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Sophie and the locust curse: Effects of locust plague on human capital accumulation

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Abstract

We investigate the impact of locust swarm invasions on human capital accumulation using data from Burkina Faso, emphasizing short-, medium-, and long-term effects. Using geo-coded data, we find that locust outbreaks reduce school enrollment of the affected cohorts in the short term, decrease their cognitive performance and educational attainment in the medium term, and lower adult incomes in the long run. Crop losses, rising food prices, and use of child labor during the locust crisis drive these effects. Early locust control proves to be a highly cost-effective way to promote education, costing just \$7.63 per additional year of schooling.

JEL classification. D70, O10, O50, Z10

Keywords. Locust swarms; Human capital accumulation; School enrollment; Cognitive skills; Labor market; Burkina Faso.

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1 Introduction

Human capital accumulation is essential for socio-economic development (Becker et al., 1990; Glewwe, 2002). However, in many regions, vulnerability to natural disasters and harsh environmental conditions hinder skill acquisition, lower productivity, undermine human capital formation, and reinforce poverty cycles (Andrabi et al., 2023; Shah & Steinberg, 2020). The problem is particularly acute in Africa, where 30–70% of the population lacks formal education, a stark contrast to 0.2% in the United States and 4.2% in China. This deficit in human capital significantly impedes progress and poses major obstacles to sustainable development across the continent.

Among the many environmental challenges in Africa, insect plagues—exacerbated by climate change—are especially damaging to human capital accumulation (Salih et al., 2020). Insects such as tsetse flies and Anopheles mosquitoes threaten public health by transmitting diseases, while agricultural pests like locusts, worms, aphids, and caterpillars devastate crops (Alsan, 2015; Depetris-Chauvin & Weil, 2018). For communities heavily dependent on agriculture, these outbreaks result in food shortages, lower household incomes, and reduced consumption. As a result, families are often forced to cut back on educational investments. The lack of effective disaster response and resource mismanagement further hinder efforts to address these issues, perpetuating underdevelopment.

This study examines the long-term effects of the 2004 desert locust invasion in Burkina Faso on human capital accumulation. Triggered by unusually heavy rainfall in 2003–2004, the locust upsurge led to the formation of massive swarms that swept across Mauritania, Niger, Mali, and eventually Burkina Faso. The invasion inflicted severe damage on crops and pastureland, resulting in widespread food shortages, declining household incomes, and reduced investments in education and health (Brader et al., 2006). The 2004 locust invasion in Burkina Faso also inspired the novel “Sophie and the Locust Curse,” which highlights community resilience in the face of disaster. While the story offers hope, the real-life impact of the locust swarms was devastating, disrupting the livelihoods and educational prospects of countless families across the region.

We treat the 2004 locust invasion as an exogenous shock, as swarm formation originated

externally through gregarization in neighboring countries. The invasion’s timing and spatial distribution were primarily determined by wind patterns transporting swarms from the Sahara Desert into Burkina Faso. This exogenous nature ensures that locust presence is uncorrelated with local socio-economic conditions influencing educational outcomes.

Our analysis integrates three data sources: the Burkinabe Response to Improve Girls’ Chances to Succeed (BRIGHT) and the Harmonized Survey on Household Living Standards (EHCVM 2018/19) datasets with locust swarm location and timing data from the Desert Locust Information Service (DLIS). Employing a household fixed-effects difference-in-differences (DID) approach, we compare educational outcomes between siblings aged 5–8 (exposed during critical enrollment years) and their younger/unborn siblings (unexposed controls) within the same households. Results show exposed children had 5.2 percentage point lower school enrollment rates ($p < 0.01$) and 0.089 SD lower cognitive test scores. Projections suggest these deficits translate to 11–14% reduced formal employment probability and 7–9% lower adult wages. Effects were concentrated in vulnerable households—those with illiterate heads (impact $2.3\times$ larger) or bottom-quartile asset ownership (impact $1.8\times$ larger)—consistent with resource-dependent human capital formation mechanisms ([Akbulut-Yuksel, 2017](#); [Dagnelie et al., 2018](#); [Lavy et al., 2016](#)).

To understand the channels through which the locust invasion affected children’s educational achievements, we examine how food prices changed and how they affected parental investment in child human capital. We show that locust invasion led to catastrophic damage to local agriculture and significantly increased crop prices. The crop failures impaired farm households’ production, causing a negative shock to household budgets and necessitating reductions in investments in their children’s human capital. Increased child labor emerged as a coping mechanism for households facing adverse income shocks, as a higher share of school-aged children were observed engaging in agriculture instead of enrolling in school or completing academic milestones during this period.

We also conduct a cost-benefit analysis and a cost-effectiveness analysis, demonstrating that early intervention strategies are economically viable. The cost-benefit analysis revealed that a one-dollar investment in early locust control could generate an impressive return of

approximately \$411 over four decades. Using Kremer’s (2003) education intervention framework, we find locust mitigation costs \$7.63 per additional student-year of schooling—more cost-effective than cash transfers ($\$ > 1000$), merit scholarship (\$370), or iron supplementation (\$36). This positions pest control as both agricultural protection and high-return human capital investment.

This study contributes to the literature in four ways. First, it constitutes an important addition to the extensive body of literature on human capital accumulation (see [Glewwe, 2002](#); [Hanushek & Woessmann, 2008, 2011](#) for comprehensive reviews in the context of developing countries). Specifically, by documenting the impacts of locust infestations on school enrollment and cognitive capacities, we broaden the scope of research on the influence of exogenous local shocks or programs on educational outcomes. Along this line of literature, existing research has examined various environmental shocks, including conflicts ([Blattman & Annan, 2010](#); [Shemyakina, 2011](#)), corruption ([Reinikka & Svensson, 2005](#)), infrastructure deficits ([Storeygard, 2016](#)), and cash transfers ([Baird et al., 2011](#); [De Janvry et al., 2006](#)). Moreover, our study adds to the literature on the long-term impacts of educational setbacks, focusing on future income and employment prospects. This dimension aligns with a broad strand of literature that highlights the enduring effects of early educational shocks and interventions ([Behrman et al., 1996](#); [Miller et al., 1995](#); [Heckman et al., 2013](#); [Osili & Long, 2008](#)).

Second, it complements the literature on early life experiences and their persistent impacts on individuals’ socio-economic trajectories ([Behrman & Rosenzweig, 2004](#); [Black et al., 2007](#); [Maluccio et al., 2009](#)). It builds upon prior studies that have examined similar shocks—such as famines ([Chen & Zhou, 2007](#)), violence and wars ([Brück et al., 2019](#); [Zhang et al., 2007](#)), income losses due to parental layoffs ([Bratberg et al., 2008](#); [Hilger, 2016](#)), weather shocks ([Maccini & Yang, 2009](#)), and adverse institutional setup ([Fuchs-Schündeln & Masella, 2016](#)), as well as pest-related agricultural shocks ([Banerjee et al., 2010](#))—and demonstrates how locust invasions serve as an additional impediment to human capital formation. Notably, most of the existing studies focus on negative shocks for fetuses and newborns, and less research has been devoted to examining school-age children ([Akresh et al., 2012](#); [Caruso &](#)

Miller, 2015; Di Maio & Sciabolazza, 2021; He & Lam, 2022; Koppensteiner & Manacorda, 2016; Quintana-Domeque & Ródenas-Serrano, 2017; Tapsoba, 2023). We contribute to this literature by employing those 5–8-year-old children when a locust swarm occurred, which helps us understand how adverse shocks at school ages would lead to profound socio-economic consequences through their impact on education.

Third, there is a thin but growing literature that focuses on the consequences of locust invasions. This literature has emerged primarily after locust data became publicly available in 2020, enabling researchers to conduct rigorous empirical analyses of these environmental shocks. Conte et al. (2023) investigate the 2004 locust plague in Mali, documenting evidence of both direct crop failure effects and speculative/anticipatory effects on child health, finding that individuals exposed to locust shocks in utero exhibited stunted growth. While some pest invasions like the boll weevil in the United States paradoxically increased school enrollment by reducing agricultural opportunity costs (Baker, 2015; Baker et al., 2020), locust swarms in agricultural economies typically generate income shocks that constrain educational investments. Marending & Tripodi (2021) examine locust plagues in Ethiopia, demonstrating significant welfare effects and impacts on agricultural markets. Chatterjee (2022) estimated substantial agricultural production losses from locust invasions, while our companion paper (He & Lam, 2022) documents the effects of locust swarms on infant mortality across Sub-Saharan Africa from 1985 to 2018, using village-by-year-month data for precise identification of locust invasion impacts. This is the first study to investigate how desert locust plagues affected educational achievement both in the short and long run. In the short run, locust invasions increase school dropouts and child labor as families face economic hardship and re-allocate household labor to compensate for lost income. In the medium run, children exposed to the disaster perform significantly worse on standardized math and language tests administered eight years later, and in the long term they are more likely to be trapped in low-skill, informal-sector jobs, limiting their future career prospects. These findings differ from studies such as Baker (2015) and Baker et al. (2020), but align with De Vreyer et al. (2015), who documented negative impacts on educational attainment by children born during the 1987-89 locust plague in Mali, showing reduced years of schooling for affected cohorts. However, our

study advances beyond De Vreyer et al. by tracking educational impacts across multiple time horizons from immediate enrollment through long-term labor market outcomes (rather than focusing solely on years of schooling) and by identifying and testing specific transmission mechanisms including crop price effects and child labor responses.

Finally, our findings contribute to broader discussions concerning African development by situating locust invasions within the context of structural challenges faced by African nations. Previous research has highlighted factors such as environmental influences (Harari & Ferrara, 2018), natural resource dependence (Berman et al., 2017), public health threats (Alsan, 2015; Depetris-Chauvin & Weil, 2018), infrastructure deficits like rural electrification (Dinkelman, 2011), and ethnic conflict (McGuirk & Burke, 2020) as impediments to development. This study complements these discussions by illustrating how locust infestations alone can help explain the long-term human capital accumulation and economic mobility in a country.

The rest of the paper is organized as follows. Section 2 introduces the background relating to the 2004 desert locust plague and the education system in Burkina Faso. Section 3 introduces the data and our variables of interest. Section 4 describes our estimation strategy. Empirical results are reported in Section 5. Section 6 discusses mechanisms. Section 7 reports cost and benefit analysis. Section 8 concludes this paper.

2 Background

2.1 Desert locust and swarms

Desert locusts (*Schistocerca gregaria*) primarily inhabit arid zones across Africa’s Sahel, the Arabian Peninsula, and Southwest Asia. While solitary-phase locusts pose minimal ecological threat (Figure 1a), environmental triggers—particularly abnormal rainfall patterns—initiate a metabolic cascade leading to gregarization. Mechanical stimulation during crowding induces serotonin production, driving behavioral synchronization, while phenyl acetonitrile secretion mediates swarm aggregation (Figure 1b-c).

Gregarious swarms exhibit exponential growth, reaching densities of 40 million individuals/km² capable of devouring 1.8 metric tons of vegetation daily (FAO, 2014). Following wind pat-

terns, these mobile swarms migrate from Saharan breeding grounds to agricultural regions, where each generation's population can increase 20-fold under optimal conditions. By the migration stage, control becomes prohibitively expensive—mature swarms require 13× more resources to eradicate than early-stage bands.

The ecological transformation from benign solitary insects to destructive swarms creates catastrophic agricultural impacts. A single swarm can decimate 100–150 km² of daily crop coverage, equivalent to food for 35,000 people annually. This biological phenomenon consequently triggers cascading socio-economic crises across vulnerable agro-pastoral communities.

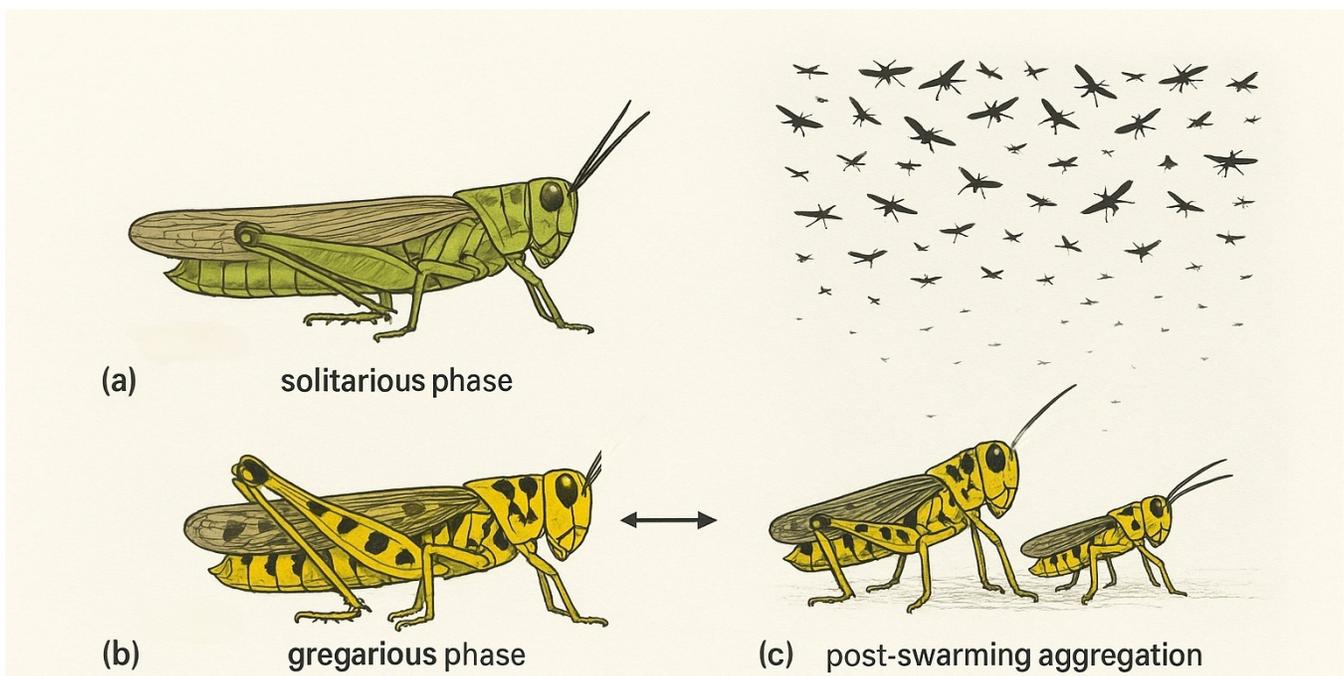


Figure 1: Different stages of locusts.

Notes: The figures show locusts at (a) solitarious and (b) gregarious stages. Figure (c) shows the gregarious locusts after swarming. Source: Humanity Development Library. (n.d.). Desert locust: Lifecycle. In Locust handbook.

2.2 The 2004 desert locust plague in Burkina Faso and its impacts

Despite extensive human interventions, severe locust plagues have persisted since the 1970s (Cressman & Stefanski, 2016). This study focuses on the notable 2003–2005 locust plague that affected multiple African countries. In 2004, unusually heavy winter and spring

rainfall transformed the dry Sahel into a lush and fertile landscape, providing abundant vegetation that nourished both local ecosystems and rapidly expanding locust populations. These extreme weather conditions created optimal circumstances for locust hatching and aggregation, leading to the formation of massive swarms within a few months. The swarms first emerged in Mauritania, Niger, and Mali before invading neighboring Burkina Faso in August 2004, as illustrated in Figure 2, which shows the northern spread of the infestation from Niger and Mali into Burkina Faso. During the harvest season, swarms caused severe damage to crops from late September to November, although the locust population had already begun to decline by the end of September. A second wave of locusts appeared in November, but their impact was reduced because most crops had already been harvested.

This invasion caused extensive damage to crops and pastures in the northern region, surpassing even the 1987–1989 plague. The crisis triggered a severe food shortage, costing the international community more than USD 400 million and resulting in harvest losses valued at up to 2.5 billion USD. Evaluated losses of cereal and staple leguminous crops in the affected zones reached 80% and 85–90% of expected production in 2004, respectively, while one-third of the pastures were also lost. More than 50% of households resorted to borrowing or selling part of their livestock, and most households were forced to reduce food consumption by 10%, with over 40% experiencing constant famine in 2005. To cope, many household heads sought employment in urban areas, leaving children responsible for farming and caring for younger siblings.

After the destructive events, the Food and Agriculture Organization and other donors provided aid to the affected areas, primarily in the form of food delivered to nearly 90% of affected households. Each household received an average of 140 kg of cereals, which represented only eight percent of their food deficit. However, with the locust invasion ending in 2005 and the crisis considered resolved, foreign assistance was soon withdrawn from villages. In summary, the locust invasion sharply exacerbated family poverty in farm households by suddenly reducing food supply, forcing them to cut expenditures such as investment in education. Many children of school age were unable to enroll, and even those previously enrolled faced a heightened risk of dropping out due to economic hardship. Some children had to

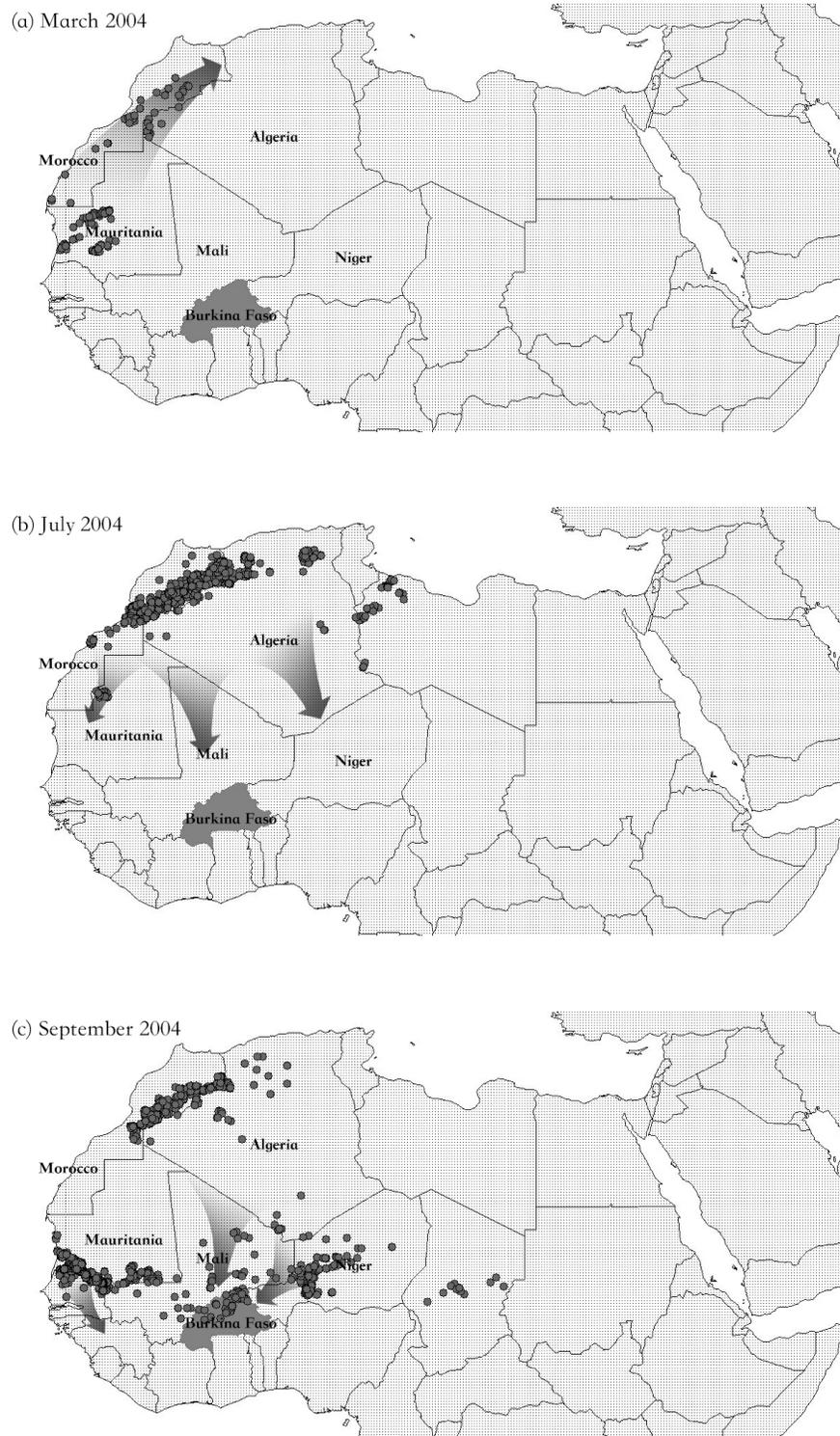


Figure 2: The movement of the swarms during the 2004 desert locust plague: (a) March 2004; (b) July 2004; (c) September 2004.

leave school to help earn money or care for siblings, and even those who remained in school often needed to work in their spare time to help support their families.

2.3 Primary education in Burkina Faso

This study focuses on primary education in Burkina Faso, which spans six years and includes three stages: preparatory (CP1 and CP2), elementary (CE1 and CE2), and middle (CM1 and CM2), typically for children aged 6–12. Although the official duration is six years, many children finish later due to delayed school entry, with the academic year starting in October. Data from the BRIGHT project indicate that about 75% of CP1 students started school at the official age, around 20% were overage, and roughly 5% were underage, with 95% of students entering between ages 5 and 8.

The Education Act in Burkina Faso requires compulsory schooling from ages 6 to 16, but limited resources hinder universal access. By law, education is free, but the government lacks sufficient resources to ensure universal access to primary education, and children must still pay for school supplies (ILAB, 2006). Under these constraints, Burkina Faso’s basic education system faces persistent challenges, including low enrollment rates, gender disparities, and uneven distribution of educational resources. For example, primary school enrollment was only 17.2% in 1980 and increased to 45% in 2003. Girls’ enrollment remains much lower than boys’, and 80% of illiterate adults are women. Geographic disparities are also pronounced, with enrollment rates in the capital, Ouagadougou, five times higher than in remote rural areas.

Government initiatives, such as the BRIGHT program launched in 2005, aimed to address these issues by constructing new schools and improving access in underserved regions. As a result, the national primary enrollment rate rose to 78% in 2010. Despite this progress, significant challenges persist, with over 30% dropout rates between 2000 and 2010. Proficiency levels remain low, as more than 83% of children have not achieved minimum reading and math standards by the end of primary school, and many are unable to complete primary or lower secondary education. This underscores the ongoing need for further improvements in the education system.

3 Data and Variables

3.1 Locust dataset

Locust data for this study are sourced from the Locust Hub of the Desert Locust Information Service (DLIS), an FAO initiative aimed at reducing crop losses and disaster risk. Since 1975, FAO country offices in Sub-Saharan Africa have monitored locust activity using satellite technology to track bands and swarms. These satellite-based data are refined at FAO headquarters and supplemented by self-reported information from local villagers to enhance accuracy. The Locust Hub provides geocoded information on desert locusts that have historically occurred in Sub-Saharan Africa and includes four databases that record the incidence of hoppers, bands, adults, and swarms. In this study, we focus on the incidence of locust swarms, as most crop damage results from this particular form. We use both the dates and the geographic coordinates of swarm events that occurred in Burkina Faso during the second half of 2004. The distribution of swarm incidence and the corresponding starting dates are shown in Figure 3.

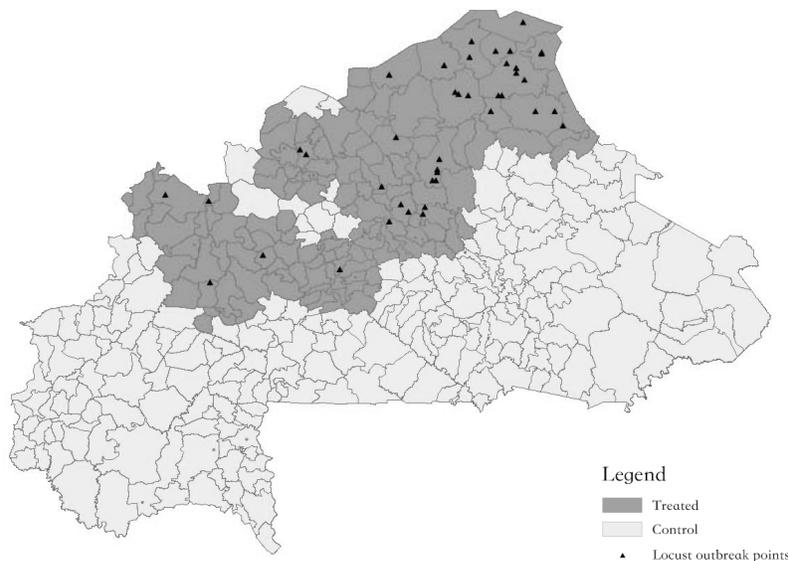


Figure 3: Swarms within Burkina Faso in 2004: The presence of swarms and distribution of treatment and control counties (50 km radius).

FAO records capture the early stages of locust activity. Swarms, driven by wind, often cause severe crop losses in regions surrounding each geocoded event. For our analysis, we define counties located within 50 kilometers of a locust event as “near” or affected by the locust plague in the baseline regression, referring to these as the treatment group. Counties more than 50 kilometers away serve as the control group. Of Burkina Faso’s 348 counties, 131 are in the treatment group, with the remaining 217 forming the control group, as detailed in Appendix Table A.1. The distributions of treated and control counties are illustrated in Figure 3. We also examine the impact of the locust plague using alternative distance thresholds, such as 30, 40, 60, 70, and 80 kilometers, as shown in Appendix Figure A.1.

3.2 The BRIGHT survey data

The BRIGHT educational outcomes stem from a comprehensive survey designed to evaluate the impact of the BRIGHT program, a Burkina Faso initiative aimed at increasing girls’ enrollment rates by constructing schools, providing resources, and implementing a ten-year plan. The dataset, which includes 290 villages selected for the BRIGHT program, was compiled by the Ministry of Education. Some villages were chosen for the program, while others with scores below a certain threshold were not. In each sampled village, a survey was conducted to collect information on households with children aged 6 to 19 years. This dataset is valuable because it contains a wide range of educational outcomes for these children.

The survey, conducted in 2012 and 2013, included both household and school questionnaires.¹ Schools were assessed for attendance, infrastructure, and available supplies. The household survey consisted of three parts. The first part collected socio-demographic information, such as family characteristics, assets, educational outcomes, and current employment details for all children. The second part recorded the child’s height, weight, and upper arm circumference. In the third part, all children were required to take math and French tests, regardless of whether they were currently enrolled in school.

¹The program began in 2005. Of the two public waves—BRIGHT I (2007–2008) and BRIGHT II (2012–2013)—only the latter contains cohorts who were of primary-school age during the 2003–2005 locust outbreak; children in BRIGHT I were all below primary-school age, leaving no treated-at-outbreak observations. We therefore rely on the second wave.

To ensure accuracy, the sample was restricted to households that had lived in their current village for at least eight years before the locust invasion, thus avoiding misclassification of treatment status. Individuals who had already enrolled in primary school before the 2004 plague were excluded, resulting in a sample of 31,621 individuals born between 1994 and 2007 at baseline.

For immediate effects, a school enrollment dummy variable was constructed. The arrival of locusts reduced agricultural production and household income, which in turn caused many farming households to delay or forgo their children’s school enrollment. As shown in Panel A of Table 1, the school enrollment rate in regions not affected by locusts reached 43%, which is 3.2% higher than in the hardest-hit regions. Educational outcomes in the medium term were assessed using the math and French tests included in the questionnaire, which were administered to all children living in the household, regardless of their school enrollment status. These test questions are taken from official government textbooks used in primary schools. Mathematical content focuses on addition, subtraction, multiplication, and fraction identification. The French test requires children to identify letters, read simple words, fill in the blank in a sentence, and match words to pictures. We use factor analysis to generate several standardized scores to proxy the outcomes regarding human capital accumulation.

3.3 The EHCVM survey data

To analyze the longer-term effects of the locust invasion on individuals and their households, this study uses data from the EHCVM 2018/19. The EHCVM is a nationally representative household survey conducted by the National Institute of Statistics and Demography (INSD) with support from the World Bank and the WAEMU Commission. The survey was carried out fourteen years after the locust attack and covers several West African countries, including Benin, Burkina Faso, Chad, Côte d’Ivoire, Guinea Bissau, Mali, Niger, Senegal, and Togo. It provides information across all regions and includes approximately 7,000 households.

The EHCVM survey uses two main instruments: a household and individual questionnaire, and a community-level questionnaire. This analysis focuses on specific variables such as total years of education, employment status, non-agricultural employment, and salary

Table 1: Descriptive statistics of outcomes by treatment

	All	Control	Treated	Unconditional Diff.	<i>p</i> -value
	(1)	(2)	(3)	(4)	(5)
Panel A: BRIGHT survey					
Ever enrolled	0.414 (0.493)	0.428 (0.495)	0.395 (0.489)	-0.032	0.000***
Z-score in Math & French tests (sample ever enrolled)	0.697 (1.135)	0.727 (1.157)	0.653 (1.095)	-0.074	0.004***
Z-score in Math & French tests (sample never enrolled)	-0.558 (0.289)	-0.564 (0.283)	-0.550 (0.293)	0.014	0.000***
Panel B: EHCVM survey					
Years of schooling	5.152 (3.980)	5.167 (3.936)	4.866 (4.724)	-0.301	0.045**
Employed	0.825 (0.380)	0.823 (0.382)	0.851 (0.356)	0.028	0.112
Employed in non-agri sect.	0.442 (0.497)	0.446 (0.497)	0.389 (0.488)	-0.057	0.014**
Hourly salary	1505.434 (601.516)	1509.195 (603.618)	1434.555 (556.941)	-74.640	0.070*

¹ Columns 4 and 5 show raw (i.e., unconditional) differences in average values across cohort, and the *p*-value for a *t*-test of differences in means. In columns (1)–(3), numbers in parentheses are the corresponding standard deviations.

information. Employment status and non-agricultural employment are represented through two distinct dummy variables. To reduce the influence of extreme values, household salary data are transformed using the local currency as a reference point and applying a logarithmic transformation. The statistics of the selected outcomes are reported in Panel B of Table 1.

In addition, the EHCVM 2018/19 collects important demographic information, including gender, religion, birth order among siblings, and marital status. These variables are included as controls in all regressions. It is important to note that the EHCVM 2018/19 survey data are only available at the province level, so the treatment/control assignments will be less accurate compared to the BRIGHT dataset. In light of this, we rely on the BRIGHT dataset for our main analyses and only use the EHCVM 2018/19 to gain a deeper understanding of the enduring effects of the locust attack on individuals and their households.

4 Estimation Strategy

4.1 Baseline model

In the baseline analysis, children born between 1997 and 2000 are defined as school-aged. These interviewees were five to eight years old and were the most likely to be candidates for primary school enrollment after the locust invasion in the new academic year of 2005. Children who were younger (born in and after 2001) or older (born in and before 1996) were less likely to be enrolled, as 95% of primary school enrollment typically occurs during these ages.

We also use dummy variables for different stages of children’s development (in utero, baby, preschool age, and school age) and dummy variables for each birth year to explore the dynamic impact of locusts on human capital accumulation. The cohort variables interact with the treatment status of the counties of residence to estimate the locust plague’s effect, denoted as *Locust*. Specifically, we estimate the following household fixed-effects model:

$$Y_{ihb} = \beta * Locust_{hb} + \alpha X_{ib} + \gamma_h + \mu_b + \epsilon_{ihb} \quad (1)$$

where the dependent variable measures the educational outcomes of child i born in year b and belonging to household h . The treatment variable, $Locust_{hb}$, is a dummy variable that takes a value of one if the child belongs to a household residing in a locust-affected area and has been exposed to the locust plague at a school entrance age. Household fixed effects are included to control for all household characteristics, including household income, parental employment status, and preferences, such as attitudes toward education. The within-household estimation of the coefficient β thus captures the within-sibling difference in the educational outcomes owing to different impacts across children of different ages and across the households affected and unaffected by the locust. Birth-year fixed effects are also included to approximate cohort-specific trends for school enrollment and the effect of current age/grade. X denotes a set of covariates. ϵ is the error term.²

4.2 Exogeneity of the treatment

Abnormal rainfall in late 2003 triggered locust breeding in the deserts of northwest Africa, which led to the spread of swarms into neighboring countries. In the second half of 2004, these locust swarms entered Burkina Faso and caused significant agricultural losses. While there may be concerns that unobserved factors could have influenced both the presence of locusts and children’s educational outcomes, it is important to note that the development of locusts—from hoppers to adults—depends heavily on soil conditions, abnormal rainfall, and the policies of neighboring governments. Crucially, the locusts that appeared in Burkina Faso in 2004 originated and reproduced in neighboring countries, specifically Niger and Mali, before moving into Burkina Faso as swarms. As shown in Appendix Figure A.2, there were no locust swarms recorded in Burkina Faso between June 1989 and August 2004.

Regarding the factors that determine the movement of swarms, FAO reports indicate that wind direction is the primary driver of large-scale locust migration, with swarms typically moving downwind. Historical wind direction and frequency data for Burkina Faso, obtained from Meteoblue’s “history+” weather simulation service, reveal a close alignment between

²Robust standard errors are clustered at the birth cohort level and at the county level. When we cluster them at the household level, the results persist. These results are shown in panel A of Table 2.

the direction of locust movement and prevailing winds, as illustrated in Appendix Figure A.3. Based on this evidence, we consider the incidence of locust swarms in Burkina Faso to be unrelated to local socio-economic factors that might otherwise influence educational outcomes, and thus treat it as an exogenous shock. Further support for this assumption is provided in Section 5.4.2, where we show that regional variations in precipitation do not correlate with the probability of being affected by the locust invasion.

5 Empirical Results

This section presents our empirical results on the impacts of the 2004 locust plague on human capital accumulation in Burkina Faso. We first examine the short-term effects on primary school enrollment, then analyze medium-term consequences on cognitive development as measured by standardized test scores, and finally investigate long-term impacts on employment outcomes and earnings.

5.1 Effect on primary school enrollment

Panel A of Table 2 presents the results for primary school enrollment rates, using both household and birth year fixed effects in the baseline model. The coefficients for the Locust variable indicate that exposure to the locust invasion during school age is associated with a 14.6% ($-0.0604/0.414$) lower likelihood of ever enrolling in school compared to siblings who were not exposed.

Columns (2) through (5) report results conditional on different sets of covariates, which consistently confirm the main findings. Column (2) adds individual-level variables such as age, gender, and birth order. Column (3) further introduces interactions between household-level characteristics and birth year dummies. Columns (4) and (5) include regional and cohort covariates, such as elevation, precipitation, temperature, soil productivity, and wind direction during the locust period, as well as whether the child was selected into the BRIGHT education promotion project, all interacted with birth year dummies. In the most restrictive specification, the effect of locust exposure on enrollment rates remains highly significant,

though it becomes slightly smaller after adjusting for these covariates. Using the covariate set in column (5) as the baseline, the results show that school-age respondents in locust-affected areas were 5.38 percentage points less likely to enroll in school than their siblings, which corresponds to a 13% decrease in the sample mean.

To further analyze the impact, dummy variables for different stages of children’s development and for each birth year are used to capture the dynamic effects of the locust invasion on human capital accumulation. We interact these cohort variables with the treatment status of the county of residence to construct the difference-in-differences specification. Figure 4(a) illustrates the estimated impact across stages of development, including in utero, infant, baby, preschool, and school age, based on the age at the next enrollment period after the disaster. Figure 4(b) displays the estimated impact of different birth cohorts from 1994 to 2006 on school enrollment in affected areas, along with a 90% confidence interval for each estimate. The results indicate that children born between 1997 and 2000, who were aged five to eight in the next enrollment year, experienced significantly lower enrollment rates than younger cohorts who did not face the choice of enrolling in school at the time of the locust invasion.

These figures also allow us to examine the parallel-trends assumption. Individuals born in and before 1996 are considered senior cohorts, as they were at least nine years old when the locust invasion occurred. It is expected that there is no significant effect on these older cohorts, since decisions regarding their school enrollment had already been made before the invasion. Figures 4(a) and (b) present the estimated coefficients for the cohort and treatment variables, confirming that senior cohorts in both treatment and control groups exhibited similar enrollment trends, consistent with our expectations.

5.2 Medium-term impacts on cognitive performance

In addition to examining immediate effects on school enrollment, we also assess whether exposure to the locust invasion during the critical school-entry age had lasting consequences on children’s cognitive development. To do this, we analyze standardized math and French test scores from the BRIGHT survey, which were collected eight to nine years after the locust plague. These scores provide a medium-term measure of human capital accumulation.

Table 2: The effect of locust plague on primary school enrollment rates

Dep. Var.	have ever enrolled in school				
	(1)	(2)	(3)	(4)	(5)
Panel A: Baseline results					
Locust_cohort (50 km)	-0.0604*** (0.0150) [0.0142]	-0.0598*** (0.0150) [0.0142]	-0.0569*** (0.0148) [0.0144]	-0.0522*** (0.0150) [0.0144]	-0.0538*** (0.0152) [0.0149]
# Obs.	31621	31621	31621	31621	31621
# Clusters	696	696	696	696	696
R^2	0.092	0.093	0.103	0.114	0.118
Birthyear FE	✓	✓	✓	✓	✓
Household FE	✓	✓	✓	✓	✓
Individual controls		✓	✓	✓	✓
Household-cohort controls			✓	✓	✓
BRIGHT-cohort controls				✓	✓
Region-cohort controls					✓
Panel B: Different distances to locust invasion location					
	30 km	40 km	60 km	70 km	80 km
Locust_cohort	-0.0488*** (0.0178)	-0.0700*** (0.0162)	-0.0590*** (0.0144)	-0.0562*** (0.0146)	-0.0543*** (0.0148)
# Obs.	31621	31621	31621	31621	31621
# Clusters	696	696	696	696	696
R^2	0.117	0.118	0.118	0.118	0.118
HH, birthyear FE	✓	✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓

¹ Individual-level controls include age, gender, and birth order among siblings. Household-cohort controls include the interactions between household-level characteristics and dummies of the year of birth. BRIGHT-cohort level controls include BRIGHT program selection interacting with the years of birth. Regional-cohort level controls include local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. The full set of controls includes all covariates listed above.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; Panel A also represents robust standard errors clustered at the household level, as reported in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

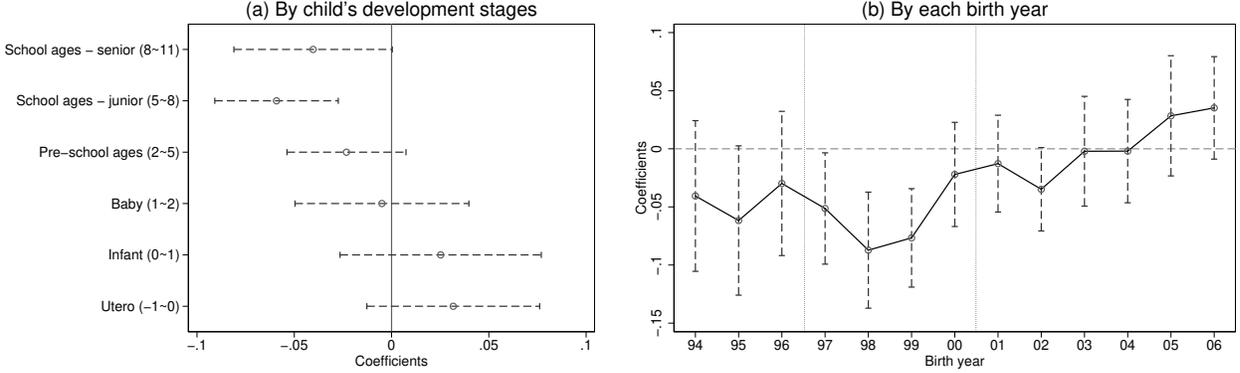


Figure 4: The effect of locust plague on primary school enrollment rates: more treatment definitions

Note: The reference group (the zero dash line) of both figures is the cohort born in 2007, who have not at all experienced the locust invasion in 2004, not even in utero. We use the distance of 50 km as being near to the plague. The 90% confidence intervals are reported in the figures.

Table 3 presents estimates of the relationship between locust exposure and standardized test performance. Using the number of correct answers, derived through factor analysis and reflecting cognitive ability in math and French, we find that children exposed to the locust plague at school age perform significantly worse. Specifically, the effect size is -0.089 in column (1), conditional on whether the child ever enrolled in school. When not conditioning on school enrollment, the effect is -0.115 , as reported in Appendix Table A.2, column (2), indicating a slightly larger but still highly significant impact. These analyses incorporate individual controls, as well as household and region-cohort controls, and further adjusts for each individual's enrollment history and its cohort trends. Replacing enrollment history with years of schooling does not change the results.

As described in the data section, the test was stopped after three consecutive incorrect answers, so the number of questions attempted also serves as an alternative measure of cognitive ability. Regardless of the metric used, children in locust-affected areas consistently scored lower than those in control areas, as shown in column (2) of Table 3. When math and French scores are analyzed separately in columns (3) and (4), the negative effect appears slightly larger for French than for math. Further, when test questions are grouped by primary school grade levels (CP1, CP2, and CE), the results in columns (5) to (7) show significant

Table 3: The effect of locust plague on the math and French cognitive tests

Dep. Var.	test z-scores						
	both subjects		by subjects		by level of questions		
	#correct ans. (1)	#questions (2)	Math (3)	French (4)	CP1 (5)	CP2 (6)	CE (7)
Locust_cohort (50km)	-0.089*** (0.026)	-0.066** (0.026)	-0.064** (0.027)	-0.074*** (0.026)	-0.052** (0.023)	-0.104*** (0.028)	-0.084** (0.035)
# Obs.	29440	31621	31621	30413	29440	31621	31621
# Clusters	696	696	696	696	696	696	696
R^2	0.610	0.515	0.497	0.560	0.669	0.511	0.319
HH, birthyear FE	✓	✓	✓	✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓	✓	✓
Enrollment covariates	✓	✓	✓	✓	✓	✓	✓

¹ The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

differences across all grades.

The results in Table 4 indicate that, for children who never enrolled in school, the locust invasion did not have an additional impact on cognitive scores after accounting for the reduced likelihood of attending school. However, when the analysis is restricted to those who did enroll in primary school, the effect of locust exposure remains significant, with a coefficient of 0.131 reported in column (2). This suggests that, among those who managed to enroll, exposure to the locust plague at school-entry age continued to have a negative effect on cognitive outcomes.

To explore the mechanisms behind these results, we examine three factors: age at school entry, dropout status, and years of schooling completed. The findings indicate that children affected by the locust invasion entered primary school later, as shown in column (3), likely due to household budget constraints following the disaster. Higher dropout rates among these cohorts also contribute to lower test scores, as reported in column (4), and affected children completed fewer years of schooling overall, as indicated in column (5).

To validate the definition of the treated cohort, we use the approach from Figure 4 to

Table 4: The effect of locust plague on Math and French cognitive tests: more explanations

Subsample	By enrollment		Potential explanations		
	never enrolled	ever enrolled	ever enrolled		
Dep. Var.	test z-scores		age of enrollment	drop-out	years attend-ed school
	(1)	(2)	(3)	(4)	(5)
Locust_cohort (50km)	0.011 (0.011)	-0.131*** (0.048)	0.137** (0.066)	0.010** (0.005)	-0.271*** (0.084)
# Obs.	17089	12351	13103	9487	12971
# Clusters	691	676	681	459	681
R^2	0.283	0.503	0.212	0.027	0.740
HH, birthyear FE	✓	✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓

¹ This table includes solely samples who had ever enrolled in primary school in columns (2)–(5).

² The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

³ Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

estimate the medium-term impact of the locust plague by stage of development and year of birth. Figures 5(a) and (b) confirm that the negative effect on test scores is concentrated among children who were of school-entry age at the time of the invasion, specifically those born between 1997 and 2000.

Taken together, these findings show that the adverse effects of locust exposure extend well beyond initial enrollment decisions. Even children who managed to enroll in school after the disaster performed significantly worse on standardized tests years later, started school later, were more likely to drop out, and completed fewer years of schooling. These results underscore the persistent and far-reaching consequences of early educational disruptions caused by the locust plague.

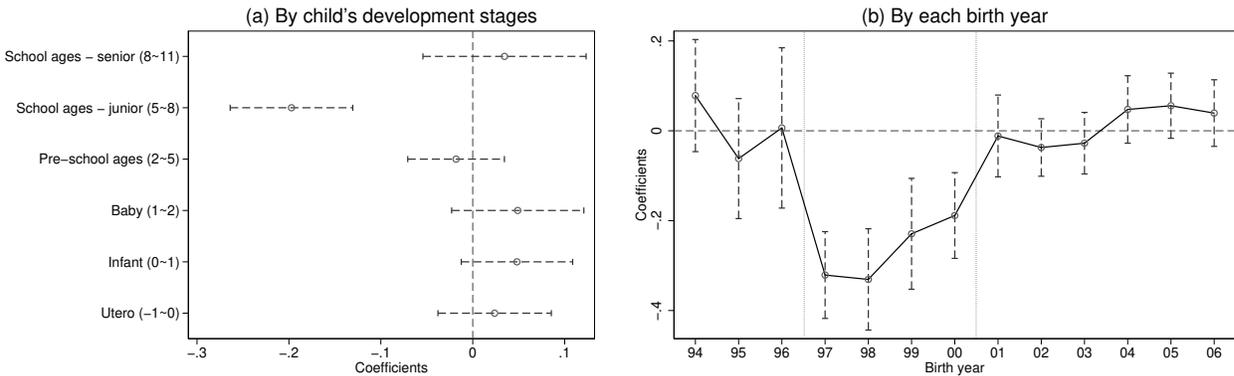


Figure 5: The effect of locust plague on the standardized score of Math and French tests: more treatment definitions

Note: The reference group (the zero dash line) of both figures is the cohort born in 2007, who have not at all experienced the locust invasion in 2004, not even in utero. We use the distance of 50 km as being near to the plague. The 90% confidence intervals are reported in the figures.

5.3 Long-term impacts on employment and earnings

Given the well-established long-term benefits of human capital accumulation for economic growth, it is essential to examine how households' decisions to reduce educational investments in response to the locust shocks can have lasting consequences. Previous research has demonstrated a strong positive relationship between education and various measures of lifetime well-being. Individuals with higher levels of schooling are less likely to suffer from

poor health, depression, and mortality (Lleras-Muney, 2005; Clark & Royer, 2013; Cutler & Lleras-Muney, 2006) and substantially less likely to experience unemployment (Case & Deaton, 2022). In contrast, dropping out of school for any reason is associated with a range of unfavorable outcomes such as drug, violent, and property crimes (Muller & Roehrkaase, 2025).

To assess these long-term impacts, we use data from the EHCVM 2018/19 survey, focusing on individuals' total years of education, employment status, and salary information, fourteen years after the locust attack. The results, presented in Table 5, show that locust exposure at school-entry age has a significant negative effect on total years of schooling, confirming the external validity of our baseline findings. Within-household comparisons reveal that individuals who experienced the locust plague at ages five to eight are 4.3 percentage points less likely to be officially employed than their siblings and 3.4 percentage points less likely to secure non-agricultural jobs. When examining individual salary outcomes, we find that locust exposure significantly reduces future wages for paid jobs by 4% (60.935/1505.434). This suggests that, for those affected during their school-age years, finding paid employment does not fully compensate for the loss in educational attainment, as their earnings remain lower than those of their non-affected siblings.

These results highlight the persistent economic consequences of educational disruptions caused by the locust plague. Children exposed to the shock at critical ages not only completed fewer years of schooling but also faced substantial disadvantages in the labor market as adults. The negative effects on both employment probability and wages indicate that the temporary disruption of the locust invasion resulted in permanent setbacks, primarily through the human capital channel identified in earlier sections.

5.4 Robustness of the effects

5.4.1 Robustness of treatment definition

To ensure the validity of our findings, we conduct several tests that address potential concerns regarding our identification strategy, measurement choices, and empirical approach.

Table 5: Long-lasting effects of locust-driven deteriorated educational achievement

Dep. Var.	years of education	employed		hourly salary
	(1)	all sectors (2)	non-agri. sect. (3)	(4)
Locust_cohort (50km)	-0.383** (0.181)	-0.043** (0.021)	-0.034* (0.020)	-60.935** (30.070)
# Obs.	14788	6968	6968	4445
# Clusters	717	709	709	664
R^2	0.068	0.142	0.128	0.014
HH, birthyear FE	✓	✓	✓	✓
Controls	✓	✓	✓	✓

¹ The controls include gender, religion, birth order among siblings, and marital status.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

We organize these into three categories: robustness of treatment definition, validation of identifying assumptions, and tests of alternative explanations.

Alternative distance thresholds Our baseline analysis defines counties within 50 km of locust events as treated. To test sensitivity to this choice, we examine alternative distance cutoffs of 30, 40, 60, 70, and 80 km. Panel B of Table 2 shows that enrollment effects remain highly significant across all specifications, though effect sizes gradually decrease beyond 60 km. This pattern suggests our 50 km baseline captures the main impact zone while avoiding excessive noise from more distant areas.

Spatial distribution of locust effects We further examine how effects vary by distance from locust events by dividing the area within 80 km into six 10 km-wide rings. The corresponding results in Appendix Figures A.4(a) and (b) reveal that areas 30–40 km from event points show the strongest impacts on both enrollment and test scores, with effects fading beyond 60 km. This non-monotonic pattern likely reflects locust movement dynamics: FAO records capture initial swarm locations, but locusts can travel 30+ km daily, potentially causing greatest damage in areas where they eventually settle rather than where first detected.

5.4.2 Validation of identifying assumptions

Tests of identifying assumptions The validity of our specification relies on the assumption that regions unaffected by locust infestations serve as a valid comparison group for evaluating the educational outcomes in locust-affected regions. To assess the validity of this assumption, we first examine whether the senior cohorts, born in and before 1996, were affected by locusts. The results in Figures 4 and 5 support our assumptions by showing no significant differences in educational outcomes for these cohorts. Additionally, we conduct a location randomization test to further address the validity of our assumption. We randomly assign the treatment status of the counties 1,000 times and assess the impact on individuals exposed to the randomized treatment during their school entrance ages. The results of this analysis, reported in columns (1) and (2) of Table A.4, indicate no significant effects on the educational outcomes of these individuals. This further strengthens our assumption that regions unaffected by locusts provide a valid counterfactual for comparing the educational outcomes in locust-affected regions.

Placebo test Then, we use the literacy and years of schooling provided by the EHCVM 2018/19 and conduct a placebo test to examine whether the locust invasion affected the individuals born between 2010 and 2013, born at least six years after the disaster, which should logically not be the case. If there are any significant effects on the outcomes, then one would suspect that the changes in enrollment status are driven by other unobserved factors. The results on literacy and years of schooling are shown in columns (3) and (4) of Table A.4; none of the coefficients are statistically different from zero at the 0.1 level of significance, supporting our parallel trends assumption.

Exogeneity of locust locations A key assumption is that locust presence is uncorrelated with local factors affecting education. We test this by examining whether locust occurrence correlates with wind patterns that brought swarms from Mali and Niger. Columns (5)-(6) of Appendix Table A.4 show that locust attacks are significantly correlated with northeast wind patterns and proximity to northern borders, conditional on province fixed effects. Im-

portantly, we find no significant differences between locust-affected and unaffected regions in geographical and climatic indicators, supporting the exogenous nature of locust locations.

5.4.3 Temporal variation and alternative explanations

Timing of locust impacts Burkina Faso experienced two distinct waves of locust activity in 2004, providing a natural test of our proposed mechanism. The first wave occurred in August-September during the harvest season (August-November according to the agricultural calendar), while the second wave hit central regions in November after most crops had been harvested.

We test whether educational impacts align with the timing of agricultural damage by comparing these two waves. Results in Figure 6 show that only the August-September wave significantly affected educational outcomes, while the November wave had no detectable impact. This pattern strongly supports our agricultural mechanism: the first wave destroyed crops during the critical harvest period, creating immediate income shocks that forced families to reduce educational investments. The second wave, occurring after harvest completion, caused minimal agricultural damage and correspondingly had no educational effects. This temporal variation provides compelling evidence that crop destruction, rather than other locust-related factors, drives the observed educational impacts.

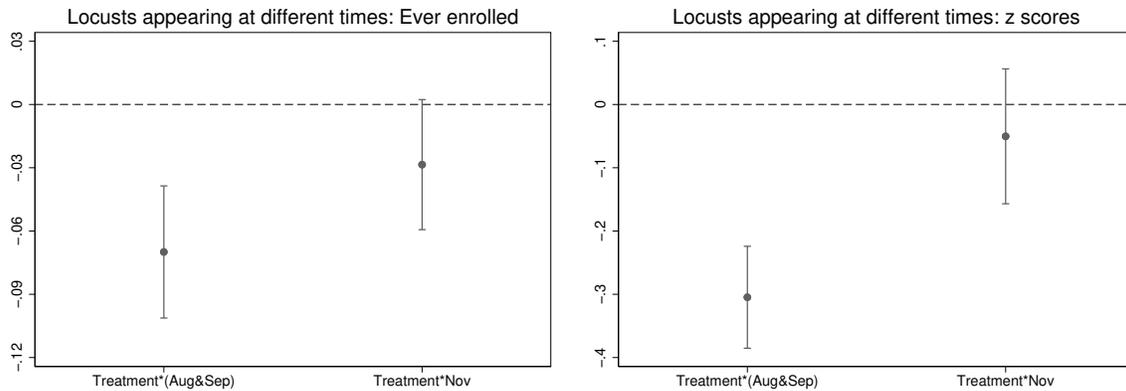


Figure 6: Different waves of the outbreak

Note: The values on the y-axis report the coefficients of the interaction term of the two rounds (August and September, and November rounds) and the treatment in the regression whose outcome variable is the school enrollment in figure (a) and the z-score of the math and French tests in figure (b).

Alternative explanations We systematically test whether other factors could explain our results by examining several potential confounding influences. First, we control for regional policies and macro-level confounders by including province-cohort fixed effects, which does not alter our findings (Appendix Table A.3, columns 1–2). Second, we test whether health interventions might confound our results by controlling for nutrition-relevant policies and vaccination coverage, but our estimates remain unchanged (Appendix Table A.3, columns 3–4). Third, we address potential conflict exposure by adding controls for violent events using ACLED data, which does not affect our results (Appendix Table A.3, columns 5–6). These tests collectively strengthen confidence that our results reflect the causal impact of locust exposure rather than confounding factors.

6 Mechanisms

The findings in the previous sections demonstrate that locust plagues have a significant and lasting impact on human capital accumulation. Building on these results and prior literature, this section examines the pathways through which locust swarms affect human capital, with a focus on food cost, malnutrition, and child labor. We also analyze the heterogeneous impacts of the locust invasion, which provide additional insight into which factors could exacerbate or mitigate the locust shock.

6.1 Effects of the locust plague on agricultural production

Burkina Faso is a predominantly agricultural country, with 80% of its population engaged in farming. The 2004 locust invasion caused widespread crop failure, resulting in a dramatic negative income shock for farm households. While crop prices rose after the invasion, this did not benefit the farmers; with most of their crops destroyed, households had little to sell and faced higher food costs (Brader et al., 2006; Conte et al., 2023).

Our analysis uses historical price data from the World Food Programme (WFP) Market Price Database, which reports monthly prices for key agricultural commodities collected at named, physical food markets. We assemble a panel of 14 markets observed monthly

from 2004–2006 and analyze six staple grains: white corn, yellow corn, millet, rice, white sorghum, and red sorghum. The main outcome variable is the monthly price of each crop in each market, measured in FCFA per kilogram. Imported crops are excluded to ensure the estimates reflect local conditions.³

We estimate the effect of the locust plague on the prices of agricultural products using the following specification:

$$\text{Price}_{mct} = \beta \text{Locust}_m \mathbb{1}\{\text{After2004m}8_t\} + \alpha_m + \gamma_c + \mu_t + \varepsilon_{mct}, \quad (2)$$

$$t \in \{2004m1, \dots, 2006m12\}.$$

where Locust_m marks markets within the locust-affected radius (time-invariant) and $\mathbb{1}\{\text{After2004m}8_t\}$ equal one for post-outbreak months; α_m , γ_c , and μ_t are market, crop, and time fixed effects that absorb time-invariant differences and common shocks. β is a difference-in-differences effect: it measures the post-vs-pre price change in treated markets net of the change in untreated markets (positive β implies prices rose in treated markets after the outbreak).

The results are summarized in Table 6. Columns (1) and (2) summarize the estimates from equation (2) and show that crop prices in locust-affected areas increased by about 40 FCFA per kilogram—roughly 20% of the sample mean—relative to contemporaneous changes in non-affected markets. Column (2) further includes controls for annual precipitation, average temperature, nighttime luminosity, and population density. In columns (3) and (4), we re-estimate at the county–crop–month level by mapping each county to its nearest active WFP market (great-circle distance, prioritizing within-province matches). The results are consistent: locust-affected locations experienced significantly higher crop prices after the plague. The results by crop groups are reported in Appendix Figure A.5.

To examine the exact timing of these effects, we interact the locust treatment with

³A “market” means the specific, physical commodity trading location enumerated by the WFP Price Database (typically the main urban wholesale/retail market of a town or city). Each WFP “market” is a named site with a consistent price series for staple foods. Each market is matched directly to locust detections by geocoordinates rather than through administrative units.

Table 6: Effects of locust plague on crop price

Dep. Var.	crop price			
	(1)	(2)	(3)	(4)
Locust $\times\mathbb{1}(\text{After2004m8})$	42.116*** (2.114)	50.781*** (2.092)	37.041*** (2.897)	41.560*** (3.898)
Observations	871	871	6591	6591
Market FE	✓	✓		
County FE			✓	✓
Year & month FE	✓	✓	✓	✓
Crop FE	✓	✓	✓	✓
Covariates		✓		✓

¹ The covariates in columns (1)–(4) include time-varying weather and socio-demographic controls and geographic controls interacting with year. Weather controls contain annual precipitation and average temperature during 2003–2006, while socio-demographic controls nighttime luminosity and the logged average population density of the county where the individual lived. Geographic controls include elevation and soil productivity.

² Robust standard errors reported in parentheses are clustered at the (market-crop) county-crop level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

monthly dummies from January 2004 to May 2005, using July 2004 as the reference. As shown in Figure 7, prices increased sharply between September and December 2004, coinciding with the harvest season. This pattern supports the crop failure mechanism underlying the observed price effects. A placebo regression using data from years without a locust shock (1997–2002) shows no similar seasonal price spike, reinforcing the robustness of our findings (see Figure 7, gray line).

6.2 Malnutrition of children

Regression analysis of height and weight indicators is reported in Panel A of Table 7. Column (1) shows that locust exposure is associated with a significant reduction in height, indicating compromised physical development. However, the effect on weight (column 2) is statistically insignificant. The height deficits likely reflect both reduced caloric intake due to higher food prices and increased physical demands from additional labor responsibilities among school-aged children in affected households.

Comparing our results with Conte et al. (2023), who found stunted growth among children exposed to locust shocks in utero, we note that our control group includes children born

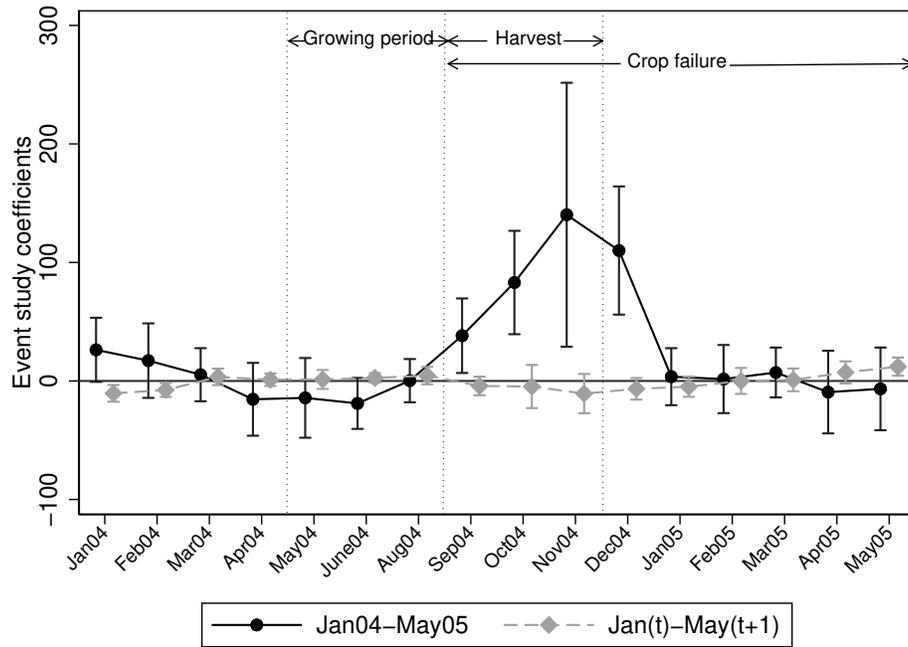


Figure 7: Impact of locust plague on crop prices

Note: The y-axis presents the estimated coefficients and their corresponding 95% confidence intervals, illustrating the effect of locust invasion on monthly crop prices (maize, millet, rice, and sorghum). The black dots and trend line depict the event study estimates spanning from January 2004 to May 2005, while the gray dots and trend line depict the placebo estimates covering the period from January of year t (by averaging the price between 1997 and 2002) to May of year $t + 1$.

between 2001 and 2006, with only a subset potentially experiencing in utero shocks. This likely attenuates the overall effect in our sample. Moreover, school-aged children in affected households may have faced increased domestic and labor responsibilities, which could reduce nutritional intake and contribute to the observed height deficits.

6.3 Child labor

A key mechanism for the decline in educational outcomes is the increase in child labor following the negative income shock. We measure child labor using a dummy variable equal to one if a school-age child reported not enrolling in school because they had to work (paid or unpaid), and zero otherwise. Panel B of Table 7, columns (1)–(4), show that the child labor channel is more pronounced in farm households, with locust exposure at school age significantly increasing the likelihood of child labor. The effect is especially strong for unpaid work, which directly prevents school enrollment.

Restricting the sample to children who had ever enrolled in school, we further examine the impact of locust exposure on work status and educational attainment. Columns (5) and (6) of Panel B, Table 7 indicate that more school-aged children in affected areas reported failing to complete primary and middle school due to work obligations. The increase in paid child labor in response to the income shock likely explains the higher dropout rates observed among the treated sample. This suggests that the reduction in family income forced children to work, limiting their ability to pursue education compared to their siblings in the same household.

6.4 Heterogeneities

To further understand the mechanisms, we examine heterogeneity in the effects of locust exposure across different subgroups.

Gender: Analysis by gender, reported in Table 8, columns (1)–(4), reveals that the negative impact on educational outcomes was substantially larger for girls than for boys. Boys exposed to locusts at school-entry age experienced a 3.9 percentage point decrease in enrollment

Table 7: Effects of locust plague on malnutrition of children and child labor

Panel A: Malnutrition of children						
Dep. Var.	height (cm)		weight (kg)			
	(1)		(2)			
Locust_cohort (50km)	-2.157*** (0.671)		-0.159 (0.292)			
# Obs.	19428		19415			
R^2	0.804		0.748			
HH, birthyear FE	✓		✓			
Controls	✓		✓			
Panel B: Child labor						
Dep. Var.	Not enrolled				Drop-out	
	all child labor		outside	domestic	outside	domestic
	non-farm (1)	farm (2)	(3)	(4)	(5)	(6)
Locust_cohort (50km)	-0.030 (0.020)	0.037*** (0.012)	0.001 (0.002)	0.036*** (0.012)	0.003* (0.001)	-0.001 (0.004)
Obs.	5172	28650	28650	28650	13103	13103
R^2	0.070	0.029	0.010	0.028	0.012	0.024
HH, birthyear FE	✓	✓	✓	✓	✓	✓
Covariates	✓	✓	✓	✓	✓	✓

¹ The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.

probability, while the effect for girls was nearly double at 7.4 percentage points. This gender disparity likely reflects household resource allocation decisions under economic stress, with families prioritizing boys' education—a pattern consistent with prevailing gender norms in Burkina Faso.

Ethnicity: Ethnic differences are also evident. The Peul ethnic group, which relies primarily on herding, was less affected by the locust shock. Table 8, columns (5)–(8), shows that ethnic groups focused on herding over cultivation experienced smaller negative impacts, likely due to risk diversification and communal insurance mechanisms that insulated them from agricultural shocks.

Household education and occupation: Table A.5, columns (1)–(4), explores heterogeneity based on the household head's education. The negative effects of the locust plague are robust for households whose heads had no or only maternal education, but not for those with heads who had completed primary school or higher. This may reflect the greater ability of educated household heads to buffer shocks. Table A.5, columns (5)–(8), further shows that the coefficient of locust exposure is more significant for farm households. For non-farm households, the main effect is seen in increased dropout rates and shorter years of schooling rather than decreased enrollment (see Table 4).

6.5 Supply sides

On the supply side, we examine whether the locust plague led to school closures or changes in the number of teachers and classrooms, using BRIGHT school questionnaire data. Table A.6, columns (1)–(3), shows no significant decline in schools, teachers, or classrooms in locust-affected regions. We also analyze the impact of international aid using AidData on World Bank projects between 2005 and 2013. Interaction terms between treatment and aid project types (health/education and transport/energy) are included in the regression, but the results show no significant compensatory effects from aid (Table A.6, columns 4–7).

Table 8: Heterogeneities based on individual’s features

Dep. Var.	by gender				by ethnicity			
	ever enrolled		z-score		ever enrolled		z-score	
	boys	girls	boys	girls	non-Peul	Peul	non-Peul	Peul
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Locust_cohort (50km)	-0.039*	-0.074***	-0.099***	-0.112***	-0.057***	0.022	-0.091***	-0.056
	(0.020)	(0.020)	(0.032)	(0.035)	(0.016)	(0.042)	(0.029)	(0.053)
# Obs.	15940	15681	14820	14620	25433	6188	23604	5836
# Clusters	692	692	689	690	673	536	668	526
R^2	0.117	0.136	0.626	0.605	0.119	0.141	0.617	0.603
HH, birthyear FE	✓	✓	✓	✓	✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓	✓	✓	✓
Enrollment			✓	✓			✓	✓

¹ The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals’ enrollment status and the trends of enrollment status across different birth cohorts.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6.6 Summary

In summary, our analyses identify several key mechanisms through which locust exposure affected human capital accumulation. The primary pathway is agricultural damage, evidenced by increased crop prices during the harvest season (Table 6, Figure 7). This income shock generated two first-order household responses: (i) compromised children’s nutritional status (Panel A of Table 7); and (ii) increased child labor participation (Panel B of Table 7). These demand-side pressures jointly led to lower school enrollment, delayed school entry, higher dropout rates, and poorer cognitive outcomes with long-run labor market penalties. The effects were most pronounced among vulnerable subgroups—girls, agricultural ethnic groups, households with uneducated heads, and farming families (Tables 8 and A.5). Supply-side factors do not account for our findings, strengthening confidence in the proposed mechanisms.

7 Cost and benefit analysis of early locust management

Understanding the benefits and costs and the cost-effectiveness of early locust management is essential to ensure that limited resources are allocated efficiently and to justify investments in prevention over costly post-disaster responses. As of today, Sub-Saharan Africa remains the world’s largest recipient of official development assistance. While a lot of funds have been allocated to education, health, governance, infrastructure, and humanitarian assistance, limited attention has been paid to the prevention of locust plagues (Nunn & Qian, 2014; Isaksson & Kotsadam, 2018).

We first analyze the costs and benefits of reallocating aid to proactive locust control, considering both the direct and indirect economic impacts. Our calculations are based on several assumptions: (1) the human capital impact estimated by our linear model applies to all populations in West African countries; (2) benefits such as improved health and reduced mortality are excluded, which likely underestimates total gains; and (3) locust control is assumed to be fully effective. These assumptions and results are detailed in Table 9.

We consider two types of benefits: long-term income gains from improved education and immediate crop loss prevention. Our results show that 37.64% of regions experienced the 2003–2005 locust infestation, leading to a 4.05% reduction in annual income for affected school-age cohorts (see column 4 of Table 5). In 2004, there were approximately 37.68 million school-age children (aged 5–9) in West Africa.⁴ With an average annual income of \$632 (at 2004 prices), and assuming a 40-year working life, the total income loss is calculated as follows: $(37.68 \text{ million} \times 37.64\%) \times 4.05\% \times \$632 \times 40 \approx \$14.52 \text{ billion}$ in lost income for the affected cohorts. The immediate crop damage from the 2004 locust plague is estimated at \$2.5 billion (World Bank, 2020), resulting in a combined total benefit of \$17.02 billion.

Early locust management involves identifying areas of locust bands and using drones and other equipment (such as electric sprayers and vehicle-mounted fog cannons) to apply locust control pesticide to these areas (Symmons & Cressman, 2001). The cost of proactive locust control is based on the estimated treatment cost of \$4,050 per km² (at 2004 prices; Millist & Abdalla, 2011). Since the initial locust bands only appear in some concentrated

⁴Due to the lack of population information of the 5–8 group, we consider the children aged 5–9 instead.

areas, we assume only 0.2% of the total area needs to be treated to prevent the formation of locust swarms (Millist & Abdalla, 2011). Then the cost of early locust management is $4,050 \text{ USD} \times 10,226 \text{ km}^2 \approx 41.42$ million USD.

The ratio of immediate crop loss prevention to control cost is $2,500/41.42 \approx 60$, highlighting the high return on investment for even short-term benefits. When considering long-term human capital accumulation, the comprehensive benefit-cost ratio is $17,020/41.42 \approx 411$. This means that every dollar invested in locust control yields an estimated \$400 in economic returns over 40 years. Notably, allocating just 0.2% of the \$20.6 billion in ODA received by sub-Saharan Africa in 2005 would be sufficient to cover the entire cost of effective locust control. If these funds were invested in early intervention, the resulting benefit would be approximately \$17.02 billion, demonstrating the enormous potential for strategic investment in locust management to generate substantial socioeconomic gains.

Then, we compare the cost-effectiveness of locust control with other interventions aimed at improving education in developing countries. Our cost calculation for locust control (\$41.42 million) results in an increase of 5.43 million schooling years ($37.68 \text{ million} \times 37.64\%$ affected children $\times 0.383$ additional years of schooling, as shown in column 1 of Table 5), yielding a cost of \$7.63 per additional year of education.

Table 10 compares this with alternative interventions. Only deworming (\$3.5) and information sessions for parents in Madagascar (\$4.8) have lower costs per additional year of schooling. Other interventions, such as free uniforms (\$99), information sessions in India (\$32), iron supplementation and deworming in India (\$36), merit scholarships (\$370), conditional cash transfers in Malawi ($> \$1,000$) and Mexico ($> \$3,000$), and computer-assisted learning (no significant impact), are substantially less cost-effective.

We acknowledge potential sources of bias in cost comparisons, as intervention costs vary by context, scale, administrative overhead, and other factors. Despite these limitations, our findings provide robust evidence that proactive locust control is among the most cost-effective strategies for improving education and human capital in Africa. Policymakers should prioritize interventions with the highest and most sustainable impacts, using context-specific strategies to address local challenges and maximize developmental returns.

Table 9: Cost and benefit analysis

	Effect size	Source
<i>Income Benefit:</i>		
Per capita income	790 USD per capita (632 USD at 2004 price levels)	The Global Economy
The rate of regions affected by locust's invasion	37.64%	Self-calculation (Table A.1)
Number of school-aged children (5–9 Y/O) in 2004 West Africa	37,679,233	Population Pyramid
Reduction in income	School-aged exposure to locusts caused a 4.05% decrease in annual income	Self-calculation (column 4 of Table 5)
<i>Lifetime income benefit:</i>	37.68 million \times 37.64% of people in the treatment group \times 9.67% income reduction \times 632 USD \times 40 years \approx 14.52 billion USD	
<i>Crop damage (immediate benefit)</i>	2.5 billion USD (estimated)	World Bank (2020)
<i>Total benefit:</i>	14.52 + 2.50 = 17.02 billion USD	
<i>Cost:</i>		
Per km ² treatment cost of early locust management	4,819 USD in 2011 (4,050 USD at 2004 price levels)	Millist & Abdalla (2011)
Treated area of early locust management	10,226 km ²	Self-calculation; Millist & Abdalla (2011); Sword et al. (2010)
<i>Total cost:</i>	4,050 USD \times 10,226 km ² \approx 41.42 million USD	
<i>Immediate benefit-cost ratio:</i>	2500 / 41.42 \approx 60.4	
<i>Total benefit-cost ratio:</i>	17020 / 41.42 \approx 410.9	

¹ Our calculation relies on several assumptions. First, we assume the impact of locust invasion on the human capital estimated by our linear model can be applied to all populations in the West African countries. Second, we ignore other benefits such as mortality and health, which tends to underestimate the gain. Third, we assume the locust population control is effective enough to fully eliminate the locusts.

Table 10: Cost-effectiveness analysis in developing countries

Programs	Estimated USD to increase one year education	Source	Countries or areas
Locust control	\$7.63	Authors' calculation	West Africa
Deworming	\$3.5	Miguel & Kremer (2004) . "Worms: identifying impacts on education and health in the presence of treatment externalities."	Kenya
Information session on returns to education, for parents	\$4.8	Nguyen (2008) . "Information, role models and perceived returns to education: Experimental evidence from Madagascar."	Madagascar
Information session on returns to education, for boys	\$32	Jensen (2010) . "The (perceived) returns to education and the demand for schooling."	Dominican Republic
Free uniforms	\$99	Evans et al. (2008) . "The impact of distributing school uniforms on children's education in Kenya."	Kenya
Iron supplementation and deworming drug	\$36	Bobonis et al. (2006) . "Anemia and school participation."	India
Cash transfers conditional on school attendance	>\$1000	Baird et al. (2011) . "Cash or condition? Evidence from a cash transfer experiment."	Malawi
Merit scholarship program	\$370	Kremer et al. (2009) . "Incentives to learn."	Kenya
Computer-assisted learning	No significant impact	Banerjee et al. (2007) . "Remedying education: Evidence from two randomized experiments in India."	India
Cash transfers conditional on attendance	>\$3000	Schultz (2000) . "Final report: The impact of PROGRESA on school enrollment."	Mexico

8 Conclusion

This study provides robust evidence on the far-reaching impacts of locust invasions on human capital accumulation in Burkina Faso and, by extension, the broader Sahel region. By leveraging detailed geo-coded data, longitudinal household surveys, and a quasi-experimental design, we demonstrate that the 2004 locust plague had profound and persistent effects on educational attainment, cognitive development, and long-term labor market outcomes for affected cohorts.

Our analysis reveals that exposure to the locust invasion during critical school-entry ages led to a significant decline in primary school enrollment, with affected children being 5.38 percentage points less likely to enroll compared to their non-exposed siblings. The disruption extended beyond immediate enrollment: children in locust-affected areas scored substantially lower on standardized math and French tests eight to nine years after the event, indicating lasting deficits in cognitive development. These educational setbacks translated into tangible economic disadvantages in adulthood. Using nationally representative data, we find that individuals exposed to the locust shock as children completed fewer years of schooling, were less likely to secure formal or non-agricultural employment, and earned significantly lower wages than their peers. These results underscore the critical role of early-life shocks in shaping long-term human capital trajectories and perpetuating cycles of poverty.

The mechanisms underlying these effects are multifaceted. The locust invasion caused widespread crop failure, driving up food prices and reducing household income. In response, families adopted coping strategies such as reducing food consumption and increasing reliance on child labor. Our findings show that the negative impact on educational attainment was most pronounced among vulnerable subgroups, including girls, children from farming households, and those with less-educated household heads. Gender disparities were especially stark, with girls experiencing nearly double the decline in school enrollment compared to boys. Ethnic groups specializing in herding, such as the Peul, were relatively insulated from the worst effects, highlighting the importance of livelihood diversification as a form of resilience.

Importantly, our study moves beyond documenting harm to evaluate the cost-effectiveness

of early locust management as a policy response. Through comprehensive benefit-cost analysis, we demonstrate that proactive locust control yields exceptionally high returns: every dollar invested in early intervention can generate up to \$400 in long-term economic benefits by preventing both immediate crop losses and future reductions in human capital. Compared to other educational interventions, locust control stands out as one of the most cost-effective strategies, with a cost per additional year of schooling as low as \$7.63—substantially lower than many widely implemented programs. This finding is particularly salient for policymakers in aid-dependent regions, where efficient resource allocation is crucial for sustainable development.

Our results also withstand a battery of robustness checks, including controls for regional policies, conflict, nutrition interventions, and supply-side factors such as school closures and international aid. Alternative explanations do not account for the observed patterns, strengthening confidence in our identification of the primary mechanisms at work.

In conclusion, locust invasions represent a critical but underappreciated barrier to human capital development in Africa. Timely, targeted, and cost-effective interventions in locust management not only protect agricultural production but also safeguard the educational and economic futures of vulnerable populations. Policymakers and development partners should prioritize early locust control as an integral component of both disaster risk reduction and human capital investment strategies, ensuring that the next generation is better equipped to break the cycle of poverty and achieve their full potential.

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Appendix Figures

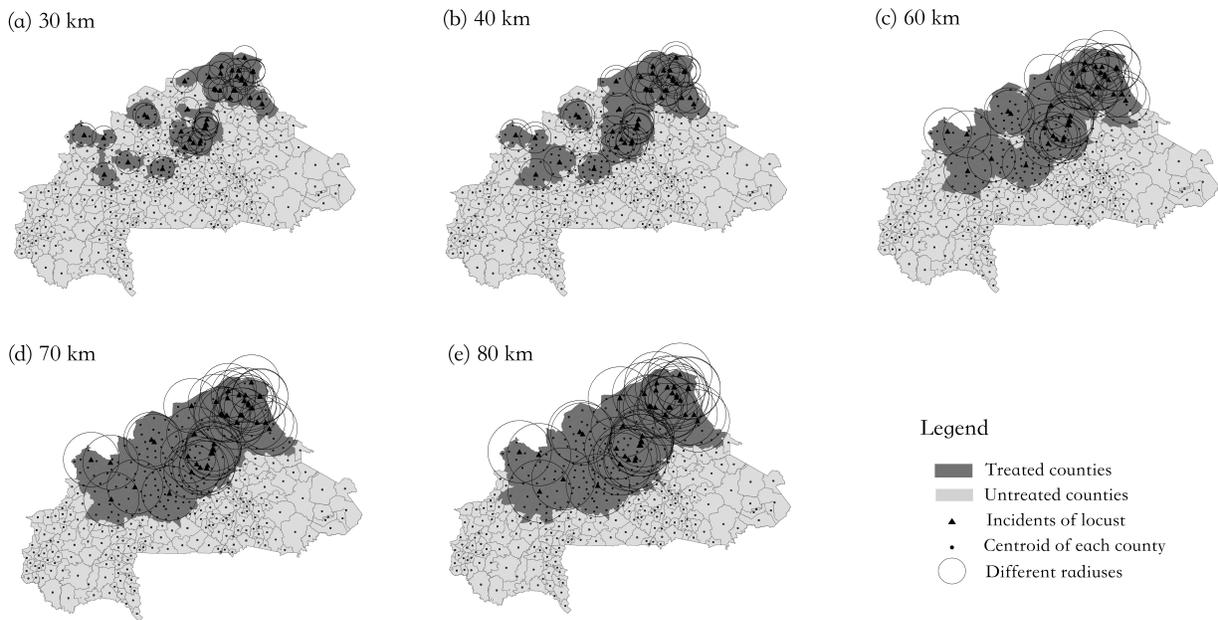


Figure A.1: Distribution of the presence of swarms differentiating between treatment and control counties (30, 40, 60, 70, and 80 km).

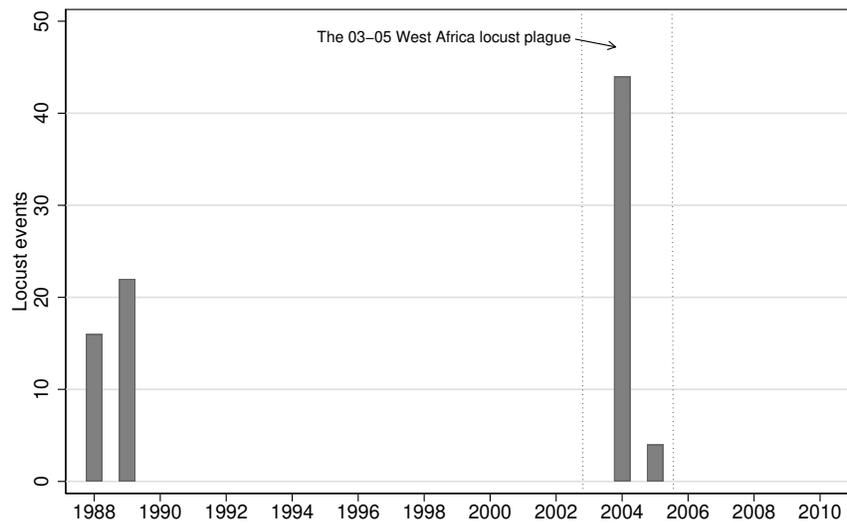


Figure A.2: The number of swarm events in Burkina Faso between 1988 and 2010

Source: FAO. Notes: There were no locust swarms in Burkina Faso between June 1989 and August 2004.

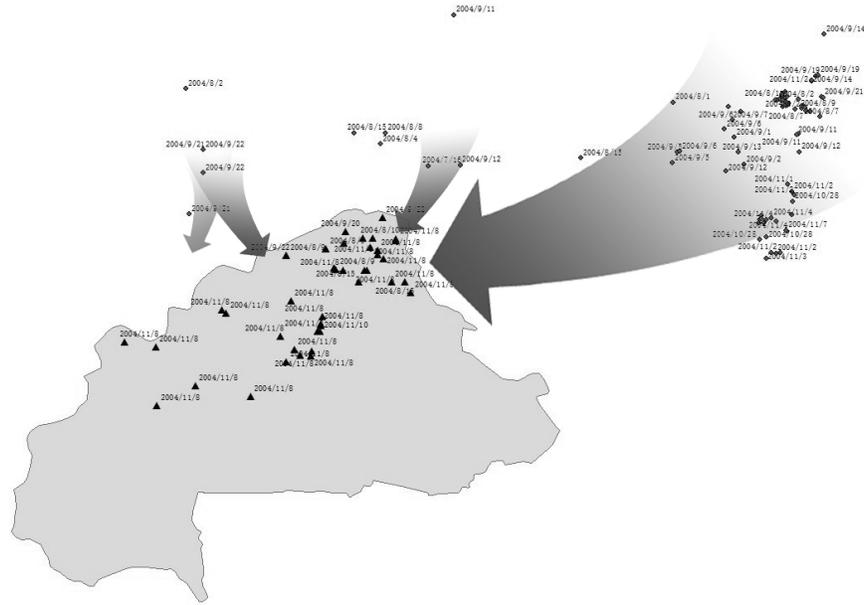


Figure A.3: Movement of the locusts and the northeast wind

Wind rose source: Meteoblue; Locust source: FAO. The dates indicate the outbreak of locust invasion at each point.

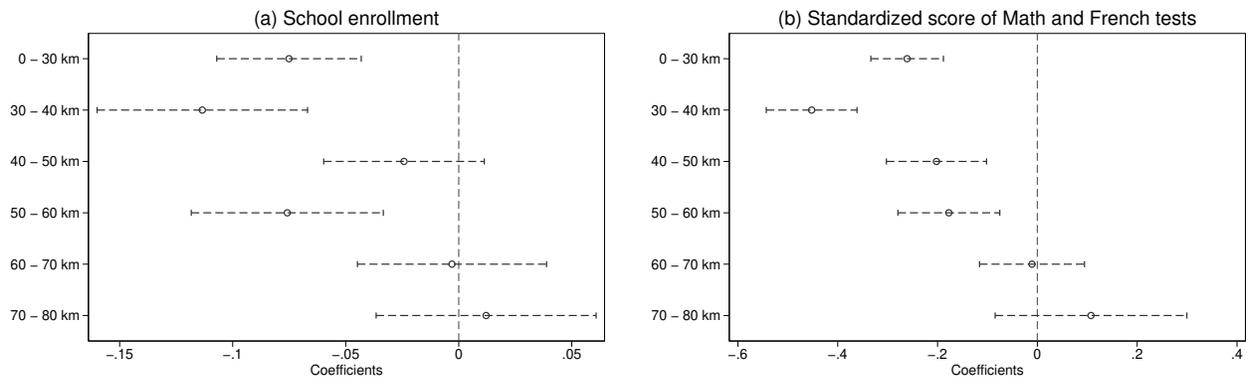


Figure A.4: The effect of locust plague on human capital accumulation across space

Note: We divide the regions that are 80 km away from the locust invasion into six groups with 10 km-wide intervals. The 90% confidence intervals are reported in the figures.

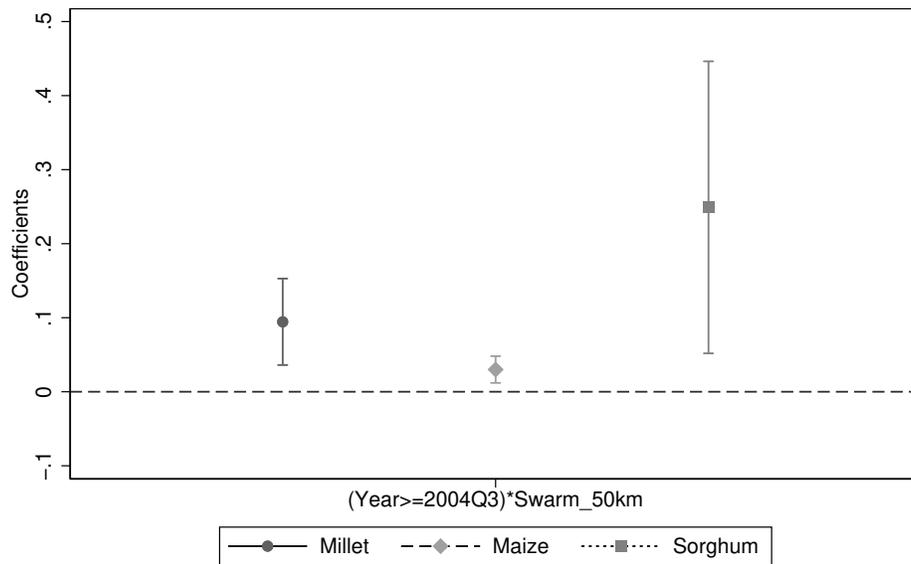


Figure A.5: Price changes (in USD) for different types of crops

Note: The y-axis reports the coefficients estimated using the identification in Table 6. The price is in USD per kilogram. The axis reports three crop groups: millet, maize (yellow and white), and sorghum (red and white). The rice sample is not included in this analysis because of its insufficient observations.

Appendix Tables

Table A.1: Summary statistics of the county-level exposure to locust and covariates at different levels

	Obs.	Mean	Std. Dev.	Min	Max	Data source
<i>County-level exposure to locust</i>						
Locust infestation	348	0.376	0.485	0	1	FAO
<i>Individual-level covariates</i>						
Age	33,822	10.63	3.788	6	19	
Male	33,822	0.507	0.500	0	1	
Birth order	33,822	2.553	1.704	1	19	
Mid-upper arm circumference (mm)	22,331	159.98	57.64	14	280	BRIGHT
Height (cm)	22,296	131.38	16.68	97	175	
Weight (kg)	22,283	27.94	10.09	11	68	
<i>Household-level covariates</i>						
Household size	33,822	9.089	3.920	2	22	
Household head education: some education	33,822	0.148	0.355	0	1	
Household head religion: Muslim	33,822	0.606	0.489	0	1	BRIGHT
Household head ethnicity: Mossi	33,822	0.410	0.492	0	1	
<i>Village-level covariates</i>						
Selected into BRIGHT	548	0.529	0.500	0	1	
# Schools	548	0.870	1.436	0	14	
# Teachers	548	5.336	12.96	0	129	BRIGHT
# Classrooms	548	4.272	8.827	0	82	
<i>County-level covariates</i>						
Precipitation (1994-2008)	5,265	0.215	0.119	0.001	0.683	
Temperature (1994-2008)	5,265	82.66	1.891	78.08	87.34	
North-east wind in 2004 (%)	348	0.431	0.064	0.321	0.554	Meteoblue
Elevation	348	311.3	50.23	181	560	USGS
Soil productivity	348	117.3	290.6	0	1717.3	

Table A.2: The medium-term effect of locust plague: Robustness

Dep. Var.	Test z-scores				
	(1)	(2)	(3)	(4)	(5)
Panel A: Different sets of covariates					
Locust_cohort (50km)	-0.259*** (0.035)	-0.115*** (0.027)	-0.097*** (0.026)	-0.094*** (0.027)	-0.089*** (0.026)
# Obs.	29449	29449	29440	29440	29440
# Clusters	696	696	696	696	696
R^2	0.246	0.601	0.605	0.608	0.610
Birthyear FE	✓	✓	✓	✓	✓
Household FE	✓	✓	✓	✓	✓
Enrollment controls		✓	✓	✓	✓
Individual controls		✓	✓	✓	✓
Household-cohort controls			✓	✓	✓
BRIGHT-cohort controls				✓	✓
Region-cohort controls					✓
Panel B: Different distances to locust invasion location					
	30 km	40 km	60 km	70 km	80 km
Locust_cohort	-0.044 (0.029)	-0.071*** (0.027)	-0.100*** (0.026)	-0.104*** (0.025)	-0.086*** (0.025)
# Obs.	29440	29440	29440	29440	29440
# Clusters	696	696	696	696	696
R^2	0.610	0.610	0.610	0.611	0.610
HH, birthyear FE	✓	✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓

¹ Individual-level controls include age, gender, and birth order among siblings. Household-cohort controls include the interactions between household-level characteristics and dummies of the year of birth. BRIGHT-cohort level controls include BRIGHT program selection interacting with the years of birth. Regional-cohort level controls include local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. The full set of controls includes all covariates listed above.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.3: Confounding factors

Dep. Var.	policies				conflicts	
	macro-level		immunization		ever enrolled	z-scores
	ever enrolled	z-scores	ever enrolled	z-scores		
(1)	(2)	(3)	(4)	(5)	(6)	
Locust_cohort (50km)	-0.048*** (0.018)	-0.083** (0.032)	-0.039** (0.018)	-0.117*** (0.028)	-0.051*** (0.015)	-0.092*** (0.026)
Province×birthyear FE	✓	✓				
Measles vaccine			0.003 (0.013)	0.031 (0.020)		
DPT vaccine			✓	✓		
Conflicts experience					0.020 (0.013)	-0.017 (0.018)
# Obs.	31621	29440	31621	29440	31621	29440
# Clusters	696	696	696	696	696	696
R^2	0.126	0.612	0.119	0.611	0.118	0.610
Household FE	✓	✓	✓	✓	✓	✓
Birthyear FE			✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓	✓

¹ The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.4: Testing the assumptions

Dep. Var.	Location randomization		Samples born after 2010		Exogeneity of locust	
	ever enrolled (1)	z-scores (2)	literacy (3)	years of sch. (4)	locust occurrence (5)	locust occurrence (6)
Locust_cohort (50 km)	0.011 (0.015)	-0.004 (0.028)	0.011 (0.019)	-0.061 (0.112)		
North-east wind					1.770** (0.768)	1.638** (0.810)
North-east wind \times Dist to the nearest NE borders					-0.685** (0.275)	-0.727** (0.282)
Elevation						0.010 (0.185)
Precipitation (04-03)						-4.345 (2.901)
Temperature (04-03)						0.043 (0.040)
Soil productivity						0.000 (0.000)
# Obs.	31621	29440	16299	16299	348	348
HH, birthyear FE	✓	✓	✓	✓		
Full set of controls	✓	✓	✓	✓		
ADM1 FE					✓	✓

¹ Variables *Precipitation (04-03)* and *Temperature (04-03)* capture the differences in precipitation and temperature between the years 2003 and 2004. *North-east wind* is the ratio of wind blowing from Mali and Niger to Burkina Faso in 2004 (in percentage) in each county, as most of the adult locusts to Burkina Faso from Niger and Mali were brought by the wind of these directions. *North-east wind \times Dist. to the nearest NE borders* is the interaction between the wind direction and distance of each county to the nearest northeast boundaries where the locusts may enter.

² The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

³ Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses in columns (1)–(4), and the standard errors are clustered at the prefecture level in columns (5) and (6); *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.5: Heterogeneities based on household's features

Dep. Var.	by household head's illiteracy				by household's farming activities			
	ever enrolled		z-score		ever enrolled		z-score	
	non/mat. (1)	CP1/higher (2)	non/mat. (3)	CP1/higher (4)	farm (5)	non-farm (6)	farm (7)	non-farm (8)
Locust_cohort (50km)	-0.057*** (0.015)	-0.022 (0.038)	-0.091*** (0.024)	-0.049 (0.073)	-0.061*** (0.016)	0.011 (0.038)	-0.090*** (0.027)	-0.111* (0.059)
# Obs.	26946	4675	25193	4247	26753	4868	24879	4561
# Clusters	696	583	696	571	696	638	696	626
R ²	0.104	0.195	0.610	0.634	0.112	0.174	0.609	0.631
HH, birthyear FE	✓	✓	✓	✓	✓	✓	✓	✓
Full set of controls	✓	✓	✓	✓	✓	✓	✓	✓
Enrollment			✓	✓			✓	✓

¹ The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A.6: Changes on the supply side in affecting the baseline results

Dep. Var.	Educational supply after 2004			Aid from World Bank			
	#schools	#teachers	#classrooms	ever enrolled		z-score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Locust × 1 (After2004m8)	-0.167 (0.152)	-1.584 (1.253)	-1.369 (0.978)				
Locust_cohort (50km)				-0.081*** (0.026)	-0.055*** (0.019)	-0.128*** (0.047)	-0.120*** (0.035)
Locust_cohort × health/edu. aid				-0.010 (0.018)		0.009 (0.030)	
Locust_cohort × energy/transp. aid					0.016 (0.015)		0.010 (0.025)
# Obs.	548	548	548	31621	31621	29440	29440
# Clusters	46	46	46	696	696	696	696
R ²	0.126	0.024	0.042	0.092	0.092	0.600	0.600
Village FE	✓	✓	✓				
After 2004 indicator	✓	✓	✓				
HH, birthyear FE				✓	✓	✓	✓
Full set of controls				✓	✓	✓	✓

¹ The full set of controls includes age, gender, birth order among siblings, the interactions between household-level characteristics and dummies of the year of birth, BRIGHT program selection, local elevation, annual precipitation, temperature, and soil productivity, interacting with the years of birth. Enrollment covariates include individuals' enrollment status and the trends of enrollment status across different birth cohorts.

² Two-way cluster-robust standard errors (by birth year and by county) are reported in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.