# The Economic Impact of Climate Variability on Agricultural Output and Income: Evidence from Armenia

Development Economics

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# INTRODUCTION

# MOTIVATION

## Climate Change

### Destabilizes Weather

- Increase in global temperatures
- Unpredictable rainfall
- More extreme events
- More droughts

### Agricultural Production

- Production capacity suffers
- Problematic for future
- FAO estimates production must increase by 60% to 100% to meet future demand

### Inequality

- Disproportional consequences to poor vs rich
- Increases poverty & inequality
- Small farmers suffer more as they depend on subsistence agriciculture

# MOTIVATION

## Armenia

1. Landlocked developing country

2. Faces extreme climate events often, especially recently

3. Heavily dependent on agriculture (put some numbers)

4. Rural Marz suffer more than urban ones (list reasons)

5. There was hope for a bit, but then more extreme climate events threw it all away

# LINK TO THE COURSE

**Carleton et al. (2022)**
- Temperature fluctuations increase mortality more than previously thought
- High-income countries can adapt, while low-income countries suffer higher mortality rate and GDP loss

**Donaldson et al. (2017)**
- Rural regions in India suffer much more from rising temperatures than urban areas
- Mechanism due to higher structural dependence on agriculture (farmers)

**Jayachandran (2006)**
- Households close to subsistence level have high wage sensitivity to shocks
- Mechanism: Drought -> food insecurity -> labour supply more inelastic

**Dell et al. (2012)**
- Rising temperatures have economic consequences on agricultural and industrial output
- Effect not only short term but long term due to factors

# LITERATURE REVIEW

## Armenian Context

**Dell & al.(2012) ; Aufhammer (2018) ; Zaveri et al. (2023)**

- Macroeconomic impacts of climate and droughts in lower-income countires
  → Negativs climate shocks due to droughts and heat reduce agricultural production, lowering economic growth and increasing poverty and political instability

**FAO (2018)**

- Crop losses in high-value crops worldwide
  → Droughts cause large yield losses in cereals, legumes, tubers, vegetables and fruits with especially high sensitivity at critical growth stages

**FAO/UN (2021)**

- Disasters in agri-food systems in low & lower-middle income countries
  → Around 34% of crop and livestock production losses are attributable to droughts, making it one of the most economically damaging hazards for agriculture

# LITERATURE REVIEW

## Armenian Context

### Dell & Coppola & al. (2021) ; Galanaki & al. (2023); IPCC (2023)

- Regional climate change hotspots and observed warming

  → Armenia lies in a Mediterranean/Middle Eastern climate « hotspot » and has experienced strong warming since mid-20th century with warmest years recorded after 2018

### Melkonyan (2019)

- Climate projections and crop yield impacts

  → Projects an additional 1.6°C warming by 2040, leading to soil-water deficits of +25-30% and expected crop yield declines of about 8-14% by 2030

### World Bank (2024); UNDP (2010)

- Agricultural vulnerability and irrigation systems

  → Agriculture remains a key sector in a water-scare country, around 40% of agricultral land is irrigated but limited eater resources and weak irrigation infrastructure make yields highly sensitive to rainfall deficits and system reliability

### FAO (2000)

- Impact of the 2000 drought in Armenia

  → Up to 70% reinfall deficit in key regions, ≅ 300'000 people affected and at least 100 million USD in total damages, including ≅ 40 million USD agricultral losses, potato output -40%, wheat -27% and nearly 100'000 rural residents requiring food assistance

# RESEARCH STRATEGY

# DATA

## Variables & Units

| Armenian Dram | Percentages | Tons | Tons per hectare | Other |
|---|---|---|---|---|
| <ul><li>Monthly household income</li><li>Monthly household income from agriculture</li><li>Monthly household food consumption</li></ul> | <ul><li>Households in poverty (according to NHS)</li><li>Households in urban areas</li><li>Share of SPEI observations above +1</li><li>Agricultural stress, percent of arable areas with VHI value below 35</li></ul> | <ul><li>Gross agricultural output</li><li>Harvest of grains & leguminous plants</li><li>Harvest of fruits & berries</li><li>Harvest of potatoes</li></ul> | <ul><li>Yield of grains & leguminous plants</li><li>Yield of fruits & berries</li><li>Yield of potatoes</li></ul> | <ul><li>Standardised Precipitation Evapotranspiration Index</li><li>Vegetation Health Index</li><li>Temperature</li></ul> |

(1 Armenian Dram = 0.0021 CHF)

# DATA

| Variable | Mean | SD | Median | Min | Max |
|---|---|---|---|---|---|
| Household Income | 174691.18 | 87785.61 | 151666.73 | 43655.19 | 429931.04 |
| Household Agricultural Income | 39837.36 | 30467.86 | 30956.55 | 0.00 | 161496.48 |
| Gross Agricultural Output | 75974.74 | 47233.25 | 69050.00 | 4900.00 | 225100.00 |
| Household food Consumption | 13102.63 | 6403.40 | 12615.93 | 1931.74 | 40376.19 |
| Rate of households in poverty | 0.24 | 0.09 | 0.24 | 0.02 | 0.43 |
| Rate of households in urban areas | 0.59 | 0.22 | 0.50 | 0.31 | 1.00 |
| SPEI (Drought Index) | 0.06 | 0.51 | 0.05 | -1.03 | 1.31 |
| Share of observations of SPEI above +1 | 0.19 | 0.16 | 0.15 | 0.00 | 0.64 |
| Fruits Yield | 6.53 | 4.19 | 5.08 | 0.41 | 18.16 |
| Grains Yield | 2.55 | 0.98 | 2.55 | 0.00 | 4.87 |
| Potatoes Yield | 20.12 | 7.40 | 19.02 | 4.44 | 39.69 |
| Grains Harvest | 35332.81 | 33626.56 | 26200.00 | 0.00 | 157500.00 |
| Fruits Harvest | 27519.59 | 31090.43 | 12150.00 | 1000.00 | 115100.00 |
| Potatoes Harvest | 48996.39 | 63787.63 | 28350.00 | 400.00 | 325700.00 |

# EMPIRICAL METHODOLOGY

Use TWFE to exploit Panel Data structure

$$Y_{dt} = \alpha + \lambda_d + \gamma_t + \beta X_{dt} + \epsilon_{dt}$$

Fixed Effects control for time-fixed and national variables

$$Y_{dt} = \alpha + \lambda_d + \gamma_t + \beta_1 X_{dt} + \beta_2 X_{d,t-1} + \epsilon_{dt}$$

Set outcome variable in Logs to linearize growth

$$Y_{dt} = \alpha + \lambda_d + \gamma_t + \beta_1 X_{dt} + \beta_2 X_{d,t-1} + \beta_3 X_{d,t-2} + \epsilon_{dt}$$

β interpreted as a semi-elasticity

**District FE**  **Year FE**  **Lags**

**Y:**
- Various individual crops harvest
- Various individual crops yield
- Household income
- Household food consumption

**X:**
- SPEI
- SPEI Share (above +1)
- Agricultural Stress
- Temperature (C°)

# IDENTIFICATION STRATEGY

## Meteorological Regressors

SPEI, SPEI Share, and Temperature

- Identification relies on randomness of weather patterns
- Conditional on FE, deviations of SPEI are determined by atmospheric factors and are independent of local economic decisions in short-run
- Allows us to have a causal interpretation of net equilibrium effect
- We do not include controls

## Vegetation Regressors

Agricultural Stress

- Flawed methodology
- Very likely endogenous
- VHI measures a biological response determined by weather inputs **and human action** (OVB)
- Recommend against interpretation
- Further research could use controls to avoid OVB

# LIMITATIONS

## Yearly Averages

- Data constraints force us to use district-year averages
- Ignores seasonal patterns
- Crops have "critical windows"
- Results in attenuation bias

## Small sizes

- Small number of districts (11)
- Insufficient for cluster-robust SE
- Small country
- High spatial correlation in weather
- Hard to identify isolated district-level weather

## Ex-Post Net Effect

- Univariate models
- Only capture net effect *after* farmer adaptation
- Can't separate biological damage vs adaptation effects

## External Validity

- Armenia-specifics
- Semi-arid climate
- Mountains
- Lake Sevan (big)
- Particular crop portfolio
- Small

# RESULTS

# RESULTS

- Many tables in appendix

- Today, focus mostly on agriculture output outcomes regressed on SPEI variables

- Aggregate agricultural output analysis doesn't wield any significant results

- Concentrate on crop-specific analysis

- Overall, find significant reductions for certain crops -> net effect of droughts is negative

Table 2: Regression results for Grains Harvest on SPEI

| Dependent Variable: | (Log) Grains Harvest | | |
| --- | --- | --- | --- |
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI | -0.4503*** | -0.4573*** | -0.4691*** |
| | (0.1064) | (0.1065) | (0.1071) |
| SPEI (Lag 1) | | -0.2992** | -0.3025** |
| | | (0.1010) | (0.1207) |
| SPEI (Lag 2) | | | -0.2425* |
| | | | (0.1214) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (18) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 191 | 191 | 191 |
| $R^2$ | 0.94570 | 0.94719 | 0.94817 |
| Within $R^2$ | 0.05653 | 0.08245 | 0.09939 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 3: Regression results for Grains Harvest on SPEI Share

| Dependent Variable: | (Log) Grains Harvest | | |
|---|---|---|---|
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI Share | -0.7772** | -0.9705*** | -1.008*** |
| | (0.2690) | (0.2807) | (0.2698) |
| SPEI Share (Lag 1) | | -0.8358** | -1.012** |
| | | (0.3403) | (0.3457) |
| SPEI Share (Lag 2) | | | -0.9098** |
| | | | (0.4027) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (18) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 191 | 191 | 191 |
| $R^2$ | 0.94375 | 0.94509 | 0.94660 |
| Within $R^2$ | 0.02257 | 0.04590 | 0.07212 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 4: Regression results for Grains Yield on SPEI Share

| Dependent Variable: | (Log) Grains Yield | | |
|---|---|---|---|
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI Share | -0.4843** | -0.4983** | -0.5060** |
| | (0.2120) | (0.2098) | (0.2134) |
| SPEI Share (Lag 1) | | -0.0607 | -0.0972 |
| | | (0.2006) | (0.1848) |
| SPEI Share (Lag 2) | | | -0.1884 |
| | | | (0.2824) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (18) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 191 | 191 | 191 |
| $R^2$ | 0.78048 | 0.78055 | 0.78114 |
| Within $R^2$ | 0.02055 | 0.02084 | 0.02348 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

# RESULTS

Table 5: Regression results for Potatoes Harvest on SPEI Share

| Dependent Variable: | (Log) Potatoes Harvest | | |
|---|---|---|---|
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI Share | -0.3500 | -0.5348* | -0.5406* |
| | (0.2041) | (0.2540) | (0.2604) |
| SPEI Share (Lag 1) | | -0.8109** | -0.8300** |
| | | (0.3189) | (0.3329) |
| SPEI Share (Lag 2) | | | -0.0928 |
| | | | (0.2677) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (18) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 194 | 194 | 194 |
| $R^2$ | 0.97369 | 0.97481 | 0.97482 |
| Within $R^2$ | 0.00872 | 0.05073 | 0.05126 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 6: Regression results for Fruits Yield on SPEI Share

| Dependent Variable: | (Log) Fruits Yield | | |
|---|---|---|---|
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI Share | 0.5624 | 0.7888** | 0.8309** |
| | (0.3438) | (0.2894) | (0.3019) |
| SPEI Share (Lag 1) | | 0.9934** | 1.132** |
| | | (0.3737) | (0.4357) |
| SPEI Share (Lag 2) | | | 0.6764 |
| | | | (0.4382) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (18) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 194 | 194 | 194 |
| $R^2$ | 0.79960 | 0.80578 | 0.80853 |
| Within $R^2$ | 0.01088 | 0.04136 | 0.05493 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

# RESULTS

Table 7: Regression results for Household Agricultural Income on SPEI Share

| Dependent Variable: | (Log) Household Agricultural Income | | |
|---|---|---|---|
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI Share | -0.3389 | -0.3282 | -0.3893 |
| | (0.4318) | (0.4687) | (0.4920) |
| SPEI Share (Lag 1) | | 0.0552 | -0.1080 |
| | | (0.7967) | (0.8750) |
| SPEI Share (Lag 2) | | | -0.8570* |
| | | | (0.4538) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (18) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 197 | 197 | 197 |
| $R^2$ | 0.71444 | 0.71445 | 0.71667 |
| Within $R^2$ | 0.00166 | 0.00170 | 0.00946 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: \*\*\*: 0.01, \*\*: 0.05, \*: 0.1*

Table 8: Regression results for Household food consumption on SPEI Share

| Dependent Variable: | (Log) Household food Consumption | | |
|---|---|---|---|
| Model: | (1) | (2) | (3) |
| *Variables* | | | |
| SPEI Share | -0.0860 | -0.1811 | -0.1932 |
| | (0.1944) | (0.2304) | (0.2334) |
| SPEI Share (Lag 1) | | -0.4673 | -0.5340* |
| | | (0.2695) | (0.2667) |
| SPEI Share (Lag 2) | | | -0.3819 |
| | | | (0.3588) |
| *Fixed-effects* | | | |
| District (11) | Yes | Yes | Yes |
| Year (20) | Yes | Yes | Yes |
| *Fit statistics* | | | |
| Observations | 220 | 220 | 220 |
| $R^2$ | 0.90574 | 0.90757 | 0.90875 |
| Within $R^2$ | 0.00073 | 0.02016 | 0.03261 |

*Clustered (District) standard-errors in parentheses*
*Signif. Codes: \*\*\*: 0.01, \*\*: 0.05, \*: 0.1*

# CONCLUSION