

Productive Assets, Child Labor, and Schooling:

Evidence from Pastoralist Communities

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SOLE@Denvor, 2nd May

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)
- Productive assets generate within-household 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 are productive assets and require child labor, especially boys' herding labor
 - Missing labor markets make production and schooling decisions non-separable
- **Empirical approach.** Household survey + 20-year history of pasture conditions
 - Estimate effects of productivity shocks throughout childhood for 3,748 children
 - Use household and birth-year fixed effects
 - Test asset-based mechanisms through child time use, herd losses, and migration dynamics

Summary of results

- Shocks affect schooling through two channels: child labor demand and income
- Droughts increase schooling during primary school age
 - Herd losses reduce demand for herding labor, 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

Literature & contribution

- Child labor, opportunity costs, and human capital investment (Atkin, 2016; Aggarwal, 2018)
 - Shah and Steinberg (2017): 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: 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 (Chantararat et al., 2013)
 - Plausibly exogenous: **climate drives rangeland health**, while overgrazing limited (Purevjav et al., 2025; Ellis and Swift, 1988; Coppock, 1993)

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

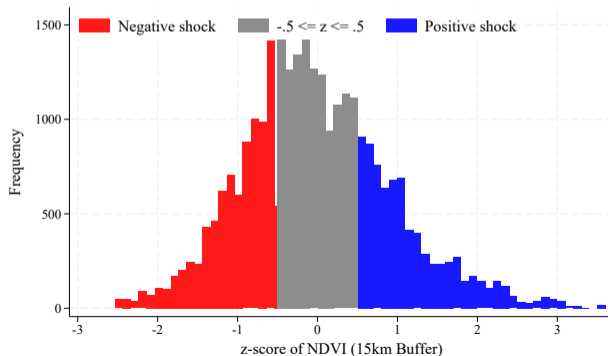
Child labor is gendered and rises with age



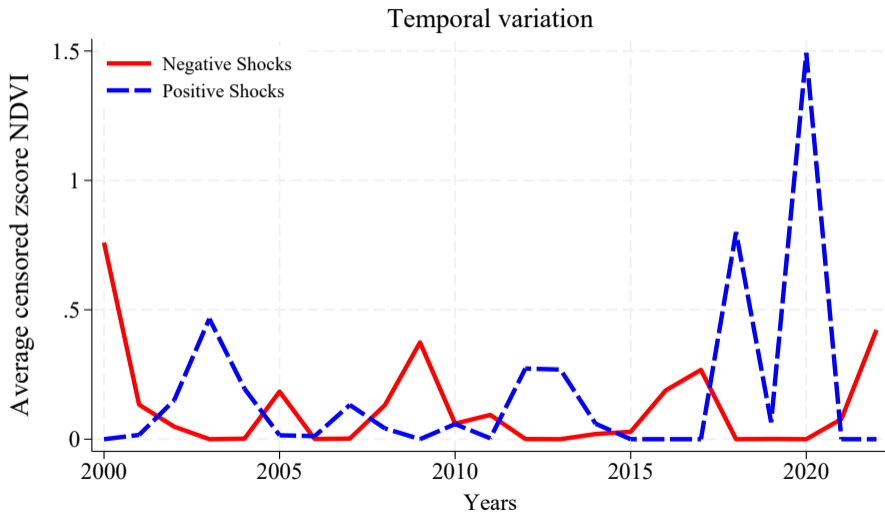
Defining shocks to livestock production

[◀ 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

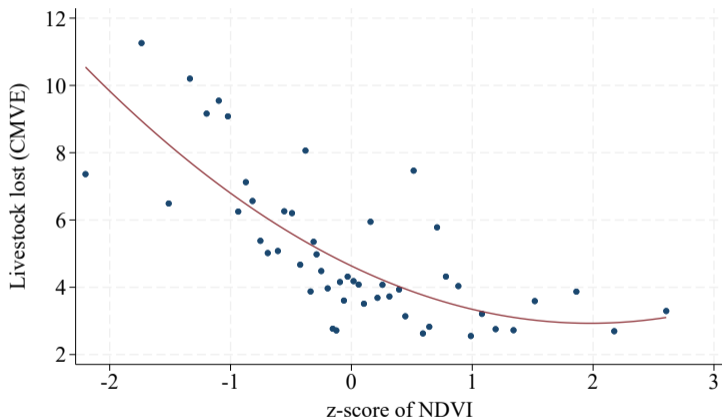


Productivity shocks vary over time



Negative shocks predict large livestock losses

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



~ 21–23 goats/sheep, 2.1–2.3 camels

▶ fig.: livestock holdings

▶ tbl.: livestock lost

Baseline specification

◀ Setup

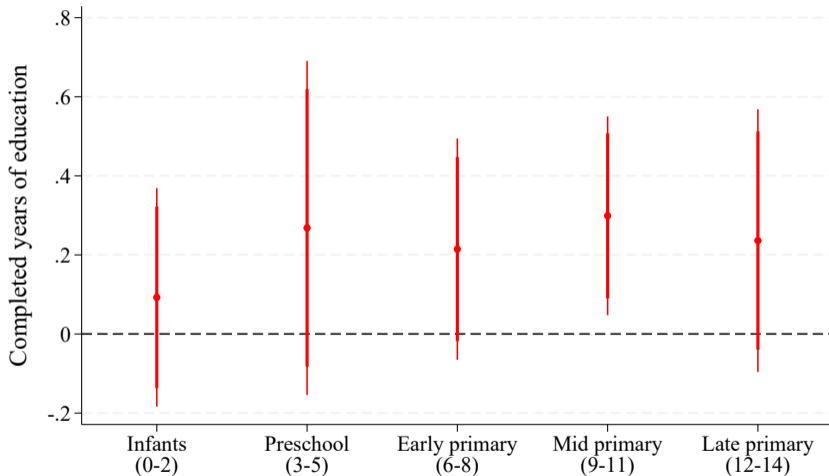
◀ Conceptual framework

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
- λ_h : household fixed effects; ϕ_t : birth-year fixed effects
- \mathbf{X}_{ih} : gender and birth-order controls

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



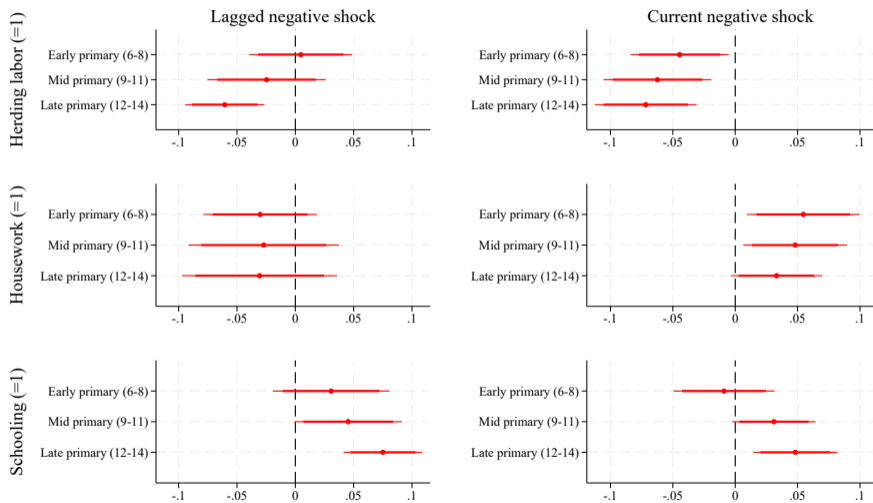
▶ tbl. FE

▶ tbl. cumulative

▶ tbl. missing

▶ tbl. buffer

Droughts reduce herding and raise schooling immediately and persistently



▶ male

▶ female

▶ tbl. child time use

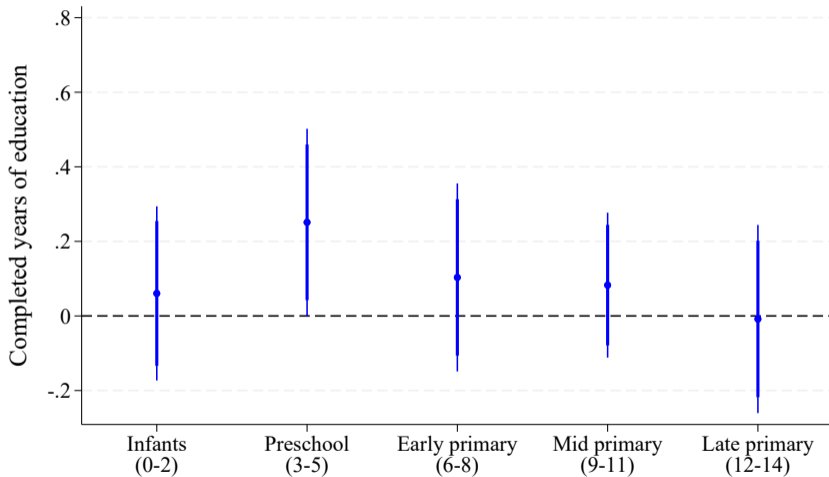
▶ tbl. HH FE

▶ tbl. HH Cluster

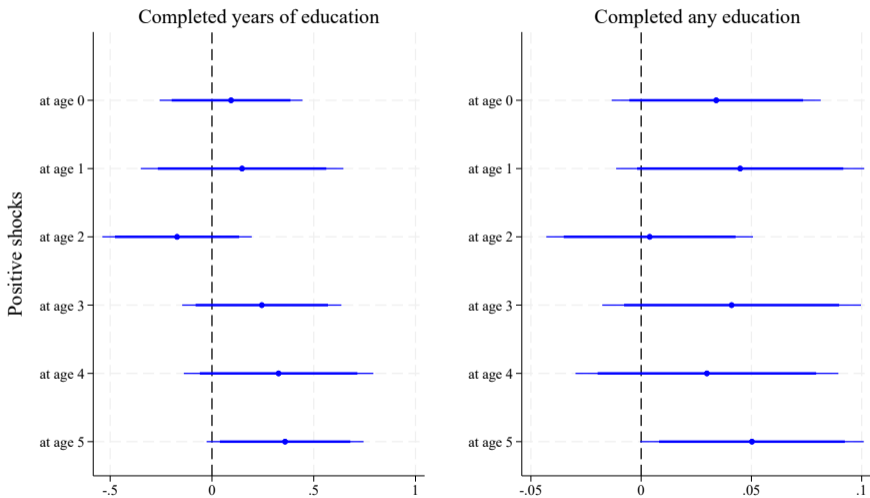
Interpreting drought effects

- 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



Positive shocks concentrated on right before primary school starts








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 here

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 pastoralism: productive assets can shape child labor demand when 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



Household level summary statistics

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

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 ≤ 9 in Kenya and ≤ 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

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

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

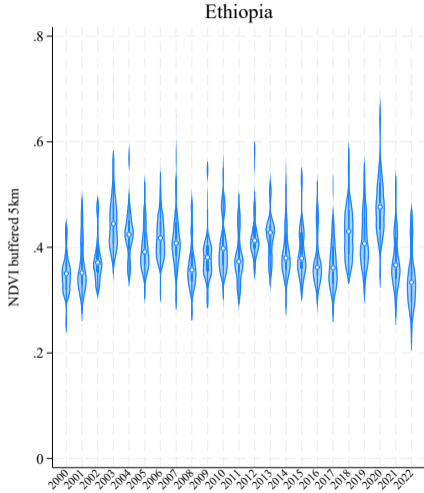
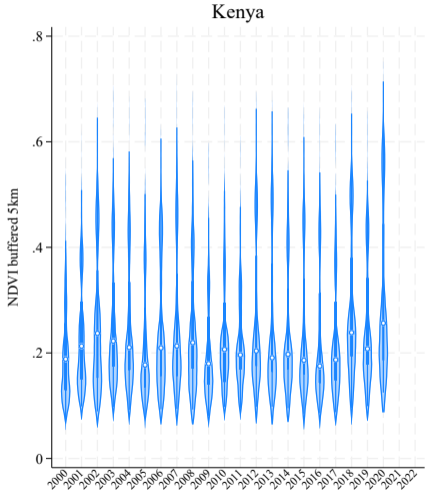
Joint test of selective attrition at child level

	Outcome: Attrit (=1)	
	(1)	(2)
Male (= 1)	-0.091*** (0.020)	-0.070* (0.038)
Age	0.039*** (0.004)	0.032*** (0.010)
First born (=1)	0.005 (0.033)	0.073 (0.122)
Second born (=1)	0.014 (0.028)	0.052 (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

Effects of shocks on fertility

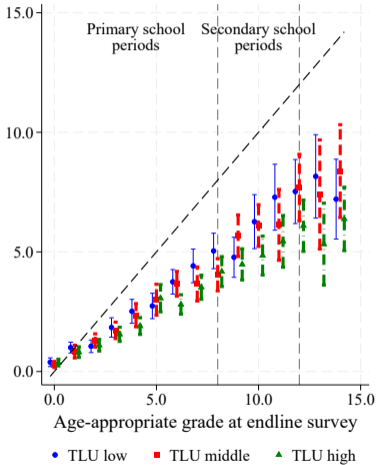
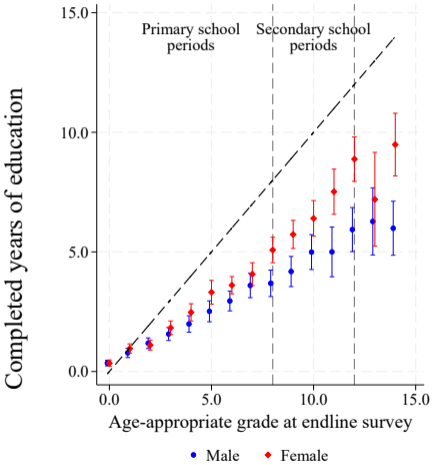
	Outcome: Number of school-aged children at endline	
	(1)	(2)
Cumulative number of positive shocks (5km)	0.163 (0.130)	
Cumulative number of negative shocks (5km)	-0.160 (0.130)	
Cumulative number of positive shocks (15km)		0.218 (0.137)
Cumulative number of negative shocks (15km)		-0.215 (0.137)
Observations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

Historical NDVI distribution since 2000



Outcome: Completed years of education

by age, gender, and livestock holdings



Summary statistics of education variables

	(1)		(2)		(3)		(4)
	Full sample		Female		Male		Pairwise t-test
	Mean	SD	Mean	SD	Mean	SD	Mean
<i>Outcome variables</i>							
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

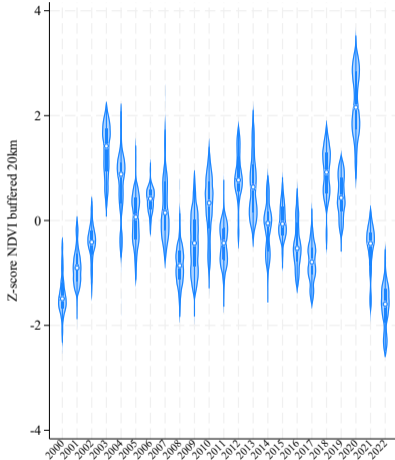
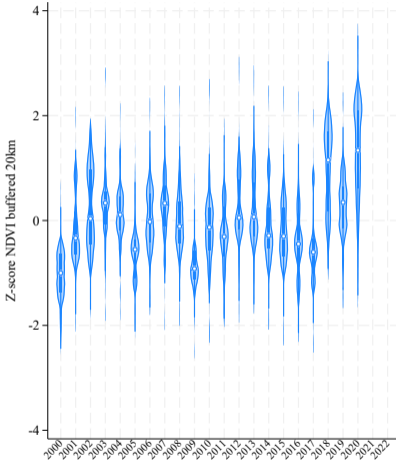
Summary statistics of control variables

	(1)		(2)		(3)		(4)
	Full sample		Female		Male		Pairwise t-test
	Mean	SD	Mean	SD	Mean	SD	Mean
<i>Control variables</i>							
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*
<i>Other variables</i>							
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

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 $<10\text{km}$ from the base camp with a longer left tail

Average z-score over time



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

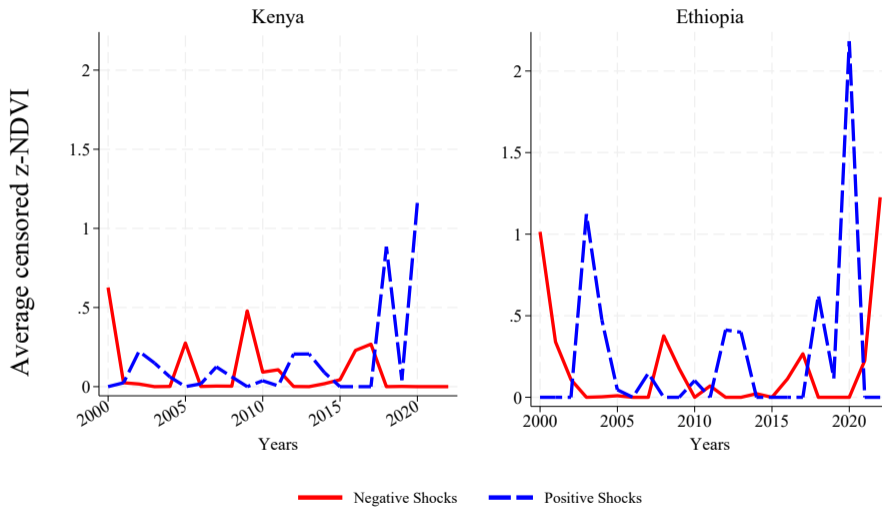
$$\begin{cases} \theta_{h_j y}^- = |NDVIz_{h_j y}^-| & \text{if } NDVIz_{h_j y} < -1 \\ [\text{Comparison group}] = 0 & \text{if } NDVIz_{h_j y} \in [-1, 1] \\ \theta_{h_j y}^+ = NDVIz_{h_j y}^+ & \text{if } NDVIz_{h_j y} > 1 \end{cases} \quad (1)$$

- $NDVIz^{-/+}$: z-score value of NDVI relative to community j if it is negative (positive)
- $NDVI_{norm}$: indicator variable taking 0 for $NDVIz$ within $[-1, 1]$
- >1 (<-1) SD positive NDVI values impacts assuming no impact in $[-1,1]$ interval

Definition of shocks – discussion

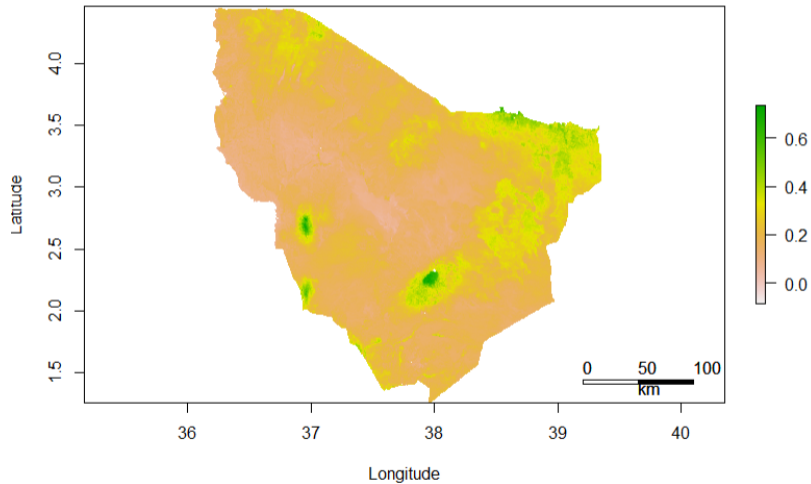
- NDVI buffered around 5km robust to trekking strategies and seasonality (Liao et al., 2017)
- Preferable because ...
 - more severe shocks to have greater impacts while allowing asymmetry between good and bad
 - robust to endogenous livestock choice (rel. to community historical dist.)
 - clearly exogenous 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

Temporal variation of shocks

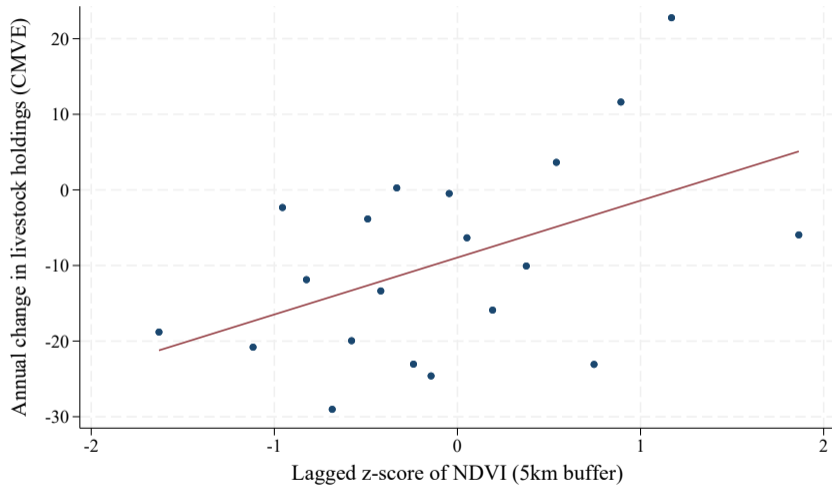


Spatial variation of NDVI in Marsabit district

2009 Kenya droughts



Annual change in livestock holdings and lagged z-score NDVI



Effects of productivity shocks on livestock loss

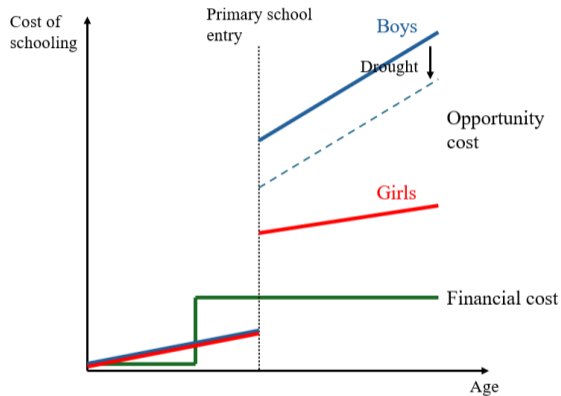
	Livestock lost due to droughts (CMVE)		Livestock lost (CMVE)	
	(1)	(2)	(3)	(4)
Positive productivity shock	0.136 (0.311)	0.228 (0.428)	-0.898*** (0.310)	-1.129** (0.484)
Negative productivity shock	-0.851*** (0.184)	-1.897*** (0.432)	3.384*** (0.773)	3.786*** (0.912)
Household fixed effects		✓		✓
Adjusted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

Set up

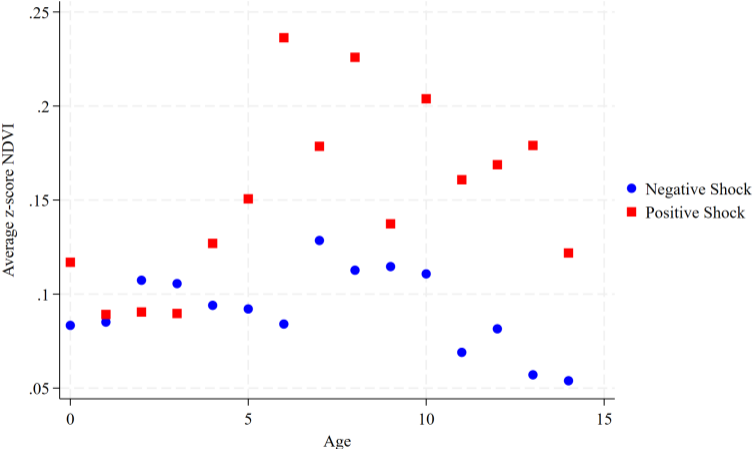
- Non-separable agricultural households with children and livestock (Son, 2025)
- Consumption side
 - Standard concave utility function: consumption and education (static, for simplicity)
 - Households supply child labor: **child time can be spent on education and labor**
 - **No outside labor market**, 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**

Conceptual framework

- HHs w/ a child and livestock: schooling vs. labor
 - Limited outside labor market ($\sim 10\%$)
 - 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



Variation of age at shocks



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

	Completed years of education at endline			
	(1)	(2)	(3)	(4)
<i>Positive productivity shocks</i>				
Infants (0-2)	0.060 (0.114)	0.069 (0.124)	0.056 (0.114)	-0.052 (0.106)
Preschoolers (3-5)	0.251** (0.123)	0.253** (0.122)	0.265** (0.120)	0.148** (0.064)
Early primary (6-8)	0.103 (0.124)	0.132 (0.135)	0.108 (0.121)	0.021 (0.069)
Mid primary (9-11)	0.083 (0.095)	0.091 (0.106)	0.044 (0.068)	-0.028 (0.055)
Late primary (12-14)	-0.008 (0.124)	0.003 (0.129)	0.042 (0.088)	-0.113 (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

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

	Completed years of education at endline			
	(1)	(2)	(3)	(4)
<i>Positive productivity shocks</i>				
Infants (0-2 yrs. old)	0.065 (0.137)	0.078 (0.146)	0.044 (0.137)	-0.122 (0.138)
Preschoolers (3-5 yrs. old)	0.223 (0.135)	0.213 (0.127)	0.239* (0.136)	0.184* (0.095)
Early primary school (6-8 yrs. old)	0.164 (0.163)	0.179 (0.169)	0.149 (0.152)	0.097 (0.087)
Mid-primary school (9-11 yrs. old)	0.135 (0.094)	0.120 (0.095)	0.051 (0.071)	0.008 (0.076)
Late primary school (12-14 yrs. old)	0.079 (0.159)	0.082 (0.161)	0.091 (0.112)	-0.037 (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

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)
<i>Positive productivity shocks</i>										
Infants (0-2)	0.060 (0.114)	-0.052 (0.106)	0.026 (0.105)	-0.058 (0.096)	0.074 (0.128)	-0.042 (0.116)	0.077 (0.204)	0.017 (0.155)	-0.219 (0.338)	-0.118 (0.171)
Preschoolers (3-5)	0.251** (0.123)	0.148** (0.064)	0.217** (0.094)	0.148** (0.062)	0.298*** (0.094)	0.172** (0.068)	0.343** (0.168)	0.192** (0.090)	0.051 (0.500)	0.433*** (0.144)
Early primary (6-8)	0.103 (0.124)	0.021 (0.069)			0.046 (0.104)	0.006 (0.065)	0.066 (0.193)	-0.067 (0.092)	0.153 (0.384)	0.052 (0.125)
Mid primary (9-11)	0.083 (0.095)	-0.028 (0.055)					0.102 (0.155)	-0.034 (0.082)	-0.042 (0.488)	-0.190 (0.154)
Late primary (12-14)	-0.008 (0.124)	-0.113 (0.087)							-0.166 (0.476)	-0.145 (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

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

	Outcome: Completed years of education at endline			
	5km	10km	15km	20km
	(1)	(2)	(3)	(4)
<i>Positive productivity shocks</i>				
Infants (0-2)	0.060 (0.114)	-0.021 (0.096)	-0.139 (0.127)	-0.133 (0.154)
Preschoolers (3-5)	0.251** (0.123)	0.167 (0.132)	0.090 (0.147)	0.128 (0.163)
Early primary (6-8)	0.103 (0.124)	0.137 (0.117)	0.091 (0.133)	0.100 (0.159)
Mid primary (9-11)	0.083 (0.095)	0.153 (0.112)	0.057 (0.131)	0.092 (0.141)
Late primary (12-14)	-0.008 (0.124)	0.018 (0.128)	-0.067 (0.126)	-0.083 (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

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

	Completed years of education at endline			
	(1)	(2)	(3)	(4)
<i>Negative productivity shocks</i>				
Infants (0-2)	0.093 (0.135)	0.105 (0.147)	-0.003 (0.147)	0.092 (0.112)
Preschoolers (3-5)	0.268 (0.207)	0.283 (0.222)	0.280 (0.220)	0.220 (0.138)
Early primary (6-8)	0.215 (0.137)	0.235 (0.152)	0.221 (0.142)	0.175 (0.119)
Mid primary (9-11)	0.299** (0.123)	0.301** (0.122)	0.227* (0.117)	0.190 (0.119)
Late primary (12-14)	0.236 (0.163)	0.260 (0.168)	0.277* (0.142)	0.086 (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

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

	Completed years of education at endline			
	(1)	(2)	(3)	(4)
<i>Negative productivity shocks</i>				
Infants (0-2)	0.138 (0.132)	0.163 (0.141)	0.081 (0.131)	0.073 (0.079)
Preschoolers (3-5)	0.260 (0.199)	0.294 (0.214)	0.291 (0.194)	0.165 (0.111)
Early primary (6-8)	0.206 (0.178)	0.236 (0.194)	0.218 (0.172)	0.129 (0.124)
Mid primary (9-11)	0.210 (0.161)	0.221 (0.175)	0.190 (0.149)	0.075 (0.122)
Late primary (12-14)	0.145 (0.141)	0.164 (0.144)	0.217* (0.125)	-0.030 (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

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)
<i>Negative productivity shocks</i>										
Infants (0-2)	0.093 (0.135)	0.092 (0.112)	0.020 (0.148)	0.062 (0.109)	-0.027 (0.169)	0.064 (0.122)	-0.048 (0.334)	0.142 (0.205)	0.324 (0.444)	0.098 (0.301)
Preschoolers (3-5)	0.268 (0.207)	0.220 (0.138)	0.171 (0.188)	0.211 (0.134)	0.100 (0.207)	0.173 (0.148)	0.098 (0.317)	0.174 (0.216)	0.421 (0.639)	0.373 (0.299)
Early primary (6-8)	0.215 (0.137)	0.175 (0.119)			0.061 (0.155)	0.156 (0.117)	0.054 (0.280)	0.152 (0.213)	0.429 (0.496)	0.181 (0.246)
Mid primary (9-11)	0.299** (0.123)	0.190 (0.119)					0.069 (0.241)	0.137 (0.153)	0.488 (0.692)	0.273 (0.280)
Late primary (12-14)	0.236 (0.163)	0.086 (0.154)							0.253 (0.537)	0.319 (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

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

	Outcome: Completed years of education at endline			
	5km	10km	15km	20km
	(1)	(2)	(3)	(4)
<i>Negative productivity shocks</i>				
Infants (0-2)	0.079 (0.172)	0.173 (0.157)	0.093 (0.135)	0.008 (0.140)
Preschoolers (3-5)	0.311 (0.205)	0.265 (0.201)	0.268 (0.207)	0.298** (0.136)
Early primary (6-8)	0.169 (0.174)	0.162 (0.161)	0.215 (0.137)	0.162 (0.130)
Mid primary (9-11)	0.125 (0.134)	0.195 (0.153)	0.299** (0.123)	0.311* (0.156)
Late primary (12-14)	0.181 (0.178)	0.197 (0.163)	0.236 (0.163)	0.244 (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

Effects of productivity shocks on cash income

	Cash earnings (USD)	Milk income (USD)
	(1)	(2)
Panel A: Positive productivity shocks		
Positive shock	6.147 (52.572)	45.979 (60.031)
Lag positive shock	11.019 (37.252)	60.500 (52.634)
Observations	7562	7555
Panel B: Negative productivity shocks		
	Cash earnings (USD)	Milk income (USD)
	(1)	(2)
Negative shock	-61.052 (39.032)	160.163 (190.428)
Lag negative shock	73.269* (36.215)	-121.827 (100.760)
Observations	7562	7555

Effects of productivity shocks on migration

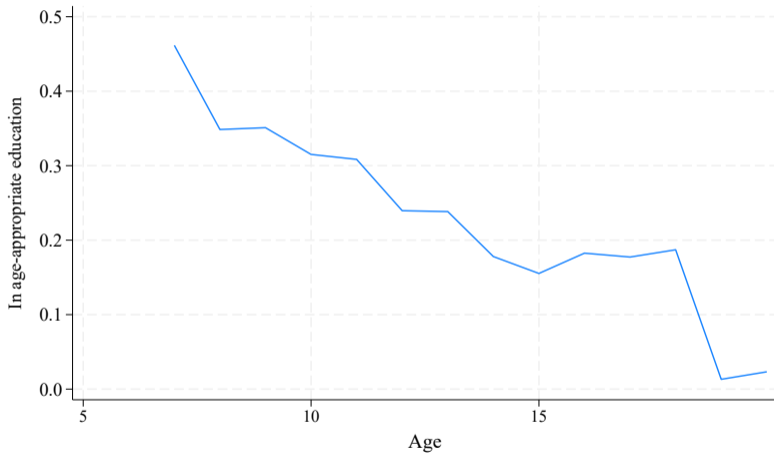
	Household fully-settled (=1)	
	(1)	(2)
Negative productivity shock	-0.087** (0.034)	-0.085** (0.035)
Positive productivity shock	0.024 (0.024)	0.038 (0.026)
Lagged negative productivity shock		0.090* (0.046)
Lagged positive productivity shock		-0.067 (0.047)
Household fixed effects	✓	✓
Adjusted R-squared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

Conflict

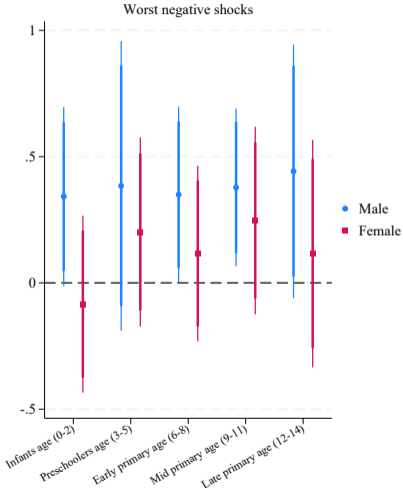
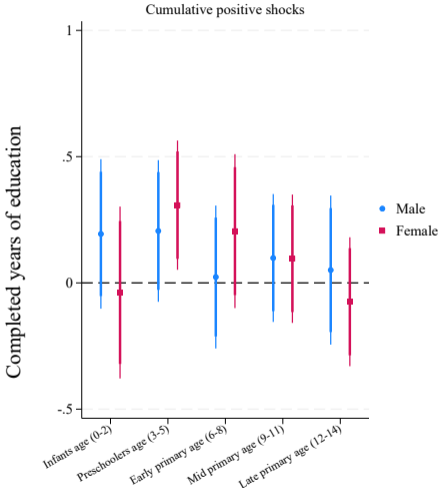
- Concern: Negative shocks increase contemporaneous migration and raiding, raising income and thus education
- This is unlikely:
 - Raiding-related livestock loss is rare: 0.034 events/year ($\sim 1\%$ of total losses) (Jensen et al., 2025)
 - Jensen et al. (2025) find increased risk of *being* raided, 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

In age-appropriate education over age

Cross-sectional evidence



Heterogeneity by gender

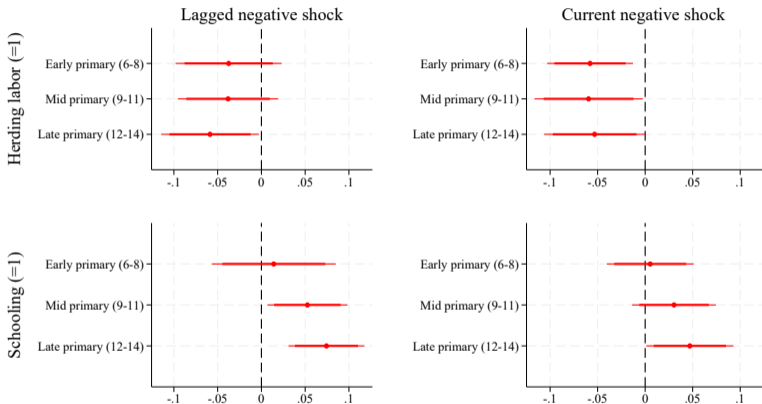


Positive shocks concentrated on right before primary school starts

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

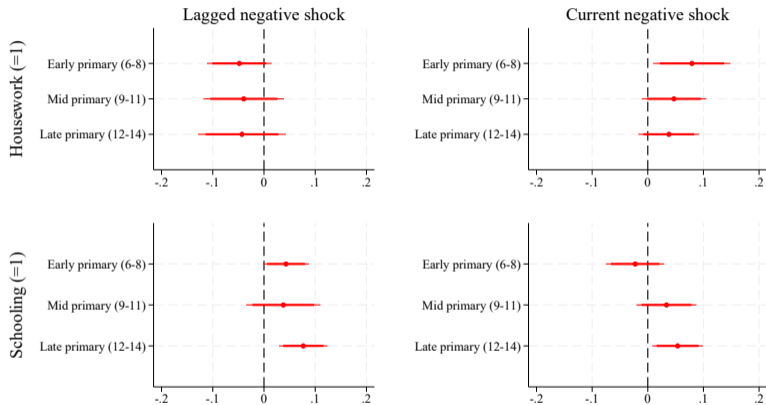
Negative shocks decrease herding and increases schooling for older male

Male



Negative shocks decrease increases schooling for older female

Female



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 (0.022)	-0.030 (0.024)	0.031 (0.024)
Binned age=9-11 × Lagged negative shock	-0.029 (0.028)	0.003 (0.025)	0.015 (0.029)
Binned age=12-14 × Lagged negative shock	-0.065*** (0.023)	-0.000 (0.030)	0.044 (0.028)
Current negative shock	-0.045** (0.019)	0.055** (0.022)	-0.009 (0.020)
Binned age=9-11 × Current negative shock	-0.018 (0.017)	-0.007 (0.018)	0.040* (0.023)
Binned age=12-14 × Current negative shock	-0.027* (0.015)	-0.021 (0.017)	0.057** (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

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 (0.025)	-0.038 (0.028)	0.025 (0.023)
Binned age=9-11 × Lagged negative shock	-0.028 (0.027)	0.013 (0.027)	0.003 (0.027)
Binned age=12-14 × Lagged negative shock	-0.071*** (0.024)	0.007 (0.031)	0.049 (0.029)
Current negative shock	-0.035 (0.022)	0.058** (0.024)	-0.017 (0.021)
Binned age=9-11 × Current negative shock	-0.027* (0.016)	-0.006 (0.018)	0.042* (0.023)
Binned age=12-14 × Current negative shock	-0.025 (0.017)	-0.022 (0.018)	0.059** (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

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 (0.016)	-0.030* (0.017)	0.031* (0.017)
Binned age=9-11 × Lagged negative shock	-0.029 (0.021)	0.003 (0.022)	0.015 (0.021)
Binned age=12-14 × Lagged negative shock	-0.065*** (0.021)	-0.000 (0.022)	0.044** (0.020)
Current negative shock	-0.045*** (0.014)	0.055*** (0.015)	-0.009 (0.015)
Binned age=9-11 × Current negative shock	-0.018 (0.017)	-0.007 (0.018)	0.040** (0.019)
Binned age=12-14 × Current negative shock	-0.027 (0.019)	-0.021 (0.017)	0.057*** (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
Observations	18587	18587	18587