Appendix

Data Construction and Imputation

To construct my main dataset, I first merge together separate datasets from the District Level Database for Indian Agriculture and Allied Sectors. These separate datasets include a dataset on crop yields, a dataset on irrigation, a dataset on crop prices, a dataset on rainfall, a dataset on fertilizer usage, a dataset on laborers and population, a dataset on operational holdings, and a dataset on sourcewise irrigation. These datasets can be merged together as all the observations in these data are recorded as a unique district-year combination. The dataset on laborers and total population is not recorded on an annual basis, but rather at 5 year intervals. Thus, I perform a linear interpolation on both laborers and total population to obtain annual district-level observations for these variables.

The only dataset I do not merge initially is the temperature dataset, since the temperature data is only recorded on a monthly basis for each district. To convert the monthly temperature data (which only recorded as a monthly maximum and minimum temperature) to annual temperature data, I first take the monthly average of temperature for all the months within a given year. Then I take the average of the monthly averages to obtain the annual average temperature for a given year. Before I merge this modified temperature dataset into the main dataset with the other variables, I turn to the main dataset for further cleaning.

In the main dataset I construct (as described in the first paragraph), I first take care of the special values. In the database, the only special value is "-1", which represents a missing observation. So I just convert these observations recorded as "-1" to missing. I then merge the temperature data into the main dataset. The annual average temperature variable does not have any special values, and any missing observations are already recorded as such. I report the specific proportion of missing observations later in the appendix.

After merging in the temperature data and doing some extra cleaning of the variable names, I adjust the crop harvest prices for inflation using the Indian Consumer Price Index. I use 2015 as the base year to compute the inflation-adjusted prices. And after this, I compute the proportion of area that is irrigated for each of the thirteen crops. Then I compute the average proportion of crop area irrigated by taking the average (using the row mean command) of the proportion of area irrigated recorded for all thirteen crops. I then proceed to impute the crop price variables as well as all the control variables — the list of control variables can be found in Table 1.

To initiate the imputation, I record all thirteen crop price variables, fertilizer usage, rainfall, and the remaining controls as imputed variables. I employ predictive mean matching for all these variables to obtain new observations. Predictive mean matching essentially draws on real values in the data based on the predictor variables in the imputation model to fill in the missing observations. The predictor variables I use for each of the thirteen crop price variables are the state, year, production, area, and irrigated area for each crop respectively. The predictor variables I use for fertilizer usage are the state, year, and the average proportion of area irrigated. The predictor variables I use for rainfall and the remaining controls are state, year, and the average annual temperature. After the imputations are performed, I clean up the main dataset further by removing the non-imputed observations and replacing them with the imputed observations.

After I perform the imputation and clean the main dataset further, I generate the crop revenues by taking the product of production and harvest price for each of the thirteen crops. Then I compute the output value of the thirteen crops by taking the sum of the revenues of all thirteen crops. I make sure to account for different units of measurement between variables by making the proper conversions. For instance, I compute revenues (in Indian rupees) by multiplying the product of production and price by 9071.85, since there are 9071.85 quintals in 1000 tons (and crop production is measured in 1000 tons while crop price is measured in rupees per quintal).

After I have all the variables I need for the analysis, I compute the annual mean temperature and rainfall by averaging temperature and rainfall within each district over the years 1966 to 2015, so that each district has one annual mean temperature value and one annual mean rainfall value. I then compute the deviation from the annual mean for these two variables by subtracting the annual mean value from the actual value. Then I compute temperature deviation squared and rainfall deviation squared by squaring temperature deviation and rainfall deviation.

Right before running the estimating equations, about 4.5% of observations are missing for annual average temperature, 2.3% of observations are missing for annual rainfall and fertilizer usage, and 3.7% of observations are missing for total output value. About 10.4% of observations are missing for average proportion of crop area irrigated, and approximately 0.2% of observations are missing for total population, agricultural laborers, and the operational holdings (marginal area to large area) variables. Lastly, about 0.6% of observations are missing for the sourcewise irrigation variables (canals area, tanks area, tube wells area, other wells area, other water sourcds area).

Figure A1: State Level Rolling Standard Deviation of Temperature

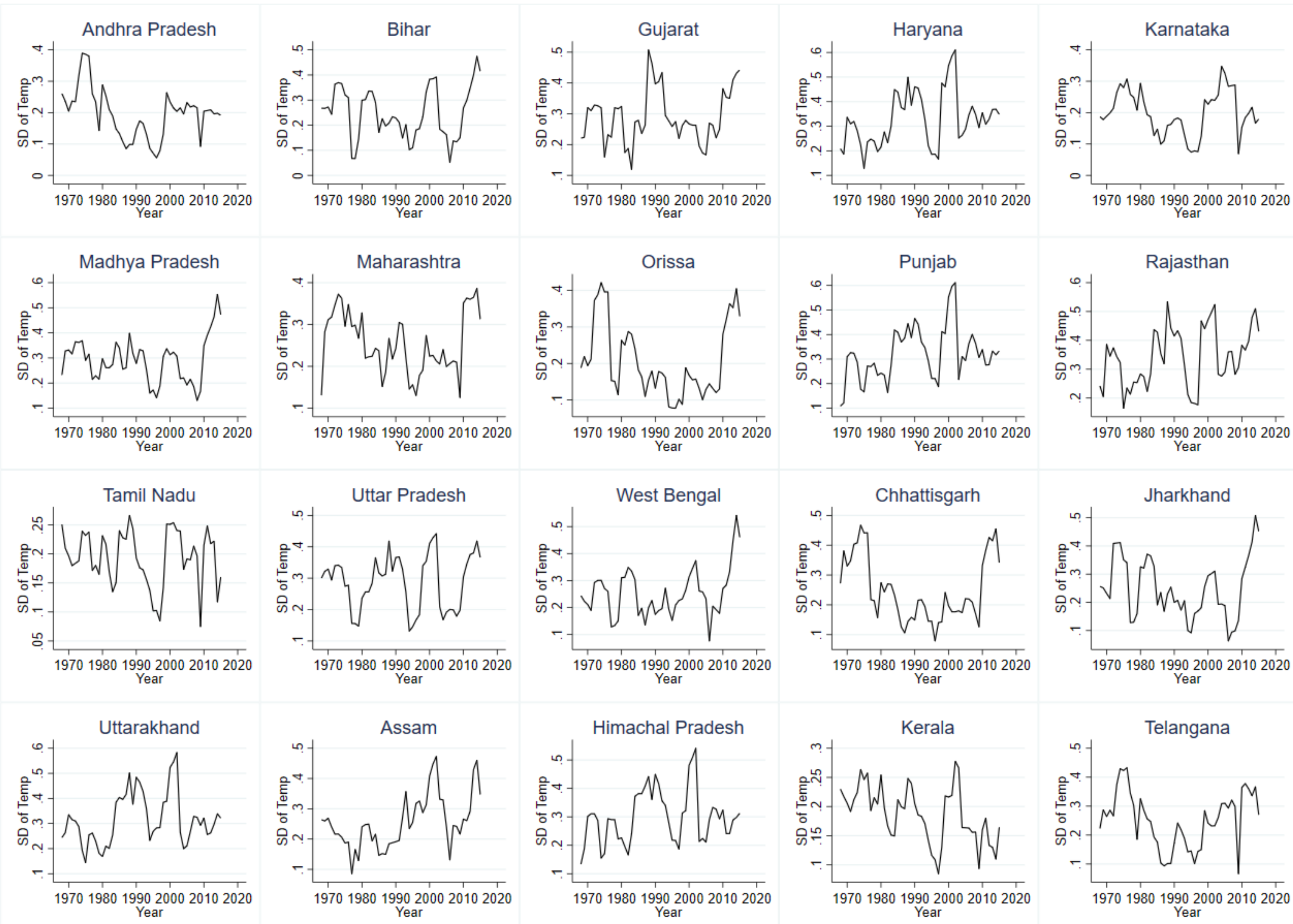

Table A1: Area (1000ha), Production (1000 tons), and Yield (kg/ha) Summary Statistics

Variables	(1) Observations	(2) Mean	(3) SD
Rice Area	15,503	128.39	159.85
Rice Production	15,503	219.26	317.88
Rice Yield	15,503	1,459.10	935.52
Wheat Area	15,490	76.35	99.34
Wheat Production	15,490	175.30	336.96
Wheat Yield	15,490	1,462.34	1,049.09
Sorghum Area	15,485	41.06	93.10
Sorghum Production	15,485	28.98	66.45
Sorghum Yield	15,485	580.05	534.42
Pearl Millet Area	15,471	33.68	91.43
Pearl Millet Production	15,499	21.82	58.53
Pearl Millet Yield	15,471	508.22	566.81
Maize Area	15,497	19.80	34.20
Maize Production	15,497	33.70	74.30
Maize Yield	15,497	1,361.28	1,123.81
Finger Millet Area	15,505	6.36	22.28
Finger Millet Production	15,505	7.19	29.11
Finger Millet Yield	15,505	353.30	565.57
Barley Area	15,505	4.26	10.41
Barley Production	15,505	5.88	15.80
Barley Yield	15,505	715.47	919.33
Chickpea Area	15,485	23.58	45.96
Chickpea Production	15,482	17.34	35.78
Chickpea Yield	15,483	618.30	655.94
Pigeonpea Area	15,491	10.30	22.66
Pigeonpea Production	15,491	7.10	15.39
Pigeonpea Yield	15,491	610.17	492.39
Groundnut Area	15,515	22.68	62.56
Groundnut Production	15,515	21.79	67.33
Groundnut Yield	15,515	749.90	609.18
Sesamum Area	15,481	6.15	12.32
Sesamum Production	15,481	1.85	4.43
Sesamum Yield	15,481	259.91	221.22
Linseed Area	15,268	2.57	7.64
Linseed Production	15,268	0.72	1.88
Linseed Yield	15,268	174.37	261.05
Sugarcane Area	15,285	12.00	29.35
Sugarcane Production	15,284	75.25	193.93
Sugarcane Yield	15,284	4,544.42	3,105.68

Table A2: Estimated Time Trend of Temperature

Variables	Temperature (°C)
Year	0.013***
	(0.000)
Observations	14,880
R-squared	0.975

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3: Main Panel Results Robustness Check (with current Fertilizer Usage)

	(1)	(2)	(3)
Temperature	-0.379***	-0.324***	-0.021
	(0.022)	(0.020)	(0.028)
Temperature Squared	-0.147***	-0.174***	-0.084**
	(0.031)	(0.030)	(0.038)
Rainfall	0.158***	0.154***	0.104***
	(0.026)	(0.028)	(0.023)
Rainfall Squared	-0.106***	-0.060***	-0.027*
	(0.032)	(0.021)	(0.016)
Effect Size	-0.673	-0.672	-0.189
P-value from F-Test	0.000***	0.000***	0.080*
Observations	13,026	13,026	13,026
R-squared	0.375	0.491	0.678

Note: The temperature and rainfall terms represent the deviation from the annual mean. Columns (1)-(2) do not include state fixed effects and year fixed effects. Column (1) includes controls for irrigation, fertilizer usage, and labor, while Columns (2) and (3) include the full set of controls for labor, land, and capital — all of which are lagged by one year. Robust standard errors are reported. *** denotes 1% significance, ** 5% significance, * 10% significance.

Table A4: Comparison between "Cold" and "Hot" Groups for Irrigation

	<26°C	≥ 26°C	Std. dev.	p-value
Total Output Value	1471.77	1326.94	1275.93	0.00
Temperature	23.55	26.97	4.01	0.00
Rainfall	1050.16	1019.52	640.44	0.01
Fertilizer Usage	0.36	0.44	0.49	0.00
Average Proportion of Crop Area Irrigated	0.30	0.32	0.19	0.00
Total Population	2240.12	2756.67	1687.03	0.00
Agricultural Laborers	197.73	340.31	278.24	0.00
Marginal Area Operational Holding	61.64	81.24	73.47	0.00
Small Area Operational Holding	63.45	98.22	62.88	0.00
Semi medium Area Operational Holding	86.77	129.68	78.84	0.00
Medium Area Operational Holding	106.13	161.04	119.08	0.00
Large Area Operational Holding	75.19	126.44	187.87	0.00
Canals Area	44.18	47.92	90.40	0.02
Tanks Area	6.97	16.41	24.06	0.00
Tube Wells Area	70.40	38.95	90.83	0.00
Other Wells Area	23.89	44.96	49.63	0.00
Other Water Sources Area	8.10	6.54	19.20	0.00

Note: Each variable is measured with the same units as in Table 1, which displays the summary statistics. The first column reports the mean of the variable for district-year observations that satisfy $< 26°C$. The second column reports the mean of the variable for district-year observations that satisfy $\geq 26°C$. For Total Output Value, the number of observations for the first column is 7,212, and the number of observations for the second column is 6,161. For Temperature and Average Proportion of Crop Area Irrigated, the number of observations for the first column is 7,260, and the number of observations for the second column is 6,175. For the remaining variables, the number of observations for the first column is 7,238, and the number of observations for the second column is 6,163.

Table A5: Heterogeneous Effects of Irrigation by Temperature

	(1)	(2)	(3)	(4)	(5)	(6)
Threshold	x=0.4	x=0.4	x=0.5	x=0.5	x=0.6	x=0.6
	$< 26°C$	$\geq 26°C$	$< 26°C$	$\geq 26°C$	$< 26°C$	$\geq 26°C$
Avg. Prop. irrigated below threshold	0.206	0.255	0.225	0.282	0.238	0.298
Avg. Prop. irrigated above threshold	0.646	0.512	0.734	0.607	0.794	0.704
Temperature	-0.001	-0.159	0.020	-0.133	0.038	-0.231
	(0.089)	(0.085)	(0.098)	(0.145)	(0.108)	(0.297)
Temperature Squared	0.133	-0.057	0.286*	-0.152	0.334*	-0.096
	(0.112)	(0.098)	(0.127)	(0.160)	(0.145)	(0.332)
$\mathbb{1}(Irrigation < x)$	0.603***	-0.006	0.853***	0.095*	0.932***	0.187***
	(0.047)	(0.026)	(0.056)	(0.037)	(0.063)	(0.056)
Temperature $\times\mathbb{1}$(Irrigation<x)	0.228**	0.173*	0.170	0.116	0.138	0.219
	(0.082)	(0.069)	(0.090)	(0.131)	(0.099)	(0.287)
Temperature Squared $\times\mathbb{1}$(Irrigation<x)	0.078	-0.084	-0.152	0.043	-0.203	-0.015
	(0.114)	(0.091)	(0.123)	(0.156)	(0.139)	(0.331)
Rainfall	0.043	0.148***	0.039	0.146***	0.047	0.146***
	(0.044)	(0.033)	(0.043)	(0.033)	(0.043)	(0.033)
Rainfall Squared	-0.008	-0.026	-0.008	-0.024	-0.009	-0.024
	(0.029)	(0.022)	(0.030)	(0.021)	(0.030)	(0.022)
Differential Effect	0.384	0.005	-0.134	0.202	-0.268	0.189
P-value from F-Test	0.017**	0.032**	0.017**	0.198	0.048**	0.219
Observations	7,555	6,412	7,555	6,412	7,555	6,412
R-squared	0.666	0.589	0.674	0.589	0.675	0.591

Note: Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Comparison between "Cold" and "Hot" Groups for Fertilizer Usage

	< 26°C	≥ 26°C	Std. dev.	p-value
Total Output Value	1416.22	1324.53	1262.56	0.00
Temperature	23.54	26.95	3.99	0.00
Rainfall	1143.21	1040.18	702.33	0.00
Fertilizer Usage	0.35	0.45	0.49	0.00
Average Proportion of Crop Area Irrigated	0.30	0.32	0.19	0.00
Total Population	2260.31	2816.80	1699.08	0.00
Agricultural Laborers	196.51	345.77	275.41	0.00
Marginal Area Operational Holding	62.75	82.99	72.89	0.00
Small Area Operational Holding	64.37	100.61	64.40	0.00
Semi medium Area Operational Holding	85.69	128.52	79.06	0.00
Medium Area Operational Holding	101.02	154.67	117.55	0.00
Large Area Operational Holding	71.63	118.78	181.71	0.00
Canals Area	42.49	50.78	89.66	0.00
Tanks Area	6.82	15.82	23.61	0.00
Tube Wells Area	66.57	38.74	89.54	0.00
Other Wells Area	22.51	43.14	48.76	0.00
Other Water Sources Area	7.87	6.49	18.97	0.00

Note: Each variable is measured with the same units as in Table 1, which displays the summary statistics. The first column reports the mean of the variable for district-year observations that satisfy $< 26°C$. The second column reports the mean of the variable for district-year observations that satisfy $\geq 26°C$. For Total Output Value, the number of observations for the first column is 7,701, and the number of observations for the second column is 6,572. For Average Proportion of Crop Area Irrigated, the number of observations for the first column is 7,238, and the number of observations for the second column is 6,163. For the remaining variables, the number of observations for the first column is 7,914, and the number of observations for the second column is 6,628.

Table A7: Heterogeneous Effects of Fertilizer by Temperature

	(1)	(2)	(3)	(4)	(5)	(6)
Threshold	x=0.25	x=0.25	x=0.50	x=0.50	x=0.75	x=0.75
	$< 26°C$	$\geq 26°C$	$< 26°C$	$\geq 26°C$	$< 26°C$	$\geq 26°C$
Avg. Prop. irrigated below threshold	0.070	0.109	0.129	0.194	0.179	0.260
Avg. Prop. irrigated above threshold	0.762	0.728	1.029	0.979	1.282	1.228
Temperature	0.096*	0.010	0.060	0.061	0.143	2.152*
	(0.049)	(0.047)	(0.087)	(0.122)	(0.141)	(0.959)
Temperature Squared	0.149*	0.002	0.018	-0.184	-0.059	-1.844*
	(0.067)	(0.065)	(0.128)	(0.154)	(0.233)	(0.841)
$\mathbb{1}(Fertilizer < x)$	-0.245***	-0.170***	0.260***	0.060	0.329***	0.750**
	(0.029)	(0.023)	(0.049)	(0.047)	(0.070)	(0.255)
Temperature $\times \mathbb{1}$(Fertilizer<x)	-0.162**	-0.060	-0.056	-0.081	-0.146	-2.170*
	(0.059)	(0.052)	(0.080)	(0.124)	(0.135)	(0.959)
Temperature Squared $\times \mathbb{1}$(Fertilizer<x)	-0.289**	-0.152	-0.015	0.143	0.068	1.793*
	(0.089)	(0.081)	(0.123)	(0.156)	(0.227)	(0.840)
Rainfall	0.061	0.151***	0.054	0.154***	0.058	0.158***
	(0.034)	(0.030)	(0.034)	(0.030)	(0.034)	(0.029)
Rainfall Squared	-0.020	-0.016	-0.015	-0.017	-0.015	-0.016
	(0.022)	(0.021)	(0.021)	(0.020)	(0.021)	(0.020)
Differential Effect	-0.740	-0.364	-0.086	0.205	-0.010	1.416
P-value from F-Test	0.002***	0.033**	0.780	0.632	0.542	0.077*
Observations	7,038	6,007	7,038	6,007	7,038	6,007
R-squared	0.727	0.696	0.723	0.691	0.724	0.694

Note: Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.