The Economic Response to Climate Change in the Farm Sector: The United States 1895-1969

Price Fishback
University of Arizona

Jonathan Fox
University of Arizona

Paul Rhode
University of Arizona

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1 Introduction

A large segment of the climate change and global warming discussion has been devoted to how human activities have contributed to climate change. Recent studies suggest that the current trends in global warming are set at least in the short run set. Even dramatic changes in human behavior are unlikely to affect the trends until well into the future. Given this, it is important to examine how economies and societies react to changes in weather and climate.

These warming trends will be of particular importance to countries with primarily agrarian economies. Although changes in climate and short run weather fluctuations affect many different industries, they have a direct and readily measurable effect on agriculture. Droughts, floods, heat waves, blizzards, cold spells, and a variety of other weather crises have direct effects on crop yields and the survival of farm animals. Consequently, these dramatic weather events can affect the prices farmers receive for their products, and thus also farm incomes and land values. However, these effects may differ across types of farm commodities. For crops sold in international markets, fluctuations in local weather may not influence farmgate prices much, while for crops with strong local markets, such disasters may lead to significant local price responses.

Our goal is to examine the sensitivity of agricultural prices and output to local and non-local weather fluctuations over a large span of time in the United States. For space considerations, we limit our analysis to only two crops. The first is corn; a crop that is both used for feed and relatively difficult to transport, and as such is primarily used and sold at the local level. The second, cotton, is much easier to transport and does not have a strong local market. In the full version of the paper, we expand the analysis to include hay and wheat, as well as three varieties of livestock in cattle, hogs and sheep.

We expect that when agricultural commodities have strong local markets, prices will be sensitive to changes in local weather. Conversely, for commodities sold in non-local markets, prices will be robust to changes in local weather, but sensitive to weather conditions affecting the aggregate market. Thus, the analysis also examines how globalization and reducing transactions costs across countries could potentially alter the effects of climate change, which are expected to vary greatly across regions. As markets become less centralized, the effect on consumers from localized dramatic weather events should be mitigated. Below we explain how adverse weather is measured.

2 Measuring Local Weather and the Palmer Drought Indices

Standard practice in the agronomic literature is to measure weather through a combination of both linear and non-linear effects on crop yields. Because both very low and very high levels of precipitation and temperature adversely affect crop yield, assuming a simple linear relationship between weather and prices or profit would be a misspecification. Generally, the non-linearity introduced is a quadratic in precipitation and temperature.

We choose a similar path, but also include measures for drought and wetness conditions developed by Palmer (1965) in his creation of the Palmer Drought Severity Index (PDSI).[1] Specifically, these drought measures are functions of monthly indices called "Z indexes" that Palmer calculated and accumulated to create his drought severity index. These Z indexes measure departures of precipitation levels from some baseline level, weighted by some factor[2] determined from the climate record in the relevant area before the actual model calculations begin. The weighting is used to ensure comparability across both regions and months (assuming that regional differences show variation similar to the monthly differences). After plotting a series of accumulated Z values against the length of drought for the thirteen driest intervals in central Iowa and western Kansas, Palmer defined these as "extreme drought," and then used this baseline to further subdivide the drought index into five more drought sections of "severe," "moderate," "mild," "incipient," and "near normal." Palmer calculated periods of wetness by reversing signs in the Z index.

3 Data and Summary Statistics

To study the effects of state-level weather fluctuations on farmgate prices, we combine two existing datasets; one containing historical crop information, the other historical climate information.

[1]We define the term "drought" as a prolonged and abnormal moisture deficiency.

[2]In Palmer's paper, these weights were developed in relation to the 12 months of driest weather on record for northwestern North Dakota, Western Kansas, Central Iowa, the Texas high plains, Edwards Plateau of Texas, Southern Texas, Western Tennessee, West Central Ohio and Northeastern Pennsylvania.

State-level information on yield, harvests, and prices[3] for commodities produced and sold across the United States was taken from the Agricultural Time Series-Cross Section Dataset (ATICS), compiled from USDA records by Thomas Cooley, Stephen DeCanio and M. Scott Matthews. This dataset covers the contiguous United States from 1866 to 1969, although due to data constraints, we limit to those years after 1895.

To adjust for inflation, commodity prices are adjusted to reflect 1982-1984 dollars using the CPI series developed by Lawrence Officer. Table 1 gives summary statistics on output and prices in 1982-1984 dollars for both the selected farm commodities, as well as the different climate variables used in estimation.

The two most important things to take from the cotton and corn summary statistics are that first, there is great temporal and spatial variation in both output and prices for both cotton and corn, and second, there is also large variation between the two commodities. This is likely a function of corn being more difficult than cotton to transport across regions and the extensive use of corn as animal feed on the farm and in local markets. Cotton is much easier to transport and is used primarily as an input in manufacturing. Only a small share of cotton is used for household production. Therefore cotton prices display much less regional variation in any year. The observed variation is primarily temporal. Corn prices vary much more across regions, and likely fluctuate much more with local weather shocks.

Map 1 shows the distribution of production across the contiguous United States for cotton and corn in 1929, a year relatively free of inclement weather. Both the cotton and corn belts are clearly visible. Also evident is that corn production is more widely distributed across the country, consistent with the existence of local markets for corn. Every state in the Union engages in at least some level of corn production, which is not true of cotton.

Monthly climate data on temperature, precipitation and the Palmer drought measures were compiled by the National Climatic Data Center. Because of the biases in raw climate data that arise from different measurement times across the different recording stations, monthly mean temperature and precipitation were adjusted for the different observation times using the model suggested by

[3]Prior to 1930, crop prices represent the farm gate price on December 1st, and afterwards are the yearly average.

Karl et. al (1986).

Because the agricultural data are measured annually and the planting and harvesting dates differ among states, for simplicity we convert all weather variables to yearly averages. Summary statistics for average temperature, average precipitation, months of extreme or severe drought, months of extreme or severe wetness and the standard deviation of the Palmer Z Index are given in the lower portion of Table 1.

Average precipitation, which is an average of average monthly precipitation from January to December, ranges from about a third of an inch per month to just over 6 inches per month. Temperature is averaged similarly to precipitation, and also represents a twelve month average of the January to December monthly averages. In our sample, this ranges from about 35° Fahrenheit to about 74° Fahrenheit. Months of extreme or severe drought and extreme or severe wetness are calculated using a form of the Palmer Drought Severity Index, the Palmer Hydrological Drought Index (PHDI). Table 1 shows that some states experienced serious drought conditions for all twelve months of the year, while other states enjoyed an entire year's worth of normal moisture levels. Extreme or severe wetness ranges similarly.

4 Price Effects for Commodities with Local and International Markets

State level price effects from state level supply shocks will be mitigated for more tradable goods sold in international markets because individual states play too small a role to affect prices much. At the extreme, if a farm commodity is perfectly tradable, the observed state average farmgate (local) price is a function only of non-local, or international supply and demand. Farmgate prices vary only with changes affecting the aggregate market. After controlling for weather that affects producers as a whole, prices will be robust to state-level weather shocks. Conversely, for perfectly non-tradable commodities with prohibitively high transportation or storage costs, the observed state farmgate price is a function only of supply and demand in the local market. If a severe drought hits, local traders do not import goods from other states or countries to mitigate the effects of the shock.

Additionally, weather affecting producers outside of the local area will not affect local prices.

Commodities generally do not fit either of these two extreme cases, but instead fall somewhere in between. Assuming tradability is only a function of the specific properties for a specific crop and does not vary temporally or spatially, we follow the setup of Mundlak and Larson (1992) and write the observed logged price of commodity c in state s during year t as function of the both international and local supply and demand:

$$ln(P^{obs}_{s,c,t}) = \tau_c ln(P^{int}_{c,t}) + (1 - \tau_c) ln(P^{loc}_{s,c,t}) \tag{1}$$

where τ_c is an index of the strength of the local market (itself a function of transaction costs and local uses for the crop) for crop c. Crops such as cotton that are easy to store, easy to transport, cost producers little to bring to the international market and have few local uses have a τ_c closer to one, while crops such as corn that are used as feed for livestock and are more difficult to transport have a stronger local market and a τ_c much closer to zero.

Figures 1 and 2 show the differential effects of positive and negative supply shocks for goods with relatively strong and weak local markets. In each of these figures, P^{int}_{buy} is the internationally determined price, and P^{int}_{sell} is the effective price received by commodity producers after taking out the marginal[4] cost of bringing the commodity to the international market. The distance between P^{int}_{buy} and P^{int}_{sell} is C^{int}_i, or the size of the marginal cost from bringing commodity i to the international market.

Figures 1a and 1b represent local markets for commodities such as corn that have higher transport costs and strong local markets. Because the cost of bringing these goods to international market is high compared to a good such as cotton, fluctuations in the local market play a larger role, while fluctuations in the international market play a relatively smaller role. In Figure 1a, an adverse weather shock would cause supply to fall from S_1 to S_2. This drives the quantity produced from Q_a to Q_b and the price to rise from P_a to P_b. The price is not driven high enough as to generate inputs into the local market. If the supply shift were drastic enough, then goods from the outside market could potentially be imported, but it would take a particularly severe supply

[4]If we assume constant marginal transaction costs, this is also the average cost

shock for that to happen. The same is true if there is a bumper year as demonstrated in Figure 1b; supply shifts out from S_1 to S_2, expanding output to Q_b from Q_a and pushing local prices down to P_b. However, local prices do not fall by enough to make exporting to the outside market worth it to local producers. Local prices would need to fall all the way down past P_{sell}^{int} before producers began exporting to other markets. The effect of the international market on the local market is also mitigated. Changes in price determined by the international market, or P_{buy}^{int}, will affect local market prices if it pulls the "band" in Figures 1a and 1b above or below the local equilibrium price. Goods with strong local markets have wider bands, so are less susceptible to changes in the international market.

Figures 2a and 2b represent local markets for commodities such as cotton that have low tranportation costs and relatively weak local markets. In these figures, the costs associated with bringing the good to international market are low so the distance C_i^{int} is small. Here the international market plays a relatively larger role in determining local prices than do the local supply and demand interactions. Because of the lower costs, it is easier for producers and consumers to mitigate the effects of positive or negative supply shocks through importing and exporting. In Figure 2a, an adverse supply shock occurs, shifting supply from S_1 to S_2 and pushing the locally produced quantity down. However, in this situation, consumers import $Q_d - Q_c$ at a price of P_{buy}^{int} to mitigate the local price effects. Although the local supply shifts in substantially, the quantity sold in the local market only falls to Q_d and the observed price rises to P_c, below the price P_b that would be observed were the outside market not present.

In Figure 2b, a positive supply shock occurs, shifting supply from S_1 out to S_2. In this case, the local supply expands by a large amount, but local producers choose to take some of that surplus to international market. Whereas price would have fallen from P_a to P_b, in this case the observed price only falls to P_c.

Considering a simplified version for cotton or corn prices where weather is the only input, then

$$ln(P_{s,c,t}) = \tau_c ln(P(Q_{c,t}^{int}(OPW_{s,t}))) + (1 - \tau_c) ln(P(Q_{s,c,t}(w_{s,t}))) \tag{2}$$

where Q^{int} is the international level of the commodity sold, $w_{s,t}$ is a measure of weather conditions in state s and year t, and OPW is a set of averaged of weather variables across states other than s producing commodity c, weighted by each state's share of the national production.[5] The full version of the paper contains a detailed description of these OPW variables.

5 Model Setup

To test the significance and magnitude of the relationship between farm commodity prices and adverse weather, we use the year-to-year variations in both weather and commodity prices to specify a regression model including state and year fixed effects. Including these fixed effects will net out much of the unobserved variable bias that seems to plague the cross-sectional models present in much of the agronomic literature (Deschenes and Greenstone 2007). In this way, we can look at the entire United States, instead of, for instance, limiting our scope to non-irrigated counties, to the time period before the large scale crop subsidies began in the 1930s, or to states that were net exporters of the different crops.

Local weather is measured using time-bias corrected temperature and precipitation, their squared terms, the number of months of extreme or severe drought, the number of months of extreme or severe wetness, and moisture variation. The last three variables are derived from the Palmer Z Index. The weather in the rest of the crop production area is measured as a weighted average of weather in other areas where the weights are state's share of output in 1929.

5.1 The New Deal and the Changing Agricultural Price Structure

Because our data spans the period of the large scale New Deal programs, it is necessary to test for the potential effects of the New Deal's agricultural policies. To test this, we estimated basic pooled and non-pooled models for each commodity, including the variables temperature, precipitation and their squared terms. Performing Chow tests for both cotton and corn, we reject each of the nulls that a pooled model is appropriate. We account for this structural change by estimating separate models for the period before 1933 and then also for 1933 and after.

[5] Each state's share of the national production was calculated for 1929 and assumed constant for the rest of the panel. 1929 was chosen since it was a year relatively free of inclement weather

5.2 Reduced Form Models

For each time period, we estimate the following reduced form models for price and quantity:

$$ln(P_{s,c,t}) = \alpha_s + \gamma_t + W_{s,t}\beta_c + OPW_{s,c,t}\omega_c + \epsilon_{1,s,c,t} \tag{3}$$

$$ln(Q_{s,c,t}) = \alpha_s + \gamma_t + W_{s,t}\beta_c + \epsilon_{2,s,c,t} \tag{4}$$

where $ln(P_{s,c,t})$ is the logged real price for commodity c in year t and state s, $ln(Q_{s,c,t})$ is the logged quantity,[6] α_s is a set of state fixed effects that net out time invariant determinants of the farmgate price, γ_t is a set of year indicators that control for annual shocks common to all states, $W_{s,t}$ is a vector of weather variables in year t and state s that could potentially affect local prices, and $OPW_{s,c,t}$ is the vector of weather variables in year t for other producers of commodity c than state s. As usual, the disturbance terms $\epsilon_{1,s,c,t}$ and $\epsilon_{2,s,c,t}$ are assumed to have conditional mean zero and defined as the other factors influencing farmgate prices and output besides weather.

Although there are certainly other factors that could potentially affect farm commodity prices, it is not likely that these unobserved effects will cause the local weather variables to be correlated with the error term. And while the variables that proxy for weather fluctuations in other producing states are weighted by that state's share of national production, because we calculate this for 1929 and fix that value over time, it is also unlikely that after including state and year fixed effects, these variables are correlated with the error term.

As stated earlier, the dependent variables in the analysis are the logged value of the real prices and quantities for cotton and corn. Since corn has strong local markets, it is expected that an adverse local weather shock will reduce the local corn supply, thereby raising the farmgate price. This would imply a positive correlation between commodity prices and variables controlling for drought and wetness conditions, as well as with the squared terms in temperature and precipitation. A negative correlation should exist between corn prices and temperature and precipitation. Cotton is sold at the international level and as such should see analogous relationships between price and

[6]After examination of the different output distributions, we concluded that they were all closer to a log-normal distribution than a normal distribution

weather shocks, but instead of local weather shocks, should be sensitive to the weighted averages of the other producer's weather.

6 Results

Tables 2a and 2b give regression results with the logged prices of cotton and corn as the dependent variables (a-cotton, b-corn) and Tables 3a and 3b give regression results with logged quantity as the dependent variable. Both tables contain six columns of regression results, representing three sets of models: one basic model without any of the OPW variables, and two with the OPW variables included.

All of the models present in Tables 2 and 3 include state and year fixed effects. Columns 1 and 2 in each table give results based on controlling for weather using just temperature, precipitation and their squared terms. Including this basic model specification allows comparison to prior work using only variables for temperature and precipitation, as well as a robustness check to see how including additional weather variables affects the coefficient estimates for temperature and precipitation.

Columns 3-6 represent the different models that include the OPW variables. Columns 3 and 4 include just temperature, precipitation and their squared terms, so are comparable to columns 1 and 2. Columns 5 and 6 add in the number of months of extreme or severe drought and wetness, as well as the standard deviation of the Palmer Z index to control for effects of changes in weather variability. Tables 3a and 3b are very similar in the variables used to Tables 2a and 2b, but do not include the OPW variables.

For the most part cotton and corn prices exhibited different sensitivities to local and non-local weather events, although there were some commonalities across the tables. In general the coefficient estimates were very similar across the different model specifications, and both including the OPW variables as well as the additional weather variables had little effect on the coefficient estimates. Also common to both the cotton and corn price regressions were the differences in price responses before and after the New Deal (ND) structural break. This is likely due to the New Deal agricultural policies, as these included price supports and subsidies for many of the different crops, although these differences could also be a function of how prices were reported by the USDA before and after

1930.[7]

Figures 3a-3d last two columns of statistically significant estimates (columns 5 and 6) from Table 2a and plots the cotton price elasticities against changes in temperature and precipitation for both the local weather and the weather in other producing states. Figures 4a-4d do the same with the coefficient estimates in Table 2b and plot the different corn elasticities. Below we describe these figures and the coefficient estimates for cotton and corn.

6.1 Cotton - Table 2a, Table 3a

Cotton output was sensitive to fluctuations in local temperature, extreme or severe drought and wetness and changes in weather variability both before and after the New Deal. However, cotton prices do not follow the same story, and show different sensitivities in the pre and post New Deal periods. Prior to the New Deal, cotton prices were most sensitive to changes in non-local weather. Increases in local weather variability tended to decrease the state farmgate price of cotton, but it was changes in precipitation and drought conditions in other producing states to which the state level prices for cotton were most sensitive. After the New Deal, state farmgate prices showed much more sensitivity to local temperature changes than they were to changes affecting other producers.

Figures 3a through 3d plot the price responsiveness of changes in temperature and precipitation in both local and non-local areas, regardless of whether the coefficient estimates were statistically significant. The statistically significant coefficient estimates included those for local temperature in the post-New Deal period and non-local precipitation in both the pre and post New Deal periods. As seen in Figure 3a, cotton price elasticity to changes in temperature is increasing as temperature increases. At about 60° F, a 1% rise in average temperature is associated with very little changes in price. However, at very low and very average temperature measurements, state-level cotton prices are very responsive (about -3.5 for temperatures below 35° F and about 3% for average temperature levels about 72° F.

The sensitivity of cotton prices to local weather in the post-New Deal period is likely a function of Mississippi taking market share from other cotton producers and a greater concentration of

[7] Prior to 1930, crop prices are recorded at December 1st, and afterwards are the yearly average.

production in Mississippi and Texas compared to the prior period.

6.2 Corn - Table 3b, Table 3b

Both before and after the New Deal, corn prices were sensitive to both local and non-local weather conditions. In both periods the coefficients on nearly all of the weather variables were statistically significant, although only the coefficients for temperature, precipitation and their squared terms were economically significant.

As with the local weather, nearly all of the OPW variables had statistically significant coefficients, although only temperature and precipitation before the New Deal and precipitation after the New Deal had economically significant coefficients.

Looking at Figures 4a through 4d, it is clear that with perhaps the exception of local temperature, before the New Deal agricultural policies, prices were much more responsive to changes in both local weather fluctuations and fluctuations in weather affecting the aggregate market. So these policies seemed to be successful in dampening the price volatility caused by changes in weather.

7 Controlling for Farmer Expectations

To control for producer expectations, we estimate an alternative model including acres planted on the right hand side. Previously we estimated equation 3, which presumably estimated the price effect from changes in supply caused by fluctuations in weather. However, if producers are good at predicting weather, this could either understate or overstate the price effects for farm commodities. Producers of multiple commodities likely adjust their output mix based on their weather expectations. For example, if they expect weather to be unfavorable to corn, but favorable to wheat, they may adjust away from corn and the price effect would be overstated for corn, but understated for wheat. Producers of a single commodity face a similar choice. If they expect weather to be unfavorable leading to decreased output and high prices, they may choose to plant more and the price effect would be attenuated.

Including the number acres planted gives a summary measure of these expectations. Although the model will still not control for long term adjustments in crop mix, adding this variable will help control for the short term adjustments to changes in farmer expectations.

We estimate the revised model using state-level farmgate prices for cotton and corn, but only for the period after 1932 as these were the years for which acres planted data existed.

Results from the model are given in Table 5. Although including acres planted did not change the weather variable coefficients much, the coefficient on acres planted was statistically significant and positive for both cotton and corn. However, these were not economically significant, as the elasticities for cotton and corn 0.0184 and 0.023, respectively. Size-wise, the temperature and precipitation coefficients in the cotton regressions are slightly smaller once the number of acres planted is included. In the corn regressions they are slightly larger. However, in both cases the difference is marginal.

From the results above, short term expectations do not appear economically important in affecting farmgate prices, and excluding them does not seem to significantly bias the weather variable coefficients for cotton and corn.

8 Concluding Remarks

In this paper we estimate the price sensitivity of seven different agricultural commodities to changes in both local and non-local weather fluctuations over a 75 year period. In the case of cotton in the period prior to the New Deal, changes in weather at both the local and national level had little effect on farmgate prices, while prices became much more sensitive to local weather fluctuations after 1933. Corn had prices more responsive to changes in temperature, precipitation and drought conditions. For corn, rises in temperature were negatively correlated with farmgate prices, suggesting the supply-side effects dominated any demand-side effects.

The effects differed between the periods prior to and after the New Deal, suggesting that changes in government policy have the ability to affect price responsiveness to local weather fluctuations. Both cotton and corn had cases where prices were sensitive to changes in a weather variable during one period, while showing little or different price sensitivity in the other. This is potentially due to the effects of the New Deal agricultural subsidies, or perhaps from changes in U.S. trade policy for these commodities.

Both the locally traded crop (corn) and the internationally traded crop (cotton) showed sensitivity to weather affecting the outside market. This finding supports the results found in Mundlak and Larson (1992) that international markets play a dominant role in determining local prices. And in the cases of both cotton and corn, attempts to control for farmer expectations did not substantially affect the coefficient estimates.

In many cases, the estimated size of the price responsiveness to weather fluctuations was small. This could be due to weather affecting both demand and supply and the interaction between the two competing effects, although comparison of Tables 2a and 2b to Tables 3a and 3b suggests that the supply side effects tend to dominate any demand side effects present.

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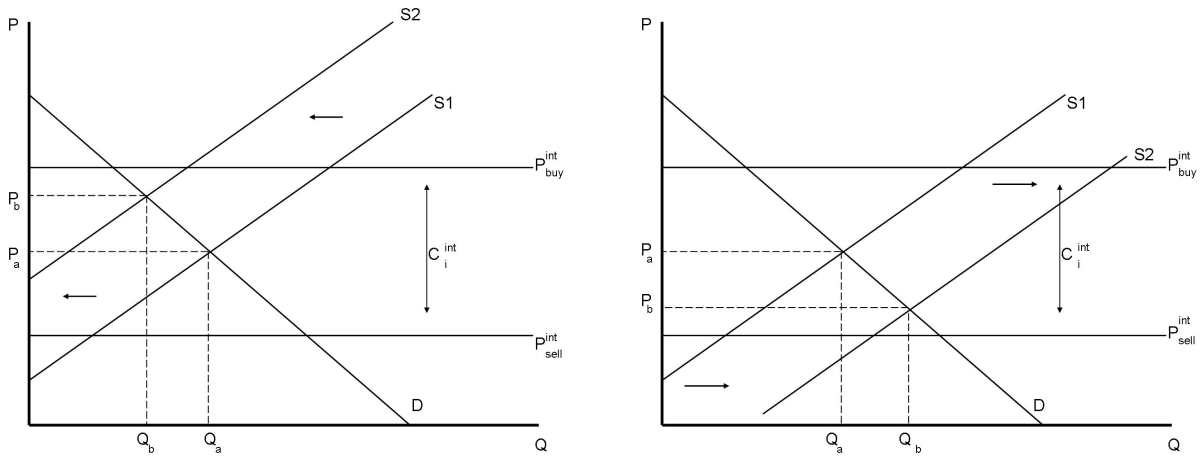
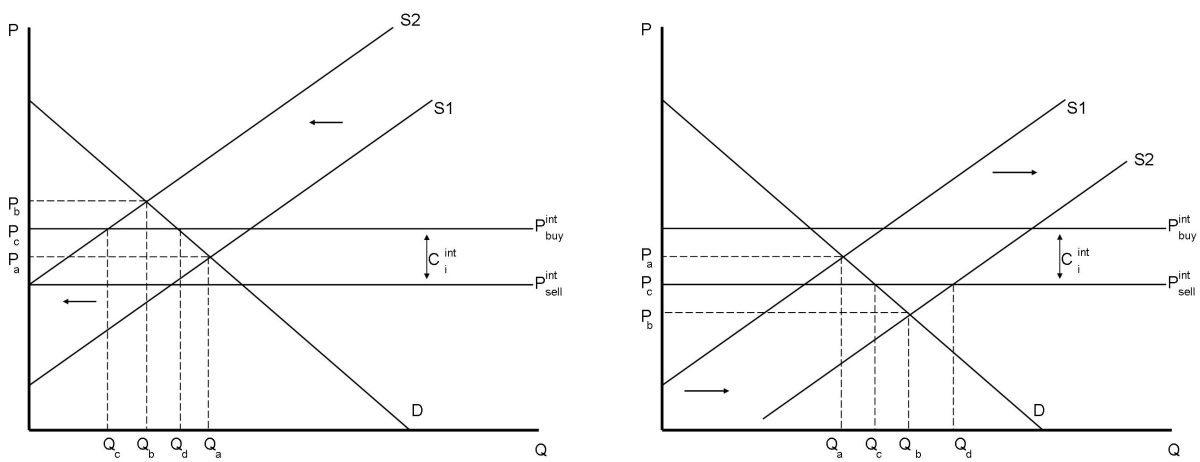


(a) Adverse supply shock (b) Positive supply shock

Figure 1: Effects for a good with a strong local market



(a) Adverse supply shock (b) Positive supply shock

Figure 2: Effects for a good with a weak local market

Figure 3a: Cotton Price Elasticity to Local Temperature

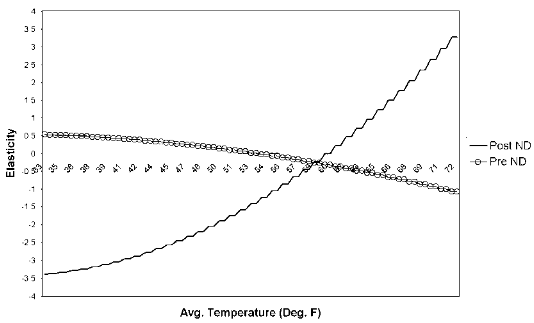


Figure 3b: Cotton Price Elasticity to Other Producer's Temperature

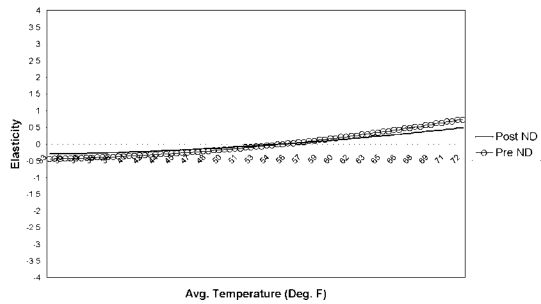


Figure 3c: Cotton Price Elasticity to Local Precipitation

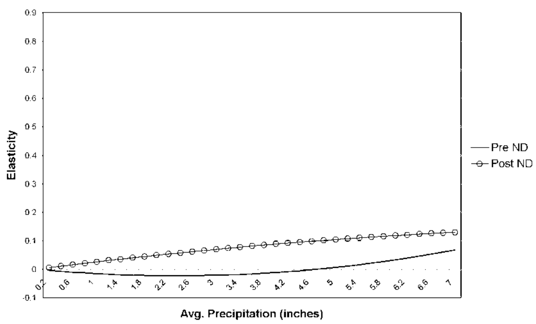


Figure 3d: Cotton Price Elasticity to Other Producer's Precipitation

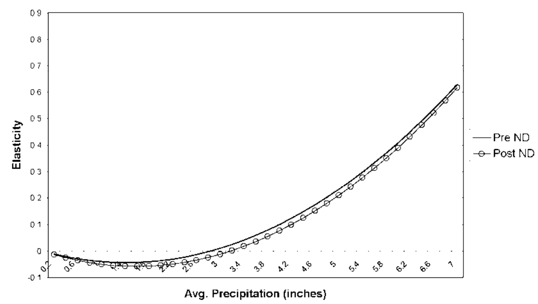


Figure 4a: Corn Price Elasticity to Local Temperature

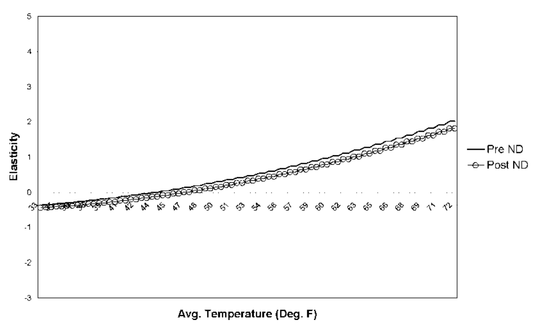


Figure 4b: Corn Price Elasticity to Other Producer's Temperature

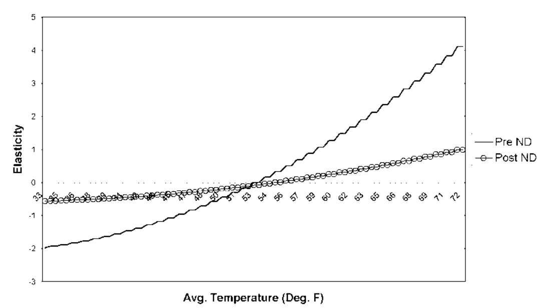


Figure 4d: Corn Price Elasticity to Other producer's Precipitation

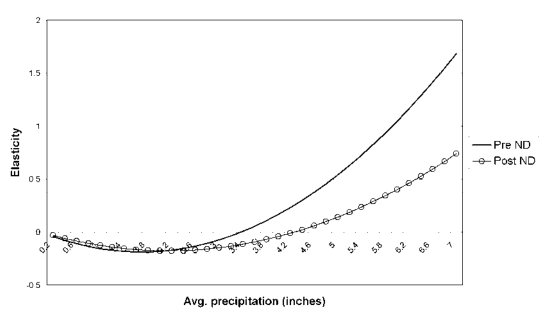
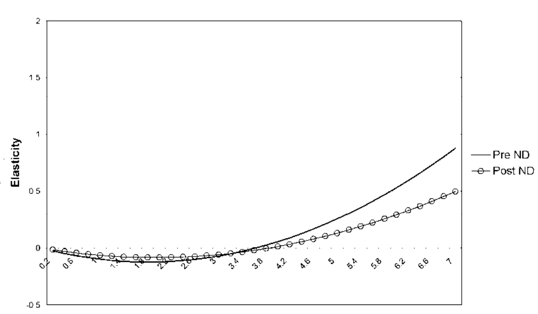


Figure 4c: Corn Price Elasticity to Local Precipitation



Map 1 - Crop Shares

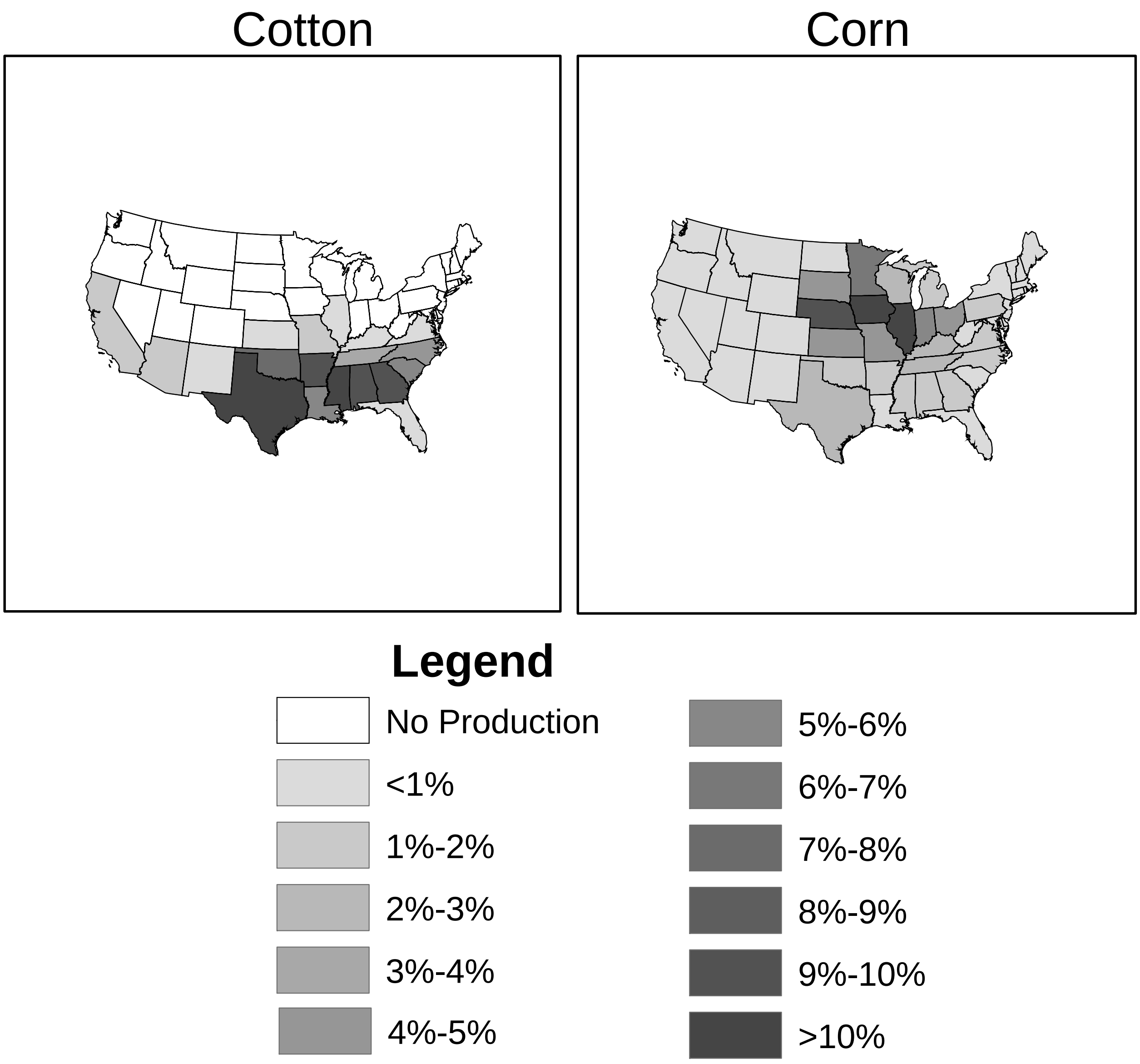


Table 1
Summary statistics for farm commodities and climate variables

Crop Prices	Mean	Std. Dev.	Min	Max
Cotton	114.65	42.43	31.71	763.77
Corn	622.95	215.48	145.25	1,840.87
Crop Output				
Cotton	126,895.10	311,783.10	0.00	2,897,100.00
Corn	51,282.21	93,885.47	0.00	815,360.00
Climate Variables				
Average temperature	52.034	7.896	35.044	73.763
Average precipitation	2.909	1.173	0.366	6.193
Months of extreme or severe drought	1.188	2.185	0.000	12.000
Months of extreme or severe wet	1.039	1.999	0.000	12.000
Moisture index std. dev.	1.687	0.394	0.643	4.293

Table 2a
Dependent variable: ln(price of cotton in $1982-3)

Variables	(1) Pre ND	(2) Post ND	(3) Pre ND	(4) Post ND	(5) Pre ND	(6) Post ND
Avg.Temperature	0.0185	-0.2646	0.0491	-0.2233	0.0427	-0.2281
	(0.36)	(3.36)***	(0.77)	(2.89)***	(0.67)	(2.90)***
Avg. Temperature Sq.	-0.0002	0.0022	-0.0004	0.0019	-0.0004	0.0019
	(0.45)	(3.35)***	(0.84)	(2.86)***	(0.72)	(2.90)***
Avg. Precipitation	-0.0142	0.0024	-0.0319	0.0007	-0.0197	0.0269
	(0.62)	(0.10)	(1.36)	(0.03)	(0.71)	(0.81)
Avg. Precipitation Sq	0.0016	0.0004	0.0037	0.0005	0.0021	-0.0006
	(0.55)	(0.13)	(1.26)	(0.19)	(0.66)	(0.19)
Months of XS wetness					0.0047	-0.0029
					(1.43)	(0.90)
Months of XS drought					-0.0001	-0.0006
					(0.05)	(0.23)
Palmer Z Index Std. Dev.					-0.0182	-0.0293
					(1.68)*	(1.64)
Other Producer's Weather						
Avg.Temperature			-0.0186	-0.0338	-0.0331	-0.0220
			(0.87)	(1.66)*	(1.56)	(1.09)
Avg. Temperature Sq.			0.0002	0.0004	0.0003	0.0002
			(1.03)	(1.77)*	(1.61)	(1.26)
Avg. Precipitation			-0.0854	-0.0302	-0.0614	-0.0729
			(3.08)***	(0.90)	(2.07)**	(1.44)
Avg. Precipitation Sq			0.0130	0.0063	0.0108	0.0115
			(3.22)***	(1.35)	(2.57)**	(1.70)*
Months of XS wetness					-0.0007	0.0064
					(0.33)	(1.41)
Months of XS drought					0.0043	0.0001
					(2.25)**	(0.12)
Palmer Z Index Std. Dev.					-0.0038	-0.0066
					(0.45)	(0.47)
Constant	4.1852	12.6839	5.3998	14.8559	7.1733	14.0625
	(2.70)***	(5.46)***	(2.03)**	(4.44)***	(2.73)***	(4.46)***
Observations	559	708	559	708	559	708
R-squared	0.97	0.85	0.98	0.86	0.98	0.86

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 2b

Dependent variable: ln(price of corn in $1982-3)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Pre ND	Post ND	Pre ND	Post ND	Pre ND	Post ND
Avg.Temperature	-0.0411	-0.0431	-0.0435	-0.0455	-0.0441	-0.0469
	(2.31)**	(2.79)***	(2.41)**	(2.92)***	(2.42)**	(3.00)***
Avg. Temperature Sq.	0.0005	0.0004	0.0005	0.0005	0.0005	0.0005
	(2.85)***	(2.98)***	(3.10)***	(3.07)***	(3.05)***	(3.01)***
Avg. Precipitation	-0.1306	-0.1160	-0.1277	-0.1109	-0.1349	-0.0870
	(4.19)***	(5.47)***	(4.10)***	(5.19)***	(3.84)***	(3.74)***
Avg. Precipitation Sq	0.0180	0.0145	0.0179	0.0140	0.0186	0.0113
	(4.35)***	(4.99)***	(4.32)***	(4.79)***	(4.28)***	(3.81)***
Months of XS wetness					-0.0022	-0.0007
					(1.09)	(0.43)
Months of XS drought					0.0012	0.0032
					(0.69)	(2.39)**
Palmer Z Index Std. Dev.					0.0164	0.0074
					(1.82)*	(1.01)
Other Producer's Weather						
Avg.Temperature			-0.1357	-0.0330	-0.1589	-0.0438
			(3.61)***	(1.23)	(4.65)***	(1.61)
Avg. Temperature Sq.			0.0013	0.0003	0.0015	0.0004
			(3.41)***	(1.27)	(4.49)***	(1.64)
Avg. Precipitation			-0.1154	-0.0759	-0.2240	-0.1658
			(1.89)*	(2.25)**	(3.38)***	(4.04)***
Avg. Precipitation Sq			0.0186	0.0088	0.0332	0.0194
			(2.06)**	(1.77)*	(3.46)***	(3.61)***
Months of XS wetness					0.0159	0.0166
					(2.93)***	(5.74)***
Months of XS drought					0.0088	0.0047
					(2.35)**	(2.91)***
Palmer Z Index Std. Dev.					0.0295	0.0365
					(1.31)	(2.99)***
Constant	7.0815	7.4973	9.6347	8.5289	10.1610	8.8258
	(14.93)***	(19.01)***	(11.32)***	(13.57)***	(12.60)***	(13.95)***
Observations	1796	1344	1796	1344	1796	1344
R-squared	0.91	0.93	0.91	0.93	0.91	0.93

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3a
Dependent variable: ln(total cotton output)

	(1) Pre New Deal	(2) Post New Deal	(3) Pre New Deal	(4) Post New Deal
Avg. temperature	1.2643	1.2799	1.1752	1.1913
	(5.42)***	(4.49)***	(5.17)***	(4.15)***
Avg. temperature squared	-0.0106	-0.0091	-0.0099	-0.0085
	(5.57)***	(3.90)***	(5.32)***	(3.65)***
Avg. precipitation	-0.1255	0.2238	0.1194	0.3020
	(0.55)	(1.05)	(0.52)	(1.26)
Avg. precip. squared	-0.0077	-0.0294	-0.0248	-0.0364
	(0.29)	(1.22)	(0.95)	(1.44)
Months of XS wet			-0.0363	-0.0298
			(2.23)**	(1.68)*
Months of XS drought			-0.0173	0.0282
			(1.57)	(1.84)*
Palmer Z Index std. dev			-0.1866	0.1761
			(3.01)***	(2.31)**
Constant	-24.4308	-32.2468	-22.1217	-29.3967
	(3.31)***	(3.60)***	(3.08)***	(3.28)***
Observations	559	708	559	708
R-squared	0.95	0.96	0.96	0.96

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3b
Dependent variable: ln(total corn output)

	(1) Pre New Deal	(2) Post New Deal	(3) Pre New Deal	(4) Post New Deal
Avg. temperature	0.2142	-0.0450	0.2173	-0.0411
	(3.05)***	(0.67)	(3.16)***	(0.65)
Avg. temperature squared	-0.0027	0.0004	-0.0027	0.0006
	(4.26)***	(0.65)	(4.38)***	(0.96)
Avg. precipitation	0.2934	0.6697	0.3571	0.4175
	(2.77)***	(5.74)***	(3.09)***	(3.35)***
Avg. precip. squared	-0.0396	-0.0771	-0.0450	-0.0469
	(2.97)***	(5.08)***	(3.25)***	(3.04)***
Months of XS wet			0.0019	-0.0129
			(0.22)	(1.66)*
Months of XS drought			0.0006	-0.0522
			(0.09)	(8.37)***
Palmer Z Index std. dev			-0.0641	-0.0948
			(1.85)*	(3.02)***
Constant	6.8718	10.3341	6.6563	10.3370
	(3.45)***	(6.36)***	(3.38)***	(6.80)***
Observations	1806	1344	1806	1344
R-squared	0.96	0.97	0.96	0.98

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4
Including Acres Planted

Dependent var: logged real price	(1)	(2)	(3)	(4)
	Cotton		Corn	
Avg. temp.	-0.2275	-0.2312	-0.0454	-0.0420
	(2.89)***	(2.93)***	(2.90)***	(2.67)***
Avg. temp. squared	0.0019	0.0019	0.0004	0.0004
	(2.88)***	(2.92)***	(2.95)***	(2.64)***
Avg. precipitation	0.0055	0.0065	-0.0881	-0.0864
	(0.18)	(0.21)	(3.90)***	(3.83)***
Avg. pcp. squared	0.0008	0.0006	0.0117	0.0116
	(0.25)	(0.19)	(3.95)***	(3.91)***
Months of XS wet	-0.0042	-0.0038	-0.0005	-0.0005
	(1.21)	(1.09)	(0.31)	(0.30)
Months of XS drought	-0.0012	-0.0012	0.0032	0.0038
	(0.45)	(0.46)	(2.37)**	(2.79)***
Acres planted		0.000017		0.000013
		(2.15)**		(1.74)*
Other producer's weather				
Avg. temp.	-0.0241	-0.0031	-0.0331	-0.0296
	(1.20)	(0.13)	(1.28)	(1.14)
Avg. temp. squared	0.0003	0.0000	0.0003	0.0003
	(1.35)	(0.19)	(1.35)	(1.20)
Avg. precipitation	-0.0747	-0.0738	-0.1538	-0.1467
	(1.33)	(1.38)	(3.84)***	(3.61)***
Avg. pcp. squared	0.0115	0.0111	0.0188	0.0177
	(1.57)	(1.61)	(3.55)***	(3.28)***
Months of XS wet	0.0063	0.0071	0.0165	0.0178
	(1.37)	(1.55)	(5.88)***	(6.08)***
Months of XS drought	0.0000	0.0001	0.0048	0.0055
	(0.03)	(0.06)	(2.96)***	(3.40)***
Constant	14.32	12.32	8.59	8.43
	(4.48)***	(3.85)***	(13.93)***	(13.66)***
Observations				
R-squared	708	708	1344	1344
Robust t statistics in parenthes	0.86	0.86	0.93	0.93

* significant at 10%; ** significant at 5%; *** significant at 1%