### Research Question & Motivation

What is the interaction btw insurance of idiosyncratic shocks (risk sharing) and irrigation?

- By insuring aggregate risk, investments into irrigation may lower demand for risk sharing.
- Access to risk sharing (ostracism, social norms) may be used to elicit better co-operation over irrigation.

I argue that this interaction is quantitatively significant. Thus, important from policy perspective in places relying heavily on irrigation, e.g. India (in 2016 8.5% of govt spending on irrigation).

### Village Economy

- N of ex post heterogeneously, infinitely lived farmers.
- Crop output of farmer i: $y_{i,t} = \phi_{i,t} \cdot \theta_{i,t}$.
- Idiosyncratic risk $\theta_{i,t}$ (machine & crop failures, health shocks):
  - Can be mitigated through informal insurance.
  - Drawn from a Markov chain with moments $E(\theta)$ and $Var(\theta)$.
- Aggregate risk $\phi_{i,t}$ (droughts):
  - Can be mitigated by investments into irrigation-capital stock depreciating at rate $\delta$.
  - Investments by farmers $\frac{1}{1-\delta}k_{t+1} = \frac{1}{1-\delta} \cdot [k_{t,1}, \ldots, k_{t,N}]$ are subsidized at rate $s_{k}$ and excludable. Also provide self-insurance.
  - Investments by government $\omega$ are financed by resources from outside, non-excludable.
  - $\phi_{t+1}$ is drawn from either of two Markov chains:
    - "Good" one with probability $P\left(\frac{1}{1-\gamma}\cdot k_{t+1,1}, \omega\right)$.
    - "Bad" one with prob. $1 - P\left(\frac{1}{1-\gamma}\cdot k_{t+1,1}, \omega\right)$.
- $E(\phi^C) > E(\phi^B)$ & $Var(\phi^C) < Var(\phi^B)$.

### Co-operation:

- Scope for co-op: 1) insurance against idiosyncratic shocks; 2) co-ordinating and sharing investments into irrigation.
- Subject to limited commitment: in every period & state $Value of coop \geq Value of non-coop$.
- Punishments: if farmers default on assigned risk sharing or irrigation investments, they get permanently excluded from:
  - risk sharing network (keep self-insurance),
  - irrigation owned by other villagers (keep access to own and government-owned irrigation).

### Estimation on ICRI SAT panel

Indirect inference approach based on 1st wave of ICRI SAT (1976-1984), 1st Minor Irrigation Census (MIC) and precipitation data from UD Delaware.
- Focus on 3 villages: Aurepalle, Kanzara, Shirapur.
- Match elasticity of consumption w.r.t. idiosyncratic income shocks from Townsend consumption smoothing test.
- Match variance of average village income and persistence of empirical rainfall process.
- Match returns to irrigation from: $\log (y_{i,t}) = \alpha + \beta_1k_{t+1} + \beta_2\text{irr}_{t+1} + \beta_3(1 - \text{irr}_t) + \beta_4X_t + \gamma_t + \epsilon_{i,t}$, where $1_{irr}$ is 1 if draught village-year, $\text{irr}_t$ is irrigated share of land.
- Directly from data: depreciation rate, share of gov-owned irrigation and subsidy rate $s_{k}$.
- Calibration fit very good (see paper).

### Result #1: Model and Estimation Validation

Combining 1st wave of ICRI SAT & 1st MIC with (unused in estimation) 2nd wave of ICRI SAT (2001-2004) & 4th MIC, I run the extended consumption smoothing test both on the actual and simulated data:
\[
\log (cons_{i,t}) := \alpha + \beta_1\log (y_{i,t}) + \beta_2\log (y_{i,t}) \cdot irr_{t+1} + \beta_3\log (y_{i,t}) \cdot \text{gov}_{t+1} + \beta_4\log (y_{i,t}) \cdot \text{gov}_{t+1} + \beta_5 + \gamma_t + \epsilon_{i,t}.
\]

<table>
<thead>
<tr>
<th>Estimates</th>
<th>Dep var: consumption</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income</td>
<td>0.31*** (0.07)</td>
<td>0.30*** (0.003)</td>
<td></td>
</tr>
<tr>
<td>Income-irrig</td>
<td>-0.57*** (-0.17)</td>
<td>-0.29*** (0.02)</td>
<td></td>
</tr>
<tr>
<td>Income-irrig-government share</td>
<td>6.70*** (1.94)</td>
<td>1.32*** (0.12)</td>
<td></td>
</tr>
<tr>
<td>Income-government share</td>
<td>-0.71 (0.42)</td>
<td>0.12*** (0.01)</td>
<td></td>
</tr>
</tbody>
</table>

Further validation: avg (across 3 villages) saving rate 10%, close to evidence in Rosenzweig and Wolpin (1993).

### Result #3: Interaction Between Risk Sharing and Irrigation

Removing risk sharing as a counterfactual allocation: 1) households with self-insurance (no state-contingent risk sharing) and access to both community- and government-owned irrigation, 2) risk sharing only (RS): households engage into risk sharing, and have access only to own and government-owned irrigation.

### Result #2: Reduce Gov Irr

Counterfactual of reducing the size of gov-owned irrigation (see paper for other villages):

<table>
<thead>
<tr>
<th>Aurepalle</th>
<th>Kanzara</th>
<th>Shirapur</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I+RS$</td>
<td>$I$</td>
<td>$I+RS$</td>
</tr>
<tr>
<td>Cons-eq. welfare</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>Irrigational Investments and Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean invest. $k'$</td>
<td>0.05</td>
<td>+87%</td>
</tr>
<tr>
<td>Var. of invest. $k'$</td>
<td>0.01</td>
<td>+227%</td>
</tr>
<tr>
<td>Mean agr. prod. $\phi$</td>
<td>0.87</td>
<td>+1%</td>
</tr>
<tr>
<td>Var. agr. prod. $\phi$</td>
<td>0.05</td>
<td>-6%</td>
</tr>
</tbody>
</table>

Removing risk sharing co-op (cf. $I+RS$ vs $I$):

1. Reduces efficiency of irrigational investments.
2. Worsens consumption insurance (state-contingent risk sharing transfers vs. simple self-insurance)
3. Villagers willing to pay btw 2%-10% of consumption to keep co-op over risk sharing.

Removing irrigation co-op (cf. $I+RS$ vs RS):

1. Lowers investment (externalities ignored).
2. Worsens consumption insurance (elasticity up).
3. Significantly destabilises co-operation in Shirapur (without irrigation co-op, risk sharing is impossible).
4. Villagers willing to pay btw 3%-16% of consumption to keep co-op over irrigation.