# Risk and Uncertainty[1]

Pierre Biscaye
Université Clermont Auvergne
UE 8 Private Sector & Development

January 2025

[1]Material from this lecture is drawn from Jeremy Magruder's UC Berkeley Microeconomics of Development course and from Emily Breza and Supreet Kaur's AEA Continuing Education Development Economics course

# Outline

Risk and firm production

Risk smoothing

Insurance vs savings

Paper presentations

Karlan et al (2014) Model

Karlan et al (2014) Empirics

Insurance adoption

# Firm optimization

Profit maximization with no uncertainty, markets constraints:

$$\max_{K,L} pF(K,L;A) - rK - wL$$

Reality: many forms of production *risk or uncertainty*

- Uncertainty around prices of output or inputs
- Uncertainty around availability or quality of inputs
- Uncertainty around external factors affecting production

Maximization problem:

$$\max_{K,L} E[pF(K,L;A) - rK - wL|X]$$

where $X$ are known factors that affect expectations (likely time-varying)

# Example sources of production risk and uncertainty

Can you think of some examples of factors creating uncertainty for production?

# Example sources of production risk and uncertainty

Can you think of some examples of factors creating uncertainty for production?

- Supply chain disruptions
  - Delays or shortages in raw materials, intermediate goods, or logistics bottlenecks
- Equipment or machinery failure
  - Downtime due to maintenance issues, unexpected breakdowns, or power outages
- Labor availability
  - Risk of insufficient or unskilled labor due to strikes, turnover, or demographic shifts
- Natural disasters and extreme weather
  - Events like floods, hurricanes, or earthquakes that disrupt operations or damage infrastructure
- Market price volatility
  - Fluctuations in input or output prices that impact profitability and production planning

# Production risk in developing countries

- Supply chain disruptions
  - Worse transport infrastructure and networks, weak enforcement of contracts
- Equipment or machinery failure
  - Poor power infrastructure
- Labor availability
  - Less access to skilled labor, greater prevalence of diseases
- Natural disasters and extreme weather
  - Greater vulnerability in many countries, limited tools for early warning, prevention, mitigation, and relief
- Some challenges more specific to the these contexts:
  - Weaker institutions, political instability, conflict
  - Limited financial markets (credit, insurance)

# Particular challenges for poor farmers

- Production function uncertainty
  - Weather risk: rainfall variability, drought, heat waves
  - Risk from pests and diseases
  - Post-harvest losses
- Input uncertainty
  - Land tenure insecurity and uncertain property rights
  - Health of labor force
  - Quality of seeds, fertilizers
- Price uncertainty
  - Seasonality of production and prices
  - Limited connections to buyers, limited access to and information about markets and prices

# Potential responses to risk and uncertainty

- **Financial mechanisms** and **precautionary behavior**: insurance, hold more liquid assets, establish access to credit
- **Risk aversion**: underinvestment, tradeoffs in risk vs returns in investments
- **Input allocation**: diversification $\Rightarrow$ risk-efficiency tradeoffs
- **Output diversification**: engage in different activities, spread risk $\Rightarrow$ reduce specialization and economies of scale
- **Forecasting**: invest in technologies to improve ability to predict outcomes and reduce (some) uncertainty

The **upshot**: potential for increased costs and decreased productivity and profits

# Outline

# When does risk matter for production decisions?

- Uncertainty does not prevent firms from maximizing profits
- Just need information about probabilities of different states of the world and can optimize
  - Examples: credit+storage to deal with price fluctuations, drought-tolerant seeds, multiple input sources, etc.
  - Low-revenue periods not an issue (as long as there is credit)

# When does risk matter for production decisions?

- Uncertainty does not prevent firms from maximizing profits
- Just need information about probabilities of different states of the world and can optimize
  - Examples: credit+storage to deal with price fluctuations, drought-tolerant seeds, multiple input sources, etc.
  - Low-revenue periods not an issue (as long as there is credit)
- Households want to avoid realization of bad states for consumption
- Why? And when would this affect production decisions?

# When does risk matter for production decisions?

- Uncertainty does not prevent firms from maximizing profits
- Just need information about probabilities of different states of the world and can optimize
  - Examples: credit+storage to deal with price fluctuations, drought-tolerant seeds, multiple input sources, etc.
  - Low-revenue periods not an issue (as long as there is credit)
- Households want to avoid realization of bad states for consumption
- Why? And when would this affect production decisions?

**Upshot:** Risk affects production decisions differently with market and separation failures

# Ex-post vs ex-ante risk smoothing

- Risk and uncertainty means there will be variation in realized incomes
- Household-producers want to *smooth* income and thus consumption
- **Ex-post smoothing**
  - Accept that you will have lower income in some periods
  - Deal with consequences: insurance, borrowing, saving, seek out other income sources, etc.
  - Better able to deal with risk $\Rightarrow$ more willing to take risk
  - What if financial markets are constrained?

# Ex-post vs ex-ante risk smoothing

- Risk and uncertainty means there will be variation in realized incomes
- Household-producers want to *smooth* income and thus consumption
- **Ex-post smoothing**
  - Accept that you will have lower income in some periods
  - Deal with consequences: insurance, borrowing, saving, seek out other income sources, etc.
  - Better able to deal with risk $\Rightarrow$ more willing to take risk
  - What if financial markets are constrained?
- **Ex-ante smoothing**
  - Try to prevent income volatility: how?
  - Reduced variance may come at the expense of income levels

# Ex-ante smoothing examples for household-producers

- Agriculture
  - Wait until monsoon realization to plant
  - Plant safer but less profitable crops
  - Plant drought-tolerant varieties
  - Do not apply fertilizer
  - Send one family member to migrate to city

# Ex-ante smoothing examples for household-producers

- Agriculture
  - Wait until monsoon realization to plant
  - Plant safer but less profitable crops
  - Plant drought-tolerant varieties
  - Do not apply fertilizer
  - Send one family member to migrate to city
- Non-farm enterprises
  - Do not start capital-intensive businesses
  - Limited business re-investment
  - Diversify income sources, lack of specialization
  - Do not adopt new products or technologies

# Weather uncertainty and farm investment in India (Rosenzweig & Udry 2013 WP)

- Combine localized annual monsoon forecast data and panel farm investment and production data from India
- Accurate forecasts significantly increase planting-stage investments; no response where forecasts are not accurate
- Use high-accuracy places in IV strategy to trace out potential profits under different investments given rainfall realizations
- Conclude that expected profit-maximizing investment level is 3 times the observed average investment
- Farmers dramatically underinvest!
  - Improving forecast accuracy and access would increase investments and average profits, even if profit variability also increases

# Risk and income diversification (Banerjee & Duflo 2007)

**Table 6: How the poor earn their money: Occupation**

| | Percent of Households that own land | Median Ares Of Land Owned | Percent of Households in which At Least One Member: Is Self Employed In Agriculture | Other | Works for a Wage or Salary in Agriculture | Other | Percent of HHs That Receive Income From Multiple Sectors |
|---|---|---|---|---|---|---|---|
| **Living on less than $1 a day** | | | | | | | |
| **Rural** | | | | | | | |
| Cote d'Ivoire | 62.7% | 300 | 37.2% | 25.9% | 52.4% | 78.3% | 72.1% |
| Guatemala | 36.7% | 29 | 64.4% | 22.6% | 31.4% | 86.4% | 83.8% |
| India - Udaipur | 98.9% | 60 | 98.4% | 5.9% | 8.5% | 90.7% | 94.0% |
| India - UP/Bihar | | 40 | 72.1% | 40.2% | 2.0% | 18.9% | 41.8% |
| Indonesia | 49.6% | 60 | 49.8% | 36.6% | 31.1% | 34.3% | 50.4% |
| Mexico | 4.0% | | 4.9% | 20.4% | 2.8% | 72.6% | 13.2% |
| Nicaragua | 50.4% | 280 | 54.7% | 11.6% | 0.3% | 42.8% | 18.4% |
| Pakistan | 30.4% | 162 | 72.1% | 35.5% | 32.6% | 50.8% | 66.8% |
| Panama | 85.1% | 300 | 69.1% | 17.7% | 0.0% | 0.0% | 19.2% |
| Peru | 65.5% | 150 | 71.7% | 25.2% | | | 34.8% |
| South Africa | 1.4% | | 0.0% | 9.1% | 27.9% | 26.6% | 0.4% |
| Tanzania | 92.3% | 182 | | | | | |
| Timor Leste | 95.2% | 100 | 78.5% | 12.0% | | | 10.4% |

- Income is extremely diverse: lack of specialization
  - Small-scale self-employment very common
- How does this protect against risk?

# Ex-post smoothing (Adhvaryu, Kala, & Nyshadham 2021)

**Table 4.** Does Household Enterprise Activity Respond to Coffee Price Fluctuations?

Open in new tab

| | **Household owns a business** | **Household owns a merchant business** | **Household owns a non-merchant business** | **1(Participation in non-farm self-employment)** |
|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** |
| Price/SD(Price) | -0.0469*** | -0.0388*** | -0.0138 | -0.0430*** |
| | (0.00978) | (0.0122) | (0.0106) | (0.0109) |
| Fixed effects | | Household, year, and month | | |
| Observations | 3,514 | 3,094 | 3,094 | 3,382 |
| Number of households | 975 | 846 | 846 | 919 |
| Mean of dependent variable | 0.386 | 0.263 | 0.242 | 0.414 |

*Source*: Authors' analysis based on data from the Kagera Health and Development Survey (KHDS) and the International Coffee Association.

# Ex-post smoothing (Colmer 2021)

TABLE 3—THE EFFECTS OF WEATHER ON THE DISTRICT LABOR FORCE SHARE OF EMPLOYMENT

| | Agriculture share (1) | Manufacturing share (2) | Services share (3) | Construction share (4) | Unemployment share (5) |
|---|---|---|---|---|---|
| Daily average temperature (°C) | −0.0714 | 0.0204 | 0.0335 | 0.0105 | 0.00700 |
| | (0.0165) | (0.00867) | (0.00953) | (0.00673) | (0.00370) |
| Monsoon rainfall (100 mm) | −0.00369 | 0.00137 | 0.000943 | 0.000414 | 0.000967 |
| | (0.00241) | (0.00115) | (0.00172) | (0.00126) | (0.000507) |
| Fixed effects | District and year | | | | |
| Other controls | Linear state-year time trends | | | | |
| Average share | 0.550 | 0.113 | 0.220 | 0.083 | 0.035 |
| Observations | 1,062 | 1,062 | 1,062 | 1,062 | 1,062 |

# Outline

# What about insurance as a smoothing strategy?

- Insurance protects against 'bad' states of the world
- Realize income $Y$ subject to uncertainty
- Define possible states by $s$
- In each period, probability $\pi_s$ of state $s$
- Price of insurance $p_s$ based on $\pi_s$ and difference between income in bad state $s$ $(Y_s)$ and desired 'safe' income
- Perfect insurance: get exactly same amount in every period for sure
  - Makes income independent of state
  - If actuarially fair insurance cost, total income after insurance premium is $E[Y]$: zero expected profit from insuring

# Perfect insurance example

- Two possible states: income in good state is \$100, but 20% chance of bad state with \$0 income
- Insurance product: $\pi_B = 0.2 \Rightarrow p_B = 0.2$ per unit of insurance, pays out 1 unit of income in bad state $B$
  - Expected profit for insurer is 0
- What is perfect insurance in this situation?

# Perfect insurance example

- Two possible states: income in good state is \$100, but 20% chance of bad state with \$0 income
- Insurance product: $\pi_B = 0.2 \Rightarrow p_B = 0.2$ per unit of insurance, pays out 1 unit of income in bad state $B$
  - Expected profit for insurer is 0

- Perfect insurance: buy 100 units, premium of \$20 per period
  - Exactly same income every period for sure: no uncertainty
  - Actuarially fair: payout $= E[Y]$

| Period | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Income realization | 100 | 0 | 100 | 100 | 100 |
| Premium | -20 | -20 | -20 | -20 | -20 |
| Payout | 0 | 100 | 0 | 0 | 0 |
| Total income | 80 | 80 | 80 | 80 | 80 |

# Savings vs. insurance

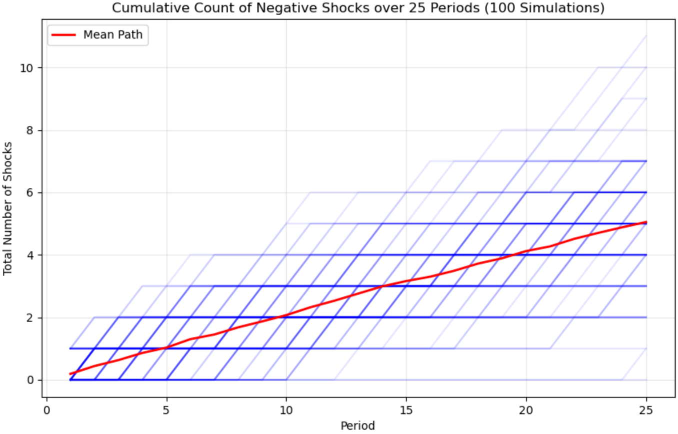
Two key forms of *consumption smoothing*

- **Savings**: even out consumption by consuming less in good states to create a buffer for bad states
  - This form of 'self'-insurance redistributes consumption *across time*
  - Must bear any bad state shock, but can reallocate its impacts across periods to mitigate utility loss
  - Vulnerable to repeated bad states
- **Insurance** allows redistribution *across states*
  - For household-producers: shock realizations have no impact on consumption (or utility)
  - Not vulnerable to repeated bad states

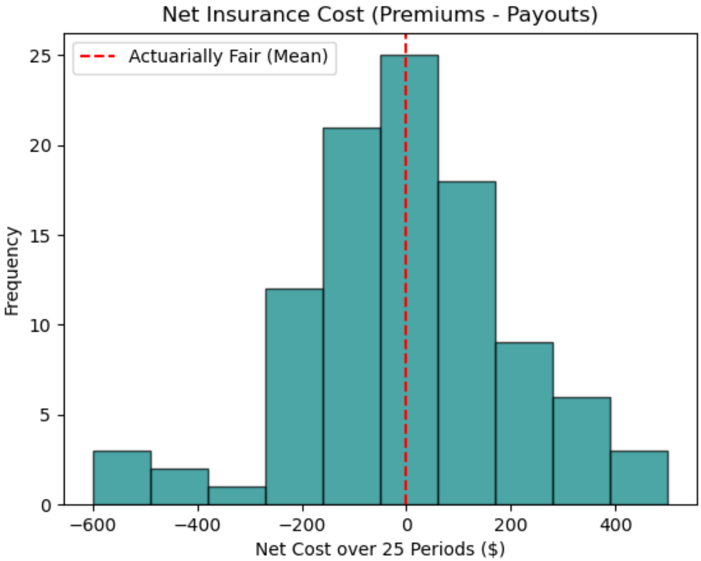
# Savings vs. insurance: simulations

- Suppose again a household that earns \$100 each period with $\pi_G = 0.8$ and \$0 with $\pi_B = 0.2$
- Situation 1: perfect insurance, premium of \$20 each period
- Situation 2: buffer stock savings, save \$20 in every good state, consume the buffer up to \$80 in bad states
- Simulate 100 realizations of consumption over 25 periods

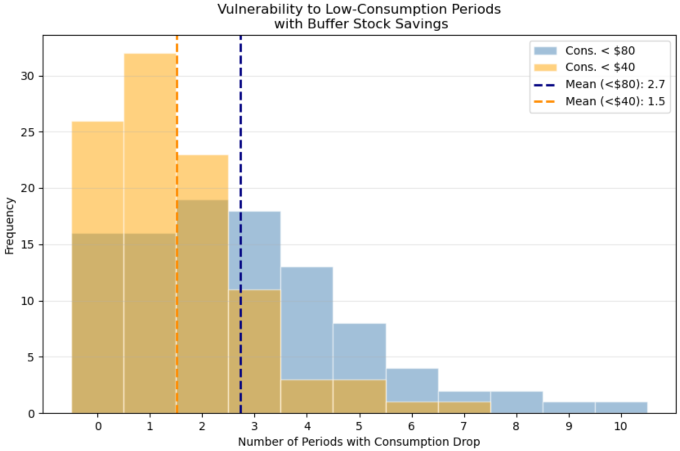
# Savings vs. insurance: idiosyncratic risk



# Savings vs. insurance: distribution of net insurance cost



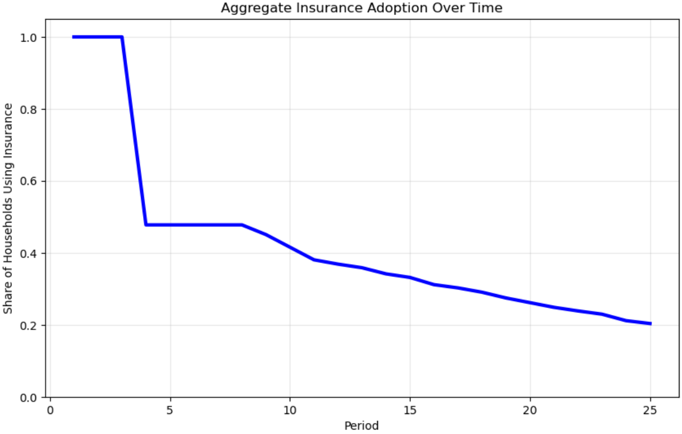
# Savings vs. insurance: vulnerability of buffer stocks



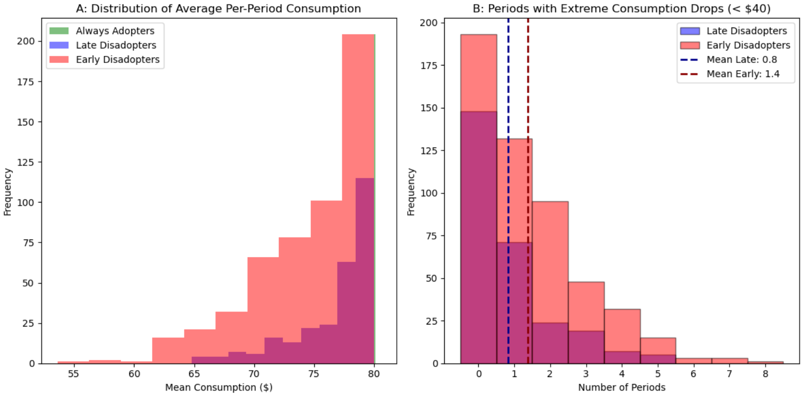
# Savings vs. insurance: behavioral responses

- Disadoption of insurance is common in many developing country settings
  - Recency bias
  - Opportunity cost of paying insurance premiums
- Suppose a behavioral model of consumption smoothing strategies:
  1. All households start adopting insurance
  2. No shock in first three periods $\Rightarrow$ disadopt insurance, permanent switch to buffer stock savings
  3. Any 8 consecutive periods with no shock $\Rightarrow$ disadopt insurance, permanent switch to buffer stock savings
  4. No re-entry to insurance market (potentially higher premiums, wait periods)
- 1000 simulations

# Savings vs. insurance: switching under behavioral responses



# Savings vs. insurance: consumption under behavioral responses



# Savings vs. insurance: simulation conclusions

- Insurance: transfer risk across *states*; perfect smoothing at the cost of the actuarial premium
  - Importance of risk pooling: need a wide net of uncorrelated risk to reach mean net cost 0
- Savings: transfer risk across *time*; smoothing vulnerable to early and repeated shocks
  - Risk of extreme poverty, food insecurity
- Behavioral responses
  - Potential rapid disadoption of insurance if considered 'unnecessary'
  - Empirical research: under-insurance of low-probability, high-impact events
  - Luck vs strategy: true risk distribution uncertain $\Rightarrow$ how to react to positive realizations?

# Developing contexts: Little formal insurance (Banerjee & Duflo 2007)

**Table 11: Market for Insurance and the poor**

| | Percent of Total Households with Insurance: | | |
|---|---|---|---|
| | Any Type | Health | Life |
| **Living on less than $1 a day** | | | |
| **Rural** | | | |
| Cote d'Ivoire | | | |
| Guatemala | | | |
| India - Hyderabad | | | |
| India - Udaipur | | | 3.8% |
| India - UP/Bihar | 9.2% | 4.7% | 3.8% |
| Indonesia | 6.0% | 3.9% | 0.0% |
| Mexico | | 50.7% | |
| Nicaragua | 0.0% | 5.5% | |
| Pakistan | | | |
| Panama | | 0.0% | 0.0% |
| Papua New Guinea | | | |
| Peru | | 5.6% | 0.0% |
| South Africa | 5.4% | | |
| Tanzania | | | |

# Communal insurance

- Stand-in for formal insurance: community members insure each other
  - Still have uncertainty around income shocks, but risk is shared
- Common in many developing contexts
  - Townsend (1994): rejects full insurance in poor villages in India, but finds HH consumption co-moves with village average and does not fully suffer idiosynratic shocks
- Any limitations?

# Communal insurance

- Stand-in for formal insurance: community members insure each other
  - Still have uncertainty around income shocks, but risk is shared
- Common in many developing contexts
  - Townsend (1994): rejects full insurance in poor villages in India, but finds HH consumption co-moves with village average and does not fully suffer idiosynratic shocks
- Any limitations?
  - Useful for idiosyncratic shocks, less so for common shocks
  - Dependent on relationships, reciprocity $\Rightarrow$ enforcement challenges (limited commitment), potential exclusion of certain households, risk of social strain
  - Transfers may be small and inadequate to fully protect against income losses
  - Moral hazard: potential risk-seeking (effort not observable)
  - Hidden income: avoid social/kin taxes (income not observable)

# Outline

# Outline

Risk and firm production

Risk smoothing

Insurance vs savings

Paper presentations

Karlan et al (2014) Model

Karlan et al (2014) Empirics

Insurance adoption

# Karlan et al (2014) ask: Does risk affect farm investment?

- Consider household-producers with production $F(L, K; A)$
- Even if $\partial F / \partial K$ is big, risk may prevent households from making important production investments
- Why? Why particularly in farming?

# Karlan et al (2014) ask: Does risk affect farm investment?

- Consider household-producers with production $F(L, K; A)$
- Even if $\partial F / \partial K$ is big, risk may prevent households from making important production investments
- Why? Why particularly in farming?
  - Want to avoid very low consumption if risky investment fails
  - Communal insurance likely to fail in farming because of serial correlation in agricultural risk
- If we want to understand the role of risk in investment, farming provides some big advantages
  - We can easily measure an important, exogenous part of that risk: weather
  - We can design an insurance product that insures against that risk

# Why does this matter?

- Policy: Huge investments from aid community in rural credit/insurance
- Academic: Lots of questions around (usually) low demand for index insurance products
  - **Index insurance** provides a payout based on a pre-determined observable threshold (e.g., rainfall levels), rather than individual losses
- Insurance should be very valuable for rainfed agriculture, yet demand is typically quite low
  - Are these products poorly designed?
  - Are farmers making a mistake in some sense, perhaps due to financial literacy? Or recency bias?
  - Or, is there another constraint that prevents farmers from leveraging the gains from insurance?

# Model: optimal responses to insurance are not so obvious

Simple setup:

- Farm households start with an endowment $Y$ and live 2 periods
- In period 1 they choose
  1. a risky input $x_r$
  2. a hedging input $x_h$
  3. a risk-free asset $a$ which offers return $R = 1/\beta$ in period 2
- In period 2 farmers produce $f_s(x_r, x_h)$, which equals
  1. $A_G f(x_r)$ in state $G$
  2. $A_B f(x_h)$ in state $B$; $A_B < A_G$
- Anticipating the experiment:
  - Farmers receive a cash grant $k$ in period 1
  - Farmers receive state-contingent payout $k_s$ in state $s$ in period 2
- Normalize units so prices of inputs are 1

# Farmers solve

$$\max_{\{a,x_r,x_h\}} u(c^0) + \beta \sum_{s\in S} \pi_s u(c_s^1)$$
$$c^0 = Y - x_r - x_h - a + k$$

- With perfect insurance, $c_G^1 = c_B^1 = c^1$

$$c^1 = \sum_{s\in S} \pi_s (f_s(x_r, x_h) + k_s) + Ra$$

- FOCs with perfect credit markets

# Farmers solve

$$\max_{\{a,x_r,x_h\}} u(c^0) + \beta \sum_{s \in S} \pi_s u(c_s^1)$$
$$c^0 = Y - x_r - x_h - a + k$$

- With perfect insurance, $c_G^1 = c_B^1 = c^1$

$$c^1 = \sum_{s \in S} \pi_s (f_s(x_r, x_h) + k_s) + Ra$$

- FOCs with perfect credit markets

$$u'(c^0) = u'(c^1)$$
$$u'(c^0) = \beta \pi_G u'(c^1) A_G f'(x_r) = \beta \pi_B u'(c^1) A_B f'(x_h)$$
$$\Rightarrow \pi_G A_G f'(x_r) = 1/\beta = R = \pi_B A_B f'(x_h)$$

## Suppose we can pool risk, but credit markets are imperfect

- Suppose borrowing is not possible: $a \geq 0$
- When the credit constraint binds, $a = 0$ and $u'(c^0) > u'(c^1)$
- FOCs for $x_h, x_r$ are the same
- What is the effect of an upfront cash grant $k$?

$$u'(c^0) = \beta \pi_G u'(c^1) A_G f'(x_r) = \beta \pi_B u'(c^1) A_B f'(x_h)$$

$$\frac{\partial u'(c^0)}{\partial k} < 0 \Rightarrow$$

$$\beta \pi_G A_G \frac{\partial u'(c^1) f'(x_r)}{\partial k} = \beta \pi_B A_B \frac{\partial u'(c^1) f'(x_h)}{\partial k} < 0$$

$$\Rightarrow \frac{\partial x_r}{\partial k} \text{ and } \frac{\partial x_h}{\partial k} > 0$$

What is the intuition behind this?

# Smoothing across time and space generate surprising effects of insurance

- What is the effect of insurance ($\uparrow k_B$) in this setting?
- $\uparrow k_B \Rightarrow u'(c^1) \downarrow$
  - Because of perfect insurance, $u'(c^1) = u'(c^1_B) = u'(c^1_G)$ so MU decreases in all states of the world
- But, $u'(c^0) = \beta \pi_G u'(c^1) A_G f'(x_r) = \beta \pi_B u'(c^1) A_B f'(x_h) \Rightarrow u'(c^0) \downarrow$
- When $a = 0$, $\downarrow u'(c^0) \Rightarrow x_r, x_h \downarrow$
- When credit constraints bind, insurance *decreases* investment
- What is the intuition?

# What if there is imperfect insurance?

- For tractability, now assume perfect credit markets but *no* insurance
- We have $c_s^1 = f_s(x_r, x_h) + k_s + Ra$
- This implies that the farmer's problem is

$$\max_{x_r, x_h, a} u(c^0) + \beta \sum_{s \in S} \pi_s u(c_s^1)$$

$$\max_{x_r, x_h, a} u(Y - x_r - x_h - a + k) + \beta(\pi_G u(A_G f(x_r) + Ra))$$

$$+ \beta(\pi_B u(A_B f(x_h) + k_B + Ra))$$

$$\frac{\partial}{\partial x_r} : u'(c^0) = \beta \pi_G A_G f'(x_r) u'(c_G^1)$$

$$\frac{\partial}{\partial x_h} : u'(c^0) = \beta \pi_B A_B f'(x_h) u'(c_B^1)$$

$$\frac{\partial}{\partial a} : u'(c^0) = \pi_G u'(c_G^1) + \pi_B u'(c_B^1)$$

# Solving the farmer's problem

$$\pi_G u'(c_G^1) + \pi_B u'(c_B^1) = \beta \pi_G A_G f'(x_r) u'(c_G^1)$$

$$\pi_B u'(c_B^1) = \pi_G u'(c_G^1)(\frac{1}{R} A_G f'(x_r) - 1)$$

$$\frac{\pi_B u'(c_B^1)}{\pi_G u'(c_G^1)} = \frac{1}{R} A_G f'(x_r) - 1$$

$$R[\frac{\pi_B u'(c_B^1)}{\pi_G u'(c_G^1)} + 1] = A_G f'(x_r)$$

$$R[\frac{\pi_G u'(c_G^1)}{\pi_B u'(c_B^1)} + 1] = A_B f'(x_h)$$

# Understanding the solution

$$R[\frac{\pi_B u'(c_B^1)}{\pi_G u'(c_G^1)} + 1] = A_G f'(x_r)$$
$$R[\frac{\pi_G u'(c_G^1)}{\pi_B u'(c_B^1)} + 1] = A_B f'(x_h)$$

- With no insurance, $u'(c_G^1) < u'(c_B^1)$ and $\pi_G + \pi_B = 1$ so that

$$\pi_G A_G f'(x_r) = R[\frac{\pi_B u'(c_B^1)}{u'(c_G^1)} + \pi_G] > R > \pi_B A_B f'(x_h)$$

- Farmers overinvest in hedging inputs relative to the complete markets case, where we had

$$\pi_G A_G f'(x_r) = R = \pi_B A_B f'(x_h)$$

# What about farmer responses to cash or insurance?

- Without insurance, you are trying to equilibrate utility today, a chance at a high utility state in the future, and a chance at a low utility state in the future
- This implies $u(c_B^1) < u(c^0) < u(c_G^1)$
- Increasing $k_b$ increases $c_B^1$, so need to transfer utility to $c^0$ and $c_G^1 \Rightarrow x_h \downarrow, x_r \uparrow$
- Increasing $k$ increases $c^0$, but effect depends on assumptions about utility function (absolute risk aversion)
  - e.g., with DARA $\frac{u''(c_B^1)}{u'(c_B^1)} < \frac{u''(c^0)}{u'(c^0)} < \frac{u''(c_G^1)}{u'(c_G^1)}$
  - $\uparrow k \Rightarrow \uparrow a$ and thus consumption in both states in period 1; equilibrating marginal utilities with DARA then implies $x_h \downarrow, x_r \uparrow$

# Model predictions

Even in a simple stylized model, predicted responses to credit and insurance interventions in contexts with market failures not obvious

TABLE I

SUMMARY OF IMPLICATIONS OF MARKET IMPERFECTIONS

| | Market environment | | Predicted change in investment | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Perfect capital markets | Perfect risk markets | Capital grant treatment only | | Insurance grant treatment only | | Capital & insurance grant treatment | |
| | | | Risky asset | Hedging asset | Risky asset | Hedging asset | Risky asset | Hedging asset |
| 1 | Yes | Yes | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | No | Yes | ++ | ++ | − | − | +[a] | +[b] |
| 3 | Yes | No | +[c] | −[d] | ++ | − − | ++ | − − |
| 4 | No | No | + | + | − | − | + | + |

*Notes.* [a]The model prediction is ambiguous, but in practice in our experiment the expected value of the insurance treatment was considerably smaller than the value of the cash grant, thus the net predicted effect in our setting is positive. [b]The model prediction is ambiguous, but in practice in our experiment the expected value of the insurance treatment was considerably smaller than the value of the cash grant, thus the net predicted effect in our setting is positive. [c]Small and positive via wealth effect, if DARA; zero if CARA. [d]Small and negative via wealth effect, if DARA; zero if CARA.

# Outline

# Two questions in this paper

1. What are the returns to capital to farmers?
2. What are the returns to insurance?

- Leads to a straightforward design
  - Some farmers (randomly) receive cash
  - Some farmers (randomly) receive index insurance
  - Some farmers (randomly) receive both
- Note: complicated sampling frame, changes in insurance product over time, discussed in detail in paper

# Do farmers want insurance?

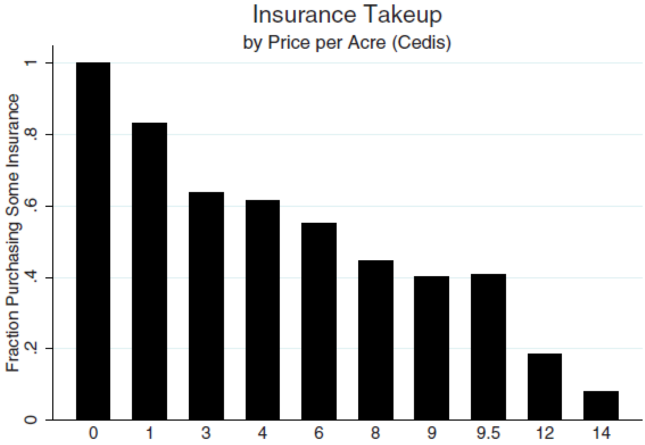
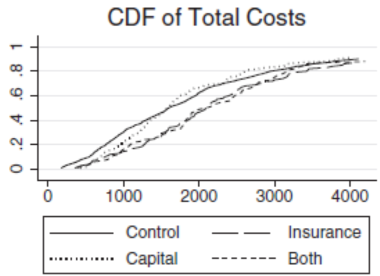
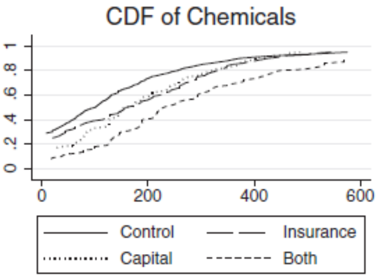


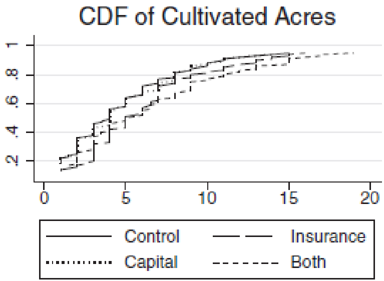

FIGURE II

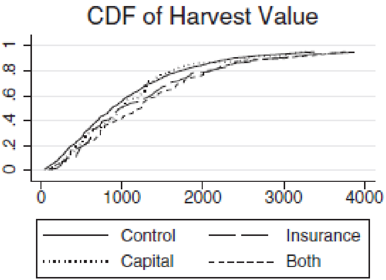
Higher adoption than in some other contexts: 40-50% for actuarially fair insurance

# How do farmers respond to capital and insurance?



# Quantifying farmer responses

TABLE IV

IMPACT ON INVESTMENT AND HARVEST (INSTRUMENTAL VARIABLES)

| Dependent variable: | (1) Land preparation costs | (2) # of Acres cultivated | (3) Value of chemicals used | (4) Wages paid to hired labor | (5) Opportunity cost of family labor | (6) Total costs | (7) Value of harvest |
|---|---|---|---|---|---|---|---|
| Insured | 25.53** | 1.02** | 37.90** | 83.54 | 98.16 | 266.15** | 104.27 |
| | (12.064) | (0.420) | (14.854) | (59.623) | (84.349) | (134.229) | (81.198) |
| Insured * capital grant treatment | 15.77 | 0.26 | 66.44*** | 39.76 | −52.65 | 72.14 | 129.24 |
| | (13.040) | (0.445) | (15.674) | (65.040) | (86.100) | (138.640) | (81.389) |
| Capital crant treatment | 15.36 | 0.09 | 55.63*** | 75.61 | −130.56 | 2.44 | 64.82 |
| | (13.361) | (0.480) | (17.274) | (68.914) | (92.217) | (148.553) | (89.764) |
| Constant | 169.38*** | 8.12*** | 171.70*** | 201.88*** | 1,394.58*** | 2,033.11*** | 1,417.52*** |
| | (10.603) | (0.399) | (13.804) | (45.383) | (84.786) | (124.294) | (90.635) |
| Observations | 2,320 | 2,320 | 2,320 | 2,320 | 2,320 | 2,320 | 2,320 |
| *R*-squared | 0.017 | 0.143 | 0.041 | 0.005 | 0.006 | 0.009 | 0.012 |
| Mean for control | 189.1 | 5.921 | 158.3 | 327.9 | 1,302 | 2,058 | 1,177 |
| $Chi^2$ test of insured and insured + capital grant treatment | 8.889 | 7.125 | 36.15 | 3.136 | 0.239 | 5.091 | 6.618 |
| *p*-value | .003 | .008 | .000 | .077 | .625 | .024 | .010 |

# Interpreting Farmer Responses

- Limited effects of cash grant only compared to insurance only or both $\Rightarrow$ risk a more important constraint to investment
  - Increases chemical inputs
- Similar effects of insurance only and insurance + cash
  - Increases chemical use and land cultivated: risky input?
  - Combined treatments has additional impact on chemical use
- Liquidity constraints not as binding as assumed (in this context)
  - "When provided with insurance against the primary catastrophic risk they face, farmers are able to find resources to increase expenditure on their farms."

# Risky investments?

- If the risk is low rainfall and insurance allows risky investment, should particularly pay off in rainy states

TABLE V

REALLOCATION OF INVESTMENTS (INSTRUMENTAL VARIABLES)

| Dependent variable: | (1) Value of harvest | (2) Proportion of land planted with maize | (3) Average weekly orchard income | (4) Household has nonfarm income generating activity (binary) | (5) # of HH members working in nonfarm income generating activity | (6) Average weekly enterprise income |
|---|---|---|---|---|---|---|
| Insured | −1,069.13* | 0.09*** | −1.59* | −0.06* | −0.11* | −8.64 |
| | (596.208) | (0.031) | (0.876) | (0.033) | (0.061) | (7.151) |
| Insured * capital grant treatment | 1,324.48 | 0.04 | 0.65 | 0.07** | 0.16** | 3.77 |
| | (821.152) | (0.029) | (0.776) | (0.033) | (0.062) | (9.126) |
| Capital grant treatment | −879.77 | 0.12*** | −0.19 | −0.04 | −0.08 | −2.83 |
| | (642.233) | (0.034) | (0.926) | (0.038) | (0.066) | (4.530) |
| Insured * total rainfall | 156.82** | | | | | |
| | (76.291) | | | | | |
| Insured * capital grant treatment * total rainfall | −155.36 | | | | | |
| | (105.649) | | | | | |
| Capital grant treatment * total rainfall | 124.95 | | | | | |
| | (83.589) | | | | | |
| Total rainfall (hundreds of millimeters) | 2,247.39*** | | | | | |
| | (624.545) | | | | | |
| Total rainfall squared | −146.65*** | | | | | |
| | (40.970) | | | | | |
| Constant | −7,154.76*** | 0.23*** | 2.42*** | 0.17*** | 0.22*** | 5.79 |
| | (2,375.086) | (0.016) | (0.613) | (0.027) | (0.038) | (4.363) |
| Observations | 2,320 | 2,782 | 2,316 | 2,320 | 2,320 | 2,350 |
| $R$-squared | 0.021 | 0.090 | 0.001 | 0.007 | 0.010 | 0.007 |
| $\text{Chi}^2$ test of joint effect of insurance and insurance+capital | 0.138 | 15.52 | 0.906 | 0.132 | 0.388 | 0.449 |
| $p$-value | .710 | 8.16e-05 | .341 | .717 | .534 | .503 |
| Mean for control | 1177 | 0.309 | 2.587 | 0.261 | 0.405 | 6.604 |

# Welfare

TABLE VI
INCOME AND HOUSEHOLD WELFARE (INSTRUMENTAL VARIABLES)

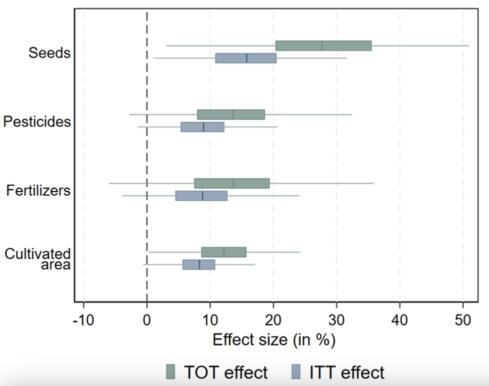
| Dependent variable: | (1) Total farm revenue (inc. insurance payouts, net of premiums) | (2) Postharvest assets (livestock + grain) | (3) Household reports having missed a meal in past 12 months (binary) | (4) Total expenditure in 12 months | (5) Utility expenses in past 12 months | (6) School expenses in past 12 months | (7) Borrowed in past 12 months from any source (binary) |
|---|---|---|---|---|---|---|---|
| Insured | 284.98*** | 530.74** | −0.08** | 46.39 | 0.36 | −0.71 | −0.00 |
| | (82.991) | (230.839) | (0.033) | (58.767) | (7.102) | (15.872) | (0.025) |
| Insured * capital grant treatment | 109.13 | 310.66 | −0.03 | 2.44 | 19.96** | 25.83 | −0.13*** |
| | (84.446) | (229.150) | (0.030) | (58.568) | (8.444) | (16.111) | (0.033) |
| Capital grant treatment | 66.93 | 606.12** | −0.08** | 7.14 | 10.30 | 24.04 | −0.06 |
| | (90.585) | (266.636) | (0.037) | (61.540) | (8.268) | (18.841) | (0.040) |
| Constant | 1,386.17*** | 1,782.29*** | 0.37*** | 470.10*** | 37.72*** | 107.94*** | 0.46*** |
| | (91.209) | (223.471) | (0.035) | (43.073) | (5.768) | (12.632) | (0.035) |
| Observations | 2,320 | 2,265 | 2,304 | 2,316 | 2,316 | 1,940 | 3,756 |
| $R$-squared | 0.023 | 0.007 | 0.013 | 0.015 | 0.050 | 0.032 | 0.203 |
| Chi² test of joint effect of insurance and insurance + capital | 17.97 | 10.68 | 9.830 | 0.581 | 5.192 | 1.984 | 13.39 |
| $p$-value | 0.0000225 | 0.00108 | 0.00172 | 0.446 | 0.0227 | 0.159 | 0.000253 |
| Mean for Control | 1,179 | 1,756 | 0.229 | 585.6 | 41.93 | 115.2 | 0.313 |

# Taking stock: several useful lessons

1. Limitation: no real hedging input in the data
    - Would have been useful for testing the model, which is really useful for intuition but was not included in published version of paper
2. Effect of cash grants inconsistent, but does increase input purchases
    - Similar to a range of studies on the impacts of rural credit
    - Will look in a future lecture at impacts of cash/credit on non-farm enterprises
3. Not much additional impact of cash + insurance
    - Suggests credit constraints may not be super important for these households
4. The absence of insurance clearly constrains these farmers
    - Access increases a variety of inputs

# A recent meta-analysis (Castaing & Gazeaud 2025)

Figure 2: The average effect of index insurance on production decisions across settings




- Significant but imprecise increases in inputs on average across 8 RCTs
- Variation in treatment effects: intervals for predicted effects in new settings comfortably include 0

# Outline

# Why is adoption of weather insurance low?

- Much research showing low adoption of insurance products, and studying potential factors
  - Liquidity constraints, lack of financial literacy, present bias, lack of trust
  - But adoption remains low even when these barriers are removed in experimental settings (Bridle et al 2018)
- Karlan et al (2014) show higher demand than other studies and clear benefits of providing insurance, but limited demand at actuarially fair price
- Also show that continued use/disadoption depends strongly on whether any payouts are received
  - Adoption challenge for technologies that only infrequently reveal their benefits
  - Related to broader literature on effects of experience on decision-making

# Payout effect: Cai, de Janvry, & Sadoulet (2020)

- RCT for weather insurance among rice producing households in China
- Cross-randomize insurance education and subsidy programs
- Analyze insurance adoption two and four years later
- Find "only positive experience with insurance (receiving payouts) increases demand, and that in general this effect does not persist over time."
- Payout effect leads to persistent adoption only with education program; other households "continuously update take-up decisions based on recent experiences"
- Evidence that "stochastic nature of payouts and low level of financial literacy" are key reasons farmer adoption is low

# Experience matters for other risk-reducing technologies: Boucher et al (2024)

- RCT in Kenya and Mozambique: communities assigned to control, drought-tolerant seeds, or DT seeds + satellite-based index insurance
  - Objective of boosting farmer resilience and productivity
- DT treatment protects against mid-season drought, mitigates long-term drops in farm investment and productivity following drought exposure
- Bundling index insurance has significant additional impact
- Farmer experience matters:
  - Drought $\Rightarrow$ benefit from the treatments $\Rightarrow$ agricultural investments $\Uparrow$ beyond pre-shock levels
  - No drought $\Uparrow$ probability technologies are abandoned

# Addressing basis risk: Feed the Future Innovation Lab for MMR 2025

- Index insurance avoids high cost of verifying individual losses
- Early applications in weather, now more on area yield
- **Basis risk**: possibility farmers experience a loss that should be covered but is not picked up by the index
  - Worsens well-being of insured households, undermines trust
- Potential response: *audit rule* activated when farmers believe index has failed
  - Formally check if conditions meet threshold for payout, issue payout if yes
  - Requires considering of when to trigger audit, how to test conditions outside of regular index procedure
  - Does not reduce importance of accurate index
- Tradeoffs:
  - Will increase costs to insurer $\Rightarrow$ require increased premiums
  - May increase trust and adoption

# Takeaways

- Benefits of insurance provision for farm investment, production, and resilience
- But limited adoption of insurance products
- Lessons for product design
  - Subsidies
  - Education
  - Experience
  - Addressing basis risk
- Role of other market failures?
- Role of other behavioral mechanisms?