# Productive Assets, Child Labor, and Schooling:

## Evidence from Pastoralist Communities

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Previous version: "Does the timing of productivity shocks affect educational attainment?"
*George F. Warren Award*
*Kanematsu & Nishijima Awards*

# Motivation

- 265 million children work worldwide, with highest rates in Sub-Saharan Africa (Ortiz-Ospina, Esteban and Roser, Max, 2024)
- Poor households trade off children's schooling and work (e.g., Ravallion and Wodon, 2000)
  - Immediate income vs. future returns to education
- Child labor demand raises opportunity cost of schooling (Shah and Steinberg, 2017; Atkin, 2016)
- Focus of this study: Productive assets generate demand for child labor (Edmonds and Theoharides, 2020)

# This paper

- **Question**. Do shocks to productive assets affect child labor and educational attainment?
- **Setting**. Pastoralists in northern Kenya and southern Ethiopia
  - Livestock require child labor, especially from older children
  - Missing labor markets make production and schooling decisions non-separable
- **Empirical approach**. Household survey + 20-year history of pasture conditions
  - Estimate effects of shocks to livestock production throughout childhood for 3,748 children
  - Use household and birth-year fixed effects
  - Test asset-based mechanisms through child time use and herd dynamics

# Summary of results

- Two conflicting factors: child labor demand vs. productivity (income effects)
- Droughts increase schooling during primary school age
  - Significant herd losses reduce demand for herding labor immediately and persistently, especially for older children
  - Greater sedentarization may reinforce this effect
- Positive shocks increase schooling around school entry
  - Income gains relax liquidity constraints
  - Children are still too young to work
  - Nutrition channel is unlikely the driver

# Literature & contribution

- Child labor, opportunity costs, and human capital investment (Atkin, 2016; Aggarwal, 2018)
  - Shah and Steinberg (2017): positive wage shocks reduce schooling during school age
  - Bau et al. (2025): positive returns to early-life investment on child labor
  - **Contribution.** Show an asset-based channel: productive assets shape child labor demand
- Early-life shocks and human capital formation (e.g., Maccini and Yang, 2009; Maluccio et al., 2009; Huang and Dong, 2025)
  - Positive early-life shocks can persistently raise education (Alderman, Hoddinott, and Kinsey, 2006)
  - **Contribution.** Productive asset losses can lower child labor demand and increase schooling
- Similar mechanisms in drought-insurance helping schooling by replacing precautionary savings (goats): child labor demand in pastoralist settings (Son, 2025; Barrett et al., 2025)

# Pastoralist children

# Data: pastoralist household survey and historical NDVI

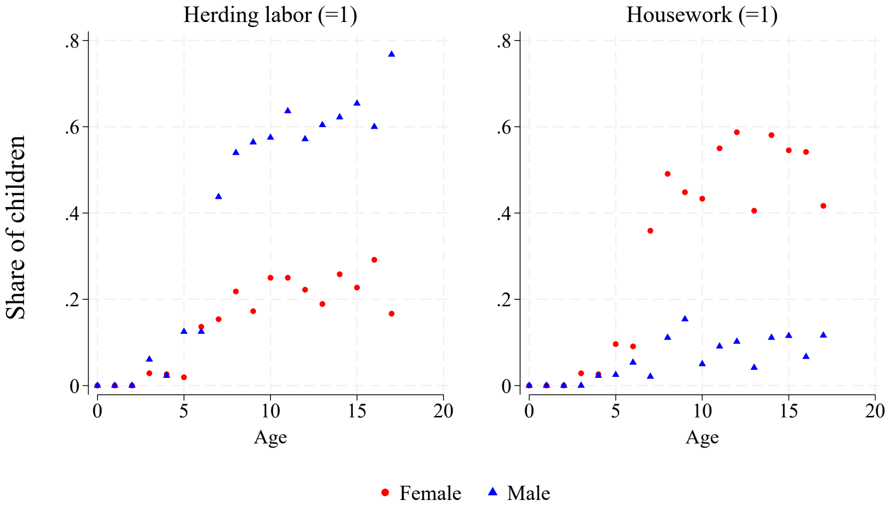
- HH survey: Pastoralists in Arid and Semi-Arid Lands relying on extensive livestock grazing Map tbl. HH- summary stat.
  - Droughts account for up to 47% of livestock losses
  - Household panel: baseline (Kenya 2009; Ethiopia 2012), follow-ups through 2015
  - Main sample: school-aged children (ages 6–20) at endline (Kenya 2020; Ethiopia 2022) Attrition rate tbl. differential attrition tbl. selective attrition tbl. joint test tbl. fertility
  - Household GPS location
- NDVI (Normalized Difference Vegetation Index) since 2000 fig.: historical dist. NDVI
  - Satellite measure of vegetation greenness
  - Highly correlated with livestock mortality and better than rainfall (Chantarat et al., 2013)
  - Plausibly exogenous: climate drives rangeland health, while overgrazing limited (Purevjav et al., 2025; Ellis and Swift, 1988; Coppock, 1993)
  - Index insurance product in this context relies on NDVI

# Context: Child labor and schooling

tbl.: outcomes tbl.: controls

- Child labor is widespread and gendered (∼70%) [next slide]
    - Older boys have high marginal product in herding
    - Work rises sharply around ages 7–10
- Livestock holdings are strongly linked to schooling
    - Herding, animal care, and trekking are physically demanding and often away from home
    - Boys and children in livestock-rich households complete less education fig: attainment
- Schooling is costly in this setting
    - 8 years primary + 4 years secondary; entry at age 6 in Kenya, 7 in Ethiopia
    - School catchment areas are 8–10 km in Borena (Kenea, 2019)
    - Very low education: <20% are in age-appropriate schooling by age 15

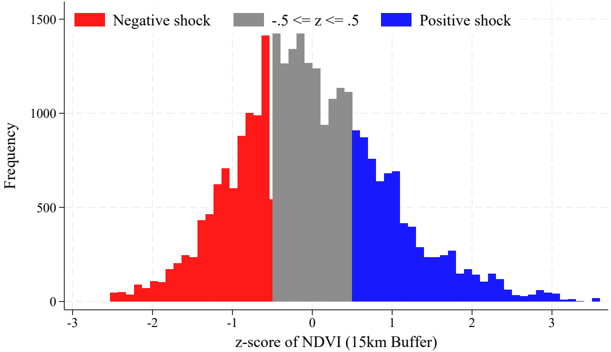
# Child labor is gendered and rises with age



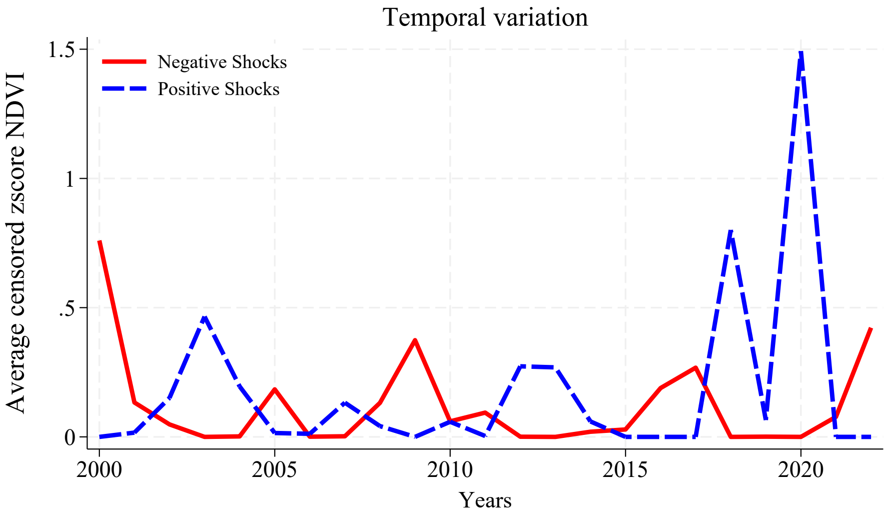
# Defining shocks to livestock production

fig: z-score over time | math def. | discussion

- Yearly average NDVI around household locations (Liao et al., 2017) migration pattern
- Shocks:= censored z-scores relative to historical distribution
  - Thresholds and buffers chosen to predict livestock losses, accounting for migration
  - Aggregated within age bins using maximum and cumulative exposure



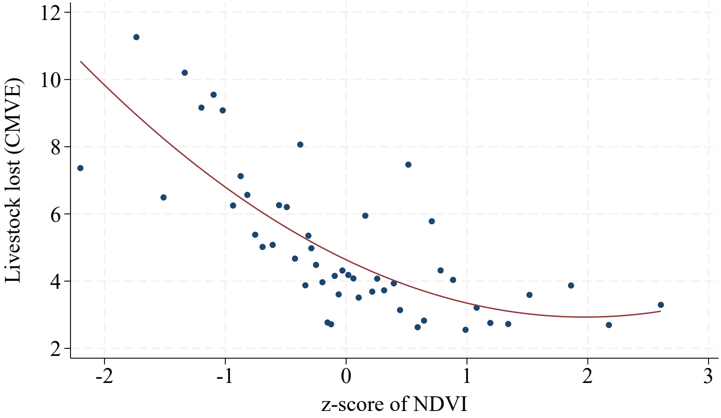
# Productivity shocks vary over time




by country
fig: spatial variation

# Negative shocks predict large livestock losses

1SD negative productivity shock is associated with 3.5 [cattle market value equivalent] loss




$\sim$ 21–23 goats/sheep, 2.1–2.3 camels fig.: livestock holdings tbl.: livestock lost

# Baseline specification

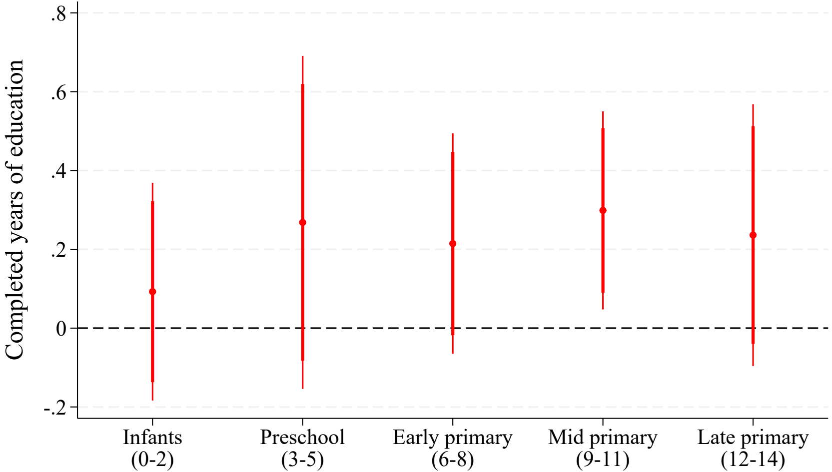
◂ Setup ◂ Conceptual framework

For child $i$ in household $h$, location $j$, born in year $t$:

$$S_{ihjt} = \sum_b \left( \zeta_b^- \theta_{h,b}^- + \zeta_b^+ \theta_{h,b}^+ \right) + \lambda_h + \phi_t + \mathbf{X}_{ih}' \beta + \varepsilon_{ihjt}$$

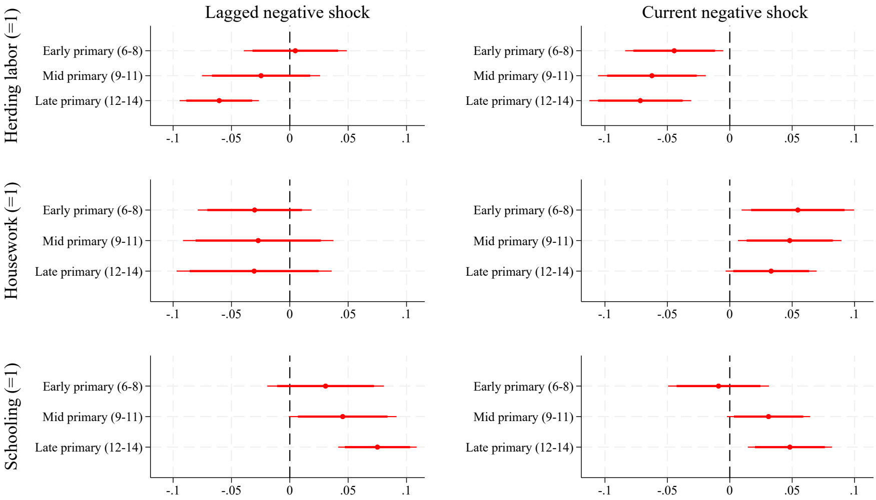
- $S_{ihjt}$: completed years of education at endline
- $\theta_{h,b}^{-/+}$: positive/negative productivity shocks during age bin $b$ $\{$Infants, Preschool, Early primary, Mid primary, Late primary$\}$ ▸ fig.: age at shock
- $\lambda_h$: household fixed effects; $\phi_t$: birth-year fixed effects
- $\mathbf{X}_{ih}$: gender and birth-order controls

# Effects of worst **negative** productivity shocks at different ages




tbl. FE  tbl. cumulative  tbl. missing  tbl. buffer

# **Droughts** reduce herding and raise schooling immediately and persistently

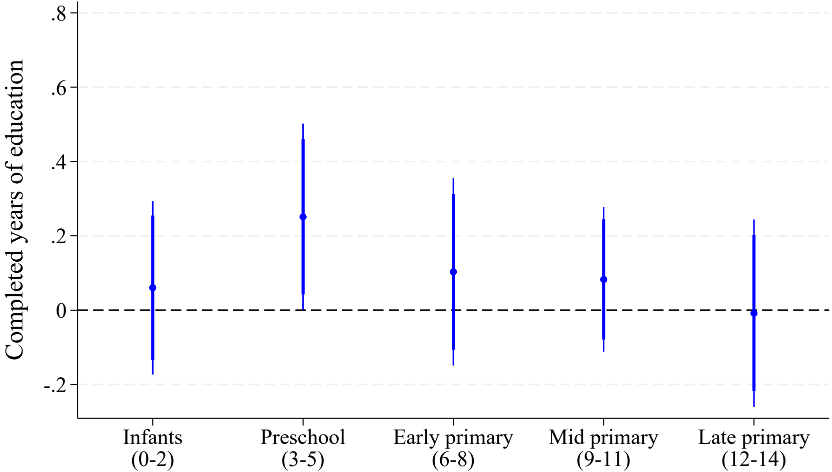



▸ male ▸ female ▸ tbl. child time use ▸ tbl. HH FE ▸ tbl. HH Cluster

# Interpreting drought effects

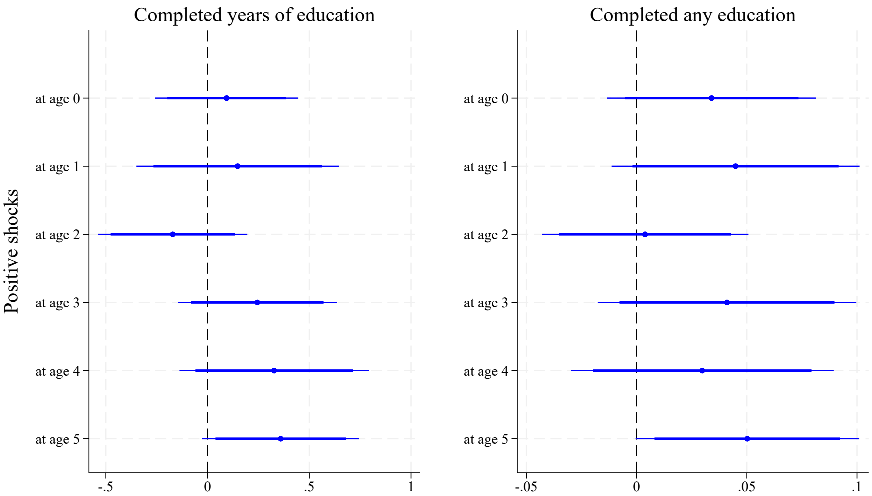
- Droughts reduce livestock assets significantly
  - Herds fall by ∼20 shoats or 2–3 large animals per 1SD shock
- Herd losses persist
  - Losses can trap households at low herd-size equilibria (Lybbert et al., 2004)
  - ... increase subsequent sedentarization (Toth, 2015) tbl: migration conflict
- Lower shadow value of child time
  - Smaller herds reduce child demand and increase schooling fig: age-app. educ. fig: by gender
  - Sedentarization further supports school attendance
- Unlike wage-channel studies (Shah and Steinberg, 2017; Atkin, 2016), productive assets shift within-household labor demand

# Effects of cumulative **positive** productivity shocks at different ages




tbl. FE tbl. best tbl. missing tbl. buffer

# **Positive** shocks concentrated on right before primary school starts




tbl. pre-school age

# Interpreting positive shocks

- Positive shocks suggestively increase milk income, but do not expand herd size (Lybbert et al., 2004; Santos and Barrett, 2019) tbl: income
- Income gains relax liquidity constraints at school entry
  - Children are still too young to work
- Null effects in the first 1,000 days, together with school meals, suggest nutrition is not the main driver
- In contrast to Bau et al. (2025), liquidity effects appear more salient than nutrition channels in this setting

# Conclusion and policy implications

- Recap
  - Droughts destroy livestock, reduce child labor demand, and increase schooling
  - Positive shocks support school entry through income effects
- External validity
  - 268 million pastoralists in Africa's drylands produce 70% of the continent's milk and meat
  - Relevant beyond pastoralists: (i) productive assets affect child labor demand (ii) labor markets are missing
- Policy implications
  - Income support can relax liquidity constraints without raising child labor demand (Edmonds and Theoharides, 2020)
  - Drought insurance may change investment behavior which could support schooling (Barrett et al., 2025)

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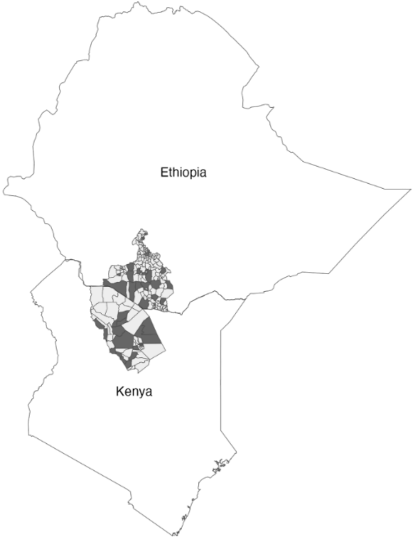
# Study sites

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# Household level summary statistics

| | Mean/SD | Min | P25 | Median | P75 | Max | Obs |
|---|---|---|---|---|---|---|---|
| Total livestock holdings (CMVE) | 22.64 | 0.00 | 4.50 | 11.08 | 26.60 | 416.95 | 1220 |
| | [32.64] | | | | | | |
| Camel holdings (CMVE) | 9.08 | 0.00 | 0.00 | 0.00 | 9.60 | 299.20 | 1220 |
| | [20.39] | | | | | | |
| Cattle holdings (CMVE) | 7.50 | 0.00 | 0.00 | 3.00 | 9.00 | 250.00 | 1220 |
| | [14.76] | | | | | | |
| Goat holdings (CMVE) | 3.26 | 0.00 | 0.64 | 1.65 | 4.20 | 63.00 | 1220 |
| | [4.58] | | | | | | |
| Sheep holdings (CMVE) | 2.79 | 0.00 | 0.00 | 0.60 | 2.85 | 77.25 | 1220 |
| | [5.95] | | | | | | |
| Livestock lost (CMVE) | 10.48 | 0.00 | 2.00 | 5.15 | 12.50 | 200.60 | 1165 |
| | [15.72] | | | | | | |
| Cash earnings (USD) | 556.97 | 0.00 | 106.01 | 255.98 | 553.67 | 10174.53 | 1152 |
| | [930.48] | | | | | | |
| Milk income (USD) | 595.50 | 0.00 | 0.00 | 124.75 | 442.21 | 11629.81 | 1152 |
| | [1313.93] | | | | | | |
| Observations | 1220 | | | | | | |

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# Attrition analysis

- At the household level
  - At the 10-year follow-up, we successfully re-interviewed 82% of baseline households (1,179 out of 1,439)
  - Households that were female-headed, had fewer adults, and did not own agricultural land were more likely to attrit from the sample (Barrett et al., 2025)
- At the child level (note: only includes those aged $\leq 9$ in Kenya and $\leq 7$ in Ethiopia)
  - Among children born in the relevant cohort at baseline, 77.3% were successfully followed up (i.e., 22.7% attrition)
  - Attrition is not differential based on the cumulative shocks
  - Older and female children were more likely to attrit, possibly due to marriage [next slide]
  - Number of children does not change by the exposure to the shocks

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# Differential attrition

| | Outcome: Attrition (=1) | |
|---|---|---|
| | (1) | (2) |
| Cumulative number of positive shocks (5km) | -0.002 | |
| | (0.027) | |
| Cumulative number of negative shocks (5km) | 0.001 | |
| | (0.027) | |
| Cumulative number of positive shocks (15km) | | 0.002 |
| | | (0.027) |
| Cumulative number of negative shocks (15km) | | -0.003 |
| | | (0.027) |
| Observations | 1493 | 1493 |

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# Selective attrition

| | Independent variable: Attrition in the endline (=1) |
|---|---|
| | (1) |
| Age | 1.81*** |
| | (.315) |
| Male (=1) | -.105* |
| | (.0547) |
| First born (=1) | .095** |
| | (.0375) |
| Second born (=1) | .0531 |
| | (.0404) |
| Third born (=1) | -.0119 |
| | (.0518) |
| 3rd | -.0119 |
| | (.0518) |
| P-value of joint F-test | 0.000 |
| N | 1774 |

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# Joint test of selective attrition at child level

| | Outcome: Attrit (=1) | |
|---|---|---|
| | (1) | (2) |
| Male (= 1) | -0.091*** | -0.070* |
| | (0.020) | (0.038) |
| Age | 0.039*** | 0.032*** |
| | (0.004) | (0.010) |
| First born (=1) | 0.005 | 0.073 |
| | (0.033) | (0.122) |
| Second born (=1) | 0.014 | 0.052 |
| | (0.028) | (0.088) |
| Third born (=1) | -0.041 | 0.025 |
| | (0.025) | (0.062) |
| F-statistics | 25.269 | 6.792 |
| p-value of joint significance | 0.000 | 0.000 |
| Household FE | | ✓ |
| Observations | 1774 | 1774 |

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# Effects of shocks on fertility

| | Outcome: Number of school-aged children at endline | |
|---|---|---|
| | (1) | (2) |
| Cumulative number of positive shocks (5km) | 0.163 | |
| | (0.130) | |
| Cumulative number of negative shocks (5km) | -0.160 | |
| | (0.130) | |
| Cumulative number of positive shocks (15km) | | 0.218 |
| | | (0.137) |
| Cumulative number of negative shocks (15km) | | -0.215 |
| | | (0.137) |
| Observations | 1493 | 1493 |

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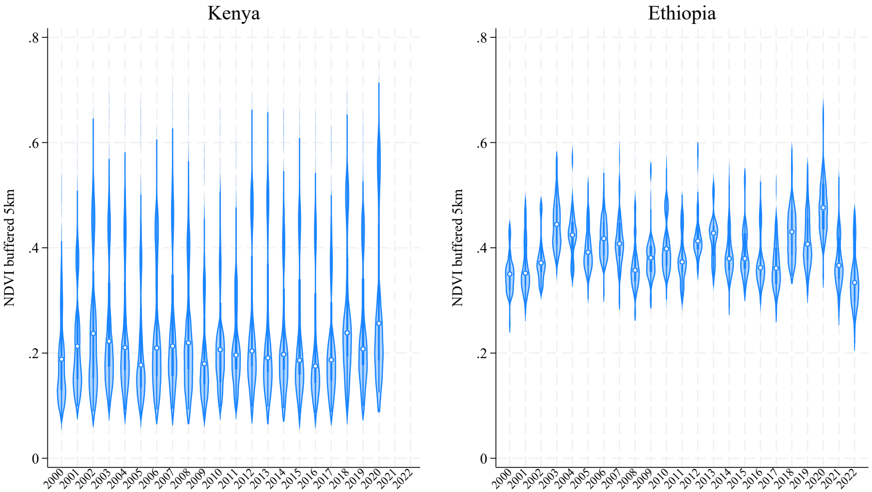
# Historical NDVI distribution since 2000

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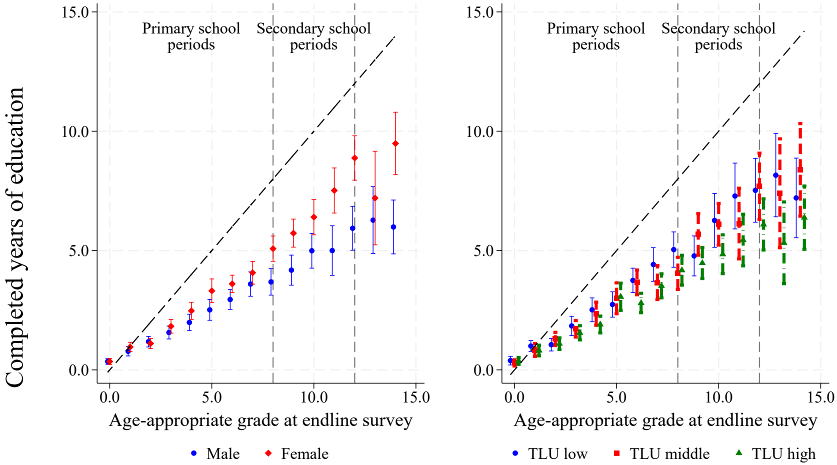
# Outcome: Completed years of education

## by age, gender, and livestock holdings

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# Summary statistics of education variables

| | (1) Full sample | | (2) Female | | (3) Male | | (4) Pairwise t-test |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean |
| ***Outcome variables*** | | | | | | | |
| Years of education | 3.29 | [3.64] | 3.59 | [3.56] | 3.04 | [3.70] | 0.56*** |
| Age appropriate education (=1) | 0.25 | [0.43] | 0.28 | [0.45] | 0.22 | [0.41] | 0.06*** |
| Educational attainment gap (yrs.) | 2.15 | [3.81] | 1.60 | [3.08] | 2.60 | [4.28] | -1.00*** |
| Currently attending school (=1) | 0.61 | [0.49] | 0.70 | [0.46] | 0.54 | [0.50] | 0.16*** |
| Observations | 3748 | | 1699 | | 2049 | | 3748 |

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# Summary statistics of control variables

| | (1) Full sample | | (2) Female | | (3) Male | | (4) Pairwise t-test |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean |
| ***Control variables*** | | | | | | | |
| Age | 12.16 | [3.80] | 11.82 | [3.62] | 12.43 | [3.93] | -0.61*** |
| Male (= 1) | 0.55 | [0.50] | 0.00 | [0.00] | 1.00 | [0.00] | -1.00 |
| First born (=1) | 0.33 | [0.47] | 0.31 | [0.46] | 0.35 | [0.48] | -0.04* |
| Second born (=1) | 0.28 | [0.45] | 0.28 | [0.45] | 0.28 | [0.45] | 0.00 |
| Third born (=1) | 0.19 | [0.39] | 0.20 | [0.40] | 0.19 | [0.39] | 0.01 |
| Fourth or more born (=1) | 0.20 | [0.40] | 0.21 | [0.41] | 0.18 | [0.39] | 0.03* |
| ***Other variables*** | | | | | | | |
| Exists siblings in the sample (=1) | 0.95 | [0.21] | 0.94 | [0.23] | 0.96 | [0.19] | -0.02* |
| # siblings in the sample (incl self). | 3.76 | [1.53] | 3.78 | [1.56] | 3.73 | [1.50] | 0.05 |
| Observations | 3748 | | 1699 | | 2049 | | 3748 |

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# Migration pattern

- Liao et al. (2017) investigated spatial rangeland utilization patterns in the Borana zone based on continuous GPS-tracking of cattle movement over seven months
  1. restrictive herding models: primarily involves linear movement between basecamp and the principal foraging areas
  2. semi-extensive herding models: involves the use of both base and satellite camps
  3. extensive herding models: founded on a distributed network of satellite camps
- The mean distance of the movement was $<$10km from the base camp with a longer left tail

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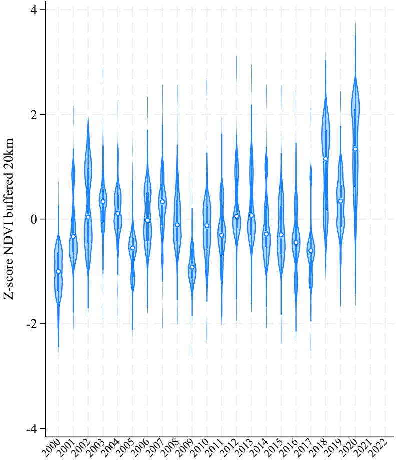
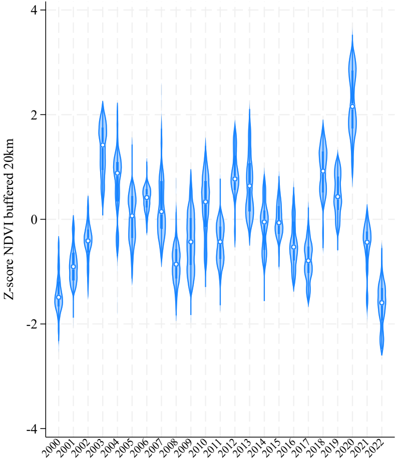
# Average z-score over time

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# Definition of productivity shocks

- Yearly average NDVI buffered around 20km for each household location (Liao et al., 2017)

- **"censored z-score NDVI"**: standard deviations, truncated $[-1, 1]$, relative to community historical distribution in absolute value

$$\begin{cases} \theta^{-}_{hjy} = |NDVIz^{-}_{hjy}| \text{ if } NDVIz_{hjy} < -1 \\ \text{[Comparison group]} = 0 \text{ if } NDVIz_{hjy} \in [-1, 1] \\ \theta^{+}_{hjy} = NDVIz^{+}_{hjy} \text{ if } NDVIz_{hjy} > 1 \end{cases} \tag{1}$$

- $NDVIz^{-/+}$ : z-score value of NDVI relative to community $j$ if it is negative (positive)

- $NDVInorm$: indicator variable taking 0 for NDVIz within $[-1, 1]$

- $>$1 ($<$-1) SD positive NDVI values impacts assuming no impact in [-1,1] interval

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# Definition of shocks – discussion

- NDVI buffered around 5km robust to trekking strategies and seasonality (Liao et al., 2017)
- Preferable because ...
  - more severe shocks to have greater impacts while allowing asymmetry between good and bad
  - robust to endogenous livestock choice (rel. to community historical dist.)
  - clearly exogenous and comparable in sds magnitude across all households
- Not following Shah and Steinberg (2017), Kaur (2019), and Jayachandran (2006) because ...
  - "too short a time series" to claim extreme deviations from people's expectations in our setting
  - do not want to impose a constant number of shocks on each household

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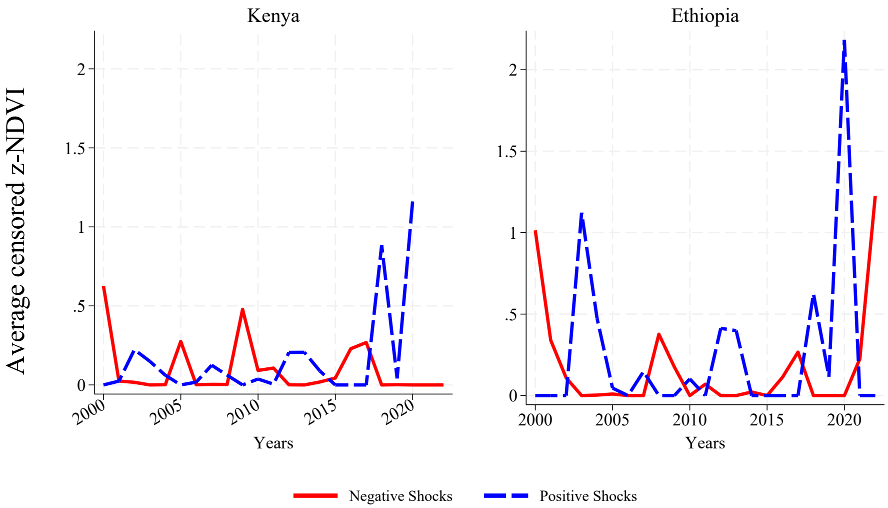
# Temporal variation of shocks

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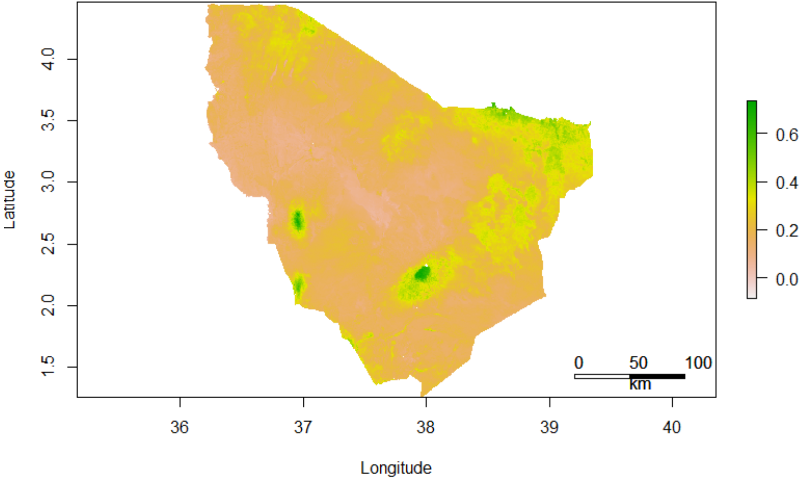
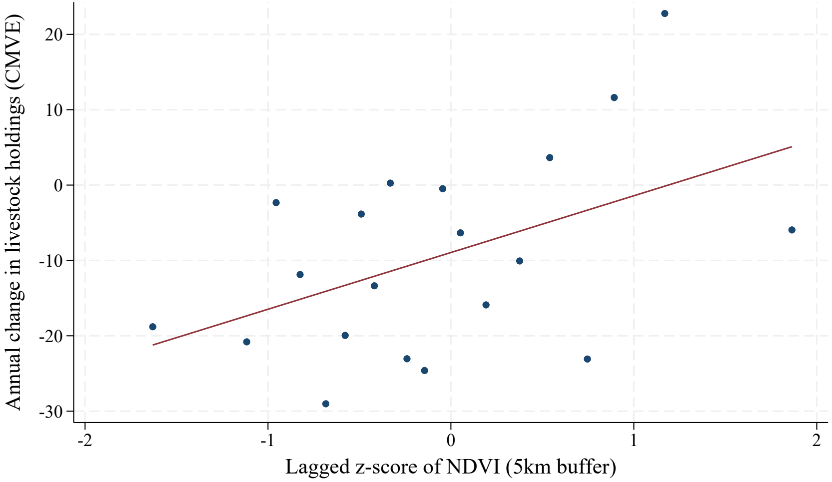
# Spatial variation of NDVI in Marsabit district

## 2009 Kenya droughts



# Annual change in livestock holdings and lagged z-score NDVI

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# Effects of productivity shocks on livestock loss

| | Livestock lost due to droughts (CMVE) | | Livetock lost (CMVE) | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Positive productivity shock | 0.136 | 0.228 | -0.898*** | -1.129** |
| | (0.311) | (0.428) | (0.310) | (0.484) |
| Negative productivity shock | -0.851*** | -1.897*** | 3.384*** | 3.786*** |
| | (0.184) | (0.432) | (0.773) | (0.912) |
| Household fixed effects | | ✓ | | ✓ |
| Adjusted R-squared | 0.002 | -0.031 | 0.031 | 0.119 |
| Observations | 1365 | 1365 | 7836 | 7836 |

Back

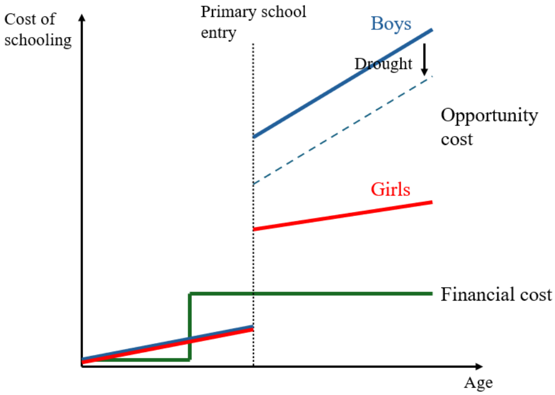
# Set up

- Non-separable agricultural households with children and livestock (Son, 2025)
- Consumption side
  - Standard concave utility function: consumption and education (static, for simplicity)
  - Households supply child labor: child time can be spent on education and labor
  - No outside labor market, and credit and insurance market are missing
- Production side
  - Households demand child labor (assuming adults supply inelastically)
  - Production function depends on child labor, varying by type and livestock size, with older boys having a higher marginal product of labor

Back

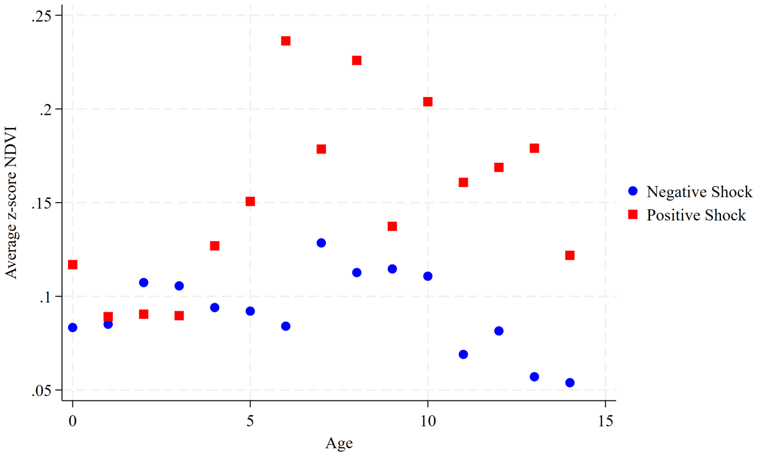
# Conceptual framework

- HHs w/ a child and livestock: schooling vs. labor
  - Limited outside labor market (∼10%)
  - Older boys involved in livestock management
  - No access to financial markets
- Heterogeneous financial and opportunity costs of schooling by age and gender
- Exogenous shocks to livestock production affect older boys most




◂ Back

# Variation of age at shocks




Back

# Effects of cumulative **positive** productivity shocks at different ages

| | Completed years of education at endline | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| ***Postive productivity shocks*** | | | | |
| Infants (0-2) | 0.060 | 0.069 | 0.056 | -0.052 |
| | (0.114) | (0.124) | (0.114) | (0.106) |
| Preschoolers (3-5) | 0.251** | 0.253** | 0.265** | 0.148** |
| | (0.123) | (0.122) | (0.120) | (0.064) |
| Early primary (6-8) | 0.103 | 0.132 | 0.108 | 0.021 |
| | (0.124) | (0.135) | (0.121) | (0.069) |
| Mid primary (9-11) | 0.083 | 0.091 | 0.044 | -0.028 |
| | (0.095) | (0.106) | (0.068) | (0.055) |
| Late primary (12-14) | -0.008 | 0.003 | 0.042 | -0.113 |
| | (0.124) | (0.129) | (0.088) | (0.087) |
| Controls | ✓ | | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ | |
| Community fixed effects | | | | ✓ |
| F-statistic for positive shocks | 1.159 | 1.161 | 2.177 | 2.259 |
| P-value for F-test for positive shocks | 0.351 | 0.350 | 0.082 | 0.073 |
| Observations | 3748 | 3748 | 3748 | 3748 |

Back

# Effects of best **positive** productivity shocks at different ages

| | Completed years of education at endline | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| ***Postive productivity shocks*** | | | | |
| Infants (0-2 yrs. old) | 0.065 | 0.078 | 0.044 | -0.122 |
| | (0.137) | (0.146) | (0.137) | (0.138) |
| Preschoolers (3-5 yrs. old) | 0.223 | 0.213 | 0.239* | 0.184* |
| | (0.135) | (0.127) | (0.136) | (0.095) |
| Early primary school (6-8 yrs. old) | 0.164 | 0.179 | 0.149 | 0.097 |
| | (0.163) | (0.169) | (0.152) | (0.087) |
| Mid-primary school (9-11 yrs. old) | 0.135 | 0.120 | 0.051 | 0.008 |
| | (0.094) | (0.095) | (0.071) | (0.076) |
| Late primary school (12-14 yrs. old) | 0.079 | 0.082 | 0.091 | -0.037 |
| | (0.159) | (0.161) | (0.112) | (0.116) |
| Controls | ✓ | | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ | |
| Community fixed effects | | | | ✓ |
| F-statistic for positive shocks | 0.773 | 0.782 | 0.974 | 1.792 |
| P-value for F-test for positive shocks | 0.576 | 0.570 | 0.449 | 0.144 |
| Observations | 3748 | 3748 | 3748 | 3748 |

▸ Back

# Effects of cumulative **positive** productivity shocks: missing values

| | Outcome: Completed years of education at endline | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full sample | | Samples older than time of the shocks | | | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| ***Postive productivity shocks*** | | | | | | | | | | |
| Infants (0-2) | 0.060 | -0.052 | 0.026 | -0.058 | 0.074 | -0.042 | 0.077 | 0.017 | -0.219 | -0.118 |
| | (0.114) | (0.106) | (0.105) | (0.096) | (0.128) | (0.116) | (0.204) | (0.155) | (0.338) | (0.171) |
| Preschoolers (3-5) | 0.251** | 0.148** | 0.217** | 0.148** | 0.298*** | 0.172** | 0.343** | 0.192** | 0.051 | 0.433*** |
| | (0.123) | (0.064) | (0.094) | (0.062) | (0.094) | (0.068) | (0.168) | (0.090) | (0.500) | (0.144) |
| Early primary (6-8) | 0.103 | 0.021 | | | 0.046 | 0.006 | 0.066 | -0.067 | 0.153 | 0.052 |
| | (0.124) | (0.069) | | | (0.104) | (0.065) | (0.193) | (0.092) | (0.384) | (0.125) |
| Mid primary (9-11) | 0.083 | -0.028 | | | | | 0.102 | -0.034 | -0.042 | -0.190 |
| | (0.095) | (0.055) | | | | | (0.155) | (0.082) | (0.488) | (0.154) |
| Late primary (12-14) | -0.008 | -0.113 | | | | | | | -0.166 | -0.145 |
| | (0.124) | (0.087) | | | | | | | (0.476) | (0.095) |
| Negative shocks | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Controls | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Household fixed effects | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | |
| F-statistic for positive shocks | 1.159 | 2.259 | 2.847 | 3.982 | 3.627 | 4.139 | 1.924 | 2.776 | 0.215 | 3.196 |
| P-value for F-test for positive shocks | 0.351 | 0.073 | 0.073 | 0.029 | 0.024 | 0.014 | 0.131 | 0.044 | 0.953 | 0.019 |
| Observations | 3748 | 3748 | 3748 | 3748 | 3279 | 3279 | 2281 | 2281 | 1377 | 1377 |

Back

# Effects of cumulative **positive** productivity shocks: different buffer sizes

| | Outcome: Completed years of education at endline | | | |
|---|---|---|---|---|
| | 5km | 10km | 15km | 20km |
| | (1) | (2) | (3) | (4) |
| ***Positive productivity shocks*** | | | | |
| Infants (0-2) | 0.060 | -0.021 | -0.139 | -0.133 |
| | (0.114) | (0.096) | (0.127) | (0.154) |
| Preschoolers (3-5) | 0.251** | 0.167 | 0.090 | 0.128 |
| | (0.123) | (0.132) | (0.147) | (0.163) |
| Early primary (6-8) | 0.103 | 0.137 | 0.091 | 0.100 |
| | (0.124) | (0.117) | (0.133) | (0.159) |
| Mid primary (9-11) | 0.083 | 0.153 | 0.057 | 0.092 |
| | (0.095) | (0.112) | (0.131) | (0.141) |
| Late primary (12-14) | -0.008 | 0.018 | -0.067 | -0.083 |
| | (0.124) | (0.128) | (0.126) | (0.126) |
| Controls | ✓ | ✓ | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | ✓ | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ | ✓ |
| F-statistic for negative shocks | 0.675 | 0.571 | 0.622 | 0.690 |
| P-value for F-test for negative shocks | 0.646 | 0.722 | 0.684 | 0.635 |
| Observations | 3748 | 3748 | 3748 | 3748 |

Back

# Effects of worst **negative** productivity shocks at different ages

| | Completed years of education at endline | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| ***Negative productivity shocks*** | | | | |
| Infants (0-2) | 0.093 | 0.105 | -0.003 | 0.092 |
| | (0.135) | (0.147) | (0.147) | (0.112) |
| Preschoolers (3-5) | 0.268 | 0.283 | 0.280 | 0.220 |
| | (0.207) | (0.222) | (0.220) | (0.138) |
| Early primary (6-8) | 0.215 | 0.235 | 0.221 | 0.175 |
| | (0.137) | (0.152) | (0.142) | (0.119) |
| Mid primary (9-11) | 0.299** | 0.301** | 0.227* | 0.190 |
| | (0.123) | (0.122) | (0.117) | (0.119) |
| Late primary (12-14) | 0.236 | 0.260 | 0.277* | 0.086 |
| | (0.163) | (0.168) | (0.142) | (0.154) |
| Controls | ✓ | | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ | |
| Community fixed effects | | | | ✓ |
| F-statistic for negative shocks | 2.028 | 2.199 | 1.586 | 1.839 |
| P-value for F-test for negative shocks | 0.102 | 0.080 | 0.193 | 0.134 |
| Observations | 3748 | 3748 | 3748 | 3748 |

Back

# Effects of cumulative **negative** productivity shocks at different ages

| | Completed years of education at endline | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| ***Negative productivity shocks*** | | | | |
| Infants (0-2) | 0.138 | 0.163 | 0.081 | 0.073 |
| | (0.132) | (0.141) | (0.131) | (0.079) |
| Preschoolers (3-5) | 0.260 | 0.294 | 0.291 | 0.165 |
| | (0.199) | (0.214) | (0.194) | (0.111) |
| Early primary (6-8) | 0.206 | 0.236 | 0.218 | 0.129 |
| | (0.178) | (0.194) | (0.172) | (0.124) |
| Mid primary (9-11) | 0.210 | 0.221 | 0.190 | 0.075 |
| | (0.161) | (0.175) | (0.149) | (0.122) |
| Late primary (12-14) | 0.145 | 0.164 | 0.217* | -0.030 |
| | (0.141) | (0.144) | (0.125) | (0.135) |
| Controls | ✓ | | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ | |
| Community fixed effects | | | | ✓ |
| F-statistic for negative shocks | 0.622 | 0.778 | 1.257 | 0.627 |
| P-value for F-test for negative shocks | 0.684 | 0.573 | 0.307 | 0.680 |
| Observations | 3748 | 3748 | 3748 | 3748 |

▸ Back

# Effects of worst **negative** productivity shocks: missing values

| | Outcome: Completed years of education at endline | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Full sample | | Samples older than time of the shocks | | | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| ***Negative productivity shocks*** | | | | | | | | | | |
| Infants (0-2) | 0.093 | 0.092 | 0.020 | 0.062 | -0.027 | 0.064 | -0.048 | 0.142 | 0.324 | 0.098 |
| | (0.135) | (0.112) | (0.148) | (0.109) | (0.169) | (0.122) | (0.334) | (0.205) | (0.444) | (0.301) |
| Preschoolers (3-5) | 0.268 | 0.220 | 0.171 | 0.211 | 0.100 | 0.173 | 0.098 | 0.174 | 0.421 | 0.373 |
| | (0.207) | (0.138) | (0.188) | (0.134) | (0.207) | (0.148) | (0.317) | (0.216) | (0.639) | (0.299) |
| Early primary (6-8) | 0.215 | 0.175 | | | 0.061 | 0.156 | 0.054 | 0.152 | 0.429 | 0.181 |
| | (0.137) | (0.119) | | | (0.155) | (0.117) | (0.280) | (0.213) | (0.496) | (0.246) |
| Mid primary (9-11) | 0.299** | 0.190 | | | | | 0.069 | 0.137 | 0.488 | 0.273 |
| | (0.123) | (0.119) | | | | | (0.241) | (0.153) | (0.692) | (0.280) |
| Late primary (12-14) | 0.236 | 0.086 | | | | | | | 0.253 | 0.319 |
| | (0.163) | (0.154) | | | | | | | (0.537) | (0.242) |
| Negative shocks | | | | | | | | | | |
| Controls | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Household fixed effects | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | |
| F-statistic for positive shocks | | | | | | | | | | |
| P-value for F-test for positive shocks | | | | | | | | | | |
| Observations | 3748 | 3748 | 3748 | 3748 | 3279 | 3279 | 2281 | 2281 | 1377 | 1377 |

Back

# Effects of cumulative **negative** productivity shocks: different buffer sizes

| | Outcome: Completed years of education at endline | | | |
|---|---|---|---|---|
| | 5km | 10km | 15km | 20km |
| | (1) | (2) | (3) | (4) |
| ***Negative productivity shocks*** | | | | |
| Infants (0-2) | 0.079 | 0.173 | 0.093 | 0.008 |
| | (0.172) | (0.157) | (0.135) | (0.140) |
| Preschoolers (3-5) | 0.311 | 0.265 | 0.268 | 0.298** |
| | (0.205) | (0.201) | (0.207) | (0.136) |
| Early primary (6-8) | 0.169 | 0.162 | 0.215 | 0.162 |
| | (0.174) | (0.161) | (0.137) | (0.130) |
| Mid primary (9-11) | 0.125 | 0.195 | 0.299** | 0.311* |
| | (0.134) | (0.153) | (0.123) | (0.156) |
| Late primary (12-14) | 0.181 | 0.197 | 0.236 | 0.244 |
| | (0.178) | (0.163) | (0.163) | (0.156) |
| Controls | ✓ | ✓ | ✓ | ✓ |
| Birth-year fixed effects | ✓ | ✓ | ✓ | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ | ✓ |
| F-statistic for negative shocks | 0.745 | 0.780 | 2.028 | 2.197 |
| P-value for F-test for negative shocks | 0.596 | 0.571 | 0.102 | 0.080 |
| Observations | 3748 | 3748 | 3748 | 3748 |

Back

# Effects of productivity shocks on cash income

| | Cash earnings (USD) | Milk income (USD) |
|---|---|---|
| | (1) | (2) |
| Panel A: Positive productivity shocks | | |
| Positive shock | 6.147 | 45.979 |
| | (52.572) | (60.031) |
| Lag positive shock | 11.019 | 60.500 |
| | (37.252) | (52.634) |
| Observations | 7562 | 7555 |

Panel B: Negative productivity shocks

| | Cash earnings (USD) | Milk income (USD) |
|---|---|---|
| | (1) | (2) |
| Negative shock | -61.052 | 160.163 |
| | (39.032) | (190.428) |
| Lag negative shock | 73.269* | -121.827 |
| | (36.215) | (100.760) |
| Observations | 7562 | 7555 |

Back

# Effects of productivity shocks on migration

| | Household fully-settled (=1) | |
|---|---|---|
| | (1) | (2) |
| Negative productivity shock | -0.087** | -0.085** |
| | (0.034) | (0.035) |
| Positive productivity shock | 0.024 | 0.038 |
| | (0.024) | (0.026) |
| Lagged negative productivity shock | | 0.090* |
| | | (0.046) |
| Lagged positive productivity shock | | -0.067 |
| | | (0.047) |
| Household fixed effects | ✓ | ✓ |
| Adjusted R-squared | 0.453 | 0.452 |
| Observations | 7001 | 6873 |

Back

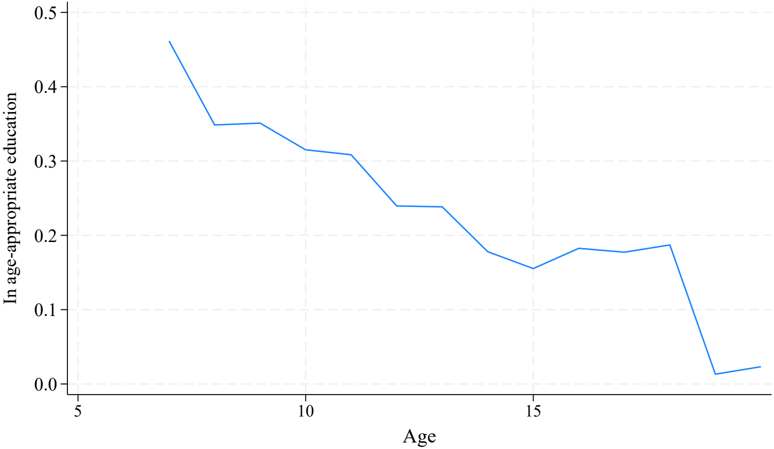
# Conflict

- Concern: Negative shocks increase contemporaneous migration and raiding, raising income and thus education
- This is unlikely:
  - Raiding-related livestock loss is rare: 0.034 events/year ($\sim$ 1% of total losses) (Jensen et al., 2025)
  - Jensen et al. (2025) find increased risk of *being* raided, not raiding
- Unfortunately no data on raiding activity, but stolen livestock must be sold quickly—otherwise it increases child labor and reduces schooling, which is against the interpretation

Back

# In age-appropriate education over age

## Cross-sectional evidence

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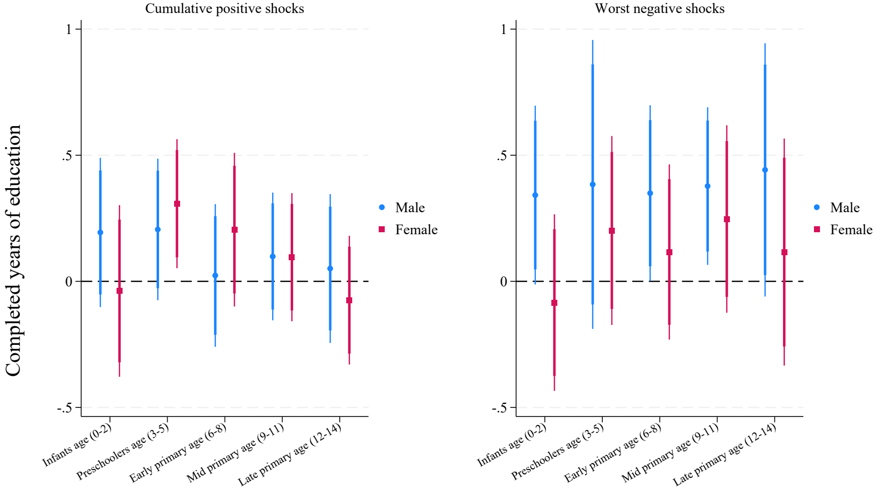
# Heterogeneity by gender



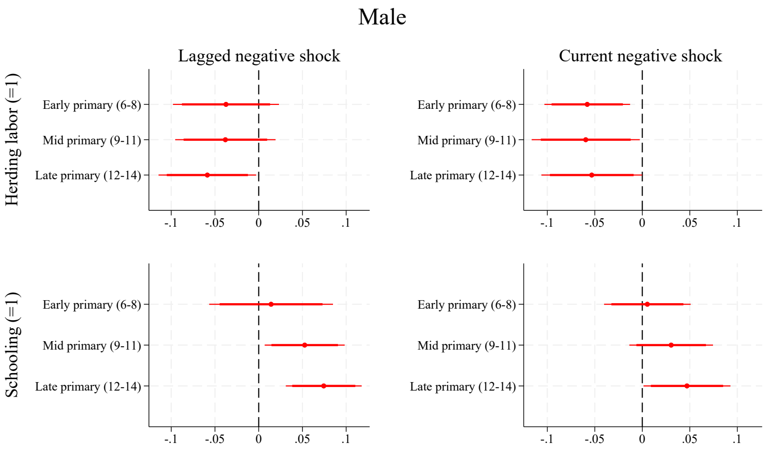

Back

# **Positive** shocks concentrated on right before primary school starts

| | Completed years of education | Completed any schooling |
|---|---|---|
| | (1) | (2) |
| at age 0 | 0.094 | 0.034 |
| | (0.172) | (0.023) |
| at age 1 | 0.148 | 0.045 |
| | (0.244) | (0.028) |
| at age 2 | -0.171 | 0.004 |
| | (0.180) | (0.023) |
| at age 3 | 0.245 | 0.041 |
| | (0.192) | (0.029) |
| at age 4 | 0.327 | 0.030 |
| | (0.228) | (0.029) |
| at age 5 | 0.359* | 0.050* |
| | (0.189) | (0.025) |
| Observations | 3748 | 3748 |

Back

# Negative shocks decrease herding and increases schooling for older male

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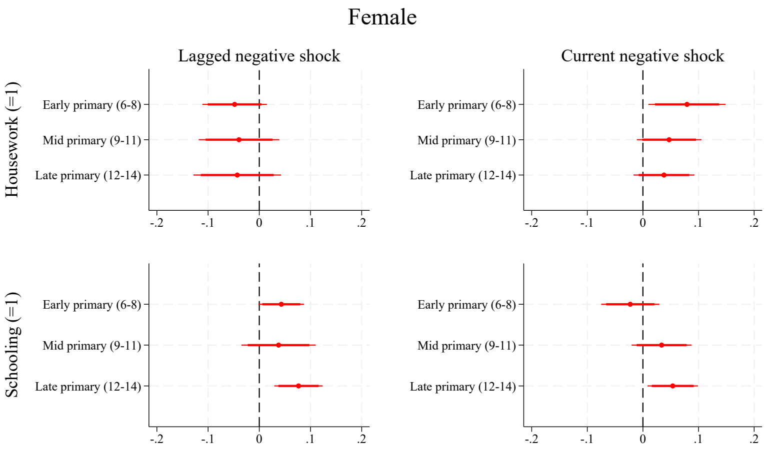
# Negative shocks decrease increases schooling for older female




Back

# Effects of productivity shocks on child time use at different stages

| | Herding labor (=1) | Housework (=1) | Any schooling (=1) |
|---|---|---|---|
| | (1) | (2) | (3) |
| ***Reference category: age 6-8*** | | | |
| Lagged negative shock | 0.005 | -0.030 | 0.031 |
| | (0.022) | (0.024) | (0.024) |
| Binned age=9-11 × Lagged negative shock | -0.029 | 0.003 | 0.015 |
| | (0.028) | (0.025) | (0.029) |
| Binned age=12-14 × Lagged negative shock | -0.065*** | -0.000 | 0.044 |
| | (0.023) | (0.030) | (0.028) |
| Current negative shock | -0.045** | 0.055** | -0.009 |
| | (0.019) | (0.022) | (0.020) |
| Binned age=9-11 × Current negative shock | -0.018 | -0.007 | 0.040* |
| | (0.017) | (0.018) | (0.023) |
| Binned age=12-14 × Current negative shock | -0.027* | -0.021 | 0.057** |
| | (0.015) | (0.017) | (0.021) |
| Controls | ✓ | ✓ | ✓ |
| Community fixed effects | ✓ | ✓ | ✓ |
| Round fixed effects | ✓ | ✓ | ✓ |
| Lagged coef. for age 9-11 | -0.025 | -0.027 | 0.045 |
| $p$-value for age 9-11 | 0.328 | 0.398 | 0.054 |
| Lagged coef. for age 12-14 | -0.060 | -0.031 | 0.075 |
| $p$-value for age 12-14 | 0.001 | 0.355 | 0.000 |
| Current coef. for age 9-11 | -0.062 | 0.048 | 0.031 |
| $p$-value for age 9-11 | 0.006 | 0.025 | 0.067 |
| Current coef. for age 12-14 | -0.072 | 0.033 | 0.048 |
| $p$-value for age 12-14 | 0.001 | 0.074 | 0.007 |
| Observations | 18587 | 18587 | 18587 |

Back

# Effects of productivity shocks on child time use: HH FE

| | Herding labor (=1) | Housework (=1) | Any schooling (=1) |
|---|---|---|---|
| | (1) | (2) | (3) |
| ***Reference category: age 6-8*** | | | |
| Lagged negative shock | 0.014 | -0.038 | 0.025 |
| | (0.025) | (0.028) | (0.023) |
| Binned age=9-11 × Lagged negative shock | -0.028 | 0.013 | 0.003 |
| | (0.027) | (0.027) | (0.027) |
| Binned age=12-14 × Lagged negative shock | -0.071*** | 0.007 | 0.049 |
| | (0.024) | (0.031) | (0.029) |
| Current negative shock | -0.035 | 0.058** | -0.017 |
| | (0.022) | (0.024) | (0.021) |
| Binned age=9-11 × Current negative shock | -0.027* | -0.006 | 0.042* |
| | (0.016) | (0.018) | (0.023) |
| Binned age=12-14 × Current negative shock | -0.025 | -0.022 | 0.059** |
| | (0.017) | (0.018) | (0.022) |
| Controls | ✓ | ✓ | ✓ |
| Household fixed effects | ✓ | ✓ | ✓ |
| Round fixed effects | ✓ | ✓ | ✓ |
| Lagged coef. for age 9-11 | -0.014 | -0.025 | 0.027 |
| *p*-value for age 9-11 | 0.584 | 0.474 | 0.144 |
| Lagged coef. for age 12-14 | -0.057 | -0.031 | 0.073 |
| *p*-value for age 12-14 | 0.005 | 0.391 | 0.000 |
| Current coef. for age 9-11 | -0.062 | 0.052 | 0.025 |
| *p*-value for age 9-11 | 0.013 | 0.025 | 0.114 |
| Current coef. for age 12-14 | -0.060 | 0.037 | 0.042 |
| *p*-value for age 12-14 | 0.012 | 0.057 | 0.018 |
| Observations | 18587 | 18587 | 18587 |

Back

# Effects of productivity shocks on child time use: Cluster SE at HH

| | Herding labor (=1) | Housework (=1) | Any schooling (=1) |
|---|---|---|---|
| | (1) | (2) | (3) |
| ***Reference category: age 6-8*** | | | |
| Lagged negative shock | 0.005 | -0.030* | 0.031* |
| | (0.016) | (0.017) | (0.017) |
| Binned age=9-11 × Lagged negative shock | -0.029 | 0.003 | 0.015 |
| | (0.021) | (0.022) | (0.021) |
| Binned age=12-14 × Lagged negative shock | -0.065*** | -0.000 | 0.044** |
| | (0.021) | (0.022) | (0.020) |
| Current negative shock | -0.045*** | 0.055*** | -0.009 |
| | (0.014) | (0.015) | (0.015) |
| Binned age=9-11 × Current negative shock | -0.018 | -0.007 | 0.040** |
| | (0.017) | (0.018) | (0.019) |
| Binned age=12-14 × Current negative shock | -0.027 | -0.021 | 0.057*** |
| | (0.019) | (0.017) | (0.019) |
| Controls | ✓ | ✓ | ✓ |
| Community fixed effects | ✓ | ✓ | ✓ |
| Round fixed effects | ✓ | ✓ | ✓ |
| Lagged coef. for age 9-11 | -0.025 | -0.027 | 0.045 |
| *p*-value for age 9-11 | 0.168 | 0.138 | 0.006 |
| Lagged coef. for age 12-14 | -0.060 | -0.031 | 0.075 |
| *p*-value for age 12-14 | 0.001 | 0.088 | 0.000 |
| Current coef. for age 9-11 | -0.062 | 0.048 | 0.031 |
| *p*-value for age 9-11 | 0.000 | 0.001 | 0.023 |
| Current coef. for age 12-14 | -0.072 | 0.033 | 0.048 |
| *p*-value for age 12-14 | 0.000 | 0.022 | 0.000 |
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