The Role of Infrastructure in Mitigating Poverty Dynamics:

The Case of an Irrigation Project in Sri Lanka

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Motivation

- Previous studies evaluate the impact of infrastructure on productivity & poverty reduction etc.
  - Jimenez (1995), Datt and Ravallion (1998), Van de Walle (1995), Jalan and Ravallion (2003), Lokshin and Yemtsov (2004, 2005), and Jacoby and Minten (2008)

- Randomized evaluation of physical infrastructure is difficult by nature
  - Duflo and Pande (2007)

- Previous studies focus only on the static poverty aspects, not on the poverty dynamics
  - Morduch (1994), Lipton and Ravallion (1995), Dercon ed. (2005), Fafchamps (2003)

Research Objectives

- To bridge the gap in the literature by:
  - Investigating poverty dynamics w/ & w/o infrastructure
  - Using unique setting to identify the causal effects

- To evaluate impacts of irrigation infrastructure on poverty reduction

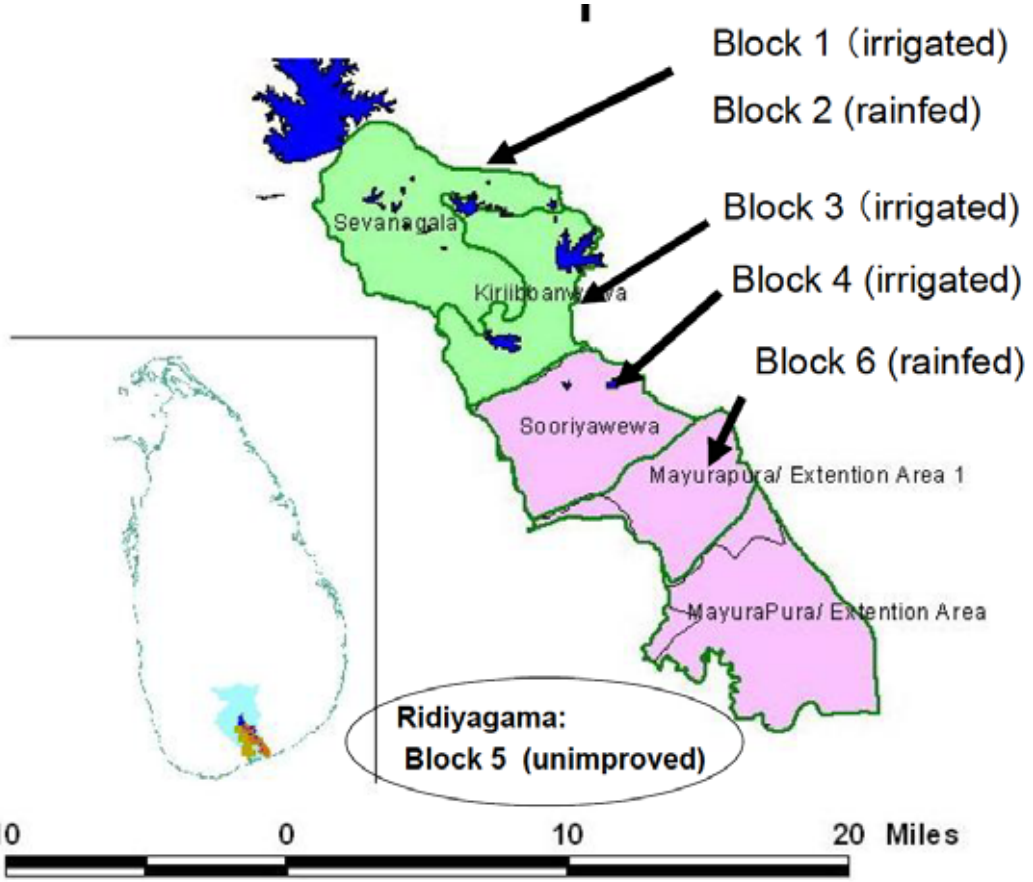
- We study a large irrigation project in Southern Sri Lanka
  - Walawe Left Bank Upgrading and Extension Project
  - Funded by the Japanese govt through OECF-JBIC-JICA

Presentation Outline

- Study site and data
- Empirical strategy and results
- Concluding remarks
- Ongoing study

The Walawe Left Bank Upgrading and Extension Project of Sri Lanka

- **Phase I (green part)**
  - Initiated in 1995
  - Completed the improvement (2,900ha) and extension (1,100ha) of irrigation systems (442km) in 2001
- **Phase II (pink part)**
  - Extension of irrigation, completed in Dec 2008
- **In total, 940 km canals, covering 9,000 ha**



Dual Canal System

Double-Cropping Paddy field under the Dual-Canal System

OFC and Complementary Infrastructure

Evaluation Strategy

- Water allocation has not been completed quickly: Initiated in 1997, 60-70% as of 2001, almost completed recently.

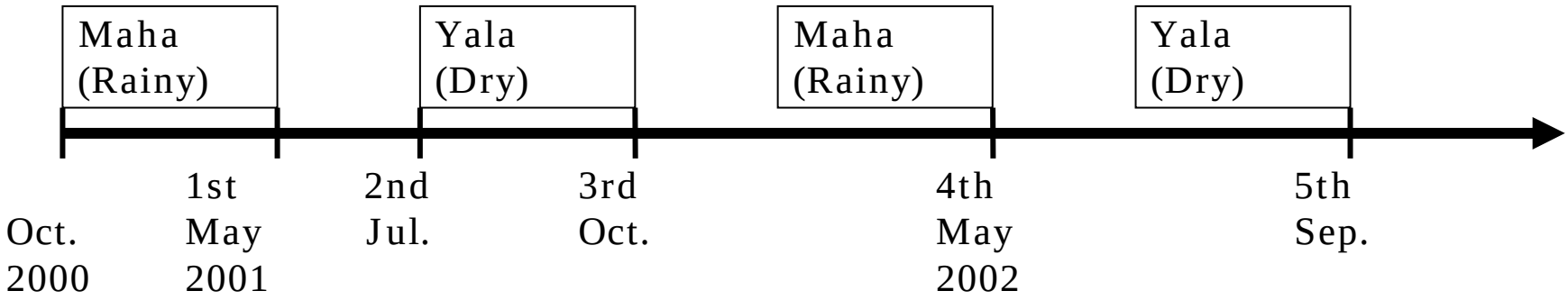
- Access to irrigation is largely exogenous
  - Govt allocated land for the married poor
  - Many applicant households (1/4) pick a lottery and receive plots based on the result of lottery.
  - Many people also resettled long time ago with expectations of getting irrigation soon.

- Possible non-randomness of program placements
  - PSM

Survey Strategy

- 5-wave panel data from 858 households
  - Stratified random sampling from around 19,000 households
  - Multi-purpose survey with carefully structured questionnaires

- Data on monthly consumption and income available
- Use only the 4th and 5th for the estimation

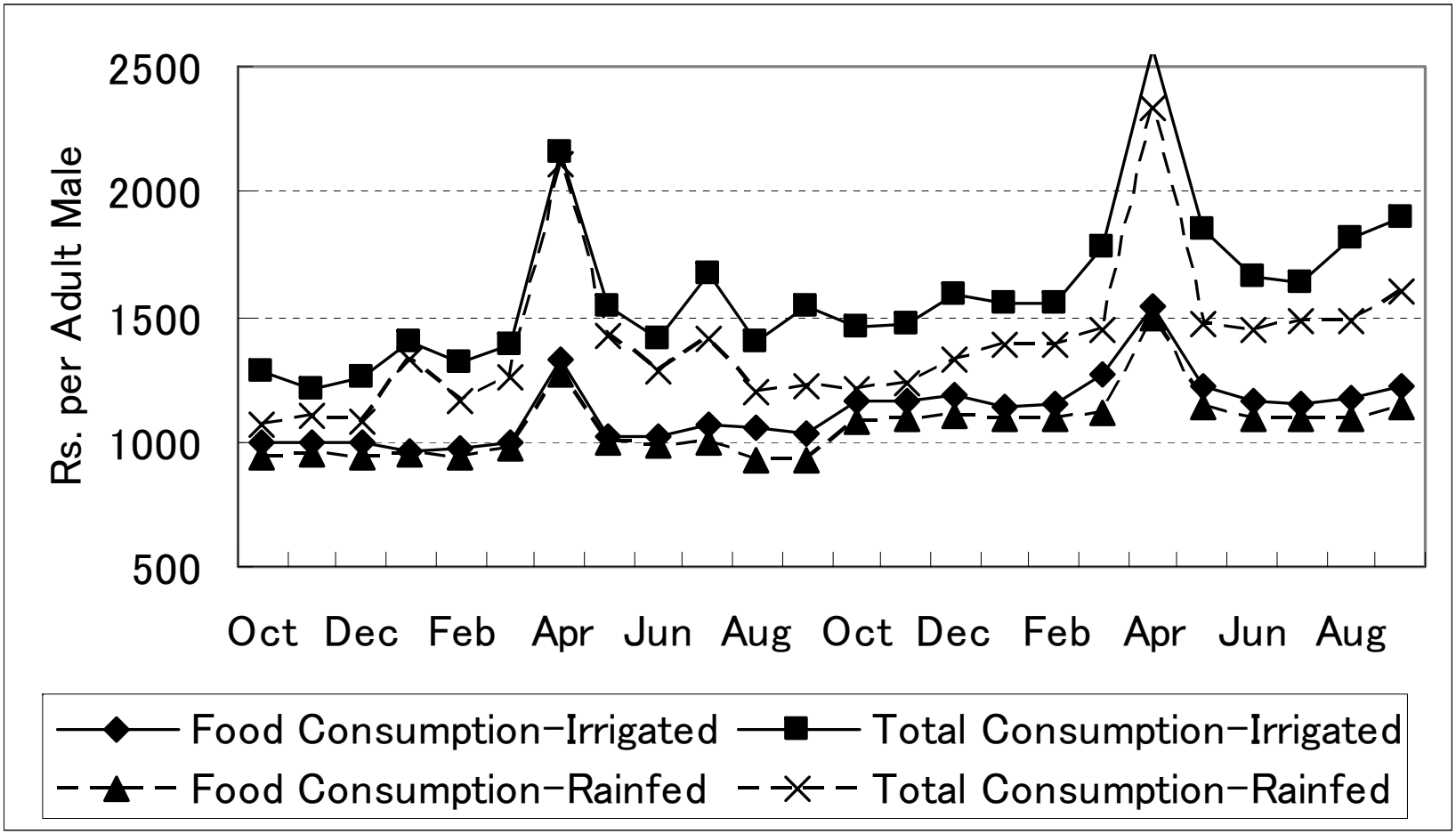


All Survey Rounds

		Maha (Rainy)		Yala (Dry)	Maha (Rainy)	Yala (Dry)	Maha (Rainy)	Yala (Dry)	Association	Experiments	Maha (Rainy)
	Oct 2000	May 2001	July 2001	Oct 2001	May 2002	Sep 2002	July 2007	Oct-Nov 2007	Jan 2009	March 2009	May 2009
Round		1	2	3	4	5	6	7	8	9	10

Average Monthly Consumption

Rainy season (Maha): Oct-March; Dry season (Yala): April-Sep



The chronic poverty is more serious in the rainfed area.

Empirical Strategies and Results

Empirical Models

A: Reduced-form PIH with Seasonality based on Paxson (1993)

B: Switching Regression Controlling for the Credit Constraints

C: Test of Model Structure by IV Estimation

D: Robustness Tests

Theory : PIH with Seasonality (Paxson 1993)

$$\underset{\{C_{jt}\}}{Max} \sum_{t=0}^{\infty} \beta^{2t} \left(\frac{\alpha_{0t} C_{0t}^{\,1-a}}{1-a} + \beta \frac{\alpha_{1t} C_{1t}^{\,1-a}}{1-a} \right)$$

$$s.t. \qquad \sum_{t=0}^{\infty} R^{-2t} \left(P_0 C_{0t} + \frac{P_1 C_{1t}}{R} \right) = W + \sum_{t=0}^{\infty} R^{-2t} \left(Y_{0t} + \frac{Y_{1t}}{R} \right),$$

LC-PIH:

$E_s^* = \omega_s Y$, where $Y = R \Pi =$ permanent income

PIH & Flavin (1981) cc:

$$E_s = (1-\pi) E_s^* + \pi Y_s$$
$$= (1-\pi)\, \omega_s Y + \pi Y_s$$
$$= Y[(1-\pi)\, \omega_s + \pi A_s]$$
$$\ln E_s \approx \ln Y + (1-\pi)\, \omega s + \pi As - 1$$

Model A : Reduced-Form PIH with Seasonality (Paxson 1993)

Assumption : Irrigation changes the permanent income and the patterns of income fluctuation, but does not affect households' preference.

$$\ln E_s = \alpha \ln Y + \gamma_s^0 + \gamma_s^Z Z + u_s$$

E_s = Monthly Consumption at the period *s*

Y = Average Monthly Income (Approximation of Permanent Income)

γ_s^0 = Monthly Fixed Effect

Z = 1[if Access to Irrigation]

$\gamma_s^Z Z$ = Consumption Fluctuation Caused by Irrigation

Hypothesis : PIH holds➔ $\gamma_s^Z Z = 0$

$\gamma_s^Z Z \neq 0$: Irrigation Increases the Consumption Even When Controlling for PI

➔Possibility of Credit Constraints？

Rainy season (Maha): Oct-March; Dry season (Yala): April-Sep

$\gamma_s^Z Z$	Log (Food Consumption)		Log (Nonfood Consumption)	
	Coef.	Std. Err.	Coef.	Std. Err.
Monthly Irrigation Effect				
October	0.198***	(0.030)	0.383***	(0.098)
November	0.194***	(0.029)	0.487***	(0.102)
December	0.193***	(0.030)	0.470***	(0.103)
January	0.169***	(0.030)	0.404***	(0.094)
February	0.175***	(0.030)	0.458***	(0.106)
March	0.225***	(0.030)	0.424***	(0.104)
April	0.150***	(0.032)	0.345***	(0.084)
May	0.172***	(0.028)	0.442***	(0.110)
June	0.153***	(0.027)	0.564***	(0.101)
July	0.154***	(0.027)	0.495***	(0.103)
August	0.167***	(0.027)	0.480***	(0.107)
September	0.168***	(0.028)	0.496***	(0.106)
Constant	6.519***	(0.059)	3.337***	(0.179)
N	9016		8813	

Model B : Endogenous Credit Constraints

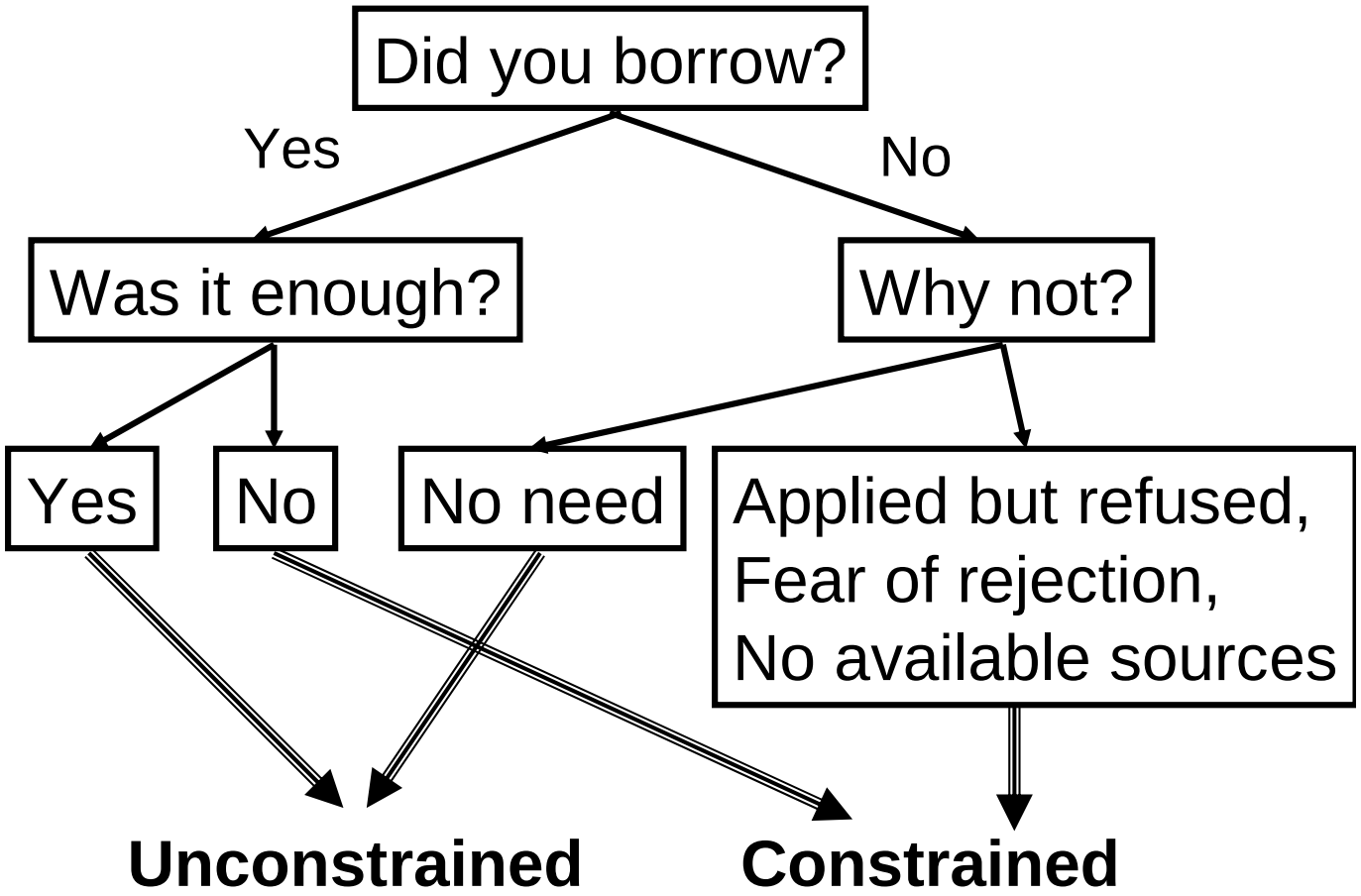
$$\ln E_s = \gamma_0^C \ln Y + \gamma_s^C + \gamma_s^{Z,C} Z + u_s^C$$ If cc=1: Credit Constrained

$$\ln E_s = \gamma_0^N \ln Y + \gamma_s^N + \gamma_s^{Z,N} Z + u_s^N$$ If cc=0: Unconstrained

$$cc_s = 1[X_s \gamma + \varepsilon_s > 0]$$

- Reduced-form PIH w/ CC estiamted by the Switching Regression Model
  - Joint-Normality
- Estimate food and nonfood consumption separately.
- **How can we measure the CC?**

Indicator of Credit Constraints (Scott, 2000)



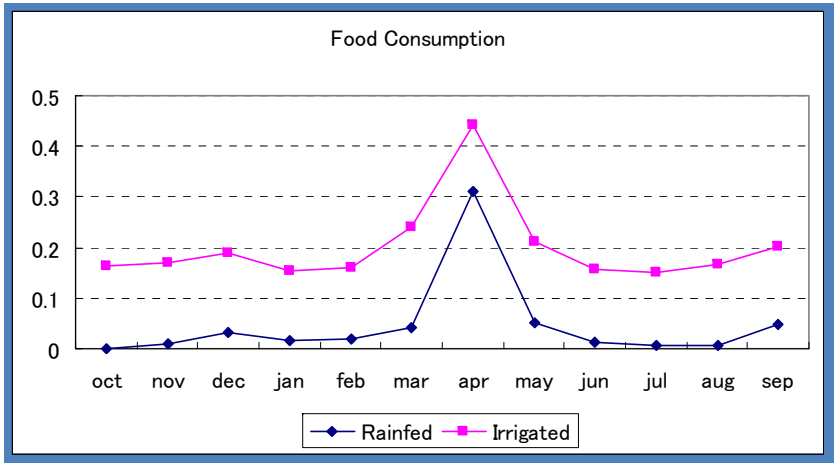
Result of Switching Regression Model: Irrigation reduces the credit constraint ➔ Reducing Transient Poverty

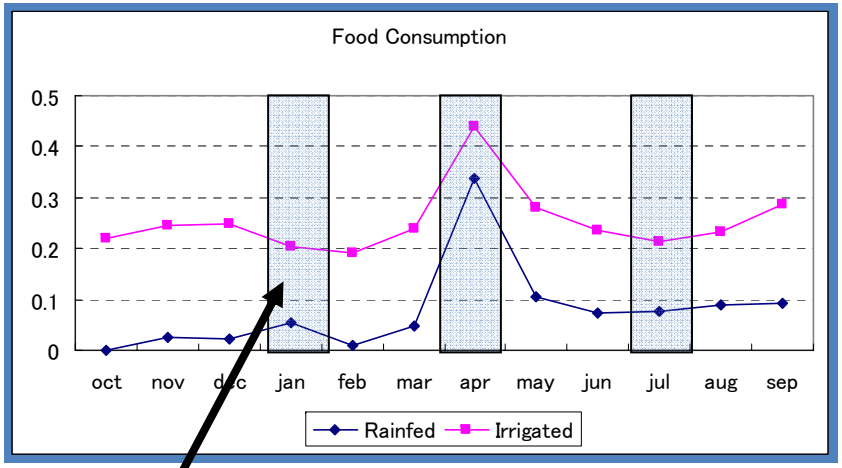
Dep. Var.: Credit Constraint	Food		Nonfood	
	Coef.	Std. Err.	Coef.	Std. Err.
Access to Irrigation Dummy	-0.181***	(0.045)	-0.149***	(0.044)
Log(Land Holding)	-0.072	(0.068)	0.107***	(0.040)
(Log(Land Holding))2	-0.022	(0.024)	0.043***	(0.014)
Monthly Income	-8.89E-06*	(4.78E-06)	-2.63E-06	(5.16E-06)
Age of Head	0.004**	(0.002)	0.002	(0.002)
Female Head	0.077	(0.059)	0.028	(0.060)
Head Count of Adult Male	-0.070***	(0.019)	-0.036*	(0.019)
Head Count of Adult Female	0.009	(0.022)	0.039**	(0.019)
Head Count of Children	-0.005	(0.014)	0.035**	(0.014)
Constant	-1.152***	(0.095)	-1.258***	(0.087)
N	8356		8166	

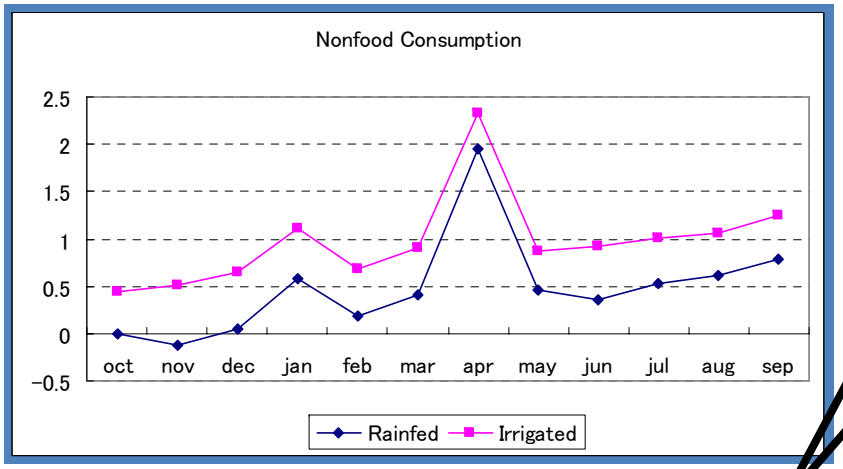
When controlling for CC, the monthly irrigation effects become insignificant for some periods.

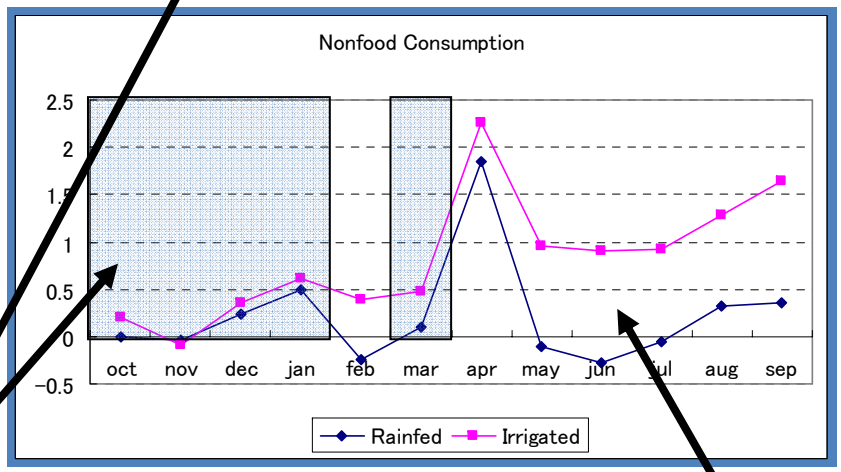
Unconstrained

Constrained









Statistically Insignificant

Gap in Dry Season

Summary of Endogenous Credit Constraint

- **Food consumption**: The month effects for the irrigated group appear "consistently" larger (persistent irrigation effects not through credit constraints)
- **Nonfood consumption for cc group**: the difference b/w irrigated and rainfed groups is significant for seven (dry) months and the significant gap partially disappears.
  - This implies that credit access can explain, at least partially, the higher monthly effect for households with irrigated lands.
- Irrigation reduces the probability of CC.
  - Irrigation reduces the possibility of transient poverty by mitigating the CC.

Model C : Test of Model Structure

- We test the validity of the theory using the structural model

$$\ln E_j = \delta_0^C \ln \overline{Y} + \delta_j^C + \pi^C A_j + \delta^C \frac{\phi(X_j\hat{\gamma})}{1-\Phi(X_j\hat{\gamma})} + \nu_j^C$$ If cc=1: Credit Constrained

$$\ln E_j = \delta_0^N \ln \overline{Y} + \delta_j^N + \pi^N A_j + \delta^N \frac{\phi(X_j\hat{\gamma})}{\Phi(X_j\hat{\gamma})} + \nu_j^N$$ If cc=0: Unconstrained

$$cc_j = 1[X_j\gamma + \varepsilon_j > 0]$$

Model Predictions: π^N =0, π^C >0	Food		Nonfood	
	π^N	π^C	π^N	π^C
A_j: Ratio of income earned in the period j to average monthly income (Instrumented by irrig*month)	0.003 (0.014)	0.059** (0.030)	-0.001 (0.031)	0.363** (0.146)

Results : Consistent with the model predictions

Model D: Robustness Tests

- Non-normality of the error terms
  - Lee (1982), and Newey, Powell, and Walker (1990)
- Endogenous Irrigation Access
  - Household-Level Fixed Effects
  - Propensity Score Matching
- Responses to AJAE review
  - Endogenous permanent income
  - Restricted model

The Propensity for Irrigation Accessibility

	October to April	May to September
Age	0.042***	0.043***
	(0.004)	(0.004)
Sex	0.189	0.118
	(0.156)	(0.156)
Education	0.040***	0.041***
	(0.015)	(0.015)
# Male	0.179***	0.130***
	(0.050)	(0.049)
Constant	-2.430***	-2.318***
	(0.292)	(0.290)
N	845	845

PSM with the radius matching

- Balancing score test OK
- Common support condition satisfied
- Robust with different matching methods

	Food C		Nonfood C		Total C		Constraint	
Month	# treat	ATT	# treat	ATT	# treat	ATT	# treat	ATT
10	525	136.261*** (41.686)	528	164.861*** (40.017)	525	290.001*** (63.89)	494	-0.042 (0.03)
11	527	127.286*** (41.743)	525	158.877*** (38.571)	524	281.335*** (62.382)	494	-0.042 (0.03)
12	527	132.545*** (43.868)	527	202.826*** (69.962)	526	329.822*** (90.479)	494	-0.042 (0.03)
1	526	103.956** (42.515)	528	150.205* (80.769)	526	197.307** (81.869)	494	-0.042 (0.03)
2	526	91.114** (45.018)	526	104.245 (81.959)	524	190.055* (99.657)	494	-0.042 (0.03)
3	526	206.973*** (46.877)	527	147.264 (96.189)	525	346.114*** (119.179)	494	-0.042 (0.03)
4	525	142.433** (60.145)	528	284.517*** (102.134)	525	425.837*** (140.143)	494	-0.042 (0.03)
5	534	148.104*** (48.037)	532	238.247** (117.025)	532	383.123*** (139.584)	506	-0.056* (0.029)
6	533	150.189*** (45.31)	533	129.018 (131.109)	532	259.406* (144.443)	506	-0.056* (0.029)
7	534	142.153*** (43.572)	533	133.332 (85.406)	533	276.184*** (103.183)	506	-0.056* (0.029)
8	534	156.814*** (44.966)	532	230.813** (107.191)	532	382.898*** (121.332)	506	-0.056* (0.029)
9	534	144.791*** (47.529)	534	243.309** (111.622)	534	388.1*** (128.039)	506	-0.056* (0.029)

Endogenous permanent income

- ln*Y* regressed on a set of physical and human asset variables

- PI returns to:
  - Irrigate land = 12%
  - Rainfed land = 5.8%
  - Education = 1.1%

	Coef.	Std. Err.
Irrigated land	0.120***	0.008
Unirrigated land	0.058***	0.006
Agri. assets	0.053**	0.024
Nonagri. assets	1.897***	0.148
Educated years of head	0.011***	0.003
Males over 16	0.074***	0.008
Females over 16	-0.046***	0.009
Children	-0.159***	0.007
Age of head	-0.038***	0.005
Age squared	0.000***	0.000
Female head	0.268***	0.028
Constant	7.946***	0.110
N	9017	
Adjusted R^2	0.15	

Back-Of-Envelope C-B analysis

- Annual consumption gain:
  $\Delta c^F = 200$Rs/M,P
  $\Delta c^{NF} = 150$Rs/M,P
  $\Sigma \Delta C = (350\text{Rs/M, P}) \times 5\text{P} \times 12{,}000\text{hh} \times 12\text{M} =$252 mill Rs
- Annual income gain:
  $\Delta y = 450$Rs/M,P
  $\Sigma \Delta Y = (450\text{Rs/M, P}) \times 5\text{P} \times 12{,}000\text{hh} \times 12\text{M} =$314 mill Rs
- Cost:
  3.02 Bill JPY (OECF-JBIC 2.57 Bill JPY; SR govt 0.45 Bill JPY)
  = 3.3 Bill Rs
- IRR:
  - Consumption: 0.252/r = 3.3 → 7.63%
  - Income: 0.314/r = 3.3 →9.52%
- We ignore: gains to new settlers; external and dynamic gains

Concluding remarks

- **Irrigation** reduces **chronic poverty** by enhancing PI possibly through improved agriculture productivity.
  - W/ irrigation, per capita food and non-food consumption expenditures and permanent income increase by around 20%, 45%, and 30%, respectively, on average.

- Also, access to Irrigation enhances credit availability and mitigates the risk of **transient poverty**
  - W/irrigation, the probability of binding credit constraint is reduced by 5.6% during the dry season.

- However, credit constraints cannot fully explain the remaining differences in the monthly effects between the irrigated and rainfed groups.
  - Access to irrigation could reduce poverty through multiple paths other than some improvement in credit access.

Ongoing study

- **Five follow-up surveys:**
  - 2006-07 Maha
  - 2007 Yala
  - Jan 2009 (institution survey)
  - March 2009 (field experiments)
  - May 2009 (hh survey for the experiments)

- **2006-07 Maha and Yala surveys:**
  - Irrigation extended to the original control group
  - Evaluation by the double-difference method

- **Field experiments:**
  - Public goods, dictator, and trust games
  - GSS type survey to compare
  - Risk and (hyperbolic) discounting

Thank you very much!