# Temperature Shocks, Farm Size Distribution and Agricultural Productivity

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# Temperature Shocks and Land Markets

- Large share of the population in developing countries is employed in agriculture
  - Climate conditions is especially important for productivity and welfare
  - Academic and policy discussions about the impact of climate shocks
  - Increasing concerns due to climate change

- Land is a central asset in rural economies
  - Source of wealth + buffer against negative shocks (Khrisna, 2010)
  - Land transactions impact farm size distribution (Restuccia et al, 2014; Foster and Rosenzweig, 2022)

- **This paper**: how do temperature shocks impact **land transactions** and the **farm size distribution**? What are the implications for aggregate agricultural productivity?

- New data from Colombia + Dynamic model of farm size distribution

# This Paper

- New longitudinal data from Colombia
  - Admin. data on land transactions (*flow*) and land properties (*stock*)
  - HH level longitudinal data focused on rural areas (*hh choices*)
- Empirical patterns
  - Farm size dynamics: farm growth and occupational choices (entry and exit)
  - RF impact of temp shocks on **land transactions** and the **farm size distribution**
- Dynamic, heterogenous agent model with two sectors (ag and non-ag)
  - Agents choices: land ownership + occupation
  - Temperature shocks: aggregate (*all farmers*) + sectoral (*agr but not non-ag*)
  - Solve the model using recent methodological advances (Auclert et al., 2021)

# Relate Literature

- Agriculture and weather shocks
  - **Weather, savings and insurance**: Paxson (1992, 1993), Jayachandran (2006), Cole et al. (2013), Fachamp (1992), Townsend (1994)
  - **Agricultural risk and production choices**: Kazianga and Udry (2006), Colmer (2021), Allen and Atkin (2022), Costa et al. (2023)
  - **Our contribution**: new evidence on the impact of temp shocks on the farm size distribution
- Heterogeneous agents and agricultural productivity
  - **Farm size distribution and productivity**: Restuccia et al. (2014), Foster and Rosenzweig (2022), Gafaro and Pellegrina (2022), Acampora et al. (2023), Arteaga (2023)
  - **Heterogenous agents and development**: Buera, Kaboski and Shin (2011), Manysheva (2022), Mazur and Tetenyi (2024), Peralta-Alva et al. (2023), Kaboski and Townsend (2011), Buera et al. (2023)
  - **Methods for HA models**: Krussel and Smith (1998), Auclert et al. (2021), Iskhakov et al. (2017)
  - **Our contribution**: dynamic heterogenous agent model with aggregate shock to agriculture

# Data

# Data

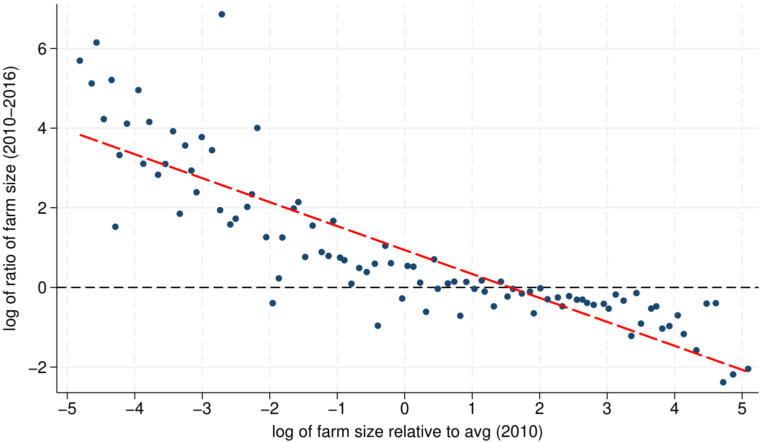
1. **Land Sales** — adm. data on land transactions (NOTARIADO Y REGISTRO)
   - Transaction-level data for plots originally granted by the government
   - 550,000 land plots, $>$ 50% of private land
   - $\approx$ 150,000 distinct transactions, but, i) only formal; ii) potentially selected sample
2. **Farm Size** — adm data on land properties (CATASTRO)
   - Full census updated every year
3. **Household** — longitudinal survey focused on small landholders (ELCA)
   - Consumption, migration, employment, land ownership
   - 4,800 rural households interviewed in three rounds (2010, 2013, 2016)
4. **Temperature** — Reanalysis data (ERA5)
   - Municipality-specific measure of atypical temperature days

# Farm Size Dynamics

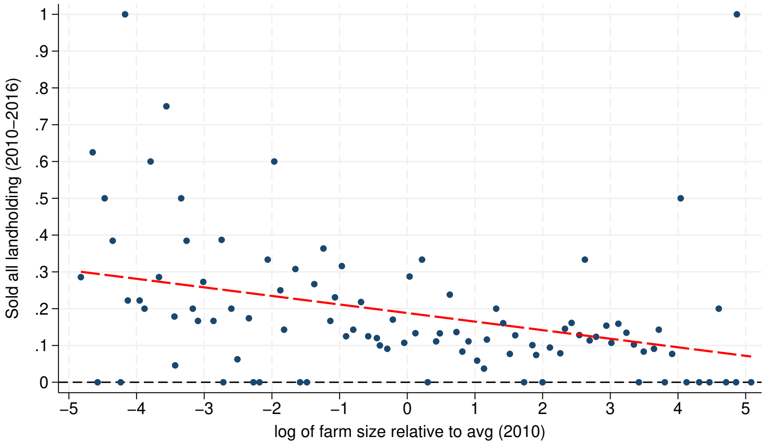
# Land markets characteristics

- Land ownership is strongly associated with *occupational choice*
  - 85% of plots operated by owners and 8% by renters (ENA, 2019)
- Extremely low adoption of agricultural insurance
  - 1% in Colombia (ENA, 2019-I)
- HHs often sell their land to smooth consumption
  - 65% of HH sold their land to pay for debts, medical treatments and education fees (ELCA)

# Farm dynamics: Higher growth among smaller farmers



# Farm dynamics: Higher exit rate among smaller farmers



# Reduced Form Impact of Temperature Shocks

# Empirical Strategy

- Estimate by OLS:

$$y_{it} = \beta TempShock_{it} + \eta_i + \theta_y + \varepsilon_{it}$$

  - $y_{it}$: outcome variable in location $i$ in time $y$
  - $TempShock_{it}$: days with adverse temperature in past 2 years
  - $\eta_i$, $\theta_t$: location and year fixed-effects
  - $\varepsilon_{it}$: clustered at the $i$ level

- Identification: conditional on FE, shocks unrelated to factors affecting outcome

- Results are robust to specifications, explanatory variables and controls

# RF Result 1: Increase in land sales

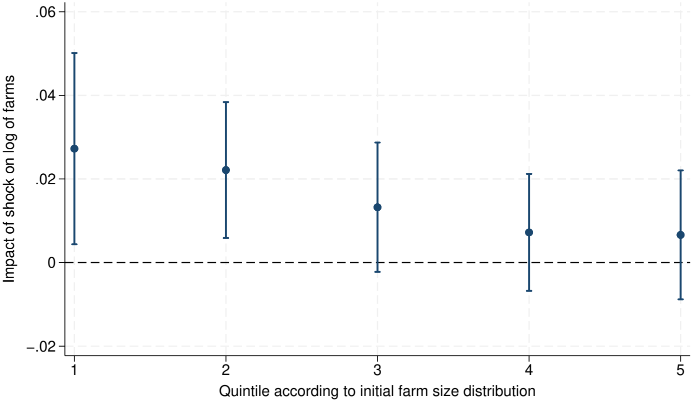
Data: Municipality level - land transactions

| | Dependent Variable | | | |
|---|---|---|---|---|
| | Total Sale (1) | Full Sale (2) | Partial Sale (3) | Mortgage (4) |
| $TempShock_{it}$ | 2.723*** | 2.147*** | 0.576* | 1.086*** |
| | (0.542) | (0.532) | (0.298) | (0.290) |
| Obs | 10392 | 10392 | 10392 | 10392 |
| $R^2$ | 0.903 | 0.900 | 0.632 | 0.749 |
| Avg. of DV | 12.304 | 10.537 | 1.766 | 2.546 |
| Municipality FE | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y |

- Shock is measured in terms of 100 days (avg shock is 277 days)

# RF Result 2: Reduction in average farm size

Data: Municipality level - land properties




- Increase in the number of smaller farms

# RF Result 3: Reduction in consumption and increase in exit rate

Data: HH level - consumption and occupational choice

| | Dependent Variable | | | | |
|---|---|---|---|---|---|
| | Farm Size | HH has land | Log of Cons. | Not in Agri | Work in other farm |
| | (1) | (2) | (3) | (4) | (5) |
| $TempShock_{it}$ | -0.416** | -0.055*** | -0.136*** | 0.061*** | -0.038** |
| | (0.194) | (0.011) | (0.025) | (0.021) | (0.015) |
| Obs | 12125 | 11988 | 7523 | 7524 | 12125 |
| $R^2$ | 0.628 | 0.666 | 0.776 | 0.715 | 0.523 |
| Avg. of DV | 2.496 | 0.894 | 0.853 | 0.245 | 0.752 |
| HH FE | Y | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y | Y |

- Shock is measured in terms of 100 days (avg shock is 277 days)

# Model

# Key ingredients

- What are the key elements that we want in the model?
  1. **Heterogeneous agents with intertemporal choices**

     $\Rightarrow$ model captures farm dynamics and consumption smoothing behavior
  2. **Discrete occupational choices**

     $\Rightarrow$ model captures exit of farmers and changes in avg farm size
  3. **Aggregate shocks**

     $\Rightarrow$ model captures the impact of shocks on the farm size distribution
- Heterogeneous agent model with aggregate shocks + Discrete choices

  $\Rightarrow$ Computationally a hard model to solve, but enormous progress recently

  $\Rightarrow$ Sequence-Space Jacobian (Auclert et al., 2022) + Discrete choice (Iskhakov et al., 2017)

# Model

- Agents choose land for the next period ($\ell' \geq 0$) and their occupation ($o$) to maximize

$$v(\ell, s_F, s_W) = \max_{c,\ell',o} \{u(c) + \beta \mathbf{E}(v(\ell', s'_F, s'_W)|\ell, s_F, s_W)\}$$

$$\text{s.t. } c = \begin{cases} s_F Z \ell^{\alpha} - p(\ell' - \ell) & \text{if } o = \text{farmer} \\ s_W - p(\ell' - \tau\ell) & \text{if } o = \text{worker} \end{cases}$$

  - $Z$: Climate conditions
  - $s_F, s_W$: Skill in farming and working (*stochastic*)
  - $\tau \in [0, 1]$: Price discount if agent chooses to become a worker

- Land market clearing requires

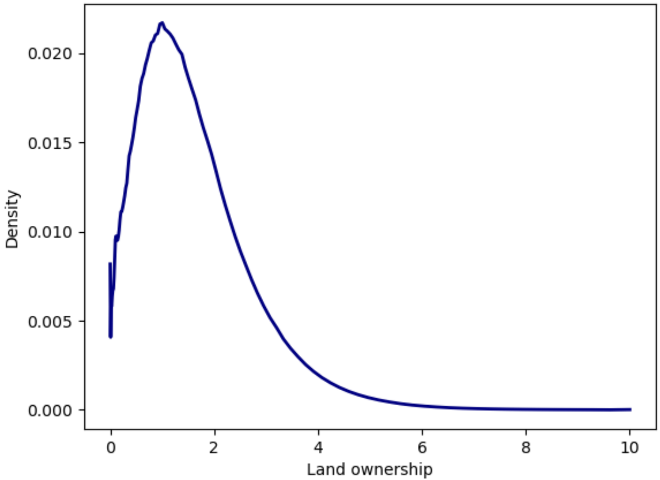
$$L = N \int \ell'(s_F, s_W, \ell) dG(s_F, s_W, \ell)$$

  - $L$: Total endowment of land
  - $N$: Total mass of agents

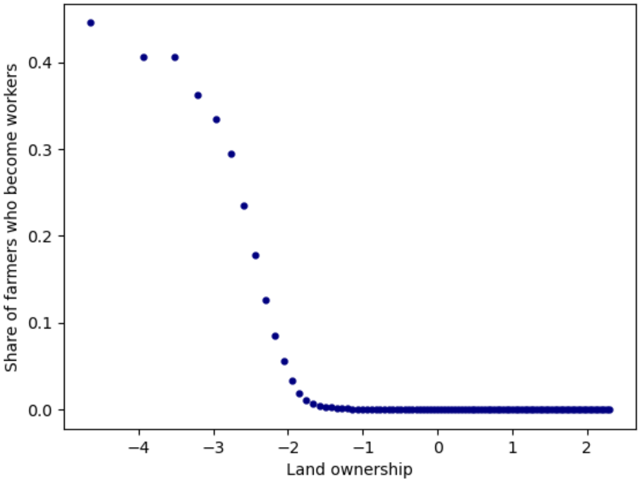
# Model simulation

- In practice, we divide a period into stages and add taste shocks to occupational choices
  - Technical problems due to non-convexities created by discrete choice
  - Taste shocks allow us to solve for the SS and IRF (Auclert et al. (2022) See details
- For the time being, focus on qualitative results
  - Key parameters set according to the literature, but no calibration
- **Counterfactual**: unanticipated negative (temporary) shock to agricultural TFP ($Z$) of 10%

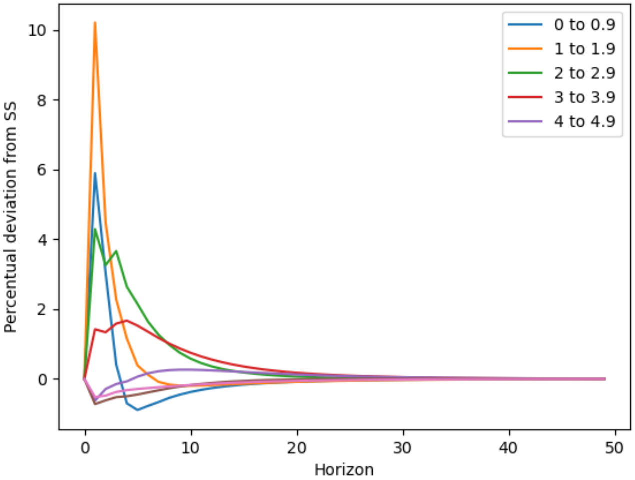
# Model simulation: Farm size distribution in SS



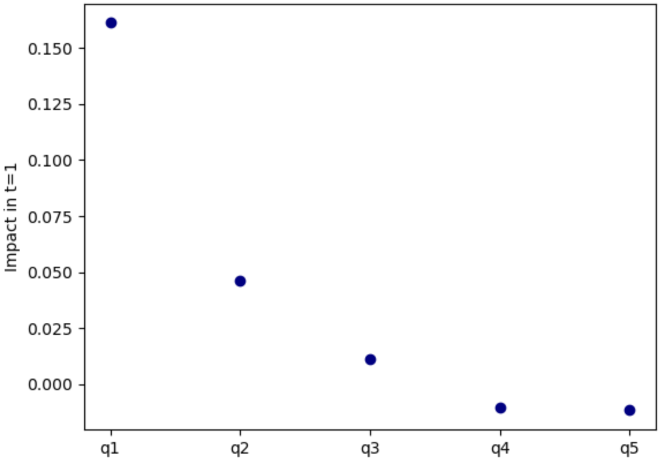
# Model simulation: Exit from agriculture in SS



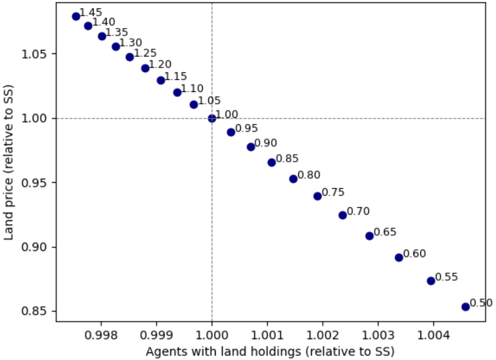
# Model simulation: IRF by group of farm size



# Model simulation: Impact of shock by quintile in $t = 1$



# Model simulation: Multiple intensity of shocks




- More negative shocks lead larger reductions in land price ⇒ Shock is **temporary**
- Workers are attracted by the low prices and buy land

# Conclusion

# Conclusion

- New evidence on the impact of temperature shocks on **land transactions** and the **farm size distribution**
- Evidence suggests that land sales act as a buffer against negative shocks
- Mechanisms
  - Negative, sectoral shock induce farmers to sell their land to smooth consumption
  - Land price drops and becomes more attractive, particularly because shock is temporary
- **Next steps**: Calibration of the model to study quantitatively
  - Impact of shocks on aggregate productivity and welfare
  - Temperature shocks based on climate change

# Model: Introducing discrete choice

- Occupational choice introduces non-convexities
  1. Problem for the solution of the SS $\Rightarrow$ FOCs are no longer sufficient
  2. Problem for solution of the IRF $\Rightarrow$ Sequence-Space Jacobian requires smoothness
- Proposal from Auclert et al (2022) $\Rightarrow$ divide problem into stages and add taste shocks
  - Solve two birds with one stone
    1. Solve SS using the upper-envelope technique (Iskhakov et al., 2017)
    2. Sequence-Space Jacobian become smooth (Auclert et al., 2017, XXX)
- Within a period, we impose 3 stages
  1. Choose occupational choice *subject to taste shock*
  2. Skill and income is revealed
  3. Consumption and land choices occur

Go back