Eradicating the Disease of the Empty Granary: Health, Structural Transformation, and Intergenerational Mobility in Ghana*

Conor Owen Carney† *University of Chicago*

Jon Denton-Schneider‡ *Clark University*

September 13, 2025

Abstract

Guinea worm disease (GWD) was known as "the disease of the empty granary" because it often incapacitated adult farmers for weeks during peak agricultural seasons. Using a difference-in-differences design, we show that its post-1989 eradication from Ghana increased agricultural productivity and women's paid employment and decreased child marriage rates. In the long run, adults who were children around 1990 are more likely to hold formal employment outside of agriculture, be literate, and live in urban areas. We also find spillover effects onto other generations: their sons' literacy rates increased and their mothers are more likely to still be alive. These results show that adult health improvements—especially those resulting from neglected tropical disease control—can be an important input into structural transformation, the loosening of intergenerational poverty traps, and healthy aging in the developing world.

Keywords: Neglected Diseases, Agricultural Productivity, Intergenerational Transmission
JEL Codes: I15, J24, J62, O13, O14, O15

*For helpful comments and suggestions, we thank Ryan Abman, Monica Carney, Dan Gilligan, Doug Gollin, Guillermo Woo-Mora, and conference and seminar participants at ASHEcon, IFPRI, LACDev, SEEDS, and UNU-WIDER Inequality over the Life Course Project Workshop. Nick Panetta provided exceptional research assistance. We gratefully acknowledge funding from UNU-WIDER.

†University of Chicago, Institute for Climate and Sustainable Growth, 1126 E. 59th St, Chicago, IL 60637. Email: cocarney@uchicago.edu. Website: sites.google.com/site/cocarno7

‡Clark University, Department of Economics, 950 Main St, Worcester, MA 01610. Email: jdentonschneider@clarku.edu. Website: jondentonschneider.com

1. Introduction

Structural transformation—the reallocation of labor from agriculture into higher-productivity sectors—is a central feature of economic development. However, the microfoundations of this process remain poorly understood (Foster and Rosenzweig, 2008). An emerging literature has emphasized the role of technological change and infrastructure investments in catalyzing rural transformation (e.g., Bustos, Caprettini and Ponticelli, 2016; Asher et al., 2023). While these factors are undoubtedly important, they are generally prohibitively costly and difficult to scale in low-income settings. This raises a natural question: Can relatively low-cost and scalable interventions—such as the control of neglected tropical diseases (NTDs)—spur economic transformation?

This paper investigates whether the eradication of Guinea worm disease (GWD), a debilitating parasitic infection, contributed to structural transformation in Ghana. GWD has particularly relevant features: while rarely fatal, it imposes substantial short-term disability, particularly during the agricultural season. In the early 1990s, Ghana became a focus of international eradication efforts led by the Carter Center, which invested heavily in low-cost water filtration technologies to break its transmission cycle. These efforts were highly successful; GWD cases in the country fell to zero by the early 2000s. Because the disease was concentrated in particular districts prior to eradication, we can leverage spatial variation in pre-eradication prevalence to assess the long-term consequences of the intervention.

Specifically, we use a difference-in-differences strategy that compares high- and low-burden districts before and after the eradication campaign. Our empirical approach is inspired by work examining the long-term economic consequences of early-life disease exposure (e.g., Bleakley, 2010). We examine outcomes across three domains: agricultural productivity, structural transformation, and intergenerational spillovers. First, we find that districts with higher initial GWD burdens experienced greater growth in agricultural productivity in the years following eradication, implying that health improvements can play a role in driving rural transformation. Next, we show that young women in these areas shifted from self-employment into paid employment on farms, likely because higher agricultural incomes allowed these households to hire additional workers. In line with previous research showing that positive weather shocks decrease child mar-

riage rates in agricultural areas where bride price is practiced (Corno, Hildebrandt and Voena, 2020), we also find that improving adult farmers' health reduced like likelihood that girls were married off.

We then turn to the long-run effects in these domains for adults who were children around the time of GWD eradication. Consistent with greater structural transformation, we show that these individuals were more likely to hold formal non-agricultural employment and live in urban municipalities. Our results also reflect reductions in child marriage, as women in these cohorts reported being older at the time of their first birth. Lastly, we document spillover effects onto other generations: the sons of men in these cohorts are more likely to be literate and their mothers are more likely to still be alive. To our knowledge, we are the first to show that childhood health improvements can result not only in more human capital for the next generation, but also greater longevity for the previous generation.

Our results contribute to several strands of the literature. First, we add to growing evidence that early-life health interventions can generate persistent economic gains (e.g., Bleakley, 2010; Alsan and Goldin, 2019). Second, we show that targeted disease eradication efforts can have broad productivity-enhancing effects, echoing insights from studies linking infrastructure investments and agricultural productivity in developing countries (e.g., Bustos, Caprettini and Ponticelli, 2016; Asher et al., 2023). Third, our findings speak to the equity-enhancing potential of NTD control: by disproportionately benefiting historically marginalized districts, these interventions may reduce spatial inequality and promote more inclusive development (Bütikofer and Salvanes, 2020; Denton-Schneider and Montero, 2025).

The remainder of the paper proceeds as follows. Section 2 provides background on GWD and the history of its eradication in Ghana. Section 3 gives a conceptual overview of our empirical strategy. Sections **??** and **??** present our difference-in-differences results on agricultural productivity at the district level and outcomes related to structural transformation and intergenerational mobility at the individual level. Section 6 concludes.

2. Background

Ghana in the late 1980s was a predominantly agrarian society, with approximately 60% of its population engaged in subsistence agriculture, particularly in the northern regions. The northern, upper east, and upper west regions, characterized by savanna landscapes and a single rainy season (May–October), relied on rain-fed crops such as millet, sorghum, and maize. Chronic water scarcity during the dry season (November–April) forced communities to depend on contaminated ponds and streams, creating ideal conditions for the spread of Guinea Worm Disease (GWD). Low infrastructure development, including limited access to boreholes or piped water, compounded this vulnerability, while low school enrollment rates and high child labor in rural areas constrained human capital development. This socioeconomic and environmental context made northern Ghana particularly susceptible to GWD's devastating effects, which disrupted agricultural productivity and perpetuated poverty. The following subsections explore the nature of GWD, its economic consequences, and the eradication efforts that transformed Ghana's trajectory.

2.1. Guinea Worm Disease and Its Impacts

Known among the Dogon people of Mali as "the disease of the empty granary," GWD, caused by the roundworm *Dracunculus medinensis*, imposed severe physical and economic burdens on Ghanaian farmers. The disease spread through the consumption of unfiltered stagnant water containing parasite larvae, a common practice among farmers working in fields during the dry season. After ingestion, larvae migrated from the intestines to mature and mate in the connective tissue of hosts' legs. Approximately one year later, female worms triggered painful blisters to exit the body, a process lasting several weeks that rendered walking nearly impossible. This debilitation curtailed farmers' ability to work, disrupting household livelihoods during critical agricultural periods.

The lifecycle of *D. medinensis* amplified its economic toll by aligning peak disability with Ghana's agricultural calendar. In northern Ghana, the dry season creates stagnant water pools that harbor the parasite, increasing infection risk as farmers rely on these sources for drinking

water. Symptoms, emerging roughly a year later, often coincided with planting (May–June) or harvesting (September–October) seasons, when labor demands were highest. Although Ghana-specific data on seasonal GWD patterns are scarce, evidence from neighboring Burkina Faso, with comparable agroecological conditions, illustrates this alignment. Figure **??** shows how GWD incidence in Burkina Faso in 1980 peaked during agricultural seasons, a pattern likely mirrored in northern Ghana. The resulting labor shortages led to reduced crop yields, lower household income, and food insecurity, often forcing children to forgo school to work in the fields, thereby limiting their education and long-term opportunities (Hotez, 2022).

GWD's impacts extended beyond agriculture to broader socioeconomic consequences. Infected individuals incurred medical expenses and lost income, straining household budgets and reducing investments in nutrition, education, and agricultural inputs like seeds or fertilizers. Malnutrition, exacerbated by poor harvests, impaired children's physical and cognitive development, further hindering human capital accumulation. In rural Ghana, where healthcare access was limited in the 1980s, traditional remedies like manual worm extraction were painful and risked secondary infections, prolonging recovery and economic losses. These effects entrenched poverty, as families struggled to invest in resources that could break the cycle of disease and deprivation.

2.2. *Eradication Efforts in Ghana*

By 1989, Ghana was among the world's most affected countries, reporting some of the highest GWD case rates in West Africa, a region that accounted for 10 of the 18 countries with endemic transmission and nearly 1 million cases globally (Ruiz-Tiben and Hopkins, 2006).[1] Figure **??** illustrates the geographic distribution of GWD in Ghana in 1989, highlighting its concentration in the northern regions. The most affected district reported a case rate of 19.3% among its entire population, implying even higher prevalence among farmers, who faced greater exposure to contaminated water (Hunter, 1997). This high prevalence likely caused significant disruptions to agricultural output, as entire communities were incapacitated during peak farming seasons.

[1] The West African countries included Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal, and Togo, with additional cases in other Sub-Saharan African countries, India, and Pakistan.

In response, the Carter Center, in collaboration with Ghana's Ministry of Health, launched a national GWD eradication campaign in 1990. The program employed three key strategies: systematic case surveillance through village-based reporting, distribution of fine-mesh cloth filters to remove *D. medinensis* larvae from drinking water, and community education to promote safe water practices and case containment. These efforts were particularly intensive in northern Ghana, where prevalence was highest. Local volunteers were trained to monitor cases and distribute filters, fostering community ownership of the eradication process. By the mid-1990s, these interventions had dramatically reduced GWD incidence, paving the way for Ghana's certification as GWD-free in 2015. The campaign not only alleviated the disease's direct health burden but also held the potential to unlock economic gains by restoring labor productivity and enabling investments in education and agriculture.

2.3. Mechanisms Linking GWD to Economic Outcomes

The economic impacts of GWD in Ghana can be understood through its effects on household labor allocation and resource constraints, which reduced agricultural productivity and human capital investments. First, GWD caused labor supply shocks by incapacitating farmers during planting and harvesting seasons. With adults unable to work, households faced reduced crop yields and income, leading to food insecurity and lower savings. In northern Ghana, where farming was the primary livelihood, these shocks were particularly devastating, as families had few alternative income sources. To compensate, children were often pulled from school to work in the fields, directly reducing their time for education and limiting their future earning potential.

Second, GWD strained household resources, forcing trade-offs between immediate needs and long-term investments. Reduced income from poor harvests, combined with medical expenses for treating GWD, left families with fewer resources for school fees, nutritious food, or agricultural inputs. Malnutrition, a common consequence of food shortages, impaired children's cognitive and physical development, further undermining human capital. These effects were amplified in northern Ghana, where poverty rates were higher and access to social services was limited.

Finally, GWD created feedback loops that entrenched poverty. Low agricultural productivity

reduced household wealth, limiting access to clean water sources (e.g., boreholes) and increasing future GWD exposure. Similarly, reduced education constrained households' ability to adopt new farming techniques or diversify into non-agricultural activities, perpetuating reliance on vulnerable water sources. The eradication of GWD, by contrast, held the potential to break these cycles, freeing adult labor for productive work, reducing child labor, and enabling households to invest in education, nutrition, and agricultural improvements. This qualitative framework suggests that GWD eradication in Ghana could have generated significant economic benefits, a hypothesis we explore in the subsequent analysis.

3. Difference-in-Differences Framework

In the remainder of the paper, we study the effects of GWD eradication using a difference-in-differences approach comparing outcomes across high- and low-GWD districts (of birth) in pre- and post-eradication years (of childhood). We now explain how we make these categorizations and describe pre-treatment differences across them.

3.1. Treatment and Control Districts

To quantify each district's exposure to GWD prior to eradication, we digitized and georeferenced archival data from Hunter (n.d.) on cases per 1,000 people in each district in 1989. Figure 1a shows the distribution of rates across Ghana. Districts in the second-highest (0.4-2.0% prevalence) and top (2.0-19.3%) quartiles lay almost exclusively within a band between the western coastal region and the far north, which contained the bottom (0-0.04%) and second-lowest (0.04-0.2%) quartiles. As Hunter (1997) argued, above-median GWD rates corresponded very closely to the overlap of low annual rainfall (under 1,270 mm, or 50 in) and the basin of Voltaian sandstone in the northeastern part of the country. It is also important to note that case rates were reported relative to the entire population but much of the GWD burden was borne by farmers, so prevalence among them would have been even higher.

Using these data, we define our treatment group as districts with above-median GWD rates in 1989. Our assumption is that prior to eradication, the geographic distribution of relative

disease intensity was stable across time. Nonetheless, the extent that it was violated—i.e., there were treatment districts with little historical GWD exposure while some control districts had a lot—comparing these groups would understate the true impacts of eradicating the disease.

Because the median was very close to 0% but very few districts had exactly zero cases, this approach balances the simple suggestion by Callaway, Goodman-Bacon and Sant'Anna (2024) of using a binary indicator for a positive "dosage" when estimating average level treatment effects with the desire to maximize power by having treatment and control groups of equal size.[2] We quantify below the average pre-treatment differences across these groups in their GWD rates, the elimination of which should be interpreted as generating our estimated effects.

3.2. *Pre- and Post-Treatment Years and Birth Cohorts*

Figure 1b shows that the reduction in Ghana's GWD cases occurred rapidly after the eradication program began in 1989. Specifically, within one year they had fallen by nearly one-third, by 1991 they were down by almost two-thirds, and within five years they had declined by over 95%. The number of villages with endemic transmission followed a similar pattern. Because we could not find post-1989 district-level data on GWD cases, we assume that these declines occurred uniformly across our treatment group.

Therefore, when studying impacts on districts or their residents, we define our final pre-treatment year as 1989. In contrast, when we examine the effects of childhoods free of GWD exposure, we set the final pre-treatment birth year to be 1972, as members of this cohort were 18 years old when the eradication campaign began. The assumption in this case is that the 1973 cohort (aged 17 in 1990) was the first to experience benefits from GWD eradication *during childhood*, which is distinct from assuming that it was the first to experience any benefits. As such, this approach only allows us to estimate long-run and intergenerational effects arising from changes in the childhood environment, which would be biased toward null results if adults also benefited from GWD eradication.

[2] Given the year-long lag between ingestion of *D. medinensis* larvae and symptomatic GWD, many of these very low but strictly positive case rates were likely due to circular migration from endemic to non-endemic districts (Watts, 1987). Thus, it is plausible that our treatment-control distinction captures the effect of eliminating any exposure to endemic GWD transmission.

3.3. *Pre-Treatment Differences*

In Figures 1c and 1c, we describe the major differences (or lack thereof) between our treatment and control groups prior to 1990 using the IPUMS 10% sample of the 1984 census (Ruggles et al., 2024) and the 1988 and 1989 waves of the Ghana Living Standards Survey (GLSS) from the Ghana Statistical Service (GSS).[3] We regress our outcomes of interest on an indicator for being in control group ("low-GWD") districts and normalize estimates and standard errors by the mean in treatment group ("high-GWD") districts. At the top of both figures is the average estimated difference in 1989 GWD cases per 1,000 people, which was almost 30 in the census sample and just above 26 in the GLSS data. As rates in the control group were effectively 100% lower, our estimates capture the difference in outcomes when moving from 2.6-3.0% GWD prevalence in a district to 0%.

At first glance, these rates might seem too low for GWD to have been a serious health issue in these areas, let alone one that could have affected their agricultural productivity. However, in the GLSS data, nearly 15% of prominent local individuals in treatment districts listed it as their community's most important health concern, meaning it beat out other scourges like malaria and diarrhea.[4] Notably, this rating was only 50% (7.4 p.p.) less common in low-GWD districts, implying substantive fears of its consequences even where prevalence was below 0.2%

Figure 1c also shows that basic characteristics such as age, sex, and labor force participation were the same across treatment and control groups in the census data. But in low-GWD districts, the shares of adults working for wages and of children attending school were both 25% (respectively 3.5 and 12.0 p.p.) higher while the share of adults working on farms was 8% (5.5 p.p.) lower, though the last of these differences is imprecisely estimated. Other labor market contrasts in the GLSS data are apparent in Figure 1d: adults in control districts were over 20% (16.4 p.p.) less likely to be self-employed in agriculture and farming households were just under 20% (5.2

[3] The GLSS is Ghana's implementation of the World Bank's Living Standards Measurement Survey (LSMS), which asks a wide range of highly detailed and consistent questions regarding topics like occupation and health.

[4] The community questionnaire was "to be asked of a group of people who are well informed about the activities, events and infrastructure of the community. The group can consist, for instance, of the chief, leading citizens, [Committee for the Defense of the Revolution] officers, traders, teachers, or others who have lived in the community for several years" (Ghana Statistical Service, 1987, p. 46).

p.p.) less likely to pay female workers, but there were no differences in the near-universal share of farming households that paid male labor. Surprisingly given the discussion in the previous section, the average number of days inactive due to illness or injury in the past month were equal across low- and high-GWD districts. However, in line with the link between agricultural precarity and child marriage in bride price socities (Corno, Hildebrandt and Voena, 2020), these rates were one-third (4.0 p.p.) lower in the control group.

4. Effects on Districts

We first use this difference-in-differences approach to study the impacts of GWD eradication on agricultural productivity. Consistent with our hypotheses, we find that it increased more in formerly high-GWD districts after 1989, and an important mechanism appears to be a greater reduction in inactive days due to illness or injury.

4.1. Data

Our first outcome of interest is a proxy for agricultural productivity based on remotely sensed NDVI data obtained through GeoQuery (Goodman et al., 2019). NDVI measures vegetation greenness on a scale from -1 to 1—which we rescale for intuitive ease to be between -100 and 100—with higher values indicating denser vegetation. However, NDVI alone cannot distinguish between agricultural activity and other forms of vegetation growth. To better isolate agricultural cycles, we calculate the difference between the maximum and minimum monthly NDVI for each district in a given year (as in Asher et al., 2023). This within-year NDVI range is designed to capture the seasonal greening and harvesting patterns that typify agricultural production. Increases in this range can indicate more intensive or productive cultivation over the year and should reflect greater agricultural production during the growing season rather than higher values at other times of the year.

To understand the impacts of changes in agricultural productivity, we use repeated cross-sectional data from GLSS rounds 1, 2, and 4 (1998), which allow us to match respondents to

consistent districts.[5] Our outcomes of interest are whether an adult is employed for wages (as opposed to self-employed) and is working in agriculture, which capture changes in labor markets and farm production. As a mechanism, we also examine the number of days that an adult reports they were inactive due to illness or injury in the past month. We also use the three GLSS rounds as well as the IPUMS 10% samples of the 1984 and 2000 censuses to study impacts on children.[6] Our outcomes of interest are whether a girl ages 12 to 18 has ever been married (GLSS) and whether a child ages 6 to 18 is attending school (census).

4.2. Empirical Specification

To test for effects of GWD eradication on agricultural productivity, we use the dynamic two-way fixed effects (TWFE) specification

$$y_{d,t} = \alpha_d + \gamma_t + \sum_{k \neq 1989} \left(\tau_k \cdot \mathbb{1}[t = k] \cdot \mathbb{1}[\text{GWD}_{d,1989} > \text{GWD}_{\text{median},1989}]\right) + \gamma_t \times \delta_{r(d)} + \mathbf{X}_{d,t}\beta + \epsilon_{d,t}, \quad (1)$$

where $y_{d,t}$ is the outcome for district d in year t, α_d and γ_t are district and year fixed effects, $\mathbb{1}[t = k]$ indicates whether an observation is from the given year k, $\mathbb{1}[\text{GWD}_{d,1989} > \text{GWD}_{\text{median},1989}]$ indicates whether a district had an above-median GWD rate in 1989, $\gamma_t \times \delta_{r(d)}$ is the interaction of fixed effects for the year and a district's region, $\mathbf{X}_{d,t}$ is a vector of time-varying controls (annual precepitation and average temperature), and $\epsilon_{d,t}$ is the idiosyncratic error term. For the GLSS and census data, we make slight modifications to equation (1): the outcome $y_{i,d,t}$ and error term $\epsilon_{i,d,t}$ are for individual i and the vector of controls X_i contains only fixed effects for age and sex.

The coefficients of interest are the τ_k, which capture the average difference in the outcome between high- and low-GWD districts within a region in a given year relative to the size of that difference in 1989. Under the identifying assumption of parallel trends, we interpret economically and statistically significant estimates of τ_k as evidence of the impacts of GWD eradication. For agricultural productivity, we use Poisson regression, which recovers the treatment effect as a percentage of the mean in the control group while avoiding the problems associated with log-linearization (Santos Silva and Tenreyro, 2006). In the difference-in-differences context, it is

[5] We could not find a map of survey clusters for round 3 (1991-92) and district codes were reported for the first time in the round 4 dataset.

[6] With only one pre-treatment census, those district-level results can only provide suggestive evidence.

identical to the Borusyak, Jaravel and Spiess (2024) imputation estimator, and it requires that the parallel trends assumption holds for the ratio of the means (Wooldridge, 2023). For individual-level outcomes, we use OLS. In all cases, we cluster standard errors by the 128 districts that existed in Ghana when eradication began.

4.3. Agricultural Productivity

We first examine the maximum-minimum gap in NDVI values. Table 1 Panel A reports the average effects in 5-year bins (1990-94 and 1995-99). Column (2) shows that in our baseline specification, this measure of agricultural productivity had increased 3.0% in treatment districts by the 1990-94 period, though it is imprecisely estimated. However, after GWD cases had fallen by over 95% in the 1995-99 period, the maximum-minimum NDVI gap had increased by a precisely estimated 8.5%, or 1.0% per year on average. These effects are robust to including controls for annual precipitation and average temperature in Column (3), and Figure 2a shows that the ratio of the outcomes evolved in parallel prior to 1990 and that the post-treatment divergence grew in magnitude over time.

4.4. Agricultural Labor Markets

Next, we study how the increase in agricultural productivity affected labor markets. Our preferred estimate in Panel B Column (3) shows that by 1998, young women (ages 15-35) in formerly high-GWD districts were 5.3 p.p. more likely to be working for wages, which was 64% of their pre-treatment mean. But the null estimates in Panel C suggest that this change was not accompanied by a movement of young women out of agriculture. Instead, they imply that young women began to earn wages for working on farms, which we interpret as increased agricultural productivity allowing for them to be hired for pay. Figures 2b and 2c show that these post-treatment patterns do not appear to arise due from a violation of parallel trends before 1990.

Given the hypotheses discussed in Section 2, we then turn to a possible channel underlying these effects: reductions in temporary disability, measured as adults' days inactive in the last month due to illness or injury. Panel D Column (3) shows that by 1998, this measure had decreased by an additional 0.29 days (22%) in formerly high-GWD districts, which is consistent

with our hypothesized mechanism of improved adult health. This effect is precisely estimated and Figure 2d shows that it is not a product of non-parallel pre-treatment trends.

4.5. Child Marriage and Schooling

Lastly, we examine the impacts on children over this period. Because positive weather shocks have been shown to reduce child marriage in agricultural communities that practice bride price (Corno, Hildebrandt and Voena, 2020), we test whether this health shock and the resulting increase in agricultural productivity had similar effects. Our preferred estimate in Panel E Column (3) shows that girls ages 12 to 18 in treatment districts in 1998 were 10.1 p.p. (82%) less likely to have been married, and this estimate is precise. It is also clear from Figure 2e that this effect does not arise from a violation of parallel trends.

Panel F provides suggestive evidence that children's schooling also increased more in formerly high-GWD districts. In Column (3), we estimate that children ages 6 to 18 in the treatment group were 3.3 p.p. (6%) more likely to be in school by 1998. While this effect is also precisely estimated, Figure 2f clarifies that there was only one pre-1990 census, so it is not possible to test whether outcomes evolved in parallel prior to 1990. Nonetheless, this result is consistent with increased investments in children's education.

5. Effects on Individuals

In this section, we study the long-run and intergenerational effects of childhood years free of GWD exposure. Our first population of interest is men who were children around 1990, and we focus on outcomes related to structural transformation and human capital. We then examine the impacts on other generations: namely, the longevity of their parents and the human capital of their children. We find positive effects in all of these domains, furthering our understanding of health as an important input into a range of novel outcomes relevant for economic development.

5.1. *Data*

We use the 10% sample of the 2021 census from the GSS. Our first outcomes of interest relate to structural transformation and human capital: whether an individual is formally employed outside of the agricultural sector, whether they can read or write in any language, and whether they live in an urban municipality (defined by the GSS as having a population of at least 5,000 people). We then turn to demography and intergenerational effects by examining a woman's age at first birth, whether a man reports that his mother is still alive, and whether a man's son can read and write.

5.2. *Empirical Specification*

These data also contain individuals' districts of birth, which we assume to be where they spent their childhoods. Because the number of districts had increased to 261 by 2021, we overlaid these boundaries onto our 1989 map of GWD prevalence and assigned each current district the case rate in the former district it overlapped with most. We therefore estimate a dynamic TWFE specification similar to equation (1):

$$y_{i,d,c} = \alpha_d + \gamma_c + \sum_{k \neq 1972} \left(\tau_k \cdot \mathbb{1}[c = k] \cdot \mathbb{1}[\text{GWD}_{d,1989} > \text{GWD}_{\text{median},1989}] \right) + \gamma_c \times \delta_{r(d)} + \mathbf{X}_i \beta + \epsilon_{i,d,c}, \tag{2}$$

where the new elements are the subscripts (for individual i from district of birth d and birth cohort c), and all else is analogous to equation (1). In this case, $\mathbf{X}_i$ contains fixed effects for i's sex and ethnic group.

The coefficients of interest are again the τ_k, which now capture the average difference in the outcome between individuals from high- and low-GWD districts of birth in the same ethnic group and region of birth for a given cohort relative to the size of that difference for those born in 1972. Because all of our outcomes are indicator variables, we use OLS for estimation and cluster standard errors by the 241 districts of birth in our sample. We also extend the analysis to examine effects on the next generation. Specifically, we attach the information regarding a father's birth district and cohort to the boys in his household and estimate a version of equation (2) that includes fixed effects for the child's age, sex, and ethnic group. Analogously, we cluster

standard errors in this specification by fathers' districts of birth.

For several reasons, we focus on the average effects for the 1974-78 and 1984-88 cohorts. First, Ghana experienced a famine in 1983, so the cohorts from treatment districts that were aged 0 to 4 at that time (i.e., were born in 1979-83) may have had negative early childhood shocks that counteracted the effects of GWD eradication. Additionally, given age heaping in the data, computing average effects for five-year bins centered around ages ending in 0 or 5 in 2021 (i.e., cohorts born in years ending in 1 or 6) helps to smooth out any distortions. However, we still show event study plots with estimates for each cohort.

5.3. *Structural Transformation and Human Capital*

Given the agricultural productivity results in Section 4.4, we begin by examining outcomes related to structural transformation. Our preferred specification in Table 2 Panel A Column (3) shows that adults in the treatment group were 1.2-1.4 p.p. more likely to hold formal employment outside of agriculture, which is about 11% of the mean for pre-1973 cohorts from high-GWD districts. Similarly, the estimates in Panel B Column (3) are of a 1.6-1.9-p.p. (around 4%) greater increase in literacy for individuals born in high-GWD districts, and the estimates in Panel C show a 3.2-3.5-p.p. greater increase in the likelihood of living in an urban municipality. In all three cases, the estimates are precise, and when taken together they suggest that GWD eradication contributed meaningfully to key outcomes in the process of structural transformation. Additionally, Figures 3a, 3b, and 3c show that these results are not continuations of non-parallel pre-treatment trends, and that the effects are indeed smaller for cohorts who were in early childhood during the 1983 famine.

5.4. *Demography and Spillovers onto Other Generations*

Lastly, we study how childhood years free of GWD exposure affected demographic outcomes and whether these effects spilled over onto other generations. Related to the child marriage result in Section 4.5, our first outcome of interest is the age at which a woman first gave birth, which should be higher for those who married at older ages. The estimates in Panel D Column (3) show that it rose 0.27-0.31 years (around 1%) more among women from high-GWD districts,

consistent with a reduction in the probability of having been married off as girls. Because it is likely that this decrease had positive impacts on their children, in Panel E we examine whether the boys aged 9 to 14 in a man's household are literate.[7] Our preferred estimate in Column (3) is of a 3.8-5.2-p.p. (8%) increase in the literacy rates of boys born to fathers from high-GWD districts, which is consistent with this intergenerational hypothesis and mirrors the effect that occurred in Brazil following the eradication of another NTD, Chagas disease (Denton-Schneider and Montero, 2025).

We also study the longevity of the previous generation, as adult sons often are often expected to financially support elderly parents—and because healthy aging is highly understudied in Sub-Saharan Africa (Duhon et al., 2023). Panel G Column (3) shows that likelihood of a man's mother still being alive rose 1.7-2.2 p.p. (about 3%) more in the treatment group. Almost all of the effects above are precisely estimated and Figures 3d 3e, and 3f show that they do not arise from non-parallel trends among pre-treatment cohorts. Thus, to our knowledge, we are the first to show that childhood health improvements can result not only in more human capital for the next generation, but also greater longevity for the previous generation.

6. Conclusion

This study investigates the economic impacts of Guinea Worm Disease (GWD) eradication in Ghana, leveraging the Carter Center's campaign beginning in 1990 to estimate causal effects on agricultural productivity, structural transformation, and intergenerational outcomes. Employing a difference-in-differences framework that compares pre- and post-eradication periods across regions with high and low GWD prevalence, we uncover significant economic benefits. Agricultural productivity, proxied by the annual maximum-minimum NDVI gap, increased by 7-8% in high-GWD regions post-eradication, driven by reductions in days inactive due to illness or injury. This finding suggests that alleviating GWD's physical burden enabled farmers to sustain labor supply during critical planting and harvesting seasons, a key mechanism in northern Ghana's agrarian economy.

[7] We focus on this range because the lower end is the first age in the 2021 census at which literacy exceeded 50% and the upper end is the last one at which it was below 90%.

The eradication also spurred structural transformation and human capital accumulation. Men who grew up free of GWD exposure were 3.3 percentage points (6%) more likely to reside in urban areas, a shift that is correlated with increased literacy rates, reflecting improved access to education. Intergenerational effects were notable: children in affected regions experienced a 2.8 percentage point (4%) increase in literacy, and the likelihood of mothers remaining alive rose by 2.0 percentage points (4%). These results highlight how GWD eradication freed household resources for education and improved health outcomes across generations, reducing cycles of poverty in a context where agriculture dominated livelihoods in the 1980s.

Our findings contribute to the literature on health and economic development by demonstrating how eliminating a debilitating disease can enhance productivity and mobility. In Ghana, GWD eradication mitigated the labor supply shocks and resource constraints that historically depressed agricultural output and human capital investments, as documented in northern regions with high prevalence (Figure **??**). However, the study has limitations. The difference-in-differences approach assumes parallel trends, which could be confounded by unobserved regional variations in infrastructure or economic policies. The NDVI measure, while useful, may not fully capture crop yield or income dynamics. Additionally, our focus on northern Ghana, where GWD was most prevalent, may limit extrenal validity to other regions or diseases.

To address these limitations, future iterations of this paper will extend the analysis by incorporating ecological and geographic predictors of GWD prevalence. Specifically, we plan to develop an empirical model that uses soil characteristics (e.g., drainage properties), water stagnation patterns, and proximity to seasonal water bodies to predict GWD rates across Ghanaian districts. This analysis will refine our causal identification by providing a more precise measure of GWD exposure, reducing reliance on regional prevalence quartiles and controlling for spatial confounders. By integrating these predictors into our difference-in-differences framework, we aim to strengthen the robustness of our estimates and explore heterogeneity in GWD's economic impacts based on environmental conditions. This extension will enhance the paper's contribution to understanding how ecological factors shape the economic consequences of disease eradication.

In conclusion, the eradication of GWD in Ghana yielded substantial economic and social gains, from increased agricultural productivity to enhanced human capital and intergenerational

mobility. These findings underscore the transformative potential of public health interventions in low-income, agrarian settings, offering insights for global efforts to combat neglected tropical diseases.

References

Alsan, Marcella, and Claudia Goldin. 2019. "Watersheds in Child Mortality: The Role of Effective Water and Sewerage Infrastructure, 1880 to 1920." *Journal of Political Economy*, 127(2): 586–638. [2]

Asher, Sam, Alison Campion, Douglas Gollin, and Paul Novosad. 2023. "The Long-Run Development Impacts of Agricultural Productivity Gains: Evidence from Irrigation Canals in India." Unpublished. [1, 2, 9]

Bleakley, Hoyt. 2010. "Malaria Eradication in the Americas: A Retrospective Analysis of Childhood Exposure." *American Economic Journal: Applied Economics*, 2(2): 1–45. [1, 2]

Borusyak, Kirill, Xavier Jaravel, and Jann Spiess. 2024. "Revisiting Event-Study Designs: Robust and Efficient Estimation." *Review of Economic Studies*, 91(6): 3253–3285. [11]

Bustos, Paula, Bruno Caprettini, and Jacopo Ponticelli. 2016. "Agricultural Productivity and Structural Transformation: Evidence from Brazil." *American Economic Review*, 106(6): 1320–1365. [1, 2]

Bütikofer, Aline, and Kjell G. Salvanes. 2020. "Disease Control and Inequality Reduction: Evidence from a Tuberculosis Testing and Vaccination Campaign." *Review of Economic Studies*, 87(5): 2087–2125. [2]

Callaway, Brantly, Andrew Goodman-Bacon, and Pedro H. C. Sant'Anna. 2024. "Difference-in-Differences with a Continuous Treatment." NBER Working Paper 32117. [7]

Corno, Lucia, Nicole Hildebrandt, and Alessandra Voena. 2020. "Age of Marriage, Weather Shocks, and the Direction of Marriage Payments." *Econometrica*, 88(3): 879–915. [2, 9, 12]

Denton-Schneider, Jon, and Eduardo Montero. 2025. "Disease, Disparities, and Development: Evidence from Chagas Disease Control in Brazil." NBER Working Paper 33518. [2, 15]

Duhon, Madeline E., Edward Miguel, Amos Njuguna, Daniela Pinto Veizaga, and Michael W. Walker. 2023. "Preparing for an Aging Africa: Data-Driven Priorities for Economic Research and Policy." NBER Working Paper 31750. [15]

Foster, Andrew D., and Mark R. Rosenzweig. 2008. "Economic Development and the Decline of Agricultural Employment." In *Handbook of Development Economics*. Vol. 4, , ed. T. Paul Schultz and John A. Strauss, 3051–3083. Amsterdam:North-Holland. [1]

Ghana Statistical Service. 1987. *Ghana Living Standards Survey: Supervisor's Instruction Manual.* Sample Surveys Section. [8]

Goodman, Seth, Ariel BenYishay, Zhonghui Lv, and Daniel Runfola. 2019. "GeoQuery: Integrating HPC Systems and Public Web-Based Geospatial Data Tools." *Computers & Geosciences*, 122: 103–112. [9]

Hotez, Peter J. 2022. *Forgotten People, Forgotten Diseases: The Neglected Tropical Diseases and Their Impact on Global Health and Development.* . 3 ed., Washington, DC:American Society for Microbiology. [4]

Hunter, John M. 1997. "Geographical Patterns of Guinea Worm Infestation in Ghana: An Historical Contribution." *Social Science & Medicine*, 44(1): 103–122. [4, 6]

Hunter, John Melton. "GWD by District, 1989." UA-17.314, Box 4188, Folder 21, John Melton Hunter Papers. University Archives & Historical Collections, Michigan State University, East Lansing. [6]

Ruggles, Steven, Lara L. Cleveland, Rodrigo Lovatón Dávila, Sula Sarkar, Matthew Sobek, Derek Burk, Dan E. Ehrlich, Quinn Heimann, and Jane Lee. 2024. *IPUMS International: Version 7.5 [dataset].* Minneapolis, MN:IPUMS. [8]

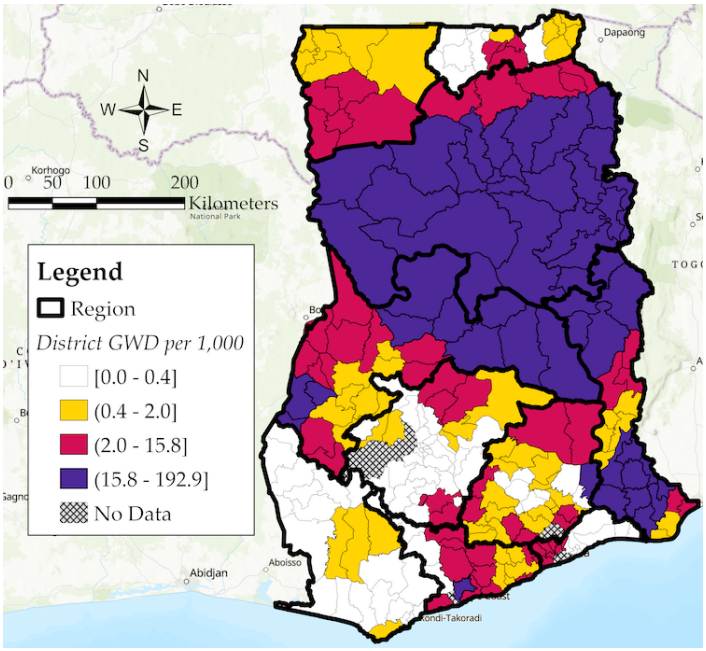
Ruiz-Tiben, Ernesto, and Donald R. Hopkins. 2006. "Dracunculiasis (Guinea Worm Disease) Eradication." *Advances in Parasitology*, 61: 275–309. [4]

Santos Silva, J. M. C., and Silvana Tenreyro. 2006. "The Log of Gravity." *Review of Economics and Statistics*, 88(4): 641–658. [10]

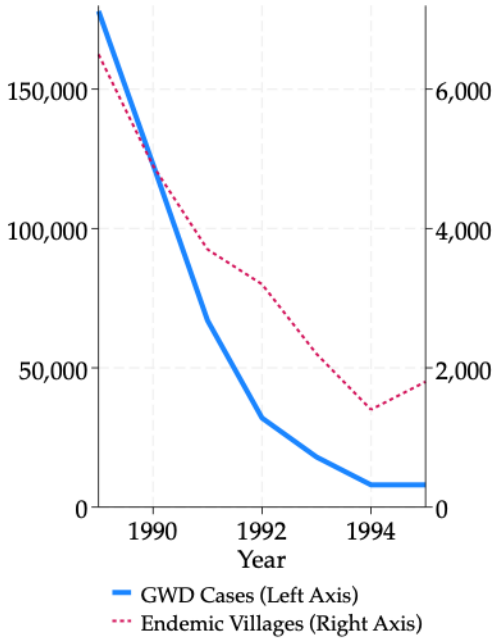
Watts, Susan J. 1987. "Population Mobility and Disease Transmission: The Example of Guinea Worm." *Social Science Medicine*, 25(10): 1073–1081. [7]

Wooldridge, Jeffrey M. 2023. "Simple Approaches to Nonlinear Difference-in-Differences with Panel Data." *Econometrics Journal*, 26: C31–C66. [11]

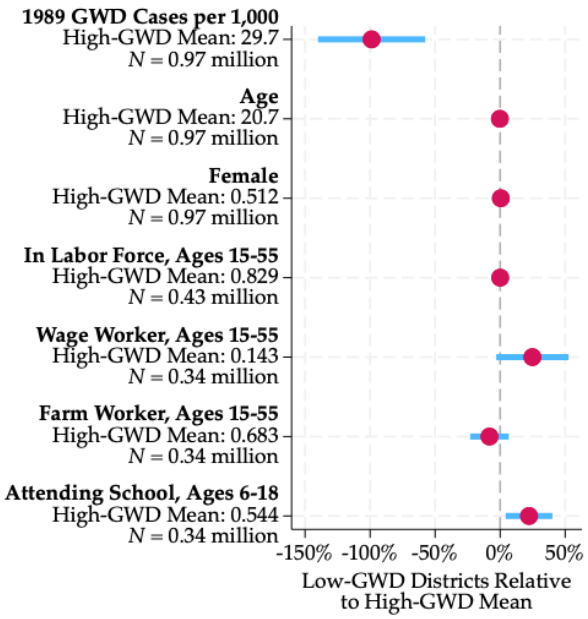
Figure 1: GWD in Ghana and Pre-Treatment Differences Across Districts [6]



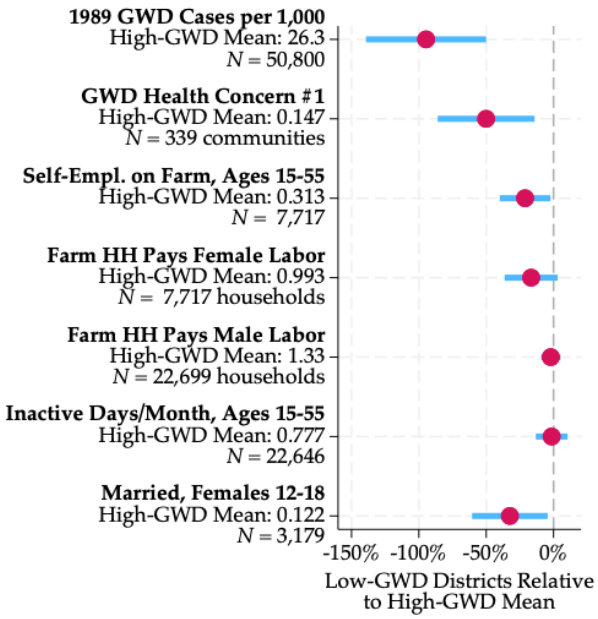
(a) GWD Cases per Thousand People, 1989



(b) GWD Eradication Progress, 1989-95



(c) Differences in 1984 Census



(d) Differences in 1988 and 1989 GLSS

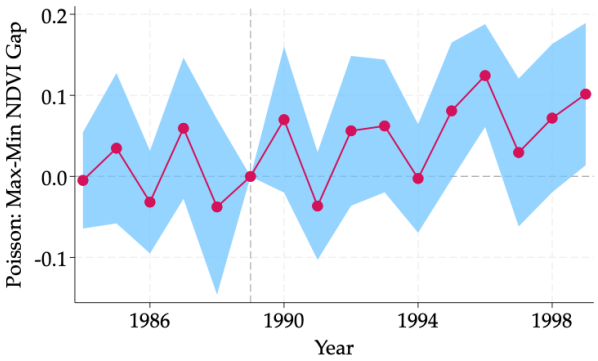
Notes: Top left panel shows quartiles of 1989 GWD cases per 1,000 people in Ghanaian districts. Top right panel shows the approximate number of GWD cases and endemic villages in each year. Bottom panels show estimates and 95% confidence intervals from regressions of the outcome on an indicator for a district having a below-median (low) 1989 GWD rate, which are then scaled by the mean in above-median (high) GWD districts. Census data are the IPUMS 10% sample and GLSS data are from the Ghana Statistical Service. Standard errors are clustered by 128 districts in the census sample and 105 districts in the GLSS data.

Table 1: District-Level Effects of GWD Eradication [11]

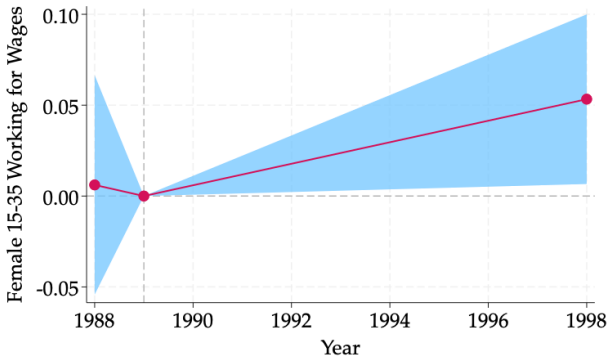
	(1)	(2)	(3)
Panel A. Poisson Regression: Maximum-Minimum Gap in NDVI Values			
Treat × 1990-94	-0.005	0.030	0.018
	(0.031)	(0.031)	(0.036)
Treat × 1995-99	0.041	0.082	0.066
	(0.033)	(0.035)	(0.037)
Average Annual Change 1990-99	0.5%/year	1.0%/year	0.8%/year
Panel B. GLSS: Working for Wages, Females 15-35			
Treat × 1998	0.029	0.053	0.053
	(0.029)	(0.024)	(0.024)
Effect Relative to Pre-1990 High-GWD Mean	35%	64%	65%
Panel C. GLSS: Agricultural Occupation, Females 15-35			
Treat × 1998	0.034	-0.023	-0.024
	(0.061)	(0.078)	(0.079)
Effect Relative to Pre-1990 High-GWD Mean	5%	-3%	-4%
Panel D. GLSS: Days Inactive in Past Month, Adults 15-55			
Treat × 1998	-0.28	-0.28	-0.29
	(0.12)	(0.12)	(0.12)
Effect Relative to Pre-1990 High-GWD Mean	-21%	-21%	-22%
Panel E. GLSS: Ever Married, Females 12-18			
Treat × 1998	-0.044	-0.077	-0.101
	(0.030)	(0.034)	(0.033)
Effect Relative to Pre-1990 High-GWD Mean	-36%	-63%	-82%
Panel F. Census: Attending School, Children 6-18			
Treat × 2000	0.073	0.032	0.033
	(0.022)	(0.015)	(0.015)
Effect Relative to Pre-1990 High-GWD Mean	13%	6%	6%
District FE and Year FE	x	x	x
Region FE × Year FE		x	x
Additional Controls (Panel A) or FE (Panels B-F)			x
Observations in Panel A	3,888	3,888	3,888
Districts in Panel A	128	128	128
Observations in Panel B	8,151	8,151	8,151
Observations in Panel C	5,454	5,454	5,454
Observations in Panel D	22,699	22,699	22,699
Observations in Panel E	3,178	3,178	3,178
Districts in Panels B-E	105	105	105
Observations in Panel F	880,325	880,325	880,325
Districts in Panel F	106	106	106

Notes: Observations in Panel A are district-years and in Panels B-F are individuals. NDVI data are from GeoQuery, and GLSS (rounds 1, 2, and 4) and census (1984 and 2000) data are from the Ghana Statistical Service. Panel A uses Poisson regression with districts weighted by land area, and Panels B-F use OLS. Additional controls in Panel A are for precipitation and temperature, and additional fixed effects in Panels B-F are for age and sex. Standard errors in parentheses are clustered by districts.

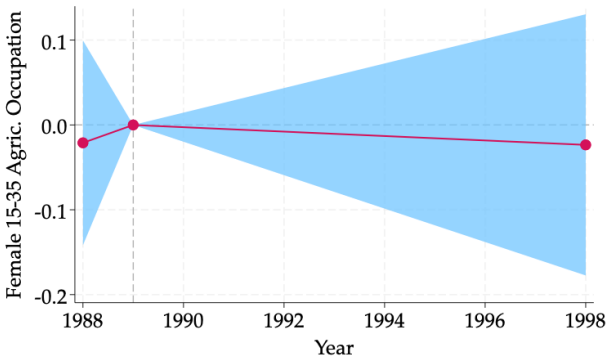
Figure 2: Plots for District-Level Effects [11]



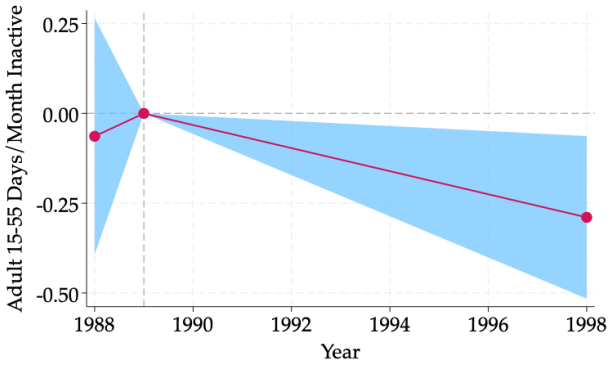
(a) Poisson: Max-Min Gap in NDVI Values



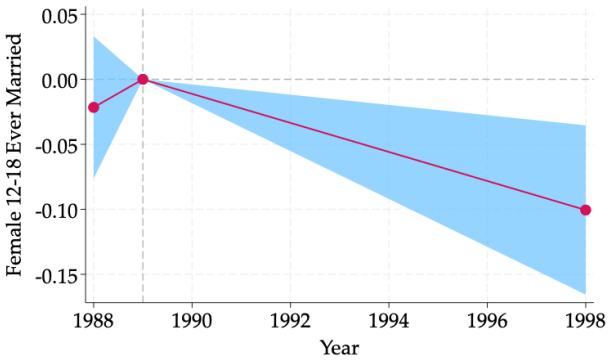
(b) GLSS: Working for Wages, Females 15-35



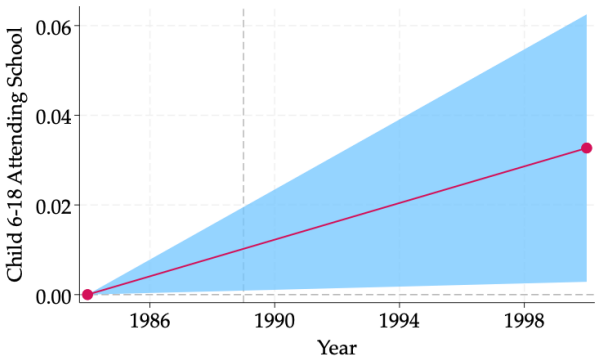
(c) GLSS: Agricultural Occupation, Females 15-35



(d) GLSS: Days Inactive in Past Month, Ages 15-55



(e) GLSS: Ever Married, Females 12-18



(f) Census: Attending School, Ages 6-18

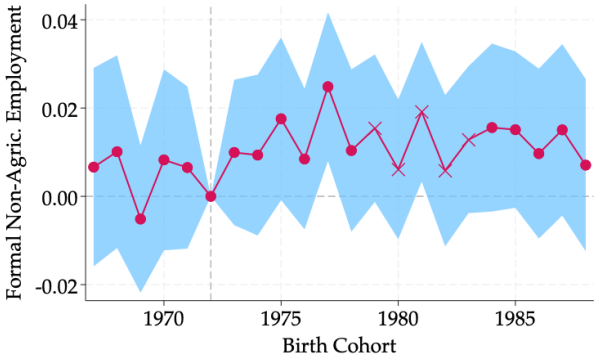
Notes: Graphs show estimates with 95% confidence intervals. NDVI data are from GeoQuery, GLSS (rounds 1, 2, and 4) data are from the Ghana Statistical Service, and census data (1984 and 2000) are the IPUMS 10% samples. Top left panel uses Poisson regression with district, year, and region-by-year fixed effects and districts weighted by land area, as in Table 1 Column (2). All other panels use OLS with district, year, region-by-year, age, and sex fixed effects, as in Table 1 Column (3). Standard errors are clustered by district.

Table 2: Individual-Level Effects of GWD Eradication [14]

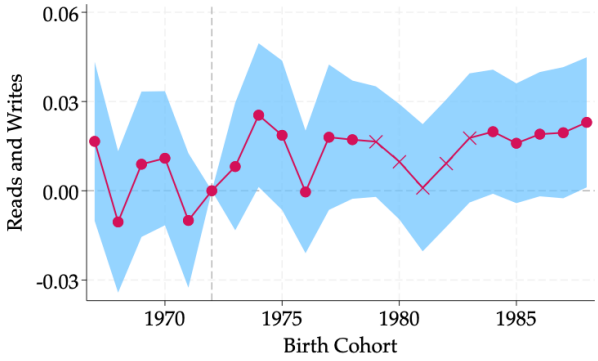
	(1)	(2)	(3)
Panel A. Formal Non-Agricultural Employment			
Treat × 1974-78 Cohorts	0.014	0.015	0.014
	(0.006)	(0.007)	(0.007)
Treat × 1984-88 Cohorts	-0.001	0.013	0.012
	(0.007)	(0.008)	(0.008)
1984-88 Cohorts' Effect / Pre-1973 High-GWD Cohorts' Mean	-1%	12%	11%
Panel B. Reads and Writes in Any Language			
Treat × 1974-78 Cohorts	0.014	0.014	0.016
	(0.008)	(0.011)	(0.010)
Treat × 1984-88 Cohorts	0.019	0.018	0.019
	(0.009)	(0.010)	(0.010)
1984-88 Cohorts' Effect / Pre-1973 High-GWD Cohorts' Mean	4%	4%	4%
Panel C. Lives in Urban Municipality			
Treat × 1974-78 Cohorts	0.023	0.035	0.035
	(0.008)	(0.010)	(0.009)
Treat × 1984-88 Cohorts	0.021	0.031	0.032
	(0.008)	(0.010)	(0.010)
1984-88 Cohorts' Effect / Pre-1973 High-GWD Cohorts' Mean	4%	6%	6%
Panel D. Woman's Age at First Birth			
Treat × 1974-78 Cohorts	0.01	0.32	0.31
	(0.14)	(0.17)	(0.17)
Treat × 1984-88 Cohorts	-0.22	0.28	0.27
	(0.16)	(0.17)	(0.18)
1984-88 Cohorts' Effect / Pre-1973 High-GWD Cohorts' Mean	-1%	1%	1%
Panel E. Man's Son Reads and Writes in Any Language, Ages 9-14			
Treat × 1974-78 Cohorts	0.028	0.038	0.038
	(0.016)	(0.019)	(0.018)
Treat × 1984-88 Cohorts	0.041	0.060	0.052
	(0.017)	(0.021)	(0.020)
1984-88 Cohorts' Effect / Pre-1973 High-GWD Cohorts' Mean	6%	9%	8%
Panel F. Man's Mother Still Alive			
Treat × 1974-78 Cohorts	0.015	0.022	0.022
	(0.011)	(0.014)	(0.014)
Treat × 1984-88 Cohorts	0.018	0.017	0.017
	(0.011)	(0.013)	(0.013)
1984-88 Cohorts' Effect / Pre-1973 High-GWD Cohorts' Mean	4%	4%	3%
Birth District FE and Birth Cohort FE	x	x	x
Birth Region FE × Birth Cohort FE		x	x
Additional FE			x
Observations in Panel A	502,526	502,526	500,877
Observations in Panel B	595,917	595,917	593,775
Observations in Panel C	598,204	598,204	596,021
Observations in Panel D	267,944	267,944	267,153
Observations in Panel E	84,969	84,969	84,706
Observations in Panel F	291,784	291,784	290,587
Birth Districts in Panels A-F	241	241	241

Notes: Data are the Ghana Statistical Service 2021 census 10% sample. In Panels A-E, regressions use adults' observations and the additional fixed effects are for sex and ethnic group. In Panel F, regressions use sons' observations with fixed effects based on fathers' information and the additional fixed effects are for own age, sex, and ethnic group. Standard errors in parentheses are clustered by (father's) birth district.

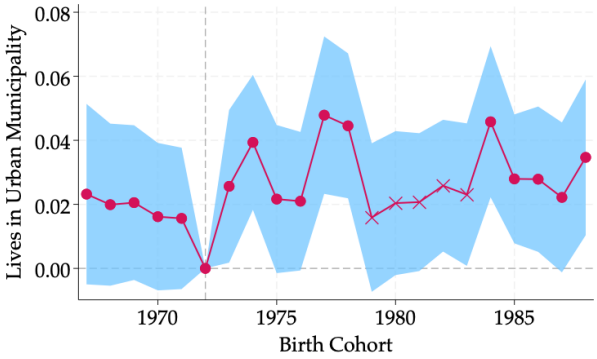
Figure 3: Plots for Individual-Level Effects [14]



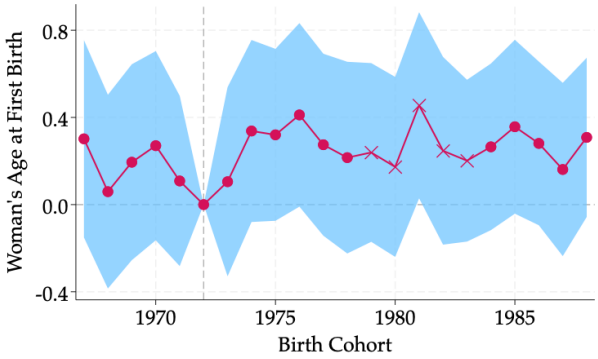
(a) Formal Non-Agricultural Employment



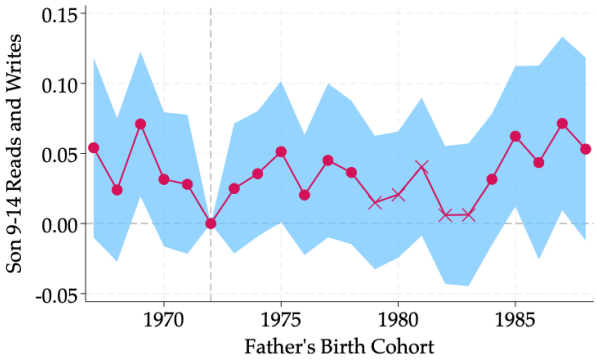
(b) Reads and Writes in Any Language



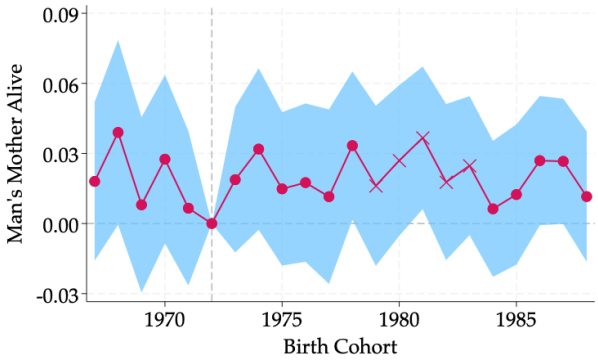
(c) Lives in Urban Municipality



(d) Woman's Age at First Birth



(e) Man's Son Reads and Writes in Any Language, Ages 9-14



(f) Man's Mother Is Still Alive

Notes: Graphs show estimates with 95% confidence intervals. Data are the Ghana Statistical Service 2021 census 10% sample. An estimate shown with an X indicates a (father's) birth cohort that was aged 0-4 during Ghana's 1983 famine. As in Table 2 Column (3), regressions using adults' observations include own birth cohort, birth district, birth region-by-birth cohort, sex, and ethnic group fixed effects, and regressions using sons' observations include the analogous fixed effects based on their fathers' observations plus fixed effects for own age, sex, and ethnic group. Standard errors are clustered by (father's) birth district.