Federal Crop Insurance and the Disincentives to Adapt to Extreme Heat

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Abstract

The United States produces 40% of the world's corn and soybeans. Given its dominant market share, any effect on US production has global repercussions. Annual fluctuations in yields crucially depend on the occurrence of extreme heat as measured by temperatures that exceed 29°C and 30°C, respectively. We examine whether the highly subsidized US crop insurance gives farmers a disincentive to use all possible adaptation strategies against extreme heat as losses are insured. We estimate a panel regression of county-level yields in 1989-2013 that interacts our exogenous weather measures with the fraction of the planted area in a county that is covered by crop insurance. Insurance coverage increased greatly over our sample period. Insured corn and soybean areas have sensitivities that are, respectively, 67% and 43% larger than uninsured areas.

We appreciate help in obtaining and interpreting the RMA data from Erik O'Dongohue at the Economic Research Service of the United States Department of Agriculture. All remaining errors are ours.

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Temperatures in many areas around the world have increased in the past several decades due to an increase in greenhouse gases from anthropogenic sources (Intergovernmental Panel on Climate Change 2013). Continued increases in greenhouse gas emissions will further increase global temperature over the next century. This prediction is robust across multiple climate scenarios.

The practical importance of global average temperature on society may appear to be limited in developed countries, but changes in local weather events can translate into changed frequency of extreme events (Brooks 2013). For these reasons, various aspects of extreme events have recently received a lot of attention both in academic and policy analyses, with a special focus on extreme heat (Schär & Jendritzky 2004, Intergovernmental Panel on Climate Change 2012).[1] For example, most of the predicted impacts from climate change in the United States come from the increased frequency of extreme heat (Climate Prospectus 2014).

The societal and economic damages associated with climate change in the United States have been studied in the burgeoning climate economics literature covering various sectors: health (Deschênes & Greenstone 2011), productivity (Graff Zivin & Neidell 2014), and agriculture (Schlenker & Roberts 2009). The predicted impacts in all these studies crucially hinge on the sensitivity to fluctuations in extreme heat.

Government programs may both enable or potentially distort societal adaptation behavior. Yet, empirical evidence about the effectiveness of governmental programs and whether they aid or interfere with improving the sensitivity of systems to fluctuations in extreme heat is limited. While humans have adapted to extreme heat over time by installing air conditioning, there is no evidence that agriculture has become less sensitive to extreme heat. There is tremendous technological progress for average yields, which have increased threefold over the last six decades. At the same time, the sensitivity to extreme heat has remained relatively constant or even worsened. For example, studies looking at the effect of extreme heat in a panel setting find similar results to a cross-section or studies that link changes in yields to changes in observed climate trends (Burke & Emerick 2013).

This paper devises a tractable empirical framework to examine whether the highly subsidized crop insurance program by the United States government makes farmers more sensitive to changes in extreme heat and thereby limits their ability to cope with extreme heat or adapt to it. Insured farmers might not engage in the optimal protection against harmful extreme

[1] The whole notion of extreme weather or climate events may cover a broad facet of climate variability under stable or changing climate conditions. Throughout, we adopt IPPC 2012's definition of "any occurrence of a value of weather or climate variable above (or below) a threshold value near the upper (or lower) ends (tails) of the range of observed values of the variable."

heat as the resulting crop losses are covered by the insurance program. To test this occurrence of moral hazard, we combine annual county-level yields and information about crop insurance coverage with high-resolution weather data sets to test whether farmers become more sensitive to fluctuations in extreme heat when a large fraction of their acreage becomes insured. Our results suggest a significant amount of moral hazard in federal crop insurance. This has important implications: first, since the federal government encourages participation in the crop insurance program through increases in premium subsidies, the presence of moral hazard implies that there will be additional cost to the program as losses exceed what they could have been without the program. Second, climate change will amplify the government induced distortion as it will increase the frequency of extremely hot temperatures. Third, our findings imply that there are possibilities to adapt to climate change as uninsured areas show lower sensitivities, but this adaptation potential is skewed by government programs that give a disincentive to engage in it. A farmer will choose subsidized yield guarantees over costly adaptation measures.

1 The Federal Crop Insurance Program

The United States Federal Crop Insurance Program (FCIP) has gained tremendous momentum in recent decades and has become one of the major agricultural support program in the United States. Created in the 1930s, the crop insurance programs have undergone many developments through the revisions in various federal farm bills, acts, and assistance programs.

The 1980 Federal Crop Insurance Act greatly expanded the program and encouraged participation by offering farmers subsidized insurance premiums. Between 1988 and 1994, annual ad hoc disaster assistance programs were used to further provide relief to beneficiaries and/or producers. The 1994 "Crop Insurance Reform Act" had the goal to eliminate annual disaster programs. It made participation in the insurance program mandatory. This act implemented catastrophic (CAT) coverage to protect producers against major losses at no cost to producers, and increased crop insurance subsidies for higher coverage levels.[2] In

[2]Contracts initially were based both on average county-level yields to avoid moral hazard as well as individual fields or farms. The latter has since become the predominant type of contract, where individual fields or farms are predominantly insured against yield losses, i.e., if yields on a field fall below a certain coverage (or guarantee) level, insurance kicks in to guarantee the chosen coverage level. The premium for an individual farmer is a function of the observed yield history for the last ten years, so lower yields eventually lead to higher premiums, but these premiums are highly subsidized. The CAT level is usually set at 50% and is 100% subsidized.

recent years, legislative mandates have further increased the premium subsidy, in addition to the introduction of new insurance products. As a result the program has experienced tremendous growth in participation, especially following the 1994 act(Annan et al. 2014).[3]

The FCIP contracts along with premium subsidies are currently administered by the Risk Management Agency (RMA) of the United State Department of Agriculture (USDA), where the subsidies cover a significant share of insurance premiums. Subsidy rates tend to be highest for the lowest coverage level and decrease in the chosen coverage level. The contracts are sold through private insurance companies, and indemnity payments are triggered whenever yield or price realizations fall below selected guaranteed levels.

2 Model

We estimate a panel regression linking log yields y_{it} in county i in year t to weather variables $\mathbf{W}_{it}$ that are interacted with the fraction of the area that is insured f_{it}

$$y_{it} = \alpha_i + \beta_{w1}\mathbf{W}_{it} + \beta_{w2}\mathbf{W}_{it}f_{it} + \gamma f_{it} + \delta_t + g_i(t) + \epsilon_{it} \tag{1}$$

We follow Schlenker & Roberts (2009) and use four weather variables $\mathbf{W}_{it}$: moderate heat (degree days 10-29°C for corn and 10-30°C for soybeans), extreme heat (degree days above 29°C for corn and 30°C for soybeans) and a quadratic in season-total precipitation. All specifications include county fixed effects α_i and year fixed effects δ_t. Since yields are trending upward over time, we control for this trend $g(t)$ in three possible ways: we include a quadratic time trend that is either (i) common to all counties or allowed to vary by (ii) states or (iii) the county.

Our key parameter of interest is β_{w2}.[4] This provides an estimate of how the insurance program gives farmers a disincentive from engaging in possible adaptation strategies to limit the damaging effect of extreme heat or suboptimal amount of precipitation (either too little or too much precipitation).

[3]The various legislative acts reviewed for this paper were taken from the website of the Risk Management Agency at USDA: http://www.rma.usda.gov/aboutrma/what/history.html

[4]The implied key variable is constructed by interacting an exogenous term $\mathbf{W}_{it}$ with the potentially endogenous variable f_{it}. The interaction term can be interpreted as exogenous, once the main effect of the endogenous variable is directly controlled for (Angrist & Krueger 1999, Section 2.3.4). The identifying assumption is that the endogenous variable and the outcome variable are jointly independent of the exogenous variable. See also Bun & Harrison (2013) for a related discussion.

3 Data

We combined publicly available data on county-level insurance coverage from the Risk Management Agency (RMA) at the United States Department of Agriculture[5] with data on total acres planted and yields from the National Agricultural Statistics Service (NASS) at the United States Department of Agriculture.[6] The fraction of the planted area that is insured is available from 1981-2013, but subsidy levels that we use as instruments in a sensitivity check are only available from 1989-2013. We limit the data to 1989-2013 in our baseline specification to make it directly comparable to our IV estimates as it has the same sample frame.

The two data source derive county aggregates in different ways: the RMA data is the sum of all actual contracts for a given year in the county. The NASS data on the other hand uses a representative subsample of all farms in the June Agricultural Survey of each year to approximate the planting area in a county and hence has sampling noise. As a result the fraction insured, the ratio of the insured planted area to the total planting area can be larger than 1 if the NASS estimate in the denominator is an underestimate of the actual planting area. Furthermore, the sampling noise in the denominator will lead to fluctuations in the ratio that will be problematic, especially in the most flexible specification with county-specific quadratic time trends, where identification rests on annual deviations from the trends that are contaminated by noise. Our baseline specification therefore uses the maximum of the reported planting area in each county as the denominator, which by definition is constant for each county. We normalize the area insured by the maximum planting area to make counties comparable, but the important thing to note is that the normalization is constant over time.

Figures A1 and A2 in the online appendix report the fraction of area insured for both corn (top row) and soybeans (bottom row) at the state level. Figure A1 corresponds to our baseline case where the maximum of the reported planting area is used as the denominator, while Figure A2 corresponds to the use of the NASS estimate of the annual total area planted as the denominator. Both figures suggest a tremendous amount of spatio-temporal variation in the fraction of the planted area that is insured. The level of variation in our county-level data is even larger than what is shown in these state level aggregates. Next, Figures A3 and A4 in the online appendix show the number of times the annual insured area exceeds the planted area for either corn or soybeans. These figures graphically display the regions where the fraction of the planted area that is insured is larger than one. The spatial patterns

[5]Downloaded from http://www.rma.usda.gov/data/sob/scc/index.html.

[6]Downloaded from http://quickstats.nass.usda.gov.

suggest that NASS underestimates the planted acreage in the Northern United States.

Finally, our weather data come from an updated version of (Schlenker & Roberts 2009), which is extended through 2013.

4 Results

Tables 1 and 2 report estimates from multiple specifications of equation (1) for corn and soybeans, respectively, using data that span 1989-2013.[7] We begin by replicating the weather-yield relationship of Schlenker & Roberts (2009) in the first three columns (1a)-(1c) in each table. Columns (2a)-(2c) provide the results for the specification that only includes an interaction term between the fraction of the area planted that is insured and the measure of extreme heat, while columns (3a)-(3c) show the results for the specification that includes interactions for all four weather variables with the fraction of the planted area that is insured. The three columns (a)-(c) within each block of results differ by the included time trend, varying from a common quadratic time trend for all counties in columns (a), to state and county-specific quadratic time trends in columns (b) and (c), respectively. All columns include year fixed effects to capture common shocks through prices or change in the regulatory environment. We see column (3c) as our preferred model, as it most flexible and captures possible time trends. Burke & Emerick (2013) have shown that various counties in the United States have experienced differentiated warming trends, which could result in a spurious correlation with trends in insurance coverage as year-to-year fluctuations in the panel are not iid.[8]

The results re-affirm previous evidence of significant nonlinear relationship between weather and crop yields (Schlenker & Roberts 2009). For example, a 10 degree days increase in moderate heat during the growing season would imply a 0.4 percent increase in corn yields, while a degree day increase in extreme heat decreases corn yields by 0.48 percent under our preferred specification in column (1c). The results also indicate a similar inverted-U-shape

[7]We examine the sensitivity of our baseline results to included years for 1981-2013, and the results are displayed in the online appendix (see Table A1 for corn and A5 for soybeans). Our baseline results are robust to what years are included in the analysis, although we find slightly smaller point estimates when we extend the time frame to 1981.

[8]Our baseline specification top-codes the fraction insured as 1, i.e., observations that are larger than 1 are set to one. See the discussion in the data section why the fraction might be larger than one. The estimates remain stable if we either drop all observations where the fraction insured is larger than 1 (see online appendix A2 for corn and A6 for soybeans) or drop all counties where the fraction insured is ever larger than 1 including years where the ratio is less than 1 (see online appendix A3 for corn and A7 for soybeans).

effect for precipitation. The magnitudes of all coefficient estimates tend to be a bit larger in the case of soybeans.

Across the wide range of specifications that include various interaction terms, we find evidence of a significant and stable negative relationship for the interaction term of extreme heat and the fraction of the planted corn area that is insured in Table 1. The sensitivity to extreme heat is 67% larger for insured corn than for uninsured corn in our preferred specification (3c). Turning to soybeans in Table 2, the relationship is still negative and significant in our most preferred specification (3c), which allows for interactions with all the four weather variables and includes county-specific quadratic time trends. The sensitivity to extreme heat is 43% larger for insured soybeans than for uninsured soybeans.

The interaction terms of precipitation and precipitation squared with the fraction of the planted corn area that is insured shows that insured fields are less sensitive to deviation from the optimal precipitation level as the linear and quadratic terms are no longer different from zero. However, the effects of precipitation fluctuations on yields are smaller than the effects of fluctuations of extreme heat (Schlenker & Roberts 2009). On the other hand, there are no significant interaction terms with precipitation in our preferred specification for soybeans.

It is useful to note that the un-interacted terms of weather retain their expected signs and are significant throughout. Finally, the interaction term for moderate heat is insignificant in all columns of Table 1 and 2, which makes it less likely that we are picking up spurious trends, as they only impact the temperature range responsible for yield losses (extreme heat), but not the range that has a beneficial effect on yields.

Our results suggest that the federal crop insurance program makes farmers more sensitive to extreme heat and thus disincentivizing them from engaging in possible adaptation strategies. Conditional on county and time fixed effects that soak up potential confounding variation, we interprete this as an evidence of moral hazard. While insurance coverage is endogenous, our coefficients of interest interact it with exogenous weather variation. The interacted coefficients correctly identify the sensitivity of the insured field, however, it could be because insured fields are different (e.g., marginal land that is ensured has higher sensitivities), or because crop insurance gives a disincentive to reduce the damaging effects. We believe it is the latter for several reasons: first, the heterogeneity story seems unlikely given that we account for county fixed effects, year fixed effects as well as county-specific time trends during a time period when insurance coverage greatly increases. The marginal decision on which areas to insure hence greatly changes over our study period.[9] Second, we find

[9]If the same marginal area was switching in and out of insurance over time, we might pick up that this

the results for extreme heat, but not beneficial moderate heat. Third, we also conduct a sensitivity analysis in the appendix where we instrument the fraction insured by subsidy rates, defined as the ratio of subsidies paid by the government to total payments for the insurance product for various coverage levels ranging from 50% to 90% in 5% intervals. It is important to note that we do *not* instrument by the overall subsidy rate, but by the coverage-specific subsidy rate. Generally, subsidy rates decrease as the coverage level increases, and hence the overall subsidy rate might reflect endogenous changes in the coverage level. Instead, the coverage-specific coverage levels keep the type of insurance constant over time.[10] While the IV setup has its own potential drawbacks - government subsidy rates might be endogenous to factors that also effect yield, we find it reassuring that we get comparable point estimates in appendix Table A4 for corn and Table A8 for soybeans. While the results are not significant for corn, the p-value is 0.14, i.e., it barely missed the 10% significance level.

5 Conclusions

This paper provides new evidence about how the highly subsidized crop insurance program by the United States government makes farmers more sensitive to fluctuations in extreme heat. We find that the fraction insured has no significant effect on moderate heat, but a statistically significant effect on extreme heat. The federal crop insurance program gives farmers a disincentive from engaging in possible adaptation strategies to cope with extreme heat thereby exacerbating potential losses. The sensitivity to extreme heat is 67% larger for insured corn than for uninsured corn, and 43% higher for soybeans. Climate change is likely to amplify the problem as it will increase the frequency of extremely hot temperatures.

Our study is an initial step towards the broader understanding of behavioral distortions from government programs and their linkages with climate adaptation. Ongoing research includes theoretical analyses of the underlying problem, a test for potential heterogeneous treatment effects, and quantifying crop insurance indemnities due to the implied moral hazard.

particular marginal area is different.

[10]If a particular coverage-level was not observed for a county in a given year, we set the subsidy rate to equal what it would have been according to our fixed effects and time trends, thereby ensuring it has no leverage in the estimation in our panel as there is no deviation in that county and year.

References

Angrist, Joshua D., and Alan B. Krueger. 1999. "Empirical Strategies in Labor Economics." Handbook of Labor Economics: 1277–1366.

Annan, Francis, Jesse Tack, Adrian Harri, and Keith Coble. 2014. "Spatial Pattern of Yield Distributions: Implications for Crop Insurance." *American Journal of Agricultural Economics*, 96(1): 253–268.

Brooks, Harold E. 2013. "Severe Thunderstorms and Climate Change." *Atmospheric Research*, 123(1): 129138.

Bun, Maurice J.G., and Teresa D. Harrison. 2013. "OLS and IV Estimation of Regression Models including Endogenous Interaction Terms." *University of Amsterdam Discussion Paper 2014/02.*

Burke, Marshall, and Kyle Emerick. 2013. "Adaptation to Climate Change: Evidence from US Agriculture." *Working Paper.*

Climate Prospectus. 2014. *American Climate Prospectus: Economic Risks in the United States.* Columbia University Press.

Deschênes, Olivier, and Michael Greenstone. 2011. "Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US." *American Economic Journal: Applied Economics*, 3(4): 152–185.

Graff Zivin, Joshua, and Matthew Neidell. 2014. "Temperature and the Allocation of Time: Implications for Climate Change." *Journal of Labor Economics*, 32(1): 1–26.

Intergovernmental Panel on Climate Change. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* Cambridge University Press.

Intergovernmental Panel on Climate Change. 2013. *Climate Change 2013: The Physical Science Basis.* Cambridge University Press.

Schär, Christoph, and Gerd Jendritzky. 2004. "Climate change: Hot news from summer 2003." *Climate change: Hot news from summer 2003*, 432: 559–560.

Schlenker, Wolfram, and Michael J. Roberts. 2009. "Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields under Climate Change." *Proceedings of the National Academy of Sciences of the United States*, 106(37): 15594–15598.

Table 1: Insurance and Weather Sensitivity: Panel Regression for Corn 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-29°C	0.290**	0.381***	0.398***	0.277**	0.380***	0.399***	0.200	0.331**	0.401***
	(0.127)	(0.130)	(0.139)	(0.126)	(0.132)	(0.142)	(0.149)	(0.138)	(0.148)
x fraction insured							0.204*	0.129	-0.006
							(0.120)	(0.092)	(0.109)
Degree Days Above 29°C	-0.469***	-0.466***	-0.476***	-0.413***	-0.399***	-0.401***	-0.347***	-0.350***	-0.369***
	(0.058)	(0.056)	(0.053)	(0.053)	(0.052)	(0.049)	(0.062)	(0.051)	(0.054)
x fraction insured				-0.112**	-0.152***	-0.173***	-0.273***	-0.273***	-0.249***
				(0.046)	(0.033)	(0.047)	(0.075)	(0.070)	(0.092)
Precipitation (m)	0.933***	0.933***	0.896***	0.921***	0.915***	0.884***	1.768***	1.569***	1.584***
	(0.216)	(0.205)	(0.225)	(0.222)	(0.209)	(0.228)	(0.338)	(0.300)	(0.320)
x fraction insured							-1.944**	-1.493**	-1.590**
							(0.759)	(0.669)	(0.679)
Precipitation (m) Squared	-0.677***	-0.668***	-0.643***	-0.663***	-0.650***	-0.629***	-1.170***	-1.031***	-1.038***
	(0.173)	(0.165)	(0.179)	(0.177)	(0.168)	(0.180)	(0.240)	(0.200)	(0.212)
x fraction insured							1.145*	0.855*	0.917*
							(0.584)	(0.513)	(0.520)
R-squared	0.2078	0.2074	0.2246	0.2128	0.2136	0.2320	0.2182	0.2171	0.2363
Observations	39702	39702	39702	39702	39702	39702	39702	39702	39702
Counties	1717	1717	1717	1717	1717	1717	1717	1717	1717
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

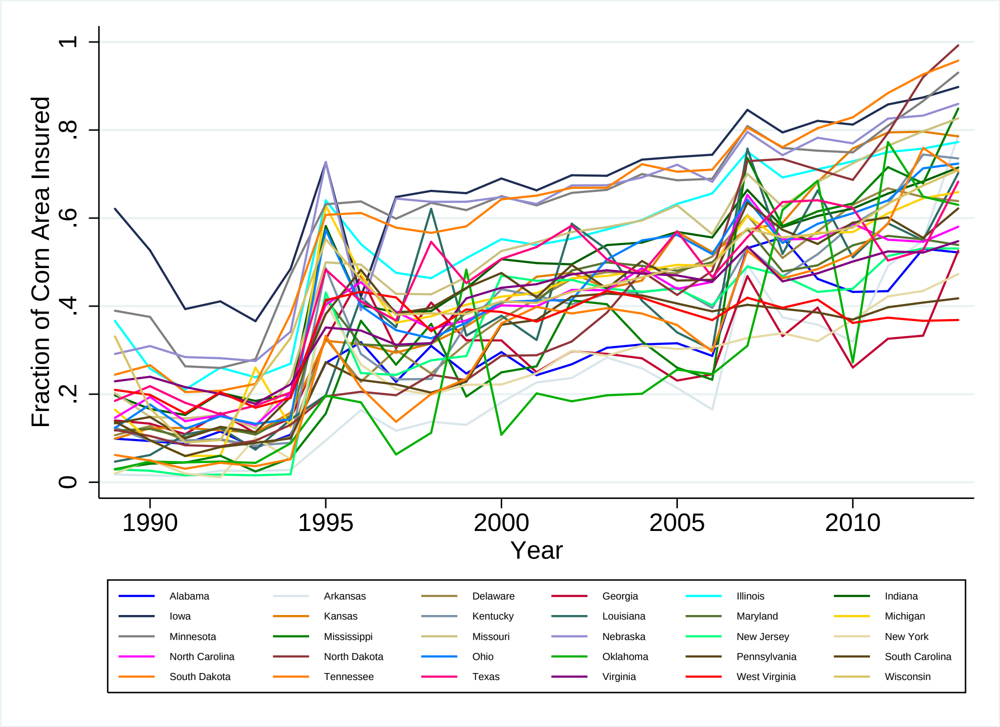
Notes: Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-29°C), extreme heat (degree days above 29°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). Ratios that are larger than one are top code at 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

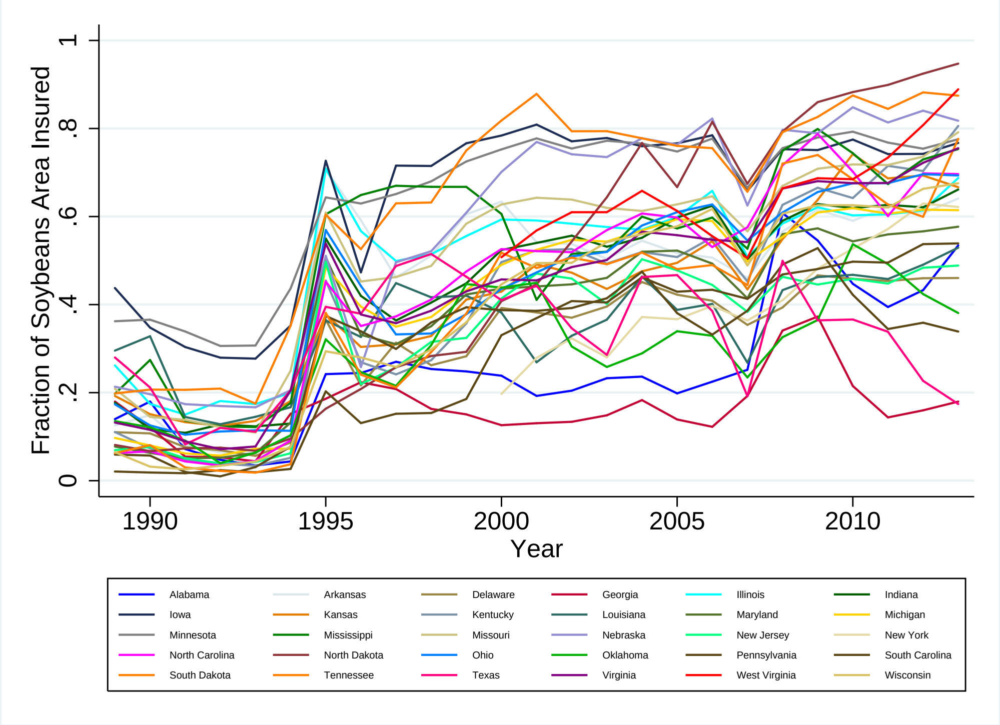
Table 2: Insurance and Weather Sensitivity: Panel Regression for Soybeans 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-30°C	0.478***	0.541***	0.577***	0.483***	0.550***	0.586***	0.402***	0.498***	0.542***
	(0.079)	(0.087)	(0.088)	(0.078)	(0.087)	(0.090)	(0.096)	(0.097)	(0.098)
x fraction insured							0.188**	0.129*	0.113
							(0.093)	(0.072)	(0.086)
Degree Days Above 30°C	-0.592***	-0.613***	-0.623***	-0.584***	-0.569***	-0.576***	-0.508***	-0.517***	-0.526***
	(0.052)	(0.052)	(0.053)	(0.055)	(0.047)	(0.046)	(0.059)	(0.053)	(0.052)
x fraction insured				-0.016	-0.100	-0.108	-0.204	-0.228**	-0.228**
				(0.107)	(0.074)	(0.073)	(0.130)	(0.101)	(0.095)
Precipitation (m)	1.537***	1.411***	1.443***	1.537***	1.406***	1.439***	2.077***	1.659***	1.661***
	(0.232)	(0.224)	(0.232)	(0.233)	(0.225)	(0.232)	(0.325)	(0.276)	(0.307)
x fraction insured							-1.262***	-0.557	-0.473
							(0.470)	(0.386)	(0.445)
Precipitation (m) Squared	-1.006***	-0.916***	-0.937***	-1.006***	-0.909***	-0.930***	-1.334***	-1.031***	-1.027***
	(0.158)	(0.151)	(0.159)	(0.161)	(0.152)	(0.159)	(0.244)	(0.200)	(0.223)
x fraction insured							0.763**	0.253	0.186
							(0.349)	(0.276)	(0.317)
R-squared	0.2916	0.3030	0.3232	0.2924	0.3045	0.3246	0.2957	0.3060	0.3260
Observations	34958	34958	34958	34958	34958	34958	34958	34958	34958
Counties	1505	1505	1505	1505	1505	1505	1505	1505	1505
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-30°C), extreme heat (degree days above 30°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). Ratios that are larger than one are top code at 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

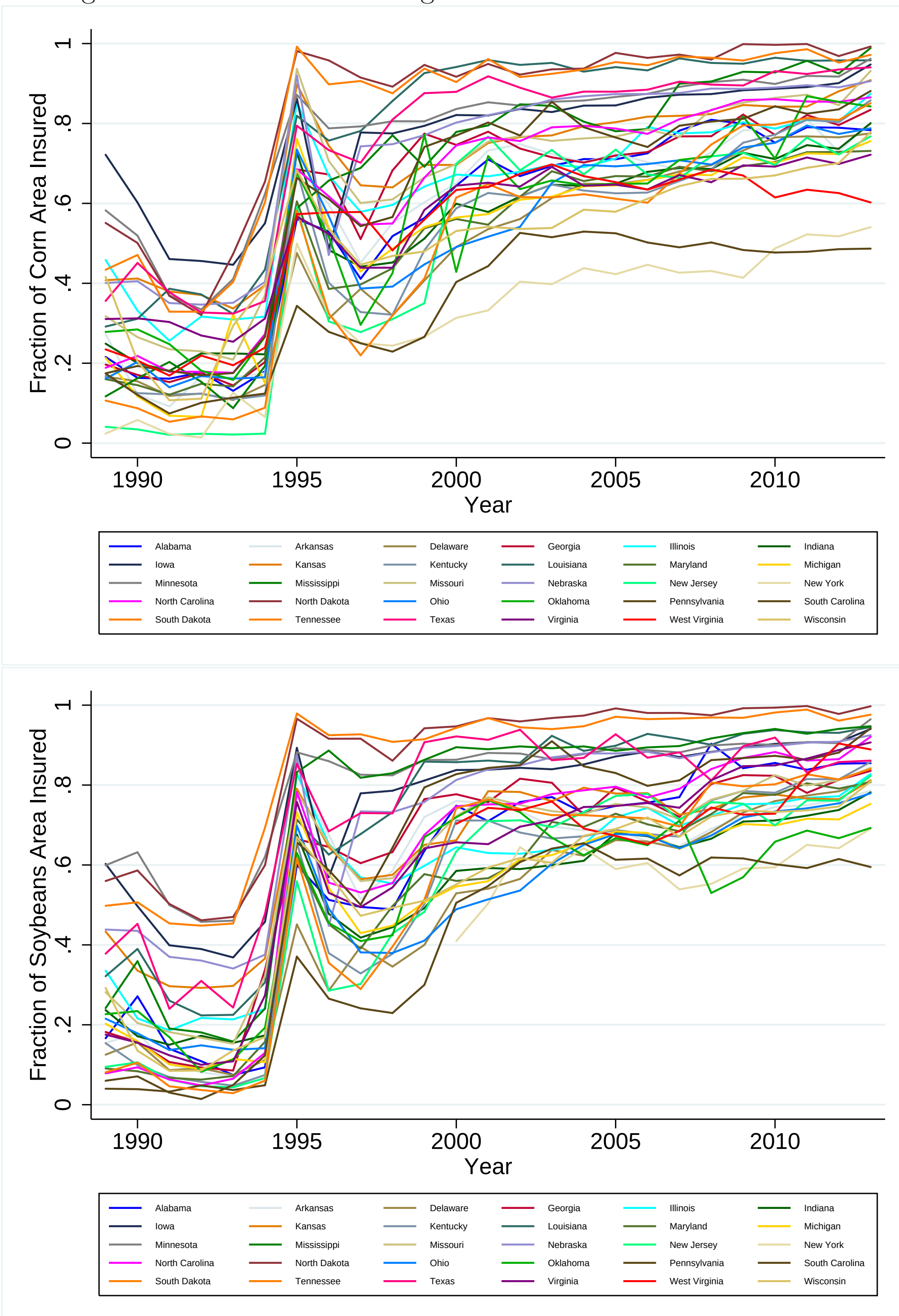
Figure A1: Area Insured





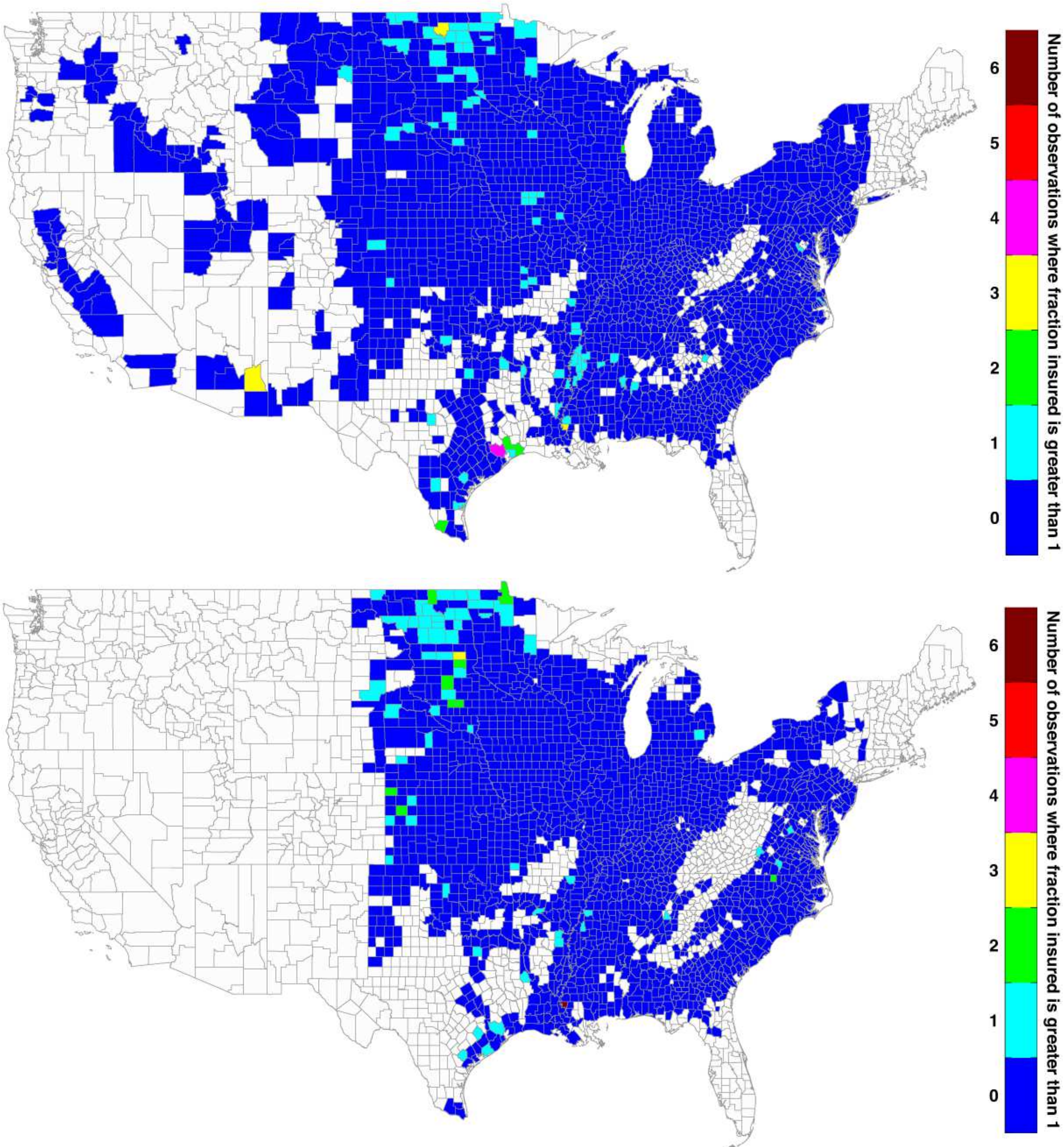
Notes: Figure displays the fraction of planted corn area that is insured for each state in 1989-2013. The top row depicts corn, the bottom row soybeans. The area (denominator) is the largest area ever planted in the county during 1989-2013. If the insured area in a county exceeds the planted area, we increase the planted area to match the insured area for this figure.

Figure A2: Area Insured using NASS Estimates of Area Planted



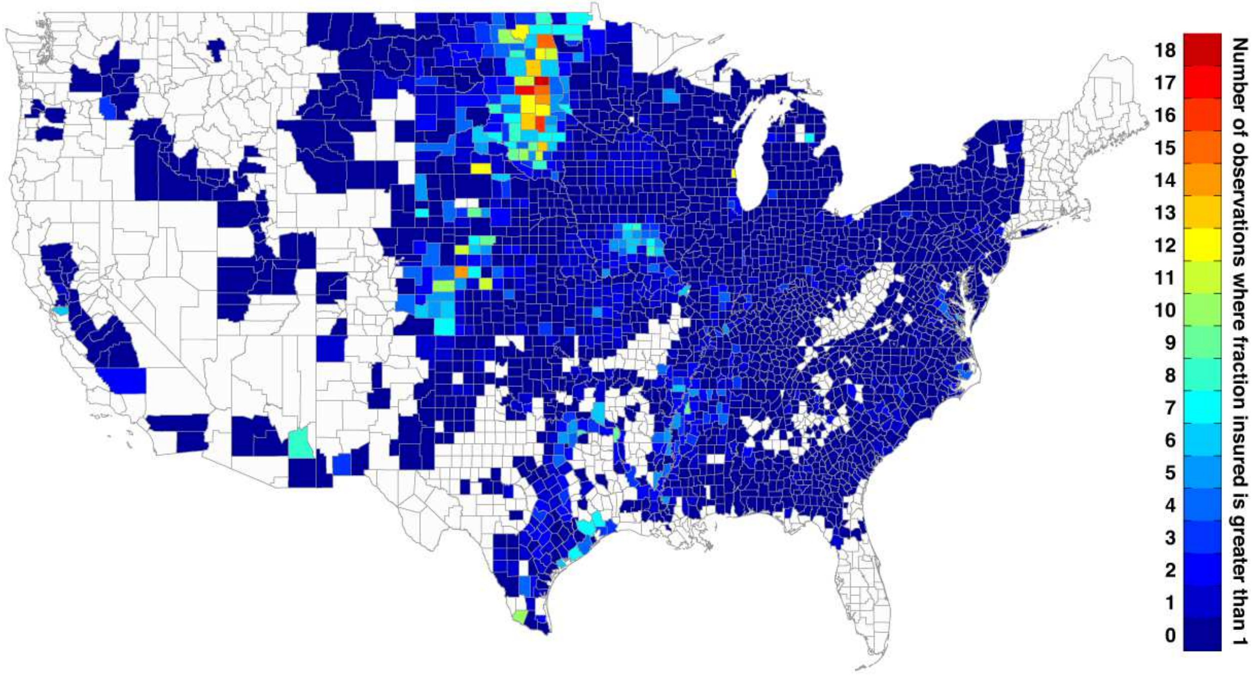
Notes: Figure replicates Figure A1 except that it choose the estimated area planted in a county from NASS as denominator. Figure displays the fraction of planted corn area that is insured for each state in 1989-2013. The top row depicts corn, the bottom row soybeans. If the insured area in a county in a given year exceeds the estimate of the planted area, we increase the planted area to match the insured area for this figure.

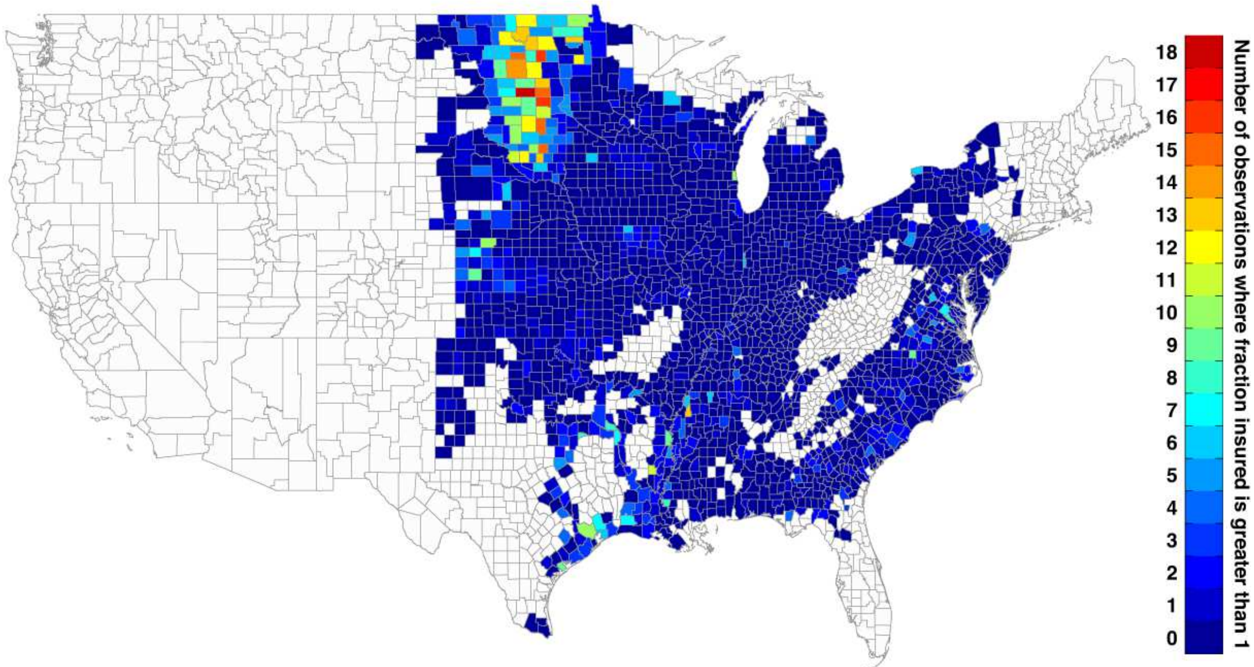
Figure A3: Counties Where Area Insured is Greater than Maximum Planting Area



Notes: Figure displays the number of times the insured area from RMA exceeds the maximum of the reported planting area from NASS for a county. The top graph shows results for corn, the bottom for soybeans. Note that the RMA data relies on actual insurance contracts in a year, while NASS uses a representative survey each year to estimate the number of planted acres.

Figure A4: Counties Where Area Insured is Greater than Annual Planting Area





Notes: Figure displays the number of times the insured area from RMA exceeds the total planting area from NASS. The top graph shows results for corn, the bottom for soybeans. Note that the RMA data relies on actual insurance contracts in a year, while NASS uses a representative survey each year to estimate the number of planted acres. The spatial patterns suggest that NASS is underestimating the planted acreage in the Northern US.

Table A1: Sensitivity to Included Years: Panel Regression for Corn 1981-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-29°C	0.310***	0.379***	0.397***	0.307***	0.384***	0.402***	0.279**	0.366***	0.428***
	(0.104)	(0.101)	(0.105)	(0.106)	(0.103)	(0.108)	(0.111)	(0.099)	(0.105)
x fraction insured							0.120	0.073	-0.071
							(0.109)	(0.080)	(0.076)
Degree Days Above 29°C	-0.511***	-0.499***	-0.510***	-0.471***	-0.466***	-0.476***	-0.437***	-0.438***	-0.464***
	(0.060)	(0.061)	(0.059)	(0.068)	(0.064)	(0.064)	(0.071)	(0.062)	(0.064)
x fraction insured				-0.095*	-0.093**	-0.096*	-0.205***	-0.184***	-0.138*
				(0.051)	(0.041)	(0.052)	(0.077)	(0.064)	(0.077)
Precipitation (m)	0.947***	0.984***	0.939***	0.940***	0.975***	0.934***	1.469***	1.368***	1.315***
	(0.215)	(0.205)	(0.219)	(0.220)	(0.208)	(0.222)	(0.249)	(0.216)	(0.236)
x fraction insured							-1.608***	-1.174**	-1.112**
							(0.595)	(0.534)	(0.559)
Precipitation (m) Squared	-0.690***	-0.706***	-0.674***	-0.681***	-0.697***	-0.670***	-0.978***	-0.909***	-0.872***
	(0.176)	(0.169)	(0.179)	(0.179)	(0.171)	(0.181)	(0.190)	(0.161)	(0.173)
x fraction insured							0.896*	0.622	0.580
							(0.477)	(0.437)	(0.459)
R-squared	0.2226	0.2180	0.2333	0.2259	0.2202	0.2363	0.2310	0.2232	0.2397
Observations	50588	50588	50588	50588	50588	50588	50588	50588	50588
Counties	1694	1694	1694	1694	1694	1694	1694	1694	1694
Years	33	33	33	33	33	33	33	33	33
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates Table 1 but expands the sample frame to 1981-2013. It regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-29°C), extreme heat (degree days above 29°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). Ratios that are larger than one are top code at 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A2: Dropping Top-Coded Observations: Panel Regression for Corn 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-29°C	0.290**	0.381***	0.401***	0.279**	0.381***	0.402***	0.204	0.333**	0.404***
	(0.128)	(0.131)	(0.140)	(0.126)	(0.132)	(0.142)	(0.149)	(0.138)	(0.149)
x fraction insured							0.198	0.127	-0.007
							(0.122)	(0.093)	(0.109)
Degree Days Above 29°C	-0.470***	-0.467***	-0.477***	-0.416***	-0.402***	-0.403***	-0.350***	-0.353***	-0.371***
	(0.058)	(0.056)	(0.053)	(0.052)	(0.051)	(0.048)	(0.062)	(0.051)	(0.054)
x fraction insured				-0.108**	-0.146***	-0.170***	-0.267***	-0.268***	-0.247***
				(0.048)	(0.035)	(0.050)	(0.079)	(0.073)	(0.095)
Precipitation (m)	0.937***	0.937***	0.901***	0.925***	0.919***	0.888***	1.774***	1.569***	1.593***
	(0.216)	(0.205)	(0.222)	(0.221)	(0.208)	(0.226)	(0.342)	(0.302)	(0.322)
x fraction insured							-1.950**	-1.485**	-1.605**
							(0.771)	(0.673)	(0.678)
Precipitation (m) Squared	-0.680***	-0.672***	-0.646***	-0.667***	-0.653***	-0.632***	-1.175***	-1.032***	-1.046***
	(0.172)	(0.165)	(0.176)	(0.176)	(0.167)	(0.178)	(0.242)	(0.202)	(0.213)
x fraction insured							1.151*	0.850*	0.931*
							(0.591)	(0.516)	(0.517)
R-squared	0.2085	0.2080	0.2253	0.2130	0.2136	0.2322	0.2184	0.2170	0.2364
Observations	39622	39622	39622	39622	39622	39622	39622	39622	39622
Counties	1716	1716	1716	1716	1716	1716	1716	1716	1716
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates 1 but drops all observations where the fraction of the area planted that is insured is larger than 1. Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-29°C), extreme heat (degree days above 29°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area that is insured (ranging from 0 to 1). All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A3: Dropping Top-Coded Counties: Panel Regression for Corn 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-29°C	0.279**	0.355***	0.370***	0.268**	0.355***	0.372***	0.176	0.297**	0.363***
	(0.129)	(0.125)	(0.132)	(0.127)	(0.127)	(0.134)	(0.144)	(0.130)	(0.140)
x fraction insured							0.231**	0.147*	0.017
							(0.112)	(0.083)	(0.101)
Degree Days Above 29°C	-0.472***	-0.469***	-0.477***	-0.418***	-0.401***	-0.401***	-0.345***	-0.346***	-0.363***
	(0.057)	(0.055)	(0.053)	(0.053)	(0.052)	(0.050)	(0.062)	(0.053)	(0.055)
x fraction insured				-0.106**	-0.155***	-0.178***	-0.286***	-0.290***	-0.269***
				(0.047)	(0.034)	(0.048)	(0.075)	(0.066)	(0.088)
Precipitation (m)	0.901***	0.907***	0.876***	0.889***	0.888***	0.861***	1.749***	1.613***	1.638***
	(0.213)	(0.203)	(0.221)	(0.219)	(0.207)	(0.225)	(0.328)	(0.307)	(0.328)
x fraction insured							-1.995***	-1.671**	-1.781***
							(0.715)	(0.655)	(0.669)
Precipitation (m) Squared	-0.649***	-0.647***	-0.626***	-0.636***	-0.627***	-0.610***	-1.163***	-1.066***	-1.081***
	(0.168)	(0.161)	(0.173)	(0.172)	(0.164)	(0.175)	(0.234)	(0.207)	(0.219)
x fraction insured							1.209**	1.000**	1.073**
							(0.546)	(0.495)	(0.502)
R-squared	0.2125	0.2120	0.2282	0.2173	0.2178	0.2350	0.2224	0.2214	0.2393
Observations	38364	38364	38364	38364	38364	38364	38364	38364	38364
Counties	1656	1656	1656	1656	1656	1656	1656	1656	1656
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates 1 but drops all counties where the fraction of the area planted that is insured is ever larger than 1, even for years where the ratio is less than 1. Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-29°C), extreme heat (degree days above 29°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). Counties where the fraction insured is ever larger than 1 are dropped, even for years where the ratio is less than 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A4: IV Regression for Corn 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-29°C	0.290**	0.381***	0.398***	0.305***	0.375***	0.436***	0.307	0.429**	0.409*
	(0.127)	(0.130)	(0.139)	(0.115)	(0.132)	(0.149)	(0.192)	(0.208)	(0.239)
x fraction insured							-0.006	-0.140	-0.039
							(0.300)	(0.311)	(0.345)
Degree Days Above 29°C	-0.469***	-0.466***	-0.476***	-0.528***	-0.373***	-0.420***	-0.462***	-0.348***	-0.359***
	(0.058)	(0.056)	(0.053)	(0.057)	(0.058)	(0.057)	(0.086)	(0.057)	(0.069)
x fraction insured				0.116	-0.212*	-0.125	-0.012	-0.264	-0.273
				(0.100)	(0.123)	(0.125)	(0.199)	(0.165)	(0.184)
Precipitation (m)	0.933***	0.933***	0.896***	0.948***	0.906***	0.913***	2.274***	1.937***	2.096***
	(0.216)	(0.205)	(0.225)	(0.214)	(0.214)	(0.235)	(0.497)	(0.433)	(0.473)
x fraction insured							-3.102***	-2.363***	-2.816***
							(1.057)	(0.884)	(0.988)
Precipitation (m) Squared	-0.677***	-0.668***	-0.643***	-0.693***	-0.641***	-0.659***	-1.596***	-1.291***	-1.411***
	(0.173)	(0.165)	(0.179)	(0.171)	(0.172)	(0.184)	(0.350)	(0.283)	(0.292)
x fraction insured							2.136***	1.495**	1.820***
							(0.786)	(0.638)	(0.683)
R-squared	0.2078	0.2074	0.2246	0.1944	0.2128	0.2005	0.2088	0.2111	0.2348
Observations	39702	39702	39702	39702	39702	39702	39702	39702	39702
Counties	1717	1717	1717	1717	1717	1717	1717	1717	1717
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates 1 but instruments the fraction of the area planted that is insured by the subsidy rate within each county, i.e., the fraction of subsidies to total premium for various coverage levels. Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-29°C), extreme heat (degree days above 29°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1), which is instrumented on the fraction of total premiums that are subsidized. Ratios that are larger than one are top code at 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A5: Sensitivity to Included Years: Panel Regression for Soybeans 1981-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-30°C	0.440***	0.477***	0.508***	0.437***	0.482***	0.516***	0.365***	0.448***	0.500***
	(0.060)	(0.052)	(0.052)	(0.062)	(0.054)	(0.053)	(0.071)	(0.063)	(0.063)
x fraction insured							0.189*	0.106	0.058
							(0.096)	(0.072)	(0.078)
Degree Days Above 30°C	-0.606***	-0.624***	-0.634***	-0.612***	-0.602***	-0.607***	-0.555***	-0.566***	-0.578***
	(0.050)	(0.046)	(0.047)	(0.047)	(0.044)	(0.043)	(0.056)	(0.050)	(0.049)
x fraction insured				0.015	-0.071	-0.087	-0.167	-0.182*	-0.176*
				(0.105)	(0.079)	(0.072)	(0.140)	(0.109)	(0.099)
Precipitation (m)	1.441***	1.394***	1.392***	1.443***	1.385***	1.385***	1.779***	1.619***	1.594***
	(0.213)	(0.198)	(0.200)	(0.217)	(0.201)	(0.201)	(0.279)	(0.237)	(0.234)
x fraction insured							-1.028**	-0.678**	-0.582*
							(0.438)	(0.342)	(0.343)
Precipitation (m) Squared	-0.961***	-0.926***	-0.923***	-0.964***	-0.918***	-0.916***	-1.160***	-1.044***	-1.019***
	(0.146)	(0.137)	(0.139)	(0.152)	(0.140)	(0.141)	(0.207)	(0.175)	(0.174)
x fraction insured							0.595*	0.360	0.275
							(0.327)	(0.260)	(0.257)
R-squared	0.2832	0.2960	0.3146	0.2834	0.2965	0.3153	0.2865	0.2979	0.3166
Observations	44471	44471	44471	44471	44471	44471	44471	44471	44471
Counties	1481	1481	1481	1481	1481	1481	1481	1481	1481
Years	33	33	33	33	33	33	33	33	33
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates Table 2 but expands the sample frame to 1981-2013. It regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-30°C), extreme heat (degree days above 30°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). Ratios that are larger than one are top code at 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A6: Dropping Top-Coded Observations: Panel Regression for Soybeans 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-30°C	0.476***	0.538***	0.574***	0.481***	0.547***	0.583***	0.398***	0.494***	0.541***
	(0.079)	(0.086)	(0.087)	(0.078)	(0.087)	(0.089)	(0.096)	(0.096)	(0.098)
x fraction insured							0.191**	0.131*	0.108
							(0.094)	(0.072)	(0.084)
Degree Days Above 30°C	-0.592***	-0.613***	-0.623***	-0.586***	-0.570***	-0.575***	-0.509***	-0.518***	-0.527***
	(0.052)	(0.052)	(0.053)	(0.055)	(0.047)	(0.046)	(0.060)	(0.053)	(0.052)
x fraction insured				-0.011	-0.098	-0.109	-0.202	-0.228**	-0.227**
				(0.108)	(0.074)	(0.074)	(0.130)	(0.101)	(0.095)
Precipitation (m)	1.538***	1.410***	1.442***	1.539***	1.405***	1.438***	2.062***	1.650***	1.661***
	(0.231)	(0.223)	(0.232)	(0.232)	(0.224)	(0.231)	(0.324)	(0.278)	(0.309)
x fraction insured							-1.229***	-0.542	-0.475
							(0.467)	(0.387)	(0.449)
Precipitation (m) Squared	-1.007***	-0.916***	-0.936***	-1.007***	-0.908***	-0.930***	-1.324***	-1.025***	-1.026***
	(0.158)	(0.151)	(0.158)	(0.160)	(0.152)	(0.158)	(0.243)	(0.201)	(0.224)
x fraction insured							0.740**	0.243	0.187
							(0.347)	(0.277)	(0.320)
R-squared	0.2915	0.3029	0.3232	0.2922	0.3044	0.3245	0.2955	0.3059	0.3259
Observations	34906	34906	34906	34906	34906	34906	34906	34906	34906
Counties	1505	1505	1505	1505	1505	1505	1505	1505	1505
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates 2 but drops all observations where the fraction of the area planted that is insured is larger than 1. Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-30°C), extreme heat (degree days above 30°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A7: Dropping Top-Coded Counties: Panel Regression for Corn 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-30°C	0.467***	0.512***	0.544***	0.474***	0.521***	0.552***	0.376***	0.473***	0.520***
	(0.080)	(0.085)	(0.084)	(0.079)	(0.085)	(0.086)	(0.096)	(0.098)	(0.102)
x fraction insured							0.218**	0.119*	0.085
							(0.093)	(0.071)	(0.081)
Degree Days Above 30°C	-0.588***	-0.608***	-0.619***	-0.588***	-0.563***	-0.570***	-0.506***	-0.514***	-0.526***
	(0.052)	(0.052)	(0.053)	(0.056)	(0.048)	(0.047)	(0.060)	(0.055)	(0.054)
x fraction insured				-0.001	-0.105	-0.113	-0.207	-0.226**	-0.221**
				(0.110)	(0.076)	(0.074)	(0.129)	(0.103)	(0.095)
Precipitation (m)	1.556***	1.432***	1.465***	1.558***	1.425***	1.458***	1.961***	1.687***	1.721***
	(0.236)	(0.228)	(0.237)	(0.237)	(0.229)	(0.237)	(0.319)	(0.291)	(0.322)
x fraction insured							-0.973**	-0.578	-0.562
							(0.431)	(0.381)	(0.444)
Precipitation (m) Squared	-1.021***	-0.933***	-0.955***	-1.022***	-0.924***	-0.946***	-1.263***	-1.053***	-1.071***
	(0.161)	(0.153)	(0.161)	(0.163)	(0.155)	(0.161)	(0.237)	(0.208)	(0.232)
x fraction insured							0.575*	0.270	0.251
							(0.318)	(0.275)	(0.317)
R-squared	0.2951	0.3051	0.3254	0.2959	0.3065	0.3266	0.2991	0.3079	0.3280
Observations	33955	33955	33955	33955	33955	33955	33955	33955	33955
Counties	1461	1461	1461	1461	1461	1461	1461	1461	1461
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates 2 but drops all counties where the fraction of the area planted that is insured is ever larger than 1, even for years where the ratio is less than 1. Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-30°C), extreme heat (degree days above 30°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1). Counties where the fraction insured is ever larger than 1 are dropped, even for years where the ratio is less than 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.

Table A8: IV Regression for Soybeans 1989-2013

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Degree Days 10-30°C	0.478***	0.541***	0.577***	0.494***	0.496***	0.511***	0.456***	0.689***	0.814***
	(0.079)	(0.087)	(0.088)	(0.077)	(0.107)	(0.117)	(0.128)	(0.147)	(0.171)
x fraction insured							0.072	-0.285*	-0.460**
							(0.157)	(0.169)	(0.210)
Degree Days Above 30°C	-0.592***	-0.613***	-0.623***	-0.611***	-0.502***	-0.411***	-0.577***	-0.542***	-0.427***
	(0.052)	(0.052)	(0.053)	(0.068)	(0.073)	(0.084)	(0.106)	(0.080)	(0.089)
x fraction insured				0.041	-0.316*	-0.574***	-0.044	-0.141	-0.424**
				(0.170)	(0.178)	(0.211)	(0.247)	(0.195)	(0.206)
Precipitation (m)	1.537***	1.411***	1.443***	1.542***	1.349***	1.344***	2.054***	1.573***	1.760***
	(0.232)	(0.224)	(0.232)	(0.233)	(0.234)	(0.249)	(0.512)	(0.425)	(0.461)
x fraction insured							-1.295	-0.330	-0.638
							(0.940)	(0.772)	(0.874)
Precipitation (m) Squared	-1.006***	-0.916***	-0.937***	-1.011***	-0.861***	-0.842***	-1.418***	-1.013***	-1.088***
	(0.158)	(0.151)	(0.159)	(0.162)	(0.158)	(0.168)	(0.361)	(0.298)	(0.328)
x fraction insured							1.034	0.235	0.353
							(0.664)	(0.547)	(0.630)
R-squared	0.2916	0.3030	0.3232	0.2896	0.1892	0.1836	0.2904	0.2930	0.2918
Observations	34958	34958	34958	34958	34958	34958	34958	34958	34958
Counties	1505	1505	1505	1505	1505	1505	1505	1505	1505
Years	25	25	25	25	25	25	25	25	25
Quadratic Time Trend	Common	State	County	Common	State	County	Common	State	County

Notes: Table replicates 2 but instruments the fraction pf the area planted that is insured by the subsidy rate within each county, i.e., the fraction of subsidies to total premium for various coverage levels. Table regresses county-level log yields on 4 weather variables: moderate heat (degree days 10-30°C), extreme heat (degree days above 30°C), and a quadratic in season-total precipitation for the months April-September as well as the interaction with the fraction of the area planted that is insured (ranging from 0 to 1), which is instrumented on the fraction of total premiums that are subsidized. Ratios that are larger than one are top code at 1. All columns include county fixed effects and year fixed effects. Columns (a) include a common quadratic time trend, columns (b) and (c) allow the quadratic time trend to differ by state and county, respectively. Standard errors are clustered at the state level and shown in parentheses. Significance levels are indicated by *** 1%, ** 5%, * 10%.