Agriculture
Technology, Subsidy, Climate Change

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Emerick, et al. "Technological innovations, downside risk, and the modernization of agriculture" AER (2016), Suri "Selection and comparative advantage in technology adoption." Econometrica (2011)

Deschenes, Greenstone. "The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather." AER (2007), Fisher, et al. "The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather: comment" AER (2012)

Introduction

- Productivity growth in agricultural sector is driver of structural transformation and economic growth for poor countries
- Failure of farmers in developing countries to use modern inputs (fertilizer)
  - procrastination and time-inconsistent preferences
  - high transaction costs due to poor infrastructure (Next paper)
  - ack of information and difficulties in learning
  - absence of formal insurance
  - (this paper) smallholder farmers lack technologies that are well suited to local conditions
- Question: can the availability of new technologies that are better suited to local conditions crowd in additional inputs and investments in other productivity-enhancing practices?

This Paper

- Technological innovation in agriculture can create a factor deepening effect where improved practices and additional inputs are used in response to innovation
- Innovative new rice variety, well suited to local conditions in flood-prone areas
- Technology downside risk by decreasing crop damage during flooding
- Production unaffected during normal years
- Randomized distribution of new rice variety across 128 villages
- Only difference: flood tolerance

Finding

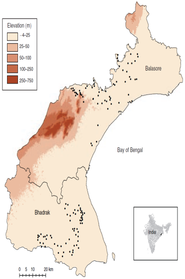
- Finding: technological innovation leads to not only avoided yield losses under flooding
- **but also significant factor deepening and adoption of improved practices as indirect benefits in normal years**
  1. new technology induces modernization of farmers' production practices
  2. improved technology crowds in more fertilizer use.
  3. more credit usage(loan) and less savings of harvest
  4. Effects of crowd-in on productivity, higher harvest in non-flood year
- Flood probability: 0.19,
- Maximum yield gain under flooding is 2 tons per hectare
- Yield gain due to purely technical features of technology: 380 kilograms per hectare
- Crowd-in induces yield gains of 280 kilograms per hectare

Finding

- Why induce adoption of other inputs and practices
  1. by reducing losses during flooding, technology have a direct effect on marginal product of inputs
  2. reduce downside risk $\Rightarrow$ reducing variance of income
     - technology increases overall output and income in low-productivity states when the marginal product of input use is low
  3. generate a wealth effect if farmers decisions are based on the expected level of output.
     - forward-looking farmers could base input-use decisions off future wealth
     - increasing expected wealth changes the level of absolute risk aversion when preferences are not constant absolute risk aversion
- Evidence for the dominant channel of 2

Experimental Design and Data

- Villages in flood-prone areas ⇒ flood risk is high
- Swarna (rice) is widely grown
- Swarna-Sub1 was still unavailable to farmers in May 2011
- Village chosen by satellite imagery affected by flooding
- A random subset of 64 affected villages selected for study



Experimental Design and Data

- Randomly divided 128 villages into treatment& control
- Each village list of 25 farmers using Swarna
- 5 farmers randomly in each of 64 treatment villages to receive minikits containing 5 kilograms of Swarna-Sub1 seeds
- Comparison group: 10 randomly selected nonrecipients in treatment & 5 randomly selected farmers in 64 control
- In addition to minikit, treatment farmers provided two-page information sheet on Swarna-Sub1
  - pictures from farmer-managed trials showing clear productivity gains of Swarna-Sub1 after flooding
  - information sheet that other than flood tolerance, Swarna-Sub1 is identical to Swarna
- Sheet not suggesting any management practices (fertilizer)

Experimental Design and Data

- Several villages in the sample were affected by heavy flooding during September 2011
- Approximately 40% of plots in our sample were fully submerged
- Implementing NGO did not provide additional seeds to treatment farmers after year one
- Swarna-Sub1 seeds were not available on the market
- Only way to continue using the variety was to save a portion of year one harvest as seeds for cultivation during year two

Data Collection

- First follow-up survey in March 2012 after first year harvest
- 1,248 farmers were reached (97.7%)
- Compliance with treatment during first year was universal
- Treatment farmers cultivated 14% of their land with Swarna-Sub1
- Second follow-up survey one year later
- 1,237 of farmers surveyed
- Compliance with treatment during the second year:
- 76 % of minikit recipients cultivated technology during year two
- Seed transfers from original recipients
- 13.3 % of control farmers cultivated Swarna-Sub1 in treatment villages and 3.3 % did so in control villages

Summary Statistics

- Village characteristics from the 2001 census.

	In experiment	Other villages in 3 states
Number households	177.72	307.66
	(175.536)	(408.872)
Household size	5.31	5.26
	(0.891)	(0.843)
Share scheduled caste	0.20	0.23
	(0.202)	(0.246)
Share scheduled tribe	0.09	0.07
	(0.181)	(0.183)
Share cultivating land	0.12	0.09
	(0.069)	(0.067)
Share agricultural laborers	0.06	0.09
	(0.066)	(0.082)
Literacy rate	0.60	0.51
	(0.110)	(0.182)

- Represent of area except village size

Summary Statistics

- Treatment and control households look similar

	Control	Treatment	p-value of difference
Panel A. Household characteristics			
Land owned in hectares	0.810	0.868	0.22
HH has private tubewell	0.332	0.325	0.82
HH has piped water	0.035	0.057	0.09
HH has refrigerator	0.078	0.076	0.92
HH has television	0.628	0.605	0.46
Education of farmer	6.896	6.946	0.83
Age of farmer	51.191	51.783	0.44
HH has thatched roof	0.557	0.548	0.78
HH has latrine	0.289	0.354	0.03
HH has electricity	0.843	0.822	0.38
HH has below poverty line card	0.574	0.559	0.64
ST or SC	0.189	0.176	0.61
Panel B. Flood exposure of cultivated plots			
Share plots low land	0.335	0.357	0.37
Share plots medium land	0.569	0.571	0.94
Share plots high land	0.081	0.067	0.34
Average flood duration in year 1	5.518	5.887	0.23
Joint p-value of household characteristics	0.26		

  - Farms are small, 56 % below poverty line
  - Electricity is widespread, piped water rare
  - Farmers cultivate 3.5 plots, flooded for 6 days

Results

- Baseline specification:

$$y_{ivb} = \beta_0 + \beta_1 treatment_{ivb} + \alpha_b + \varepsilon_{ivb}$$

- y_{ivb} outcome farmer i in village v, block b
- α_b fixed effect for block
- Error term is clustered at the village level since this corresponds to the first tier of randomization
- β_1 plot level regressions $\Rightarrow$ average effect across all plots, not just plots cultivated with Swarna-Sub1.
- Main results are unaffected by controlling for household covariates

Cultivation Practices and Inputs

- Effect on cultivation practices

	Area planted (1)	log area (2)	Use Swarna (3)	Use TV (4)	Broadcast (5)
Panel A. Year 1					
Original minikit recipient	0.068 (0.045)	0.088 (0.048)	−0.157 (0.018)	−0.029 (0.016)	−0.022 (0.012)
Block fixed effects	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	0.92	−0.36	0.47	0.21	0.10
Observations	1,248	1,238	4,215	4,214	4,221
R^2	0.167	0.197	0.129	0.153	0.094
Panel B. Year 2					
Original minikit recipient	0.109 (0.056)	0.098 (0.044)	−0.101 (0.017)	−0.041 (0.016)	−0.063 (0.017)
Block fixed effects	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	1.00	−0.20	0.36	0.28	0.19
Observations	1,237	1,175	4,589	4,588	4,582
R^2	0.112	0.161	0.115	0.270	0.242

- Small expansion in cultivated area (0.07 hectares or 9 %)
- Swarna is popular rice, alternative local “traditional” (TV) low yield by survive during flooding
- Both Swarna and TV declined

Cultivation Practices and Inputs

- Crowding out of traditional varieties is one of the channels through which the innovation affects output
- Broadcasting seeds: cheaper, less productive, and traditional planting method of manually
- Farmers given access to improved technology less likely to broadcasting (22% reduction)
- Treatment farmers more likely to use labor-intensive method of manually transplanting seedlings.17 Panel A shows that plots

Cultivation Practices and Inputs

- Effect on fertilizer usage during year 2

	All (1)	Urea (2)	DAP (3)	MOP (4)	Gromor (5)
Original minikit recipient	396.703	13.428	393.768	90.579	−101.073
	(179.631)	(34.372)	(136.410)	(58.170)	(67.759)
Rice area (hectares)	3,835.891	694.814	2,288.634	623.535	228.909
	(315.559)	(108.483)	(253.521)	(132.287)	(66.481)
Block fixed effects	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	3,781.48	664.70	2,016.80	702.82	397.15
Observations	1,237	1,237	1,237	1,237	1,237
R^2	0.619	0.496	0.526	0.279	0.064

- Improved technology ⇒ greater fertilizer use during year two
- Increase in fertilizer expenditure is on phosphate (DAP) and potassium (MOP) fertilizers
- These fertilizers used earlier in growing season
- Earlier: risk of exposure to flooding is highest
- Close gap between actual & recommended fertilizer

Storage and Credit

- Large storage after harvest
- Harvest 2,945 kg, 1,711 kg consumed or store
- Enough to feed 11 adults, hh size 5.3 persons
- Stored rice is liquid asset
- another explanation insure against future consumption variability.

Storage and Credit

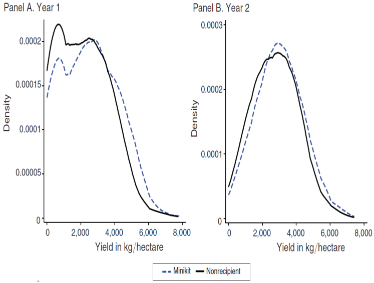
	Storage rate (1)	Storage rate (2)	Loan (3)	Coop loan (4)	Other loan (5)
Panel A. Year 1					
Original minikit recipient	−0.026	−0.016	0.063	0.033	0.030
	(0.015)	(0.027)	(0.039)	(0.028)	(0.032)
Original minikit recipient*HH has BPL card		−0.017			
		(0.034)			
Block fixed effects	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	0.73	0.73	0.43	0.24	0.19
Observations	1,183	1,180	1,248	1,248	1,248
R^2	0.113	0.117	0.122	0.154	0.055
Panel B. Year 2					
Original minikit recipient	−0.050	−0.085	0.068	0.050	0.023
	(0.017)	(0.024)	(0.027)	(0.024)	(0.019)
Original minikit recipient*HH has BPL card		0.061			
		(0.031)			
Block fixed effects	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	0.70	0.70	0.19	0.12	0.08
Observations	1,167	1,164	1,237	1,230	1,237
R^2	0.070	0.073	0.058	0.057	0.014

Storage and Credit

- Treatment store a smaller share of their harvest for future consumption
- BPL (below poverty line) cards serve as consumption insurance: HH can purchase 30 kilograms of rice per month at highly subsidized rates
- Column 2: storage effect from HH who do not hold BPL cards
- Improved technology: less downside risk: increases agricultural credit
- Credit uptake increased by 6.3%

Effects on Productivity

- Plot level yield



- Year one, severe flooding, significant mass of distribution at low yields
- Year 1 rightward shift: technical +small crowd-in
- Year 2 rightward shift throughout distribution of yield

Effects on Productivity

- Technology led to an increase in yield

	Year 1	Year 2			
	(1)	(2)	(3)	(4)	(5)
Original minikit recipient	314.97	283.45	230.30	196.54	169.14
	(86.28)	(77.48)	(73.73)	(68.06)	(64.84)
Broadcast planting			−801.22	−679.36	−419.08
			(129.45)	(117.53)	(108.50)
Tons fertilizer per hectare				4,350.39	3,237.30
				(997.70)	(831.35)
Tons fertilizer per hectare^2				−4,025.26	−2,942.84
				(1,628.52)	(1,266.48)
Traditional variety					−442.46
					(70.86)
Irrigated					711.64
					(92.21)
Has credit					150.79
					(69.04)
Block fixed effects	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	2,213.39	2,817.97	2,819.53	2,819.53	2,819.13
Observations	4,184	4,573	4,568	4,568	4,514
R^2	0.409	0.159	0.200	0.236	0.302

Effects on Productivity

- Year 2, all productivity due to crowd-in, 10% increase in productivity.
- Test crowd-in channel by adding main outcome measures
- Merely correlations and not causally
- The effect is still significant, crowd-in effect is an important determinant of overall productivity effect of technology
- How large are these indirect effects of the new technology?
- Compare yield vs trial laboratory (technical)
- Flood probability 0.19
- Gain from technology 380kg, 283kg (estimate) from crowd-in (43%)
-

Shifts in the Marginal Productivity of Inputs

- Sample of fields not cultivated with Swarna-Sub1

	Yield (1)	Use Swarna (2)	Use TV (3)	Broadcast (4)	Fertilizers: All (5)	Fertilizers: DAP (6)
Original minikit recipient	172.901	−0.008	0.023	−0.042	63.022	100.389
	(77.156)	(0.021)	(0.018)	(0.019)	(57.614)	(47.962)
Area of plot	−223.539	0.006	0.023	0.033	3,538.521	2,094.537
	(121.532)	(0.039)	(0.037)	(0.035)	(371.851)	(263.348)
Owned land	34.201	0.062	−0.025	0.055	119.388	87.608
	(66.644)	(0.020)	(0.018)	(0.018)	(63.060)	(43.477)
Block fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Land quality indicators	Yes	Yes	Yes	Yes	Yes	Yes
Land slope indicators	Yes	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	2,757.37	0.40	0.32	0.20	1,098.14	590.57
Observations	4,087	4,087	4,086	4,082	4,087	4,087
R^2	0.18	0.15	0.31	0.27	0.52	0.43

- If it is just marginal productivity, then no effect on cultivation with Swarna by treatment farmers
- But effects persist on plots where Swarna-Sub1 was not used

Shifts in the Marginal Productivity of Inputs

- Rule out the mechanism where the new technology simply increases the marginal products of inputs.
- Concern: endogeneity of plot choice
- If treatment farmers allocated Swarna-Sub1 to their worst lands
- To reducing these selection concerns: self-reported land quality

Changes in Mean Yield Rather than Variance

- Two more Chanel: downside risk vs income effect
- Ideal experiment: promising compensation to control farmers in amount equal to gain in expected output from Swarna-Sub1
- During the first year of the study there was spatial variation in the intensity of flooding
- Flood shock equivalent to gain in expected output caused by Swarna-Sub1
- Gain from Swarna-Sub1 equivalent to 1.4 days flood
- Compare severe flood plots: an additional 1.4 days of flood exposure is around one-fifth effect of Swarna-Sub1
- Seems downside risk is the main channel

Introduction

- Suri "Selection and comparative advantage in technology adoption." Econometrica(2011)
- Why does yields of staples decline in developing (like Kenya) despite growth in technology?
- Average annual % changes in yields

	1961–1970	1971–1980	1981–1990	1991–2004
Kenya				
Maize	0.362	2.373	1.169	−1.198
Wheat	5.646	2.333	−3.078	0.984
India				
Maize	1.502	0.842	1.900	2.572
Wheat	4.876	2.514	3.343	1.235
Rice	0.954	1.714	3.310	0.838
Mexico				
Maize	2.057	4.267	−0.548	1.447
Wheat	4.586	3.204	−0.255	1.664
Zambia				
Maize	−0.267	10.403	1.571	−1.707

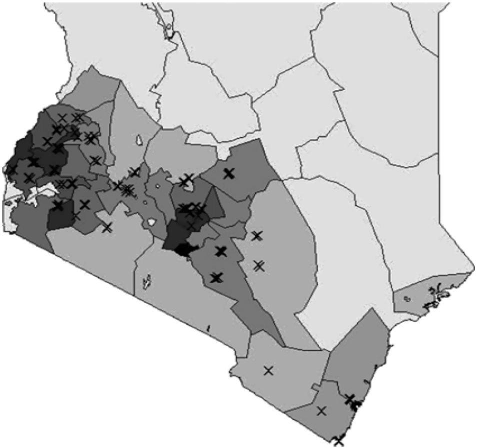
Introduction

- Fertilizer can improve yields, but not used
- Empirical puzzle: why adoption rates remained persistently low over a long period
- Results: if farmer heterogeneity is taken into account, there is no puzzle
- Important heterogeneity: distribution cost + tech. benefits

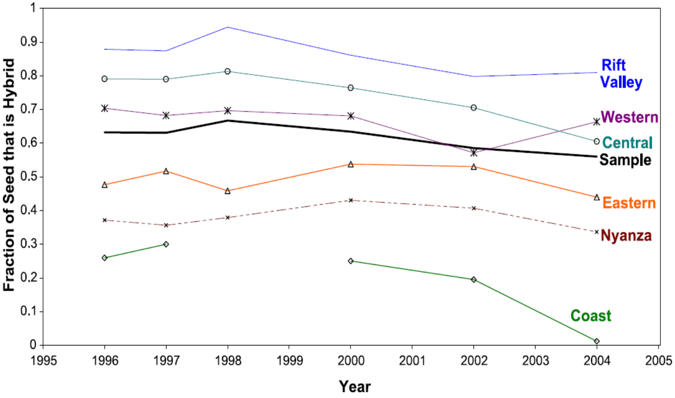
Institutional Context and Data

- Maize main staple in Kenya, 90% of population depend on it for income
- Hybrid maize increases yields
- 70% of plots planted with a hybrid
- Recycle seed (last year harvest) is low yields
- KARI (research institute) produces seeds
- Same price across country, no variation
- Household level panel survey of Kenya (1200 hh)
- Data on 1997, 1998, 2000, 2002, 2004
- 1997 & 2004 detailed information
- Great across heterogeneity + persistence

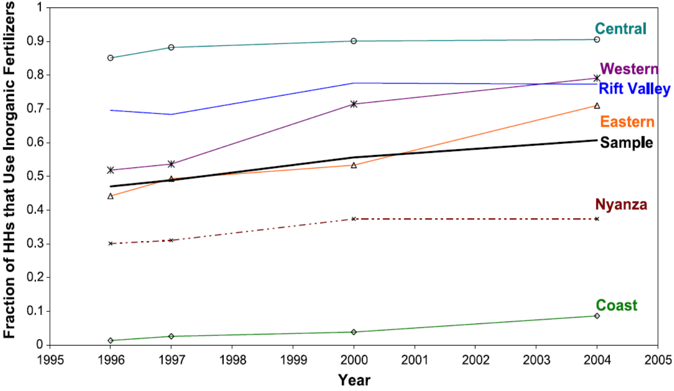
Population density and location of sample villages



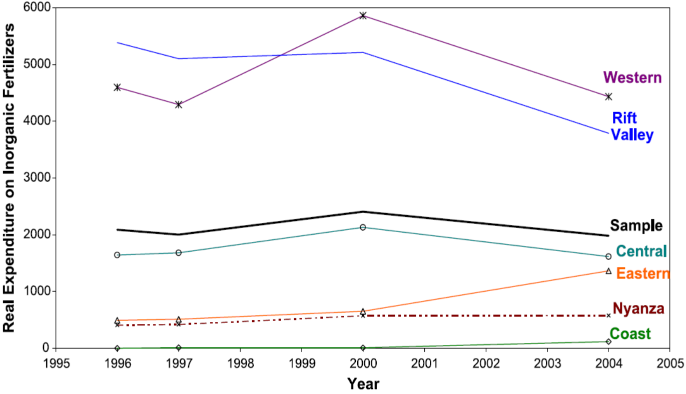
Hybrid maize adoption patterns by province



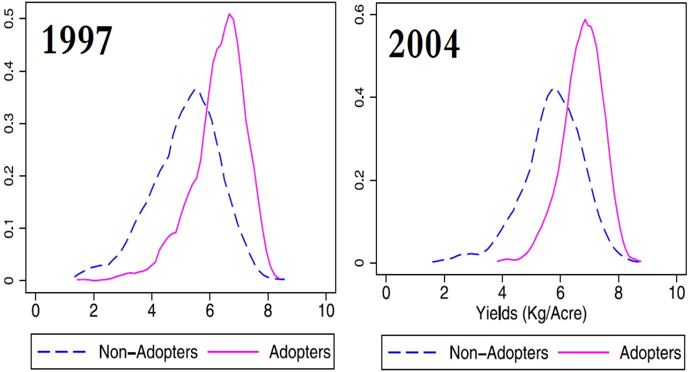
Fraction of households using inorganic fertilizer by province



Real expenditure on inorganic fertilizer by province



Marginal distribution of yields by sector



Summary Statistics by Sample Year

	1997 Sample	2004 Sample
Yield (log maize harvest per acre)	5.907 (1.153)	6.350 (0.977)
Acres planted	1.903 (3.217)	1.957 (2.685)
Total seed planted (kg per acre)	9.575 (7.801)	9.072 (6.863)
Total purchased hybrid planted (kg per acre)	6.273 (6.926)	5.080 (5.260)
Hybrid (dummy)	0.658 (0.475)	0.604 (0.489)
Fertilizer (kg DAP (diammonium phosphate) per acre)	20.300 (38.444)	24.610 (34.001)
Fertilizer (kg MAP (monoammonium phosphate) per acre)	1.566 (10.165)	0.308 (4.538)
Fertilizer (kg CAN (calcium ammonium nitrate) per acre)	6.473 (24.727)	8.957 (21.702)
Total fertilizer expenditure (KShs per acre)	1361.7 (2246.3)	1354.6 (1831.2)
Land preparation costs (KShs per acre)	960.88 (1237.1)	541.43 (1022.8)
Family labor (hours per acre)	293.25 (347.49)	354.27 (352.68)
Hired labor (KShs per acre)	1766.0 (3346.4)	1427.4 (2130.3)
Main season rainfall (mm)	620.83 (256.43)	728.11 (293.29)
Distance to closest fertilizer seller (km)	6.288 (9.774)	3.469 (5.964)
Household size	7.109 (2.671)	8.409 (3.521)

Summary Statistics by Hybrid/Nonhybrid Use

	1997 Sample		2004 Sample	
	Hybrid	Nonhybrid	Hybrid	Nonhybrid
No. of households	791	411	726	476
Yield (log maize harvest per acre)	6.296 (0.934)	5.158 (1.167)	6.751 (0.692)	5.738 (1.030)
Total maize acres cultivated	1.982 (3.557)	1.753 (2.428)	2.087 (3.029)	1.758 (2.042)
Total seed planted (kg per acre)	9.669 (6.569)	9.394 (9.750)	8.746 (4.156)	9.569 (9.608)
Fertilizer (kg DAP per acre)	28.755 (44.115)	4.028 (13.266)	37.148 (37.294)	5.488 (13.909)
Fertilizer (kg CAN per acre)	9.087 (29.715)	1.442 (7.152)	12.708 (24.961)	3.235 (13.622)
Land preparation costs (KShs/acre)	1043.9 (1242.7)	801.08 (1211.7)	659.83 (1079.7)	360.83 (901.0)
Expenditure on fertilizer (KShs/acre)	1922.3 (2542.9)	282.64 (740.53)	1893.3 (1964.7)	533.09 (1211.4)
Inorganic fertilizer use (dummy)	0.7421 (0.4378)	0.2311 (0.4221)	0.8994 (0.3009)	0.4055 (0.4915)
Main season rainfall (mm)	651.70 (228.82)	561.44 (293.88)	825.41 (215.20)	579.69 (332.05)
Hired labor (KShs/acre)	1864.3 (2680.6)	1576.7 (4347.8)	1616.5 (2197.4)	1139.0 (1991.6)
Family labor (hours/acre)	260.35 (264.13)	356.57 (461.71)	343.6 (336.1)	370.58 (376.33)
Distance to closest fertilizer seller (km)	4.684 (7.993)	9.374 (11.93)	2.419 (2.420)	5.069 (8.760)
Household size	7.162 (2.616)	7.007 (2.773)	8.457 (3.340)	8.336 (3.783)

Breakdown of Labor Costs by Hybrid/Nonhybrid Use

	1997 Sample		2004 Sample	
	Hybrid	Nonhybrid	Hybrid	Nonhybrid
Hired labor (KShs/acre)				
Land preparation	408.4 (1171)	514.2 (3178)	408.2 (869.1)	501.8 (1096)
Planting	159.8 (318.9)	105.4 (293.5)	143.4 (354.1)	76.67 (216.9)
Weeding	678.8 (1149)	651.8 (1484)	635.7 (1088)	403.1 (915.5)
Harvest	365.1 (642.5)	196.6 (766.1)	151.1 (303.5)	96.42 (340.5)
Postharvest activities	236.5 (472.6)	98.65 (308.6)	241.1 (576.7)	47.37 (182.1)
Fertilizer application	15.21 (84.67)	10.02 (156.4)	13.24 (79.32)	2.374 (28.04)
Other	0.501 (9.727)	0 (0)	23.84 (281.6)	11.26 (227.5)
Family labor (hours/acre)				
Land preparation	47.95 (113.5)	102.4 (214.6)	51.93 (98.22)	97.79 (180.1)
Planting	29.12 (31.81)	35.23 (45.19)	38.27 (56.13)	39.55 (49.01)
Weeding	93.75 (107.1)	127.5 (151.6)	120.1 (151.3)	134.6 (160.2)
Harvest	42.45 (46.04)	49.54 (143.0)	58.77 (72.36)	49.60 (62.80)
Postharvest activities	44.07 (55.77)	39.89 (70.00)	68.54 (91.76)	44.69 (59.98)
Fertilizer application	3.171 (8.778)	1.935 (15.09)	3.928 (9.976)	1.510 (6.706)
Other	0.047 (1.313)	0 (0)	2.041 (13.62)	2.814 (24.73)

Transitions Across Hybrid/Nonhybrid Sectors

Transition in Terms of Technology Used (1997 2000 2004)			Fraction of Sample (%) ($N = 1202$ Households)
N	N	N	20.38
N	N	H	2.83
H	N	H	6.07
N	H	H	4.91
H	N	N	5.99
H	N	H	3.16
H	H	N	7.15
H	H	H	49.50

Model

- Farmers compare H/N yields and cost to pick
- Log of production:

$$y_{it}^H = \beta_t^H + x_{it}'\gamma^H + u_{it}^H \qquad y_{it}^N = \beta_t^N + x_{it}'\gamma^N + u_{it}^N$$

- Put structure:

$$u_{it}^H = \theta_i^H + \zeta_{it}^H \quad u_{it}^N = \theta_i^N + \zeta_{it}^N$$

- Farmers know θ not ζ
- Relative magnitude of $\theta_i^H \& \theta_i^N$ not identified, so

$$\theta_i^H = b_H(\theta_i^H - \theta_i^N) + \tau_i \qquad \theta_i^N = b_N(\theta_i^H - \theta_i^N) + \tau_i$$

- Where $b_H = (\sigma_H^2 - \sigma_{HN})/(\sigma_H^2 + \sigma_N^2 - 2\sigma_{HN})$ and so on.

Model

- τ_i farmer i absolute advantage (not vary by tech)
- Orthogonal to $\theta_i^H - \theta_i^N$
- if $\theta_i \equiv b_N(\theta_i^H - \theta_i^N)\&\quad \phi \equiv \frac{b_H}{b_N} - 1$, then

$$\theta_i^H = (\phi + 1)\theta_i + \tau_i \qquad \theta_i^N = \theta_i + \tau_i$$

- Interested in structural parameter ϕ and distribution of θ_i
- Substitute in prod. func. and use $y_{it} = h_{it}y_{it}^H + (1 - h_{it})y_{it}^N$

$$y_{it} = \beta_t^N + \theta_i + (\beta_t^H - \beta_t^N)h_{it} + X_{it}'\gamma^N + \phi\theta_i h_{it} + X_{it}'(\gamma^H - \gamma^N)h_{it} + \tau_i + \varepsilon_{it}$$

- Since, the coefficient on h_{it} , $\phi\theta_i$ depends on the unobserved θ_i , this is a correlated random coefficient (CRC) model
- where the θ_i are correlated with adoption decision

Model

- Estimate two components
  1. ϕ how important differences in comparative advantage
  2. distribution of θ_i: heterogeneous returns to hybrid
- θ_i: relative productivity in hybrid over nonhybrid
- High θ_i but low gains in switching $\Rightarrow \phi < 0$
- $\Rightarrow \phi$: sorting in economy
- If $\phi < 0$: less inequality in yields compared to an economy where individuals are randomly allocated to a technology
- If $\phi > 0$: self-selection process: greater inequality in yields
- If $\mu_i = \theta_i + \tau_i \Rightarrow \quad \mu_i$ is a household-specific intercept (average yield) and $\phi\theta_i$ is household specific return to hybrid.
- Sign of ϕ = sign covariance b/w hh yield and its return to hybrid
- $\phi < 0$ farmers who do better on average, do worse at hybrid

Role of Fixed Costs in the Adoption Decision

- How changes in infrastructure and access to seed & fertilizer distributors affect adoption decisions?
- Generalization of Roy model
- Adopt if:

$$E(u_{it}^H - u_{it}^N) > A_{it} + \Delta_{it}^s - (\beta_t^H - \beta_t^N) + \sum_{j=1}^{J}(\gamma_j^N {x^*_{jit}}^N - \gamma_j^H {x^*_{jit}}^H)$$

- $A_{it} = \frac{a_{it}}{p_{it}}$ where a_{it} (fixed) cost of obtaining hybrid 0seed, p_{it}price of maize
- $\Delta_{it}^s = \frac{\delta_{it}^s}{p_{it}}$ where$\delta_{it} = (b_t - c_{it}s^*$, b_t: per-unit cost of hybrid seed, c_{it} is the (≈ 0) per-unit costs of replanting nonhybrid seed from the previous year harvest, $s^* \approx s_{it}^*$: quantity of seed used

Role of Fixed Costs in the Adoption Decision

- Data: revenue in hybrid is double in nonhybrid
  - 30% is due to differential seed & fertilizer costs
  - 4%: land preparation cost differences
  - 7% hired labor cost differences
- Data: ${x^*}_{jit}^{H} \approx {x^*}_{jit}^{N}$ & $\gamma_j^H \approx \gamma_j^N$
- So, adoption rule reduce to

$$E(u_{it}^H - u_{it}^N) > A_{it} + \Delta_{it}^s - (\beta_t^H - \beta_t^N)$$

- Therefore:

$$(\theta_i^H - \theta_i^N) > A_{it} + \Delta_{it}^s - (\beta_t^H - \beta_t^N) \qquad \phi\theta_i > A_{it} + \Delta_{it}^s - (\beta_t^H - \beta_t^N)$$

Role of Fixed Costs in the Adoption Decision

- So, technology choice depend on
  1. unobserved, farmer-specific, time-invariant comparative advantage θ_i
  2. pure macroeconomic factors $\beta_t^H - \beta_t^N$
  3. time-varying costs of obtaining hybrid A_{it}
     - affect demand for hybrid seed, but not yields directly
  4. real relative purchase costs of hybrid seed Δ_{it}^s
- Define $\alpha_i \equiv E_t[A_{it}]$, $\nu_{it} = A_{it} - \alpha_i$

$$\phi\theta_i - \alpha_i > \Delta_{it}^s - (\beta_t^H - \beta_t^N) + \nu_{it}$$

- α_i fixed costs,

Estimating a Model With Heterogeneous Returns

- Estimate production function.
- Olley, Pakes (1996) Levinsohn, Petrin (2003)focus on unobserved time-varying productivity
- Inconsistent here
  - returns to hybrid are heterogeneous and correlated with decision to use hybrid
  - dynamics is important, entry & exit
  - here static heterogeneity is key
- Chamberlain (1982) correlated random effects approach

$$y_{it} = \delta + \beta h_{it} + \theta_i + \phi\theta_i h_{it} + u_{it}$$

- where: $u_{it} \equiv \tau_i + \varepsilon_{it}$, $\beta_{it}^H - \beta_{it}^N \equiv \beta \quad \forall t$

Estimating a Model With Heterogeneous Returns

- Eliminate dependence of observed θ_i on endogenous input (h_{it}) following Chamberlain

$$\theta_i = \lambda_0 + \lambda_1 h_{i1} + \lambda_2 h_{i2} + \lambda_3 h_{i1} h_{h2} + \nu_i$$

- θ_i depend on full history of inputs & their interactions
- Normalize: $\sum \theta_i = 0$
- Interaction $h_{i1} h_{i2}$ ensure ν_i is orthogonal to every history of hybrid use
- To identify λ_3 necessary to have farmers planted hybrid in both periods
- Substitute into production equation:

$$\begin{aligned} y_{i1} &= \delta_1 + \gamma_1 h_{i1} + \gamma_2 h_{i2} + \gamma_3 h_{i1} h_{i2} + \xi_{i1} \\ y_{i2} &= \delta_2 + \gamma_4 h_{i1} + \gamma_5 h_{i2} + \gamma_6 h_{i1} h_{i2} + \xi_{i2} \end{aligned}$$

Estimating a Model With Heterogeneous Returns

- Six reduced form coefficients $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6$, form five structural parameters $\lambda_1, \lambda_2, \lambda_3, \beta, \phi$
- Estimation using minimum distance
- Structural parameters are overidentified

$$\begin{aligned}
\gamma_1 &= (1+\phi)\lambda_1 + \beta + \phi\lambda_0 \qquad \gamma_2 = \lambda_2 \\
\gamma_3 &= (1+\phi)\lambda_3 + \phi\lambda_2 \qquad \gamma_4 = \lambda_1 \\
\gamma_5 &= (1+\phi)\lambda_2 + \beta + \phi\lambda_0 \qquad \gamma_6 = (1+\phi)\lambda_3 + \phi\lambda_1
\end{aligned}$$

- λ_0 no structural parameter and obtained by $\sum \theta_i = 0$ from $\lambda_0 = -\lambda_1 \overline{h_{i1}} - \lambda_2 \overline{h_{i2}} - \lambda_3 \overline{h_{i2} h_{i1}}$
- Extension: fertilizer is the other endogenous covariate

$$\begin{aligned}
\theta_i &= \lambda_0 + \lambda_1 h_{i1} + \lambda_2 h_{i2} + \lambda_3 h_{i1} h_{i2} + \lambda_4 h_{i1} f_{i1} + \lambda_5 h_{i2} f_{i1} + \lambda_6 h_{i1} h_{i2} f_{i1} \\
&\quad + \lambda_7 h_{i1} f_{i2} + \lambda_8 h_{i2} f_{i2} + \lambda_9 h_{i1} h_{i2} f_{i2} + \lambda_{10} f_{i1} + \lambda_{11} f_{i2} + \nu_i
\end{aligned}$$

OLS and Fixed Effects Estimates

- Dependent variable is yields (log maize harvest per acre)

	OLS, Pooled	OLS, Pooled	OLS, Pooled	FE	FE
Hybrid	1.074 (0.040)	0.695 (0.039)	0.541 (0.041)	0.017 (0.070)	0.090 (0.065)
Acres (× 1000)	—	–	0.035 (5.749)	—	−0.509 (0.140)
Seed kg per acre (× 10)	—	–	0.184 (0.024)	—	0.179 (0.032)
Land preparation costs per acre (× 1000)	—	–	0.066 (0.016)	—	0.075 (0.023)
Fertilizer per acre (× 1000)	—	–	0.075 (0.009)	—	0.054 (0.012)
Hired labor per acre (× 1000)	—	–	0.037 (0.006)	—	0.027 (0.008)
Family labor per acre (× 1000)	—	–	0.374 (0.050)	—	0.467 (0.072)
Year = 2004	0.501 (0.038)	0.480 (0.035)	0.566 (0.041)	0.444 (0.032)	0.587 (0.044)
Constant	5.200 (0.038)	4.636 (0.080)	3.954 (0.113)	5.896 (0.051)	−2.383 (5.582)
Province dummies	No	Yes	Yes	—	—
R-squared	0.266	0.400	0.502	0.049	0.089

- OLS 54-100% gains, FE: 9%
- ⇒ substantial heterogeneity in production

CRE Model Reduced Forms and Structural Estimation

- Dependent variable is yields (log maize harvest per acre)

Reduced Form Estimates

	Without Covariates		With Covariates		With Covariates and Interactions of Covariates with Hybrid	
	Yields, 1997	Yields, 2004	Yields, 1997	Yields, 2004	Yields, 1997	Yields, 2004
Hybrid, 1997	0.674 (0.075)	0.538 (0.065)	0.579 (0.064)	0.415 (0.060)	0.467 (0.242)	0.501 (0.228)
Hybrid, 2004	0.809 (0.072)	0.723 (0.062)	0.411 (0.065)	0.563 (0.063)	1.214 (0.259)	0.630 (0.230)

Optimal Minimum Distance (OMD) Structural Estimates

	Without Covariates	With Covariates	With Covariates and Interactions of Covariates With Hybrid
β	0.0322 (0.0701)	0.1588 (0.0653)	−0.3039 (0.2522)
λ_1	0.5795 (0.0621)	0.4166 (0.0570)	0.5683 (0.2103)
λ_2	0.7332 (0.0684)	0.4062 (0.0622)	1.0447 (0.2351)
χ_1^2	44.63	0.193	460.5

- Yield β close to FE
- χ^2 for reject fixed effect model

IV and Treatment Effect Estimates

- Two-step control function procedure
  1. probit on hybrid adoption decision
  2. selection correction terms are computed as controls
- Estimates:
  - average treatment effects (ATE) (use second stage)
  - treatment on treated (TT) (adjust ATE for hybrid)
  - marginal treatment effects (MTE) (whether people more likely to hybrid have higher/lower returns from planting hybrid)
  - local average treatment effects (LATE)

IV and Treatment Effect Estimates

- Heckman two-step estimator
  1. probit of hybrid adoption $h_i = Z_i'\pi + u_i^s$
  2. sector-specific yield functions

$$y_i^H = X_i'\gamma^H + \lambda^H[\phi(Z_i'\hat{\pi})/\Phi(Z_i'\hat{\pi})]$$
$$y_i^L = X_i'\gamma^L + \lambda^L[\phi(Z_i'\hat{\pi})/(1-\Phi(Z_i'\hat{\pi}))]$$

- Exclusion restriction: distance to the closest fertilizer store
  - proxies for technologies availability

IV and Treatment Effect Estimates

- Heckit and treatment effect estimates under non-random assignment

	Heckman Two-Step Estimates: Selection Correction λ		Implied Treatment Effects		
Year	Hybrid Sector	Nonhybrid Sector	ATE	TT	MTE Slope
1997	−0.854 (0.170)	1.659 (0.864)	2.391	0.917	−2.512 (0.880)
2004	−0.957 (0.181)	0.028 (0.152)	1.279	0.921	−0.985 (0.237)

IV (LATE) Estimates (Conditional on Covariates)

First stage: Effect of distance	−0.288 (0.108)	—
First stage: Effect of distance interacted with wealth quintile (× 100)		
Second wealth quintile (coefficient on interaction)	—	−0.221 (0.302)
Third wealth quintile (coefficient on interaction)	—	−0.057 (0.032)
Fourth wealth quintile (coefficient on interaction)	—	0.329 (0.288)
Fifth wealth quintile (coefficient on interaction)	—	0.507 (0.273)
F test p-value on excluded instruments	0.008	0.108
Second stage: Effect of predicted hybrid on yields	2.768 (1.123)	1.536 (0.816)

- A nonzero MTE slope: heterogeneity in returns
- Negative MTE slope: farmers who are more likely to use hybrid are those who have the lower relative returns to using hybrid

Motivation for Heterogeneity in Returns

- Selection return by hybrid history
- Dependent variable is yield (log maize harvest per acre)

	Without Covariates		With Covariates	
Variable	1997 Yield	2004 Yield	1997 Yield	2004 Yield
Hybrid stayers	1.505 (0.066)	1.280 (0.056)	0.869 (0.073)	0.683 (0.063)
Leavers	0.809 (0.094)	0.648 (0.079)	0.537 (0.084)	0.370 (0.069)
Joiners	1.007 (0.114)	0.883 (0.096)	0.469 (0.101)	0.498 (0.084)
Acres ($\times$ 100)	—	—	0.561 (0.782)	−0.744 (0.802)
Seed kg per acre ($\times$ 10)	—	—	0.218 (0.035)	0.197 (0.032)
Land preparation costs per acre ($\times$ 1000)	—	—	0.066 (0.023)	0.058 (0.021)
Fertilizer per acre ($\times$ 1000)	—	—	0.063 (0.012)	0.061 (0.012)
Hired labor per acre ($\times$ 1000)	—	—	0.028 (0.008)	0.057 (0.010)
Family labor per acre ($\times$ 1000)	—	—	0.415 (0.075)	0.318 (0.064)

- If no selection: no difference between groups

Motivation for Heterogeneity in Returns

- Heterogeneity by observable returns in the hybrid/nonhybrid sector
- Dependent variable is yield (log maize harvest per acre)

	OLS With Covariates		FE With Covariates	
Variable	Hybrid	Nonhybrid	Hybrid	Nonhybrid
Acres ($\times$ 10)	0.144 (0.056)	−0.053 (0.149)	−0.381 (0.153)	−0.941 (0.379)
Seed kg per acre ($\times$ 10)	0.281 (0.035)	0.129 (0.036)	0.219 (0.047)	0.147 (0.063)
Land preparation costs per acre ($\times$ 1000)	0.056 (0.018)	0.135 (0.031)	0.033 (0.024)	0.097 (0.060)
Fertilizer per acre ($\times$ 1000)	0.064 (0.008)	0.143 (0.032)	0.040 (0.011)	0.081 (0.086)
Hired labor per acre ($\times$ 1000)	0.047 (0.007)	0.026 (0.010)	0.054 (0.011)	0.035 (0.029)
Family labor per acre ($\times$ 1000)	0.297 (0.064)	0.435 (0.081)	0.497 (0.094)	0.581 (0.177)
Year = 2004	0.568 (0.050)	0.595 (0.068)	0.467 (0.058)	0.689 (0.096)
Average return (β) when returns vary by observables (evaluated at mean X's)	0.480 (0.048)		0.091 (0.076)	
Number of observations	1517	887	1517	887

- Last row: significant return to hybrid

CRC Estimates

- Two period basic comparative advantage, CRC reduced form
- Dependent variable is yield (log maize harvest per acre)

	Without Covariates		With Endogenous Covariates		With Interactions With Hybrid	
	Yields, 1997	Yields, 2004	Yields, 1997	Yields, 2004	Yields, 1997	Yields, 2004
Hybrid, 1997	0.833 (0.121)	0.471 (0.099)	0.719 (0.103)	0.316 (0.088)	0.926 (0.252)	0.139 (0.092)
Hybrid, 2004	1.139 (0.122)	0.766 (0.103)	0.702 (0.110)	0.508 (0.092)	0.474 (0.122)	0.520 (0.222)
Hybrid 1997 × hybrid 2004	−0.458 (0.156)	−0.194 (0.132)	−0.358 (0.132)	−0.098 (0.110)	−0.084 (0.147)	−0.115 (0.117)
Acres (× 10)	—	—	0.106 (0.067)	−0.006 (0.098)	−0.220 (0.302)	−0.799 (0.300)
Seed kg per acre (× 10)	—	—	0.230 (0.052)	0.433 (0.060)	0.211 (0.062)	0.200 (0.086)
Land preparation cost per acre (× 1000)	—	—	0.124 (0.025)	0.133 (0.039)	0.033 (0.051)	0.353 (0.077)
Fertilizer per acre (× 1000)	—	—	0.079 (0.018)	0.042 (0.014)	0.281 (0.073)	0.106 (0.035)
Hired labor per acre (× 1000)	—	—	0.025 (0.014)	0.053 (0.010)	0.008 (0.014)	0.049 (0.019)
Family labor per acre (× 1000)	—	—	0.399 (0.115)	0.186 (0.071)	0.676 (0.187)	0.198 (0.128)
R-squared	0.285	0.232	0.454	0.441	0.486	0.489

- Recall the estimates:

$$y_{i1} = \delta_1 + \gamma_1 h_{i1} + \gamma_2 h_{i2} + \gamma_3 h_{i1} h_{i2} + \xi_{i1}$$

- $\phi < 0 \Rightarrow$ households that do better on average, do relatively worse at hybrid

CRC Estimates

- Two period basic comparative advantage, CRC model OMD structural

	With Only Hybrid Endogenous					
	Full Sample			Without HIV Districts		
	Without Covariates	With Covariates	With Interactions With Hybrid	Without Covariates	With Covariates	With Interactions With Hybrid
λ_1	0.648 (0.093)	0.565 (0.087)	0.456 (0.090)	0.471 (0.099)	0.305 (0.089)	0.139 (0.092)
λ_2	1.007 (0.112)	0.665 (0.104)	0.473 (0.116)	1.139 (0.122)	0.710 (0.112)	0.466 (0.123)
λ_3	1.636 (4.854)	−1.690 (4.316)	−0.485 (0.199)	−4.800 (9.173)	−0.936 (0.308)	−0.497 (0.257)
β	−0.543 (1.874)	1.023 (1.480)	3.534 (24.05)	2.287 (4.222)	0.623 (0.100)	0.790 (0.169)
ϕ	−0.794 (0.411)	−1.317 (1.262)	−17.82 (137.4)	−1.010 (0.228)	−1.518 (0.310)	−2.196 (1.142)
χ^2_1	40.089	11.25	139.5	175.5	114.1	305.2

- structural coefficients: average return to hybrid (β), comparative advantage coefficient (ϕ), projection coefficients (λ)
- Two district with high mortality because of HIV are excluded

CRC Estimates

- Joint sector comparative advantage CRC model OMD structural estimates

	With Joint Sector Fertilizer-Hybrid Decision			
	Full Sample		Without HIV Districts	
	With Covariates	With Interactions With Hybrid	With Covariates	With Interactions With Hybrid
β	0.639 (0.095)	1.148 (0.813)	0.420 (0.051)	0.901 (0.175)
ϕ	−1.602 (1.684)	−3.133 (4.003)	−1.687 (0.554)	−2.051 (1.282)

- joint hybrid–fertilizer decision on the part of the farmer so that he is in the technology sector if he uses both hybrid and fertilizer

CRC Estimates

- Comparative advantage CRC model OMD estimates: bot hybrid and fertilizer endogenous

With Both Fertilizer and Hybrid as Endogenous

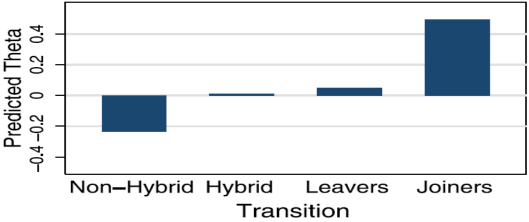
Projection: $\theta_i = \lambda_0 + \lambda_1 h_{i1} + \lambda_2 h_{i2} + \lambda_3 h_{i1} h_{i2} + \lambda_4 h_{i1} f_{i1} + \lambda_5 h_{i2} f_{i1} + \lambda_6 h_{i1} h_{i2} f_{i1} + \lambda_7 h_{i1} f_{i2} + \lambda_8 h_{i2} f_{i2} + \lambda_9 h_{i1} h_{i2} f_{i2} + \lambda_{10} f_{i1} + \lambda_{11} f_{i2} + v_i$

	Full Sample		Without HIV Districts	
	With Covariates	With Interactions With Hybrid	With Covariates	With Interactions With Hybrid
β	0.088 (0.096)	0.915 (0.417)	0.603 (0.060)	0.686 (0.174)
ϕ	−0.449 (0.176)	−3.772 (2.707)	−1.788 (0.277)	−2.118 (0.641)

-
- Fertilizer can be correlated with θ
- Again, ϕ is always negative

Recovering the Distribution of $\hat{\theta}$

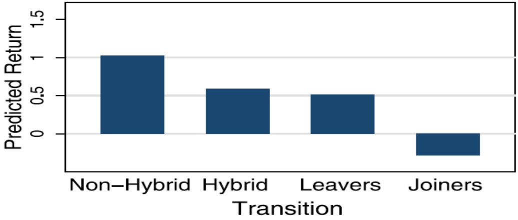
- Distribution of comparative advantage



- nonhybrid stayers have the most negative $\hat{\theta}$
-
-
-

Recovering the Distribution of $\hat{\theta}$

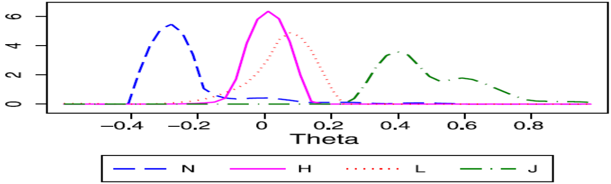
- Distribution of return $\beta + \phi\theta_i$



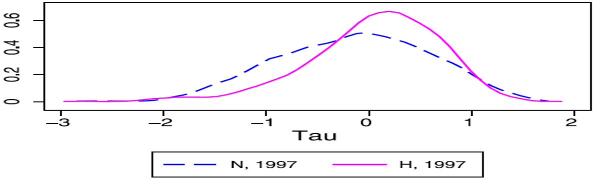
- $\phi < 0$, Order is reverse: joiner, leaver zero returns.

Recovering the Distribution of Return

- Endogenous hybrid and fertilizer use



- Distribution of τ by adoption decision in 1997



Discussion

- Although hight average return, some leave and joint because of low return for them.
- New puzzle: very large counterfactual returns to growing hybrid for nonhybrid stayers
- Dependent variable: $\hat{\theta}$

	(1)	(2)	(3)	(4)	(5)
Distance to closest fertilizer seller (× 100)	−0.301 (0.122)	−0.289 (0.121)	−0.285 (0.121)	−0.285 (0.121)	−0.315 (0.063)
Distance to motorable road (× 100)	−0.904 (0.503)	−0.887 (0.501)	−0.901 (0.502)	−0.898 (0.501)	−0.978 (0.285)
Distance to matatu stop (× 100)	0.032 (0.298)	−0.034 (0.298)	−0.016 (0.298)	−0.028 (0.299)	−0.021 (0.165)
Distance to extension services (× 100)	−0.130 (0.155)	−0.063 (0.155)	−0.063 (0.155)	−0.061 (0.155)	0.002 (0.091)
Tried to get credit (× 10)	—	−0.138 (0.153)	—	—	—
Tried but did not receive credit (× 10)	—	—	0.027 (0.347)	—	—
Received credit (× 10)	—	—	—	−0.047 (0.154)	−0.164 (0.144)
Dummies for household head education	No	Yes	Yes	Yes	Yes
(*p*-value on joint significance)		(0.002)	(0.002)	(0.000)	(0.000)
Province dummies	Yes	Yes	Yes	Yes	No

- lower $\hat{\theta}$: have much higher cost determinants

Discussion

- Recall fixed seed price across country
- $\Rightarrow$ suppliers had no incentives to locate far away
- Observables in regressions:
  - distance to closest fertilizer seller
  - distance to closest matatu (public transport) stop
  - distance to closest motorable road
  - distance to closest extension services
- Those with high return and non-hybrid: very high costs and supply constraints

Table of Content

Emerick, et al. “Technological innovations, downside risk, and the modernization of agriculture” AER (2016), Suri “Selection and comparative advantage in technology adoption.” Econometrica (2011)

Deschenes, Greenstone. “The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather.” AER (2007), Fisher, et al. “The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather: comment” AER (2012)

Introduction-Production Function

- Emissions of greenhouse gases: higher temperatures and increased precipitation
- Probably largest effects in agriculture
- Inconclusive literature (Schlenker, Hanemann, Fisher: SHF)
- Literature employs production function or hedonic approach
- Disadvantage: do not account for the full range of compensatory responses to changes in weather made by profit-maximizing farmers
- Farmers alter their use of fertilizers, change their mix of crops
- Farmer adaptations are constrained in production function approach
- Biased downward

Introduction-Hedonic

- Hedonic: measure directly effect of climate on land values
- If land markets operating properly, prices reflect present discounted value of land rents
- Validity rests on consistent estimation of the effect of climate on land values
- Unmeasured characteristics (soil quality, its option value) are important determinants of values
- Hedonic approach confound climate with other factors

Introduction-Paper

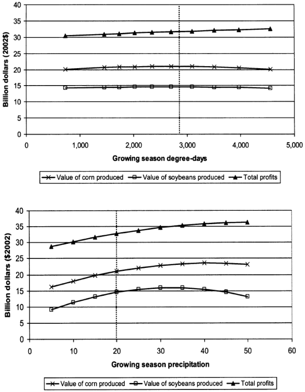
- Exploit the presumably random year-to-year variation in temperature and precipitation to estimate whether agricultural profits are higher or lower in years that are warmer and wetter
- Estimate impacts of temperature and precipitation on agricultural profits and then multiply them by predicted change in climate to infer the economic impact of climate change in this sector.
- County-level panel on agricultural profits, production, soil quality, climate, weather
- Effect of weather on agricultural profits and yields, conditional on county and state by year fixed effects
- Identification: county-specific deviations in weather from county averages after adjusting for shocks common to all counties in a state.

Identification

- Assumption: this variation orthogonal to unobserved determinant of agricultural profits
- Solution to omitted variables bias problems that plague the hedonic approach
- Limitation: farmers cannot implement the full range of adaptations in response to a single year's weather realization
- Overstate damage associated with climate change or downward-biased

Results

- Fitted quadratic relationships between aggregate profits



- Slightly beneficial for profits and yields

Results

- Using long-run climate change predictions:
  - \$1.3 billion (2002\$) or 4.0% increase in annual agricultural sector profits
  - 95-% confidence interval -\$0.5 billion to \$3.1 billion, !!!
- This very large effect with wide ranges is unlikely
- This hedonic approach sensitive to controls
- This paper: overall effect is small + considerable heterogeneity
- California harmed substantially by climate change (\$750 m)
- Winners are South Dakota (\$720 m) & Georgia (\$540 m)

Conceptual Framework

- Approach differs from hedonic in
  1. Under an additive separability assumption, its estimated parameters are purged of the influence of all unobserved time invariant factors
  2. Not feasible to use land values as dependent variable once county fixed effects are included. This is because
     - land values reflect long-run averages of weather, not annual deviations from these averages
     - no time variation in such variables
  3. Approximate effect of climate change on land values
     - how farm profits affected by increases in temp. & precipitation
     - multiply these estimates by predicted changes in climate to infer the impact on profits
     - if change is permanent calculate change in land values
     - value of land is equal to present discounted stream of rental rates

Economics of Climate Change from Annual Variation

- Two issue in inferring long run from annual changes
- First, short-run variation: temporary changes in prices, obscure the true long-run impact of climate change
- consider farmer unable to switch crops in short-run

$$\pi = p(q(w))q(w) - c(q(w))$$

- quantity (q) a function of weather w

$$\partial\pi/\partial w = (\partial p/\partial q)(\partial q/\partial w)q + (p - \partial c/\partial q)(\partial q/\partial w)$$

- a weather shock that reduces output $(\partial q/\partial w < 0)$
- short run, supply is likely to be inelastic $(\partial p/\partial q)_{Short\ Run} < 0$
- increase in prices, mitigate losses due to lower production
- more elastic in long run $(\partial p/\partial q)_{Long\ Run} > (\partial p/\partial q)_{Short\ Run}$

Economics of Climate Change from Annual Variation

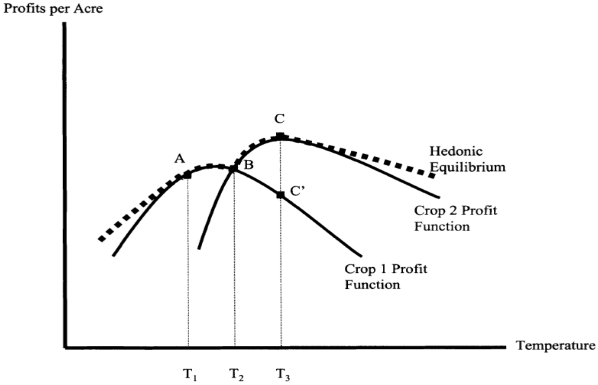
- first term positive in short run, but in long run it will be substantially smaller or even zero
- second term difference between price and marginal cost multiplied multiplied by change in quantities due to change in weather
- it measures change in profits due to the weather-induced change in quantities
- it is the long-run effect of climate change on agricultural profits (holding constant crop choice)

Economics of Climate Change from Annual Variation

- although short-run variation, estimates purged of price changes (first term)
- why? because estimates are small even in short run
- also state by year interactions adjusts for crop price levels
- Second: farmers cannot undertake full range of adaptations in response to a singe year's weather realization
- Long run they may switch crops

Economics of Climate Change from Annual Variation

- Theoretical relationship between profits and temprature



- Crop 1 maximizes $T_1 \& T_2$,Crop 2 between $T_2 \& T_3$
- Crops 1 & 2 produce identical profits at T_2

Economics of Climate Change from Annual Variation

- Temp.from T_1 to T_3
- Farmers switch to crop 2 & point C
- Long run difference $C - A$,short run $C' - A$ (downward biased estimate of long-run effect)
- Noteworthy, if new temperature $\geq T_1$ & $\leq T_2 \Rightarrow$ farmer's short-run and long-run profits are equal
- $\Rightarrow$ paper's estimates is downward biased relative to preferred long-run effect that allows for all substitutions
- If the degree of climate change is "small" however, paper's estimates are equal to the preferred long-run effect
- In response to year-to-year fluctuations, farmers are able to adjust their mix of inputs (fertilizer and irrigated water usage)
- Paper's estimates are preferable to production function estimates that do not allow for any adaptation.

Data Sources and Summary Statistics

- Agricultural production from 1978, 1982, 1987, 1992, 1997, 2002 Census of Agriculture
- All farms $1,000 or more of agricultural products
- Dependent variable: county-level agricultural profits per acre of farmland
- Profits per acre is a measure for rent per acre.
- Compare profit by acre vs rent
- 1999 Agricultural Economics and Land Ownership Survey
- Rent $35, agricultural profits $42
- Overstate rental rate modestly
- Scales down profits by 0.83 to obtain a welfare measure
- Examine relationship between yields and annual weather fluctuations

Soil Quality Data

- National Resource Inventory (NRI) in census year
- Survey of soil samples from roughly 800,000 sites
  - measures of susceptibility to floods
  - soil erosion (K-Factor),
  - slope length
  - sand content
  - irrigation
  - permeability

Climate and Weather Data

- Parameter-Elevation Regressions on Independent Slopes Model (PRISM)
- Interpolation model of precipitation, temperature at 4×4 kilometer
- Data from National Climatic Data Center's Summary of Month Cooperative Files
- Month-by-year measures

Climate and Weather Data

- Monthly appropriate for hedonic analysis of land values
- Not good for annual agricultural profits
- Weather during growing is important
- Standard approach: convert daily temperatures into degree-days (represent accumulated heating units)
- Temp.in a thresholds is useful
- Base of 8 c & ceiling of 32 c
- Growing season degree-days between April 1 & Sept. 30

Climate Change Predictions

- Two sets of predictions
- Uniform increases of 5F in temperature + 8% in precipitation end of 21 century
- Non-linear prediction from e-aer.org

Summary Statistics

- Agricultural Finances, Soil, and Weather Statistics

	1978	1982	1987	1992	1997	2002
FARMLAND AND ITS VALUE						
Number of farms	799.3	796.3	745.4	688.3	684.9	766.5
Land in farms (th. acres)	363.7	352.4	345.5	338.4	333.4	336.1
Total cropland (th. acres)	158.7	156.0	158.3	155.9	154.1	155.3
Avg. value of land & buildings ($1/acre)	1,370.4	1,300.7	907.3	892.2	1,028.2	1,235.6
Avg. value of machinery & equipment ($1/acre)	—	—	126.7	118.8	129.2	145.8
ANNUAL FINANCIAL INFORMATION						
Profits ($mil.)	—	—	14.4	14.0	18.6	10.0
Profits per acre ($1/acre)	—	—	41.7	41.3	55.7	29.7
Farm revenues ($mil.)	88.7	80.0	71.5	72.9	79.9	74.9
Total farm expenses ($mil.)	—	—	57.2	58.9	61.3	64.9
Total government payments ($mil.)	—	—	4.8	2.3	1.9	2.4
MEASURES OF SOIL PRODUCTIVITY						
K-Factor	0.30	0.30	0.30	0.30	0.30	0.30
Slope length	218.9	218.9	218.3	217.8	218.3	218.3
Fraction flood-prone	0.15	0.15	0.15	0.15	0.15	0.15
Fraction sand	0.09	0.09	0.09	0.09	0.09	0.09
Fraction clay	0.18	0.18	0.18	0.18	0.18	0.18
Fraction irrigated	0.18	0.18	0.18	0.18	0.19	0.19
Permeability	2.90	2.90	2.90	2.88	2.88	2.88
Moisture capacity	0.17	0.17	0.17	0.17	0.17	0.17
Wetlands	0.10	0.10	0.10	0.10	0.10	0.10
Salinity	0.01	0.01	0.01	0.01	0.01	0.01

- Farmland and its value,annual financial information, oil productivity

Summary Statistics

- Climate Change Statistics

	Nonirrigated counties			Irrigated counties		
	Actual	Predicted	Difference	Actual	Predicted	Difference
A. Benchmark global warming model						
January mean temperature	28.4	33.4	5.0	32.3	37.3	5.0
April mean temperature	52.0	57.0	5.0	52.2	57.2	5.0
July mean temperature	74.7	79.7	5.0	74.4	79.4	5.0
October mean temperature	54.2	59.2	5.0	55.0	60.0	5.0
January total precipitation	1.51	1.63	0.12	1.84	1.99	0.15
April total precipitation	2.38	2.57	0.19	2.07	2.24	0.17
July total precipitation	2.76	2.98	0.22	2.23	2.41	0.18
October total precipitation	2.27	2.45	0.18	1.73	1.87	0.14
Growing season degree-days	3,184.8	3,905.7	720.9	3,289.1	4,018.7	729.5
Growing season total precipitation	16.86	18.21	1.35	13.55	14.63	1.08
B. Hadley 2 global warming model, long term (2070–2099)						
Growing season degree-days:						
All counties [2,262]	3,184.8	4,387.2	1,202.4	3,289.1	4,449.1	1,160.0
Std deviation	(1,459.3)	(1,162.3)	(1,272.2)	(1,503.4)	(1,153.6)	(1,196.2)
Northeast region [178]	2,556.3	3,366.7	810.4	3,581.7	4,050.9	469.2
Midwest region [735]	2,977.4	3,998.7	1,021.3	3,214.0	4,372.2	1,158.2
South region [986]	4,097.6	5,796.3	1,698.7	4,451.2	6,026.6	1,575.4
West region [363]	2,581.6	3,538.3	956.7	2,720.8	3,669.8	949.0
Growing season total precipitation:						
All counties [2,262]	16.86	19.88	3.02	13.55	16.77	3.22
Std deviation	(6.79)	(7.99)	(3.23)	(8.63)	(9.02)	(3.23)
Northeast region [178]	23.52	27.54	4.02	24.21	27.81	3.60
Midwest region [735]	19.22	22.69	3.47	17.96	21.39	3.43
South region [986]	21.23	25.67	4.44	22.47	27.51	5.04
West region [363]	9.30	10.30	1.00	6.51	8.67	2.16
C. Observed weather variation (1987–2002)	Proportion of counties with degree-days below/above average (degrees):					
	±400	±600	±800	±1,000	±1,200	±1,400
1. Removed year effects	0.261	0.166	0.106	0.055	0.025	0.013
2. Removed state * year effects	0.245	0.150	0.093	0.049	0.022	0.010
	Proportion of counties with precipitations below/above average (inches):					
	±1.0	±1.5	±2.0	±2.5	±3.0	±3.5
1. Removed year effects	0.731	0.604	0.499	0.404	0.321	0.252
2. Removed state * year effects	0.623	0.474	0.353	0.255	0.181	0.128

The Hedonic Approach

- Hedonic cross-sectional model

$$y_{ct} = X'_{ct}\beta + \sum_i \theta_i f_i(\overline{W}_{ic}) + \epsilon_{ct} \qquad \epsilon_{ct} = \alpha_c + u_{ct}$$

- where y_{ct}: value of agricultural land per acre, county c, year t
- $\overline{W}_{ic}$ climate variables
- Climatic variables with linear and quadratic terms
- Interactions of all climate variables and indicators for non-irrigated and irrigated counties
- θ "true" effect of climate on farmland values

The Hedonic Approach

- Assumption: $E[f_i(\overline{W}_{ic}\epsilon_{ct}|X_{ct}] = 0$
- Invalid if there are unmeasured permanent α_c, transitory u_{ct} covary with climate variables
- To obtain reliable θ collected a wide range of potential explanatory variables
  1. May error terms are correlated among nearby geographical areas (unobserved soil productivity is spatially correlated)
     - adjust the standard errors for spatial dependence (spatial dependence between two observations decline as distance increases)
     - $+$ allows for heteroskedasticity of an unspecified nature
  2. Weight by square root of acres of farmland
     - value of farm land with large agricultural operations will be more precise (correct for heteroskedasticity)
     - weighted mean of dependent variable is equal to the mean value of farmland per acre in the country

A New Approach

- Claim: cross-sectional hedonic equation misspecified
- Solution:

$$y_{ct} = \alpha_c + \gamma_t + X'_{ct}\beta + \sum_i \theta_i f_i(W_{ict}) + u_{ct}$$

- Important differences:
  - this includes a full set of county fixed effects α_c (absorb all unobserved county-specific time invariant determinants)
  - this includes year indicators γ_t (preferred specification state by year fixed effects γ_{st}
  - y_{ct} now county-level agricultural profits (country fixed effect absorb all land value, it is long run)
  - because of country fixed effect, $\overline{W}_{ic}$ turn to W_{ict}
- Requires $E[f_i(W_{ict})u_{ct}|X_{ct}, \alpha_c, \gamma_{st}] = 0$

Results-Hedonic Approach

- Does Climate Vary with Observables?
- Hedonic assumption: climate variables are orthogonal to unobservables
- If so
  1. consistent inference will not depend on functional form assumptions on relation between observable confounders and farm values.
  2. unobservables may be more likely to be balanced
- Next table shows association between July temperature and precipitation normals and selected determinants of farm values
- F-statistics from tests means are equal across quartiles
- A value of 2.37 (3.34) indicates that the null hypothesis can be rejected at the 5% (1%) level.

Results-Hedonic Approach

- Means of county-level by quartile of the July temperature (precipitation), adjusted for year effects

	[A] July temperature normals					[B] July precipitation normals				
Quartile	1	2	3	4	*F*-Stat	1	2	3	4	*F*-Stat
Farmland values ($1/ac)										
Value of land/bldg	1,118.3	1,770.7	1,608.9	1,481.1	25.5	1,149.6	1,458.9	2,252.2	2,194.7	148.9
Soil characteristics										
K Factor	0.32	0.30	0.32	0.30	10.8	0.32	0.30	0.32	0.26	33.0
Slope length	280.3	244.4	242.1	230.1	3.6	323.9	199.2	185.2	161.6	54.7
Fraction irrigated	0.05	0.06	0.07	0.06	3.9	0.07	0.05	0.03	0.04	11.6
Moisture capacity	0.17	0.18	0.18	0.15	50.7	0.16	0.18	0.19	0.15	106.9
Salinity	0.05	0.03	0.01	0.02	15.8	0.05	0.01	0.00	0.00	48.0
Socioeconomic and locational attributes										
Population density	31.3	83.8	60.1	64.9	19.7	35.9	53.4	127.0	108.2	54.0
Per capita income	16,510	16,369	16,017	14,847	14.1	16,014	16,206	16,777	15,043	17.3

- Observables are not balanced across quartiles of weather

Results-Hedonic Approach

- Differences in means are large ⇒ rejection not from sizes
- Population density is associated agricultural land values
  - invalidate of hedonic approach to learn about climate change
  - because density has no direct impact on agricultural yields
- Conventional cross-sectional hedonic approach may be biased due to incorrect specification of the functional form of the observed variables and potentially due to unobserved variables

Replication of the SHF (2005) Hedonic Approach

- 1982 census
- Quadratic in each of the eight climate variables
- They claim pooling irrigated & nonirrigated ⇒ bias
- But they have the same coefficients.
- Benchmark scenario increases of 5F in temp & 8% in prec. : -$543.7 billion with cropland weights or $69.1 billion with crop revenue weights
- Similar to what reported in SHF (2005)

Robustness of SHF Results

- Two robustness:
  1. Drops all covariates, except climate variables
     - -$98.5 billion with the cropland weights and $437.6 billion with the crop revenue weights
  2. Adds state fixed effects
     - -$477.8 billion and $1,034 billion
     - As large as the entire value of agricultural land and buildings in US!!
- If weight by acres of farmland: $225.1 billion, -$315.4 billion, -$0.6 billion
- SHF related to choice of weights
- Fails to produce robust estimates

New Hedonic Estimates-Paper Specification

- Impact of benchmark climate change on agricultural land values:

Specification	A		B		C	
Weights	(0)	(1)	(0)	(1)	(0)	(1)
Single census year						
1978	131.9	131.1	141.2	154.7	321.3	255.6
	(35.6)	(35.7)	(38.0)	(31.3)	(46.1)	(31.8)
1982	36.3	36.1	19.2	40.8	203.3	154.6
	(28.6)	(25.7)	(28.7)	(24.4)	(46.6)	(32.2)
1987	−55.9	−9.6	−49.3	−8.7	45.9	51.3
	(25.8)	(21.5)	(27.5)	(20.0)	(38.8)	(22.6)
1992	−50.4	−23.0	−32.9	−8.1	22.3	46.4
	(35.0)	(31.6)	(32.5)	(24.5)	(50.3)	(25.2)
1997	−117.0	−55.5	−89.0	−33.5	25.5	65.8
	(32.7)	(38.7)	(35.3)	(31.1)	(46.5)	(24.1)
2002	−288.6	−139.5	−202.1	−101.0	−8.8	60.9
	(59.2)	(61.4)	(58.4)	(49.5)	(77.0)	(38.7)
Pooled 1978–2002						
All counties	−75.1	−16.9	−45.6	0.7	95.2	110.8
	(28.0)	(30.7)	(30.6)	(26.3)	(41.6)	(23.4)
Nonirrigated counties	−63.9	−28.6	−44.7	−10.9	66.1	82.1
	(24.3)	(28.5)	(28.0)	(24.6)	(35.5)	(17.9)
Irrigated counties	−11.2	11.6	−0.9	11.6	29.1	28.6
	(13.7)	(11.2)	(12.2)	(9.6)	(13.1)	(10.4)
Soil variables	No	No	Yes	Yes	Yes	Yes
Socioecon. vars	No	No	Yes	Yes	Yes	Yes
State fixed-effects	No	No	No	No	Yes	Yes

- (0) = unweighted; (1) square root of acres of farmland
- A,B,C three specifications

More Hedonic Estimates

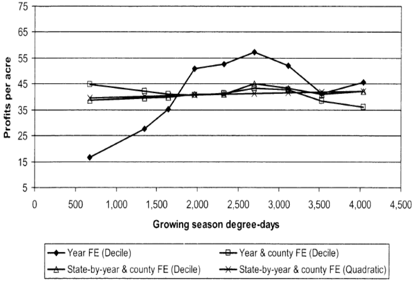
- Weighted by acre in each country to get national average
- For year-specific estimates, heteroskedastic consistent standard errors
- For pooled estimates, clustering at county level
- Year-specific estimates
  - Variation in estimates
  - Range between -$202 b & $321 b (-18%, 29% of total value of land)
  - The second panel reports the pooled results,
- Pooled: ranges -$75.1 b to $110.8 b
- Predicted effects of climate change are concentrated in the nonirrigated counties
- Estimates sensitive to choices about proper set of covariates and weighting scheme.

Summary of Hedonic

- Findings:
  1. observable determinants of land prices are poorly balanced across quartiles of climate normals
  2. more reliable hedonic specifications suggest that on net climate change will be modestly beneficial for the US agriculture sector
  3. hedonic are extremely sensitive to small decisions about specification, weighting, sample

Impact of Climate Change from Local Variation in Weather

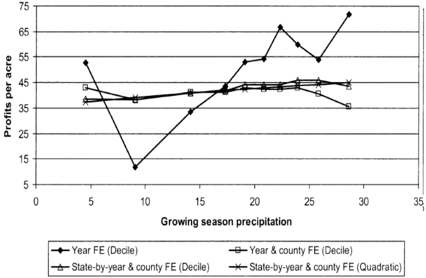
- Relationship profits per acre and growing season degree-days



- Decile: parameter estimates on indicator variables for deciles of distribution of growing season degree-days at midpoint of each decile's range
- Last quadratic in degree-days, $\Rightarrow$ plots the conditional means at the midpoints of each decile's range

Impact of Climate Change from Local Variation in Weather

- Relationship profits per acre and growing season precipitation



Impact of Climate Change from Local Variation in Weather

- Findings:
  - "Year FE" variation in profits per acre
  - Addition of county fixed effects to specification greatly reduces the variation in profits per acre
  - Modeling of degree-days with a quadratic provides a good approximation to less parametric approach
  - Adjusted models show that even relatively large changes in degree-days will have modest effects on profits per acre

Fixed Effects Estimates of Agricultural Profit Model

- Impact of three global warming scenarios

	(1)	(2)	(3)	(4)
A. Benchmark climate change model				
All counties	−1.51	−1.54	0.69	0.73
	(0.49)	(0.49)	(0.43)	(0.43)
	[0.81]	[0.81]	[0.85]	[0.85]
B. Hadley 2 climate change model medium term (2020–2049)				
All counties	−0.75	−0.79	0.72	0.66
	(0.66)	(0.67)	(0.64)	(0.64)
	[1.14]	[1.14]	[1.19]	[1.19]
C. Hadley 2 climate change model long term (2070–2099)				
All counties	−1.79	−1.86	1.34	1.29
	(0.97)	(0.97)	(0.91)	(0.92)
	[1.59]	[1.59]	[1.67]	[1.67]
Nonirrigated counties	−1.66	−1.73	1.16	1.10
	(0.72)	(0.73)	(0.68)	(0.69)
Irrigated counties	−0.14	−0.13	0.19	0.18
	(0.55)	(0.55)	(0.50)	(0.50)
Impact of change in degree-days	−1.47	−1.55	0.47	0.39
	(0.94)	(0.95)	(0.87)	(0.87)
Impact of change in total precipitation	−0.33	−0.32	0.87	0.89
	(0.28)	(0.28)	(0.29)	(0.29)
Soil controls	No	Yes	No	Yes
County fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	No	No
State * year fixed effects	No	No	Yes	Yes

Fixed Effects Estimates of Agricultural Profit Model

- Columns 1&2, includes unrestricted year effects
- Columns 3& 4 replaced with state by year effects
- Focus on C
- Climate change increase in agricultural profits by $1.3 billion
- Not-statistically significant
- After adjustment for state by year effects, precipitation impact significant & positive
- Overall effect concentrated in nonirrigated counties
- Across estimates C1,2 negative, C3,4 positive
- Estimated profits are higher with state by year fixed effects: local price changes do not appear to be a major concern in this context.

Robustness

- Robustness

	Hadley 2 long run (2070–2099)		
	Predicted change (billion dollars)	Standard error	Percent effect
(1) Model weather variables linearly	1.47	(0.75)	4.6
(2) Model weather variables with cubics	3.59	(2.03)	11.1
(3) Model weather variables with indicator variables	0.75	(1.34)	2.3
(4) Control for harmful degree-days	1.33	(0.93)	4.1
(5) Minimize the influence of outliers	−0.24	(0.41)	−0.7
(6) Fully interacted by state	0.17	(11.00)	0.5
(7) Irrigation cutoff = 5%	1.23	(0.91)	3.8
(8) Irrigation cutoff = 15%	1.29	(0.97)	4.0
(9) Assume equal weather coefficients in nonirrigated and irrigated counties	1.27	(0.99)	3.9
(10) Growing season = April–October	0.57	(2.02)	1.8
(11) Two growing seasons, April–October and November–March	−0.98	(5.04)	−3.0
(12) Unweighted regression	−0.52	(2.46)	−1.6

- Again not statistically significant

Robustness Specification

- Row 4: considers possibility of harmful degree-days
- Accumulated days w/ mean temperature above 93.2F in
- Row 5: consider possibility outliers drive results
- "rreg" robust regression routine in STATA (Berk 1990)
- Routine excluding outliers, observations with values of Cook's D ¿ 1
- Then weights observations based on absolute residuals ⇒ large residuals are downweighted.
- Row 6: separate estimate for each state

Impact of Climate Change Across States

Predicted impact on state agricultural profits (largest to smallest)				
State (1a)	Billions of $s (1b)	Std Error (1c)	State (2a)	Percent (2b)
South Dakota	0.72	(0.09)	West Virginia	189.6
Georgia	0.54	(0.61)	Arizona	118.9
Arizona	0.49	(0.81)	South Dakota	109.2
Nevada	0.49	(0.81)	South Carolina	102.8
Kansas	0.24	(0.15)	Georgia	71.7
New York	0.23	(0.07)	Nevada	69.6
South Carolina	0.23	(0.09)	Wyoming	45.4
Kentucky	0.21	(0.28)	New York	43.4
Pennsylvania	0.17	(0.06)	Louisiana	43.2
North Dakota	0.16	(0.07)	North Dakota	40.0
Louisiana	0.15	(0.42)	Kentucky	27.1
Missouri	0.10	(0.07)	Utah	22.6
Oregon	0.10	(0.32)	Pennsylvania	20.0
West Virginia	0.08	(0.10)	Kansas	19.7
Wyoming	0.07	(0.09)	Oregon	18.3
Minnesota	0.07	(0.07)	Missouri	13.1
Michigan	0.05	(0.05)	Michigan	9.3
Washington	0.04	(0.85)	Indiana	5.9
Utah	0.04	(0.19)	Minnesota	5.6
Indiana	0.04	(0.12)	Washington	4.7
New Mexico	0.01	(0.15)	Virginia	3.0
Virginia	0.01	(0.06)	New Mexico	2.4
Oklahoma	0.00	(0.15)	Oklahoma	−0.2
Idaho	0.00	(0.10)	Idaho	−0.6
Iowa	−0.01	(0.07)	Iowa	−0.9
Connecticut	−0.03	(0.10)	Wisconsin	−2.5
Delaware	−0.03	(0.10)	Tennessee	−9.2
Massachusetts	−0.03	(0.10)	Texas	−10.0
Maryland	−0.03	(0.10)	Ohio	−10.2
Maine	−0.03	(0.10)	Illinois	−12.1
New Hampshire	−0.03	(0.10)	Maryland	−12.7
New Jersey	−0.03	(0.10)	Arkansas	−13.0
Rhode Island	−0.03	(0.10)	California	−15.0
Vermont	−0.03	(0.10)	New Jersey	−18.2
Tennessee	−0.03	(0.07)	Delaware	−23.2
Wisconsin	−0.03	(0.05)	Connecticut	−25.5
Ohio	−0.07	(0.08)	Massachusetts	−28.3
Arkansas	−0.11	(0.27)	Maine	−28.3
Montana	−0.12	(0.06)	Florida	−28.6
Mississippi	−0.16	(0.18)	Colorado	−36.3
Texas	−0.16	(0.50)	Vermont	−36.4
Illinois	−0.18	(0.13)	Montana	−40.2
Colorado	−0.21	(0.22)	Nebraska	−40.8
Alabama	−0.21	(0.33)	Mississippi	−42.7
Florida	−0.45	(0.44)	North Carolina	−46.0
North Carolina	−0.65	(0.24)	Alabama	−46.7
Nebraska	−0.67	(0.22)	Rhode Island	−84.9
California	−0.75	(1.50)	New Hampshire	−127.4

Response of Crop Yields to Climate Change

- Large declines in yields: profit is biased (relative to long-run)
- Short-run price increases.
- Dependent variables: county-level total production per acre

	Corn for grain (1a)	Corn for grain (1b)	Soybeans (2a)	Soybeans (2b)
US total value (billion dollars)	22.54	22.54	16.32	16.32
County mean of dep. variable	114.77	114.77	36.63	36.63
US total production (billion bushels)	8.67	8.67	2.38	2.38
Predicted impact of Hadley 2 long-term (2070–2099) scenario on crop yields				
All counties	−0.06	0.01	−0.05	0.02
	(0.07)	(0.07)	(0.02)	(0.02)
Percent of US total yield	−0.7	0.1	−2.0	0.7
Nonirrigated counties	−0.10	0.00	−0.04	0.01
	(0.06)	(0.05)	(0.01)	(0.01)
Irrigated counties	0.04	0.01	−0.01	0.00
	(0.03)	(0.03)	(0.01)	(0.01)
Impact of change in temperature	−0.34	−0.16	−0.12	−0.04
	(0.07)	(0.06)	(0.02)	(0.01)
Impact of change in precipitation	0.28	0.17	0.07	0.05
	(0.03)	(0.02)	(0.01)	(0.01)
Soil controls	Yes	Yes	Yes	Yes
County fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	No	Yes	No
State * year fixed effects	No	Yes	No	Yes

- Overall, no significant results
- Increase in temperature is harmful for yields, increase in precipitation is beneficial

Introduction

- A reply
- Fisher, Hanemann, Roberts, Schlenker, "The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Comment",AER,(2012)
- DG find no statistically significant relationship between
  - agricultural profits and weather variables in same years
  - corn and soybean yields (output per acre) and weather
- If short-run weather fluctuations have no influence on agricultural profits or output, then in the long run, when adaptations are possible, climate change is likely to have no impact or even prove beneficial
- This finding was robust

This Paper

- This paper reconciles their findings with others in the literature
- Differences mainly from three sources
  1. data & coding errors in DG's weather data, agricultural data, construction of climate-change scenarios
  2. particular climate change scenario which is used for impact predictions
  3. standard errors that are biased due to spatial correlation.
- Correcting DG's data and coding errors makes predictions for climate-change impacts unambiguously negative in all but one specification
- Exception is a profit regression with state-by-year fixed effects where the standard errors are very large because state-by-year fixed effects absorb almost all variation in weather

This Paper

- DG's measure of profits is reported sales in a given year minus reported production expenditures in that year
  - Not include implicit costs like farm household labor or inventory adjustments
  - Not control for crops produced in the reporting (last) year but not sold until a later (this) year
- Problem: storage are captured by the error term and are also correlated with weather
- Induced correlation violates identification assumption and causes the estimated effect of weather to be biased toward zero.

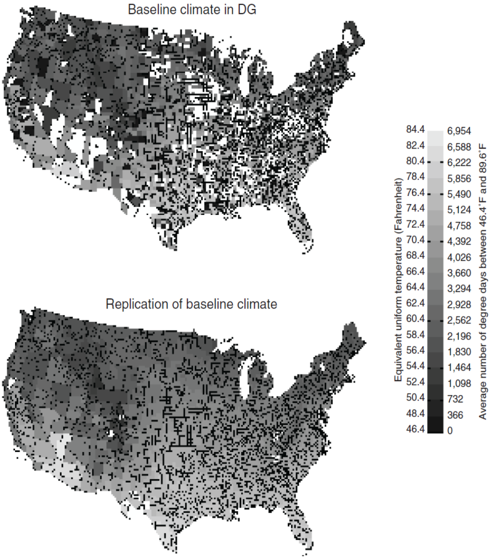
Data Irregularities

- DG's data & STATA code from AER website
- DG have two weather variables
  - dd89: growing degree days for each year and county
  - dd89-7000: average number of degree days in each county between 1970 and 2000
- Not consistent with each other
- Correlation is only 0.39
- If reconstruct same weather variables from raw data sources $\Rightarrow$ correlation of 0.996

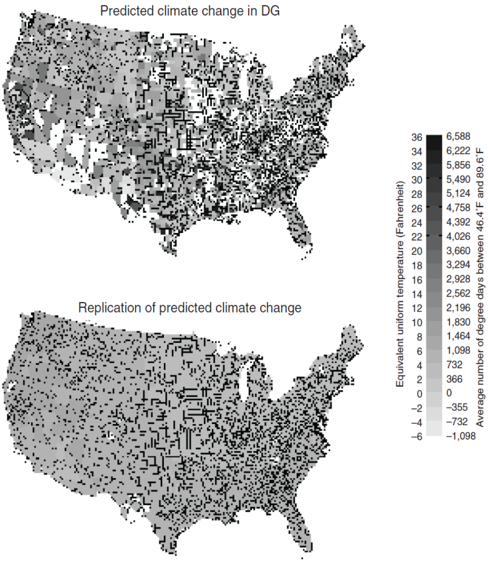
Data Irregularities

- Average of dd89 is much lower & standard deviation much higher than in our replication
- DG's baseline climate measure (dd89-7000) has a value of zero degree days for 163 counties
- If correct $\Rightarrow$ temperatures not exceed 8C (46.4F) in those counties during the growing season
- Implausible in any state, yet many of these counties are in warm southern states such as Texas
- Figures draw degree days variable in DG and replication
- Discontinuity in DG's $\Rightarrow$ excess weather variation $\Rightarrow$ bias especially in state-by-year fixed effects
- Within-state-year temperature deviations in our replicated dataset are one-seventh size of DG's.

Climate Change Predictions



Baseline Climate In DG



Data Irregularities

- DG's changes in climate vary widely over contiguous US
- Range from 880 growing degree days to 6,572
- Pattern is odd
- DG use historic county-level data + climate predictions (uniform across each state)
- Los Angeles and San Francisco have same prediction
- Baseline is county historic values
- So, variation only by baseline
- $\Rightarrow$ regression towards mean
- $\Rightarrow$ cooler counties becoming much warmer and some very warm counties becoming cooler

Data Irregularities

- Regression-toward-the-mean effect by errors in baseline degree-day measure
- Error in coding: consider missing baseline as zero!!
- Results: some counties experience decline in average temperature!!
- Important counties are missing (this error not corrected for sake of comparison)
  - 66 of Iowa's 99 counties are missing from their dataset
  - Iowa: largest producer of corn and soybeans

Replication and Comparison

- Much of the difference in predicted impacts of climate change between SHF and DG from data issues
- Result comparison by various data sources

	Corn		Soybeans		Profit (sales – expenditures)			
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Regression diagnostics								
Variance explained by weather	11.6%	19.6%	14.4%	30.6%	0.4%	1.5%	0.4%	0.6%
Climate change impact (percent)								
Hadley II-IS92a scenario	−0.80	−10.61	−2.73	−15.63	−6.63	−36.50	3.75	1.21
(SE)	(1.24)	(1.45)	(1.38)	(1.60)	(3.03)	(5.41)	(2.82)	(12.88)
[SE clustered by state]	[2.08]	[4.18]	[2.08]	[4.93]	[4.98]	[10.34]	[3.98]	[15.18]
Hadley III-B2 scenario		−42.01		−51.59		−55.99		−3.28
(SE)		(3.23)		(3.65)		(8.93)		(20.61)
[SE clustered by state]		[11.14]		[11.80]		[16.58]		[25.12]
Observations	6,623	6,623	5,140	5,140	9,024	9,024	9,024	9,024
Soil controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	No	No
State-by-year FE	No	No	No	No	No	No	Yes	Yes

- a,b same coefficient, a: DG data, b: replicated data without error

Replication and Comparison

- First row: variance explained by weather variables
- (b) explain twice of variance in dependent variable as (a)
- Recall (b) has a lower variance than DG's original
- $\Rightarrow$ DG's weather data had significant measurement error
- Predicted impacts are insignificant under (b)
- Clusters error by county: allows for heteroskedasticity and autocorrelation of counties across year
- But assumes observations are identically distributed in space
- Second standard errors [square brackets] cluster by state after specifying the panel structure of our data
- Allowing for spatial correlation of counties within a state in a year
- Increases standard errors considerably

Replication and Comparison

- DG used different climate change predictions than studies
- Other used Hadley III model
- Significant & become larger in magnitude
- 4a and 4b use state-by-year fixed effects
- Insignificant impacts under this
- State by-year fixed effects have advantage of capturing regional price effects
- Especially useful if certain crops is concentrated geographically
- California produces 85% of lettuce in US
- Accounting for region-specific price responses should therefore make predicted impacts more negative as it cancels out the counterbalancing price response
- It is counterintuitive that predicted changes in profits are negative and significant in a regression using year fixed effects

Replication and Comparison

- Why this happen when use state-by-year fixed effects?
- There is no statistical significance because there is too little statistical power
- While we fail to reject no impact, we also fail to reject large negative impacts
- They absorb a significant amount of weather variance
- After removing county and state-by-year fixed effects, remaining weather variance pertains only to yearly within-state deviations from county means
- Ex. amount by which northern Iowa is warmer than normal in a given year compared to how much southern Iowa is warmer than normal in the same year
- Generally, whenever northern Iowa is warmer than normal, so is southern Iowa, because temperatures vary smoothly in space

Replication and Comparison

- Temperature variation under various sets of fixed effects

	Variable dd89 in DG			Replication of dd89		
	R^2	σ_e	$\lvert e\rvert > 1F$	R^2	σ_e	$\lvert e\rvert > 1F$
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
No fixed effects (FE)		6.85F	91.2%		6.10F	89.9%
County FE	0.845	2.70F	56.8%	0.940	1.50F	65.0%
County + year FE	0.867	2.50F	55.0%	0.979	0.88F	24.4%
County + state-by-year FE	0.879	2.39F	50.8%	0.997	0.35F	1.3%

- Regressions of degree days against different fixed effects
- Reports R^2, standard deviation of residual, fraction of residuals with an absolute value greater than 1F
- Very small deviation when county+state-by-year FE
- DG's: county FE= 2.70F, county+state-by-year FE=2.39F
- These differences suggest a noise-to-signal ratio of DG's temperature measure of about 7 to 1 in their preferred fixed-effects model.

Profit and the Role of Storage

- Why yield insensitive to inclusion of state-by-year fixed effects and profit sensitive?
- DG's profit measure=sales - production expense in one year
- Sales revenue is not revenue from crops grown in a year
- Farmers accumulate stocks in high-yielding years
- low-yielding years deplete stocks
- Creates a disconnect between weather-related shock
- Storage decision error in profit regressions
- error directly related to yield shock $\Rightarrow$ correlated with weather
- Endogeneity bias toward zero
  - because storage is greater and sales lower in good years with positive weather shocks
  - inventories are depleted in bad years with negative weather shocks

Profit and the Role of Storage

- Presumably, state-by-year+county FE account for incentive to accumulate or deplete inventories, Which connected to prices
- However, this would work only if prices of all commodities within a county move together ⇒ no sub-state price variation
- To test this, regress sales against value of production

	(1)	(2)	(3)	(4)
Coefficient	0.822***	0.870***	1.015	0.978
(SE)	(0.029)	(0.028)	(0.039)	(0.034)
p-val. for coeff. = 1	<0.0001	<0.0001	0.70	0.52
Observations	10,891	10,891	10,891	10,891
County FE	Yes	Yes	No	No
Year FE	Yes	No	Yes	No
State-by-year FE	No	Yes	No	Yes

- 1 & 3 year fixed effects, 2 & state-by-year fixed effects
- 1& 2 county fixed effects
- 1& 2 use deviations from county means for identification

Profit and the Role of Storage

- Regressions capture how much sales differ from average in relation to production value relative to its average
- If storage variations are fully accounted for in the model, the coefficient should be one
- $\Rightarrow$ sales should increase one-for-one by the value of each extra unit that is produced
- 3 & 4 identification relies on cross-section

Profit and the Role of Storage

- 1& 2: storage is an important factor in sales
- Coefficients are significantly different from one
- State-by-year fixed effects do account for some of the tendency to store yield shocksv (2 closer to one than 1)
- Alternative explanation for why coefficients less than one is measurement error and attenuation bias
- However, if drop county fixed effects in 3 & 4 and
- $\Rightarrow$ no longer rely on year-to-year deviations that give incentives for storage
- $\Rightarrow$ coefficient is no longer different from one
- If measurement error was a pervasive problem, these coefficients should also be biased toward zero