00171***	-0.000643***	-0.000180***	3.13e-05***
	(5.47e-05)	(4.70e-05)	(1.52e-05)	(4.53e-06)
Knot 2 to Inf	0.00202***	0.000307***	0.00242***	-0.000239***
	(3.16e-05)	(2.01e-05)	(4.09e-05)	(1.36e-05)
Constant	-0.0176	0.0711***	0.399***	0.225***
	(0.0265)	(0.0161)	(0.0237)	(0.0272)
Knot 1	22℃	23℃	20℃	0℃
Knot 2	26℃	26℃	30℃	26℃
Observations	30,261	30,261	29,014	29,014
R-squared	0.508	0.392	0.533	0.338

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: The first knot is searched over the temperatures from 0 to 25 ℃ and the second knot is searched over the temperatures from 26 to 36 ℃.

Table 7. Piecewise Linear Regression Results (Three Knots): Crop Insurance Indemnity Associated with Drought/Excess Moisture per Dollar of Liability (1989-2014)

VARIABLES	(1) Corn $\frac{Drought\ Loss}{Lia}$	(2) Corn $\frac{Moisture\ Loss}{Lia}$	(3) Soybeans $\frac{Drought\ Loss}{Lia}$	(4) Soybeans $\frac{Moisture\ Loss}{Lia}$
-9℃ to Knot 1	-0.000521***	-0.00117***	-0.000291***	-0.00300***
	(3.94e-05)	(0.000121)	(3.51e-05)	(0.000250)
Knot 1 to Knot 2	0.000214***	1.93e-05***	2.57e-05***	3.36e-05***
	(1.00e-05)	(5.14e-06)	(9.60e-06)	(4.10e-06)
Knot 2 to Knot 3	-0.00214***	-0.000585***	-0.000188***	-0.000247***
	(6.08e-05)	(3.55e-05)	(1.29e-05)	(1.37e-05)
Knot 3 to Inf	0.00213***	0.000323***	0.00243***	0.000620***
	(3.22e-05)	(1.95e-05)	(3.94e-05)	(0.000170)
Constant	0.553***	0.375***	0.631***	0.438***
	(0.0447)	(0.0357)	(0.0395)	(0.0392)
Knot 1	-1℃	-7℃	-1℃	-8℃
Knot 2	22℃	22℃	18℃	25℃
Knot 3	26℃	26℃	30℃	36℃
Observations	30,261	30,261	29,014	29,014
R-squared	0.513	0.394	0.534	0.340

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: The first knot is searched over the temperatures from -8 to -1 ℃, the second knot is searched over the temperatures 0 to 25 ℃ and the third knot is searched over the temperatures from 26 to 36 ℃.

Table 8. Actual Crop Insurance Indemnity per Dollar of Liability and Simulated Crop Insurance Indemnity per Dollar of Liability (1989-2014)

VARIABLES	(1) N	(2) Actual Mean	(3) Plus 1°C Mean
Corn			
Total Loss	30,261	0.119	0.148
Heat Loss	30,261	0.00564	0.0113
Freeze Loss	30,261	0.00170	-0.000445
Drought Loss	30,261	0.0619	0.0974
Moisture Loss	30,261	0.0298	0.0261
Soybeans			
Total Loss	29,014	0.107	0.114
Heat Loss	29,014	0.00437	0.00769
Freeze Loss	29,014	0.000911	-8.70e-05
Drought Loss	29,014	0.0562	0.0742
Moisture Loss	29,014	0.0291	0.0249

Note: The simulation is based on the estimates from the 3 ℃ temperature bin regressions. The estimates are reported in figures 2, 3, and 4.