Reassessing China's Rural Reforms: The View from Outer Space

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- Perceived success of HRS led to other liberalizing reforms, kickstarting China's miracle

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- **This project:** Use historical satellites to measure what was actually going on on the ground, creating our own data to assess the effects of the HRS

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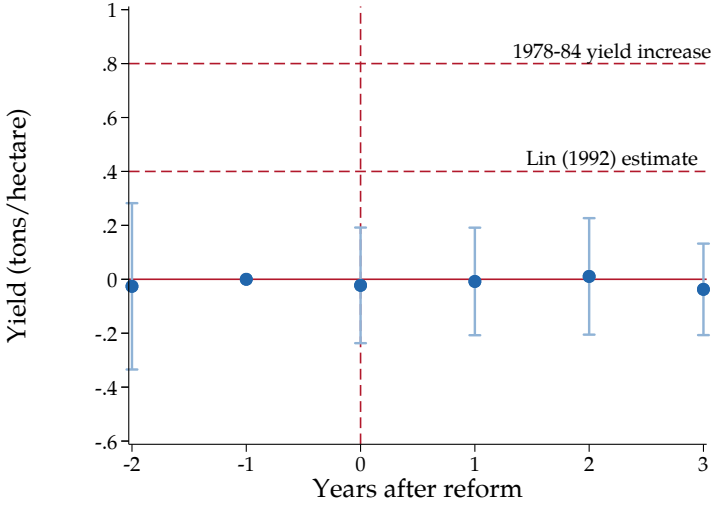
   - A novel staggered differences-in-discontinuities design that identifies the effect at province boundaries
   - A staggered rollout design using county gazetteers from Almond et al (2019)

Preview: we find no evidence that the HRS increased yields in China



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3. **Main Finding:** We do not find statistically significant evidence that decollectivization increase agricultural productivity
   - However, our satellite data indicates that aggregate yields still increased
   - Points to other policy reforms—most likely a major procurement price reform—as the main factor in China's agricultural takeoff

Where This Paper Fits In

- Understanding the drivers of China's miracle
  - *HRS:* McMillan et al (1988), Lin (1992), Almond et al. (2019), Chen and Lan (2020)
  - *Importance of agriculture in growth accounting:* Young (2003), Brandt et al. (2008)
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- Growing intersection between remote sensing and economics
  - *Nighlights to measure growth in autocracies:* Henderson et al (2012), Hodler and Raschky (2014), Martinez (2022)
  - *Daytime + ML to measure poverty:* Jean et al (2016), Yeh et al (2020), Huang et al (2021)
  - **This paper:** novel application of older satellites to economic history, with potential applications to other settings without reliable data

Historical Background

What was Household Responsibility?

Pre-Reform

- Households organized into work teams of 20-30
- Households receive basic grain ration based on the number of family members. Work points determine an additional cash reward if there's a surplus (but these are rare)
- Team sells all grain to the state, for a fixed procurement price

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Post-Reform

- Households keep surplus after fulfilling quota and paying agricultural taxes
- Two main varieties: *baochan daohu*, collective retains decision-making over cropping; *baogan daohu*, households get full responsibility over production
- In effect, a fixed-rent system where the landlord is the state—household becomes residual claimant on output

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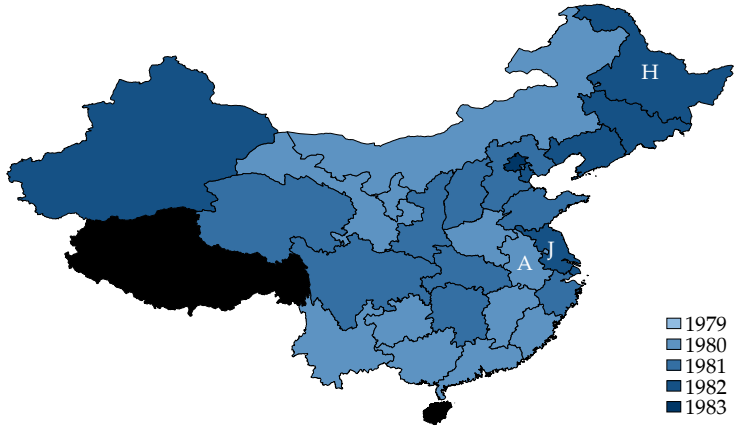
- Anhui, Sichuan, Guizhou were early leaders; after 1982, when HRS became national policy, Jiangsu, Heilongjiang were notable laggards

When did provinces have 50% of work teams adopt HRS?



Back

Data and Measurement

Remotely Sensed Data

- **Satellite sources:** Advanced Very High Resolution Radiometer (AVHRR), 1978-2013
  - Roughly 1km resolution, twice (!) every day
  - Use red and near-infrared bands to construct the **Normalized Difference Vegetation Index**:

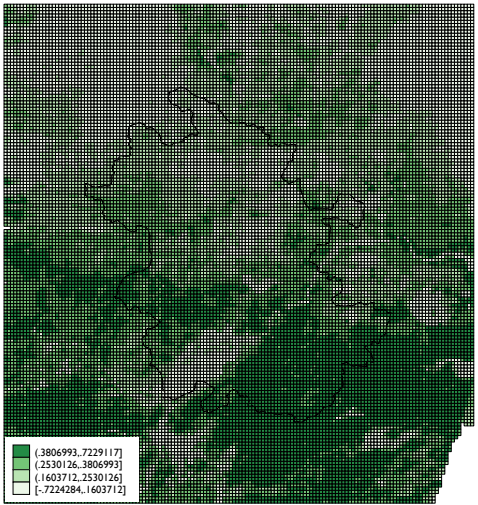
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

  - Large literature in remote sensing + environmental science showing NDVI strongly predicts yields (agricultural output over area)[1]
- **Our data:** aggregate up to 0.5-degree grid-cells (roughly 5km x 5km at Anhui's latitude)

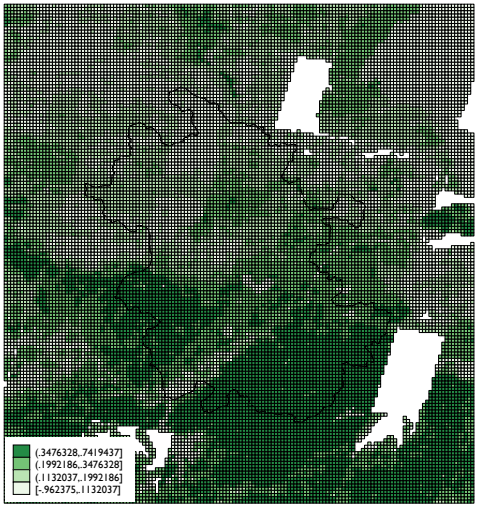
[1] Sharma et al (1993), Hamar et al (1996), Qiu et al. (2003), Moriondo, Maselli, and Bindi (2007), Liu et al (2013), Vittek et al (2014), Wang et al (2014), Lobell, et al. (2015), Burke and Lobell (2017), Kasampalis et al (2018), Cao et al (2020), Bognar et al (2022)

NDVI in Anhui

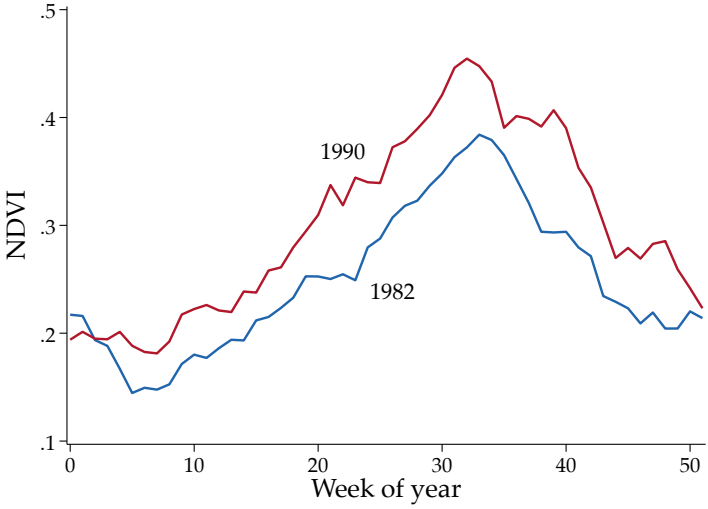
1978 Q2



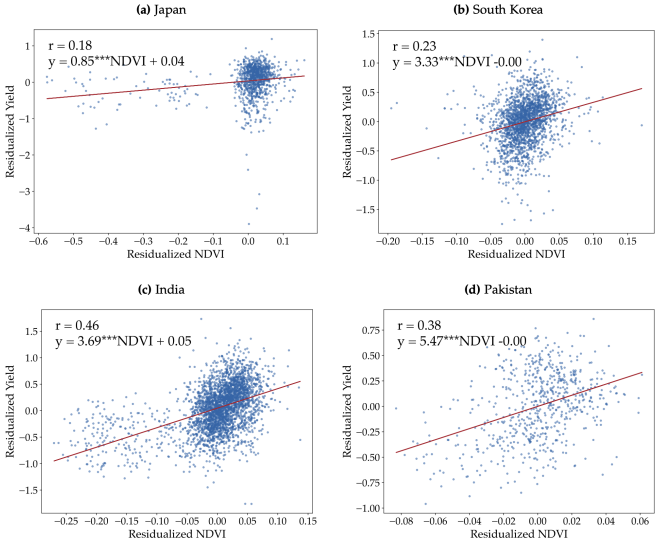
1981 Q2



NDVI in China: Seasonal Cycles



Peak NDVI predicts yield across a variety of contexts



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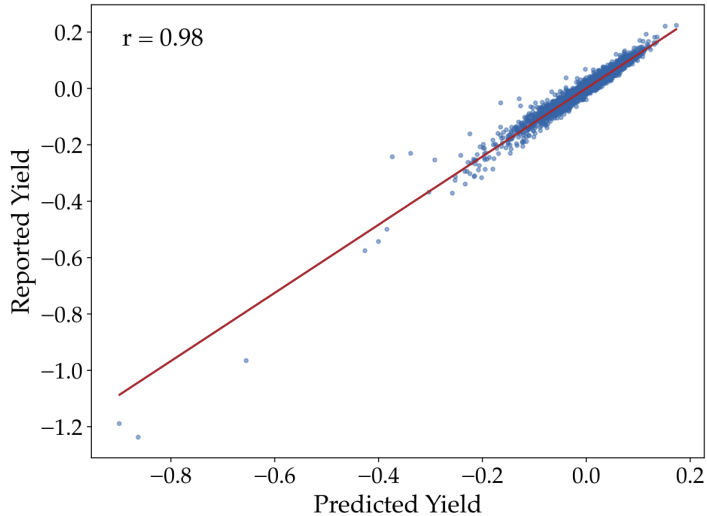
- **Solution:** train a random forest to predict yields from satellite data of the previously shown *neighboring countries*, use that model to predict
- Random forests have been successfully used to predict agricultural yields in a wide variety of contexts (Jeong et al. 2016; Cao et al. 2020; Marques Ramos et al. 2020)

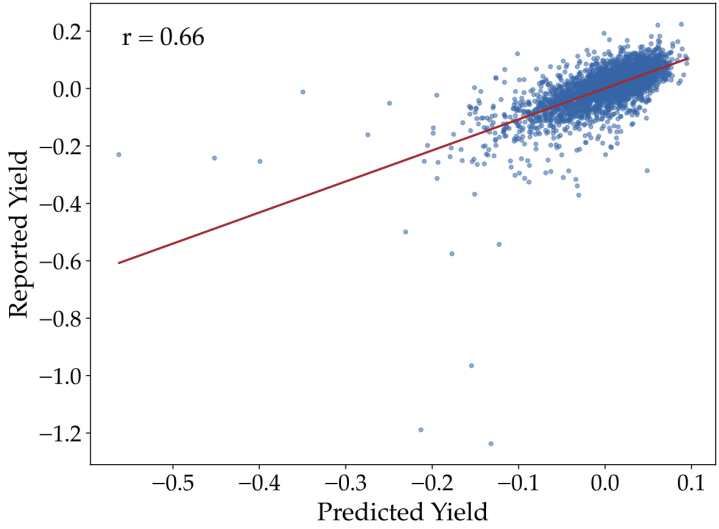
Training the Random Forest

- **Training Data:** Pooled sample of sub-national data from neighboring countries with similar agricultural mix: Japan, South Korea, India, Pakistan
- Use harmonic regression to smooth NDVI, take deciles within each geographic unit—creates 160 features for each yearly observation
- **Prediction:** creates yearly observations of predicted grain yield $\hat{y}$
- Validate both in-sample and using 5-fold cross validation (hold out 1/5 of data in training, validate against that 1/5, repeat over all 5 holdout "folds")

In-Sample Fit



Out-of-Sample Fit (5-fold cross validation)



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>1SD temp. shock in growing months	0.0847**	
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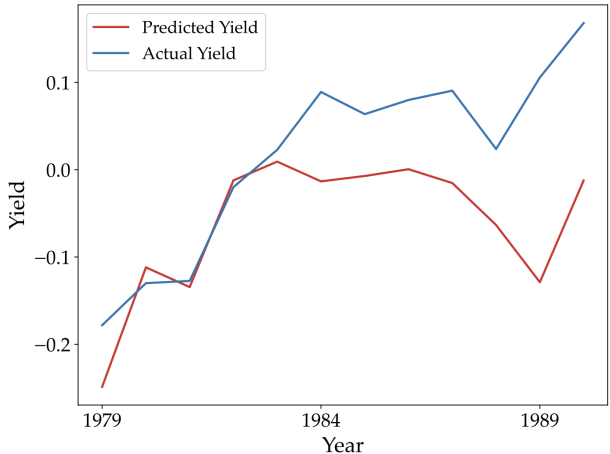
- Elasticities consistent with climate literature—indicate we can detect $\approx 5\%$ changes in yields

Aggregate yields did appear to increase throughout the late 1970s



Empirical Results

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- **Solution:** Compare cells just on either side of provincial borders (geographic regression discontinuity), include cell-level fixed effects, to control for fixed differences of places (difference-in-discontinuities)

Estimating Equation

Formally, for cell i in border group b in year t, at horizon h, we estimate

$$y_{i,b,t+h} - y_{i,b,t-1} = \underbrace{\beta_h \Delta D_{i,b,t}}_{\text{Pooled treatment effect}} + \underbrace{\gamma_{b,t+h}(R_i \times B_{b,t})}_{\text{Control province fit}} + \underbrace{\delta_{b,t+h}(R_i \times B_{b,t} \times \Delta D_{i,b,t})}_{\text{Treated province fit}} + \underbrace{B_{b,t}}_{\text{border-year FE}} + e^h_{i,b,t}.$$

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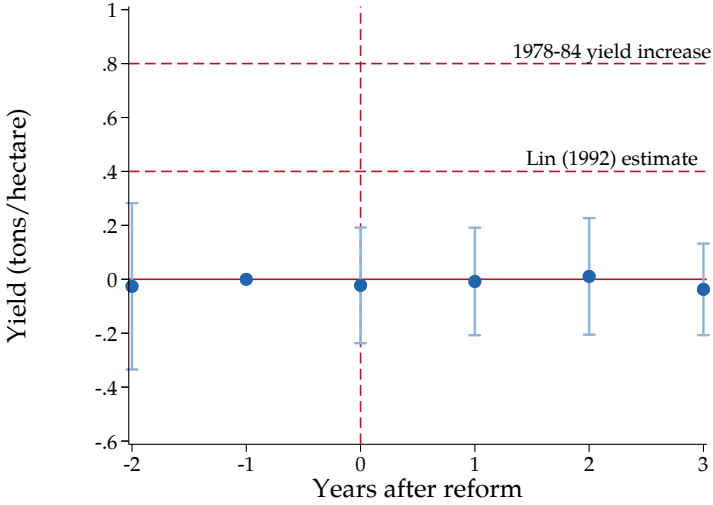
To prevent negative weighting, for each time period t we restrict the sample to just-treated units and "clean control" (or never-treated) units:

$$\begin{cases} \text{newly treated:} & \Delta D_{i,t} = 1 \\ \text{or clean control:} & D_{i,t+h} = 0 \end{cases}$$

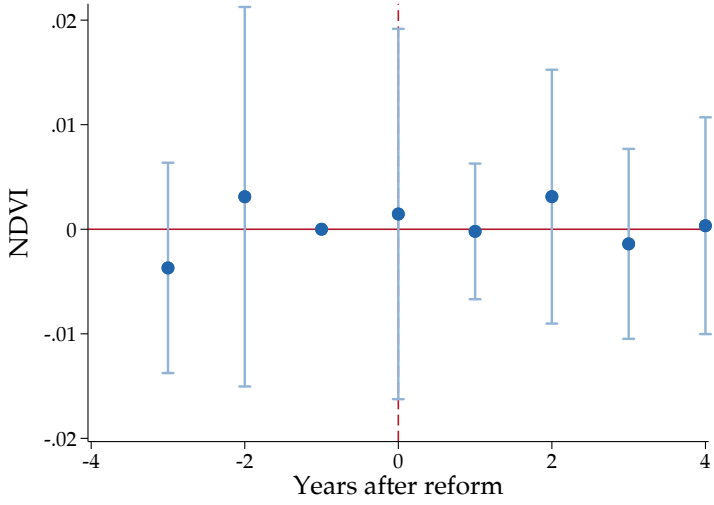
SEs computed using a 2-stage bootstrap: (1) bootstrapping estimated relationship for yields (Sexton and Laake 2009), then plugging in predicted yield estimates into RD; (2) bootstrapping RD by border clusters ($B = 73$)

Effect of HRS adoption on estimated yield



Effect of HRS adoption on Max NDVI

TWFE version



Taking Stock

- Initial results very surprising—we observe a null effect of the HRS at provincial boundaries
- Does this reflect a quirk of the identification strategy? Are border areas unrepresentative in some way?
- (If time): alternative identification strategy, using county-level rollout data from gazetteers, collected by Almond et al. (2019), finds a similar answer

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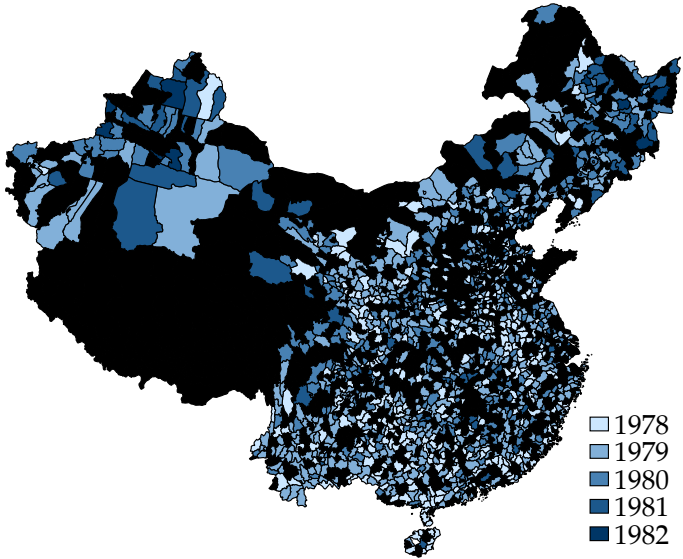
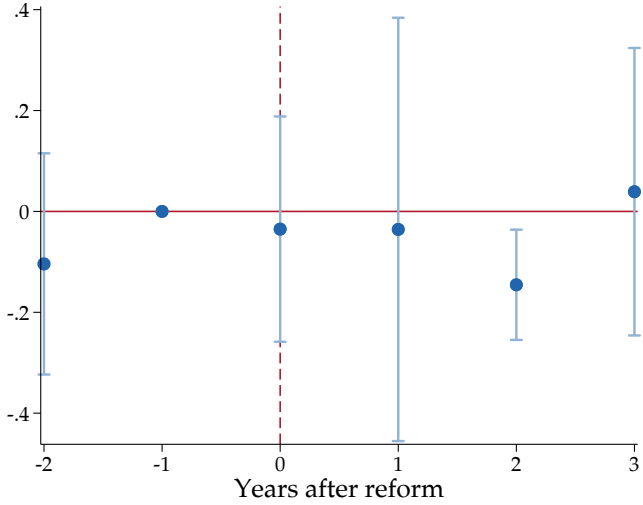
- Estimate similar Dube et al (2023) staggered rollout: for county i at year t at horizon h after reform,

$$y_{i,t+h} - y_{i,t-1} = \beta \Delta D_{i,t} + \delta_t^h + \varepsilon_{i,t}^h$$

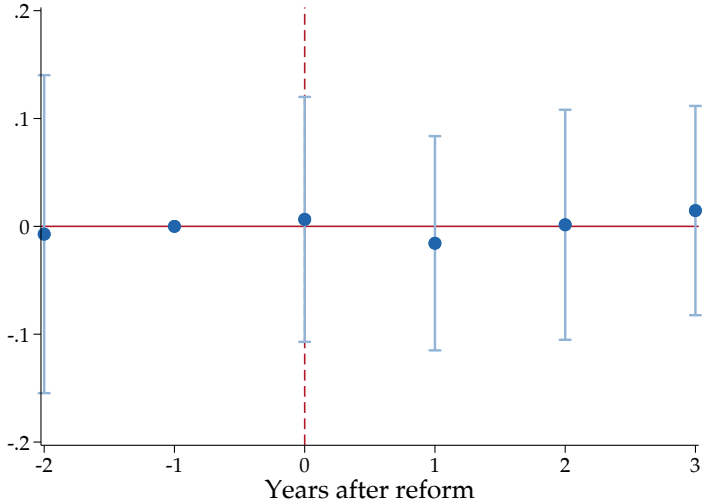
County Reform Dates in Almond et al (2019)



NDVI after Almond (2019) county decollectivization



Predicted yield after Almond (2019) county decollectivization



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  - Bramall (2003) notes that national agricultural growth accelerated in 1976-80; points out that early decollectivizers did not grow faster than late decollectivizers; points to procurement price reform instead

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- **Qualitative Evidence:** skepticism around governments' claims around HRS:
  - A 1983 CIA report attributes yield growth instead to "good weather, increased use of fertilizer and equipment, and other related reforms, such as a more rational state pricing system"
  - Bramall (2003) notes that national agricultural growth accelerated in 1976-80; points out that early decollectivizers did not grow faster than late decollectivizers; points to procurement price reform instead
- Highlights the need for careful causal identification—contribution of this paper

Broader Takeaways

- We should treat broad claims founded on data from autocratic regimes with skepticism—particularly when there are political incentives to misreport
- Satellite data presents an invaluable window in the past for big questions in growth and development
- We have presented evidence that suggests we need to revise our view of one of the central causes of China's economic takeoff
- Future work will continue to explore the policies behind the Chinese Miracle

Thank you!

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Appendix Slides

Estimating Continuous Treatment

$$
\begin{aligned}
y_{i,b,t+h} - y_{i,b,t-1} = {} & \alpha_h \Delta D_{i,b,t} + \beta_h \Delta D_{i,b,t} \times HRS_{i,b,t} \\
& + \gamma_{b,t+h}(R_i \times B_{b,t}) + \delta_{b,t+h}(R_i \times B_{b,t} \times \Delta D_{i,b,t}) \\
& + B_{b,t} + e^h_{i,b,t}.
\end{aligned} \tag{1}
$$

Continuous Effects

	Horizon (h years after reform)			
	0	1	2	3
Linear				
α_h	1.16	1.05	1.15	-0.00
	(0.78)	(0.67)	(0.94)	(0.94)
β_h	-1.33	-1.29	-1.45	-0.01
	(0.93)	(0.78)	(1.11)	(1.07)
Binned				
$50\% \leq HRS < 60\%$	-0.01	-0.01	-0.02	-0.02
	(0.02)	(0.01)	(0.01)	(0.0)
$60\% \leq HRS < 70\%$	-0.01	-0.06	-0.05	-0.03
	(0.01)	(0.04)	(0.05)	(0.04)
$70\% \leq HRS < 80\%$	0.00	0.01	-0.02	-0.01
	(0.01)	(0.01)	(0.02)	(0.01)
$80\% \leq HRS < 90\%$	0.00	0.02	0.02	0.02
	(0.01)	(0.02)	(0.03)	(0.02)
$90\% \leq HRS < 100\%$	0.01	0.03	-0.01	0.02
	(0.04)	(0.04)	(0.04)	(0.02)

Threats to Identification

- Confounding treatment
- Spillovers
- Core vs. border differences

Confounding Treatment

- Were there other policy changes at the same time that affected yields at the border?

Confounding Treatment

- Were there other policy changes at the same time that affected yields at the border?
  - Biggest policy change was 1979 rise in procurement prices, but this was largely uniform across provinces
  - Can look at province-level event studies of inputs
  - Given null finding, requires somewhat convoluted story of cancelling out positive effect of HRS

Confounding Treatment

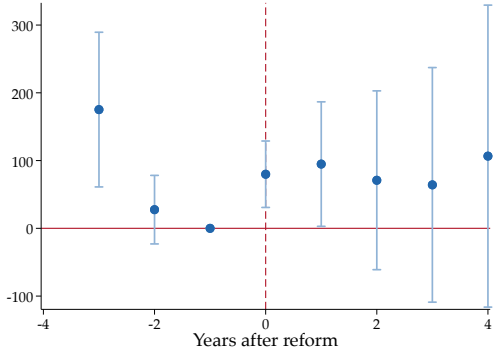

Figure 1: Draft animals

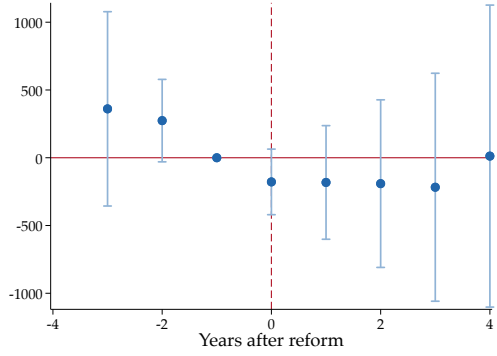

Figure 2: Farm machinery horsepower

Confounding Treatment

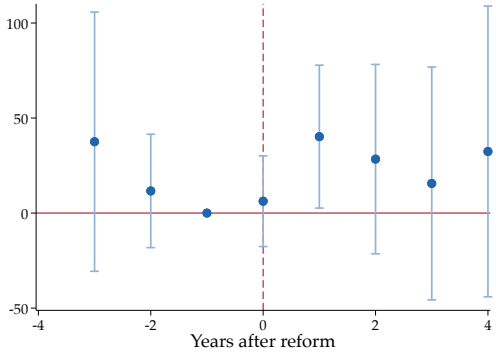

Figure 3: Fertilizer application

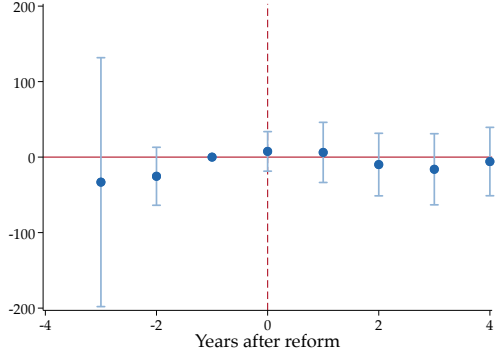

Figure 4: Total agricultural investment

Spillovers

- Did the reform spread across boundaries?
  - Several institutional features restrain spillovers:

Spillovers

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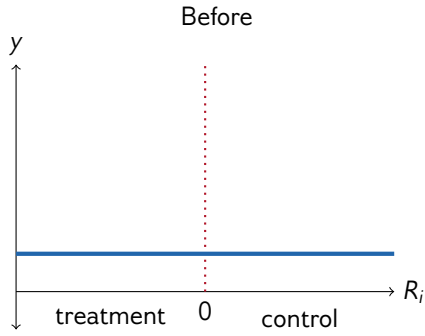
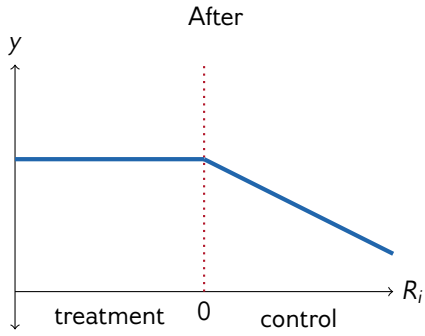
Spillovers

- Did the reform spread across boundaries?
  - Several institutional features restrain spillovers:
    - Totalitarian control over labor mobility under the *hukou* system Detail
    - Strong ideological control over province boundaries (Teiwes and Sun 2016)
  - Can test for spillovers under the weak assumption that effects on yields would decay with distance to the border

Spillovers


Before
y
R_i
treatment
0
control


After
y
R_i
treatment
0
control

Spillovers into untreated provinces, in distance to the border

$$y_{i,b,t+h} - y_{i,b,t-1} = \beta_h \Delta D_{i,b,t} + \gamma_{t+h} R_i + \delta_{t+h}(R_i \times \Delta D_{i,b,t}) + B_{b,t} + e^h_{i,b,t} \quad (2)$$

	Horizon (h years after reform)			
	0	1	2	3
Linear				
γ_{t+h} (in 1000 km)	0.03	-0.08	0.02	-0.12
	(0.07)	(0.14)	(0.19)	(0.16)
Binned				
0km $\leq R_i <$ 10km	-0.00	0.00	0.00	0.01
	(0.00)	(0.04)	(0.06)	(0.02)
10km $\leq R_i <$ 20km	-0.00	0.00	0.00	0.01
	(0.00)	(0.04)	(0.06)	(0.01)
20km $\leq R_i <$ 30km	-0.00	0.00	0.00	0.00
	(0.00)	(0.04)	(0.06)	(0.01)
30km $\leq R_i <$ 40km	-0.00	0.00	0.00	0.00
	(0.00)	(0.04)	(0.06)	(0.01)

Institutional Details about the HRS

Back

- **Land Rights:** the collective/village kept ownership of the land (Benjamin and Brandt 2002). In most villages, the village executive committee controlled tenancy/use rights, with occasional reallocations despite the law mandating 15 years of tenure (Brandt, Rozelle and Turner 2004).
- **Capital:** the communes' capital—tractors, agricultural machines—was distributed to households (Eisenman 2018, p.258)
- **Land Markets:** "Land... can also move among households in rental transactions. Although 70 percent of surveyed villages report that households enjoy unencumbered rights to rent land in 1995, the land rental market is thin." (Brandt, Rozelle and Turner 2004).
- **Labor Markets:** "The market for agricultural labor is equally thin. Only half of all villages report the use of hired farm labor in 1995, up from one quarter in 1988" (Brandt, Rozelle and Turner 2004). However, *nonfarm* labor was widespread: "employment in local village and township-run enterprises, family businesses, and long-term employment outside the village doubled between 1988 and 1995" (Brandt, Rozelle and Turner 2004)

Politically Correlated Measurement Error in Official Yields

- We can model the official yield $\tilde{y}_{i,t}$ as a function of the true yield $y_{i,t}$:

$$\tilde{y}_{i,t} = \lambda y_{i,t} + \varepsilon_{i,t}$$

- Suppose the true relationship between yield and the HRS is

$$y_{i,t} = \beta_0 + \beta_1 HRS_{i,t} + \eta_{i,t}$$

but since we only have official yield data what we actually estimate is

$$\tilde{y}_{i,t} = \tilde{\beta}_0 + \tilde{\beta}_1 HRS_{i,t} + \tilde{\eta}_{i,t}. \tag{3}$$

- Then the coefficient will be the true β plus a classic OVB term:

$$\tilde{\beta}_1 = \lambda\beta_1 + \frac{\mathrm{Cov}(HRS_{i,t}, \varepsilon_{i,t})}{\mathbb{V}(HRS_{i,t})}.$$

Lots of Measurement Error Math (continued)

- If $\text{Cov}(HRS_{i,t}, \varepsilon_{i,t}) \neq 0$ or $\lambda \neq 1$, then $\beta_1 \neq \tilde{\beta}_1$ and our estimate of β_1 will be biased. We can check if the first of these conditions holds by bringing in the satellite data, which can be modeled as

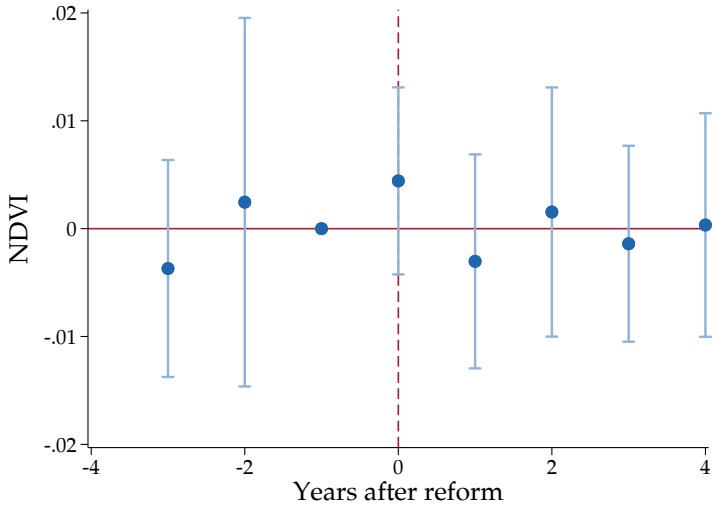
$$\bar{y}_{i,t} = \kappa y_{i,t} + \theta_{i,t}$$

- We know that $Cov(\theta, HRS) = 0$, which implies that $\bar{\beta}_1 = \kappa\beta$.
- The satellite-based regression results in column 4 suggest that $\bar{\beta}_1 \approx 0$
- If we rule out the degenerate case where $\kappa = 0$, then the true relationship between NDVI and HRS is $\beta_1 = 0$. Since we found a positive $\tilde{\beta}_1$, $\text{Cov}(HRS_{i,t}, \varepsilon_{i,t}) > 0$
- Consistent with a story where provinces sought to present good economic news about the rollout of reform and exaggerated their grain yields as the HRS spread Lin 1992 table

More Detailed Sample Description

- 22 provinces (drop municipalities, Tibet, Xinjiang, Hong Kong, Macau)
- 73 border groups

Peak NDVI effect (no clean controls) Back



Qualitative Evidence about the Spread of the HRS

- Unger (1985) interviewed 28 migrants to Hong Kong from 28 villages in Anhui, Fujian, Hubei, Jiangsu, Jiangxi, Shandong, Tianjin, and Zhejiang:
  - "Fully twenty-six out of the twenty-eight villages in my sample had indeed decollectivized into family smallholdings by the end of 1982. But official proclamations to the contrary, twenty-four of the twenty-eight interviewees report that in their own villages the decision as to precisely what type of system would be adopted was made exclusively by officials at levels far above the village. In only two villages had the team cadres and peasants themselves taken the initiative"
- Thaxton (2008) looks at Da Fo village:
  - "Da Fo's farmers launched themselves into private trade and began to reclaim market space before the Cultural Revolution had ended, before the CCP's Eleventh Congress, and before the baochan daohu system gained acceptance by the party's Central Committee. They also rejected all central and county government attempts to enlist their participation in the household responsibility system between 1979 and 1982, engineering their own silent land- to-the-tiller movement in this period."

- Bramall (1995):
  - The process of decollectivization - the best-known part of the reform package - did not begin in Sichuan until the autumn of 1977. Moreover... the dominant characteristic of this institutional change was its gradualism. Experimentation was very much the norm, and many of the province's most prosperous counties shifted to family farming (baogan dao hu) only after the autumn of 1982 - and then only at the behest of central government. It is therefore difficult to use the phrase "almost spontaneous" to describe either the process of institutional change, or the rural reform package as a whole."

The Hukou System (pre-1984)

- To move from a rural to urban area, needed a certificate of employment or school admission, or police permission
- State monopoly on urban housing
- Hotels or inns required official travel documents
- After 1960, you were required to show official travel certificates before buying a train, bus, or boat ticket
- In urban areas, residents had to show a ration card to draw grain tickets, which could then be exchanged for food
- Travellers had to bring their own grain to state grain stations where they would be exchanged for grain tickets

Back to ID threats

Replicating Lin (1992)

We can return to the original Lin (1992) regression, which estimates for province i in year t,

$$\ln(Y_{it}) = \alpha_1 + \alpha_2 \ln(\text{Land}_{it}) + \alpha_3 \ln(\text{Labor}_{it}) + \alpha_4 \ln(\text{Capital}_{it}) + \alpha_5 \ln(\text{Fertilizer}_{it}) + \alpha_6 \text{HRS}_{it} + \alpha_7 \text{MP}_{t-1} + \alpha_8 \text{GP}_t + \alpha_9 \text{NGCA}_{it} + \alpha_{10} \text{MCI}_{it} + \alpha_{11} T_t + \sum_{j=12}^{39} \alpha_j D_j + \varepsilon_{it} \quad (4)$$

Y_{it} is agricultural output, $\text{HRS}_{i,t}$ is the share of work teams in a province that have adopted household farming, $\text{MP}_{i,t-1}$ is the lagged index of market prices divided by input prices, GP_t is the index of above-quota prices divided by manufactured input prices, NGCA_{it} is the share of total sown area dedicated to nongrain crops, MCI_t is a multiple cropping index, T_t is a linear time trend, and D_j is a province-level dummy variable.

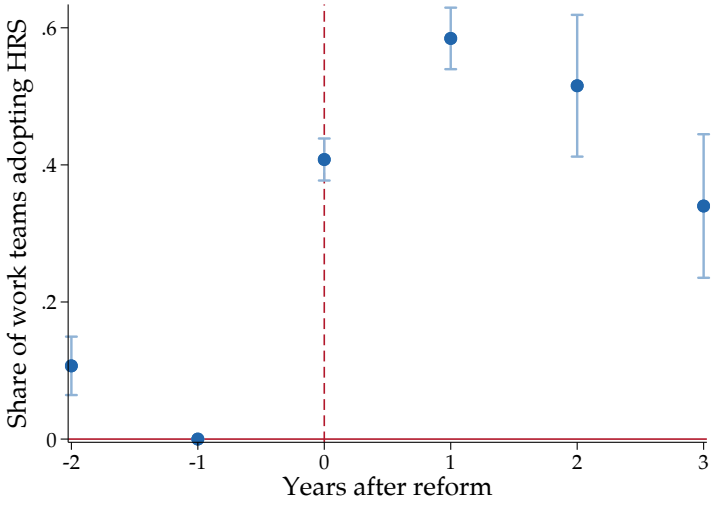
Running Lin (1992) with satellites

Measurement Error

	(1) VFO	(2) VFO (year effects)	(3) Grain yield	(4) Q2 NDVI mean
HRS share	0.220***	0.177***	0.221***	-0.0502
	(0.0300)	(0.0459)	(0.0535)	(0.0985)
ln(Land)	0.594***	0.470***	-0.502*	0.0655
	(0.115)	(0.110)	(0.205)	(0.377)
ln(Labor)	0.104***	0.125***	0.0493	-0.0548
	(0.0288)	(0.0275)	(0.0513)	(0.100)
ln(Capital)	0.0675	0.173**	0.0354	-0.0359
	(0.0607)	(0.0593)	(0.108)	(0.229)
ln(Fertilizer)	0.172***	0.149***	0.165***	0.206*
	(0.0246)	(0.0240)	(0.0438)	(0.0872)
Observations	364	364	364	300
R^2	0.842	0.865	0.536	0.104

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

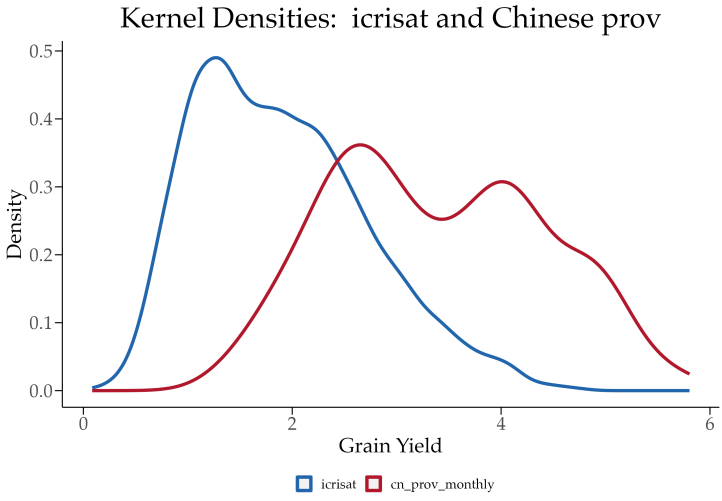
Event Study



Back to ID strategy

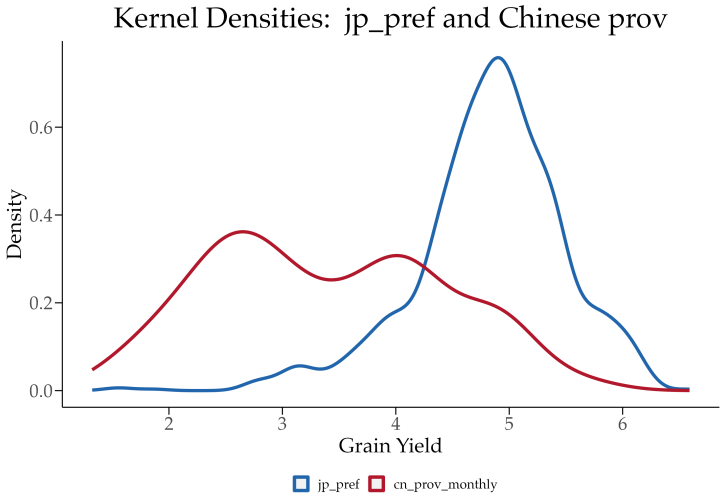
Icrisat Density Comparison

Back



Japanese Prefecture Density Comparison

Back



Korea Density Comparison

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