Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Small at Birth, Stunted for Life: Do Postnatal Interventions for Low-Birth-Weight Infants Improve Child Growth?

Sikota Sharper

sikotasharper@gmail.com

Kwame Nkrumah University

John N. Ng'ombe

North Carolina A&T State University

Chikumbe Sankwa Evans

Kwame Nkrumah University

Research Article

Keywords: Low birthweight, Essential Newborn Care, Regression discontinuity differences-in-differences, Child stunting, Zambia

Posted Date: February 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8753911/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Small at Birth, Stunted for Life: Do Postnatal Interventions for Low-Birth-Weight Infants Improve Child Growth?

Sikota Sharper[1], John N. Ng'ombe[2], Chikumbe Sankwa Evans[1,3]

[1] Department of Economics and Finance, Kwame Nkrumah University, Kabwe, Zambia.
[2] Department of Economics, North Carolina A&T State University, Greensboro, North Carolina, USA
[3] Department of Economics, University of Zambia, Lusaka, Zambia
Correspondence: email sikotasharper@gmail.com, Department of Economics and Finance, Kwame Nkrumah University, Kabwe, Zambia.

Abstract

Low birth weight remains a leading risk factor for child growth faltering and early-life morbidity worldwide, prompting many low- and middle-income countries to adopt targeted newborn care policies that intensify postnatal support for at-risk infants. This study evaluates whether such policy targeting translates into measurable improvements in child growth, using evidence from Zambia's 2014 Essential Newborn Care (ENC) Policy, which expanded postnatal interventions for infants born below 2,500 grams. We draw on pooled data from the Zambia Demographic and Health Surveys (2007-2018), focusing on children aged 0-59 months with valid birthweight and anthropometric measurements. Our empirical strategy employs a regression discontinuity difference-in-differences (RD-DID) design that exploits the sharp eligibility threshold at 2,500 grams and compares changes in the discontinuity before and after the policy rollout. We estimate local linear RD-DID models across multiple bandwidths and account for birth heaping through donut and jittering adjustments. We find steep birthweight gradients in stunting and related outcomes, underscoring the vulnerability of low-birth-weights infants. However, we find little evidence that the policy led to meaningful improvements in child growth at the eligibility cutoff. Estimated effects on stunting, underweight, wasting, thinness and diarrhoea morbidity are consistently small, imprecisely estimated, and statistically insignificant across a wide range of specifications. Taken together, the findings suggest that, in its current form, Zambia's low-birth-weight newborn care policy has generated limited gains in early-life growth, underscoring potential gaps between policy design, implementation, and effective delivery of postnatal care in resource-constrained settings.

Key words: Low birthweight, Essential Newborn Care, Regression discontinuity differences-in-differences, Child stunting, Zambia

JEL Codes: I15; I18; J13; O15

1.0 Introduction

Child undernutrition remains one of the most persistent public health and development challenges in sub-Saharan Africa (SSA), with Zambia among the most affected countries. Poor nutrition in early life accounts for nearly half of all deaths among children under five and leaves lasting scars on human capital formation. Despite modest progress over the past decade, the prevalence of child undernutrition in Zambia remains alarmingly high. According to the 2018 Zambia Demographic and Health Survey (ZDHS) (ZDHS, 2018), 35% of children under five are stunted, 12% are underweight, and 4% are wasted—only marginal improvements from 40%, 15%, and 6%, respectively, in 2013. These national averages mask substantial spatial inequalities: stunting rates exceed 45% in Northern and Luapula Provinces and remain significantly higher in rural (36%) than urban (32%) areas (LCMS, 2022; ZDHS, 2018). Chronic undernutrition thus continues to underlie nearly half of all child deaths in Zambia.

Stunting is not merely a failure of physical growth: it reflects cumulative nutritional and health deprivation with profound lifelong consequences. A large body of evidence shows that early-life undernutrition irreversibly impairs cognitive development, reduces school enrolment and learning outcomes, and lowers adult productivity and earnings (Barham et al., 2013; Miguel & Kremer, 2004). These individual-level losses aggregate into substantial macroeconomic costs, with stunting estimated to reduce Gross Domestic Product (GDP) by 2-3% annually in low-income countries (Alderman et al., 2017; Hoddinott et al., 2013). In this sense, childhood stunting represents both a public health failure and a binding constraint on long-run economic growth.

In Zambia, growth faltering emerges early and accelerates rapidly after infancy. Stunting prevalence rises sharply after 6 months of age and peaks between 18 and 24 months, when nearly 46% of children are stunted, compared with just 19% among infants aged 0-6 months (LCMS, 2022; Levin et al., 2025; UNICEF, 2024). This pattern underscores the

biological and economic importance of the first 1,000 days—from conception through early childhood. This is a critical window during which nutritional insults can permanently alter neurodevelopment, immune function, and later-life human capital (Currie & Almond, 2011). Interventions during this period could therefore offer the highest potential returns.

A key driver of early growth faltering is low birth weight (LBW), defined as the birth weight below 2,500 grams. LBW infants face elevated risks of infection, growth failure, and mortality and are significantly more likely to become stunted in early childhood (Aryastami et al., 2017). In Zambia, poor maternal nutrition, adolescent pregnancy, infectious disease burden, and limited access to antenatal care contribute to a high incidence of LBW. The consequences are intergenerational: undernourished girls are more likely to become undernourished mothers, perpetuating a cycle of low birth weight and stunting across generations. These dynamics highlight the critical importance of interventions that target not only prenatal conditions but also the postnatal period for LBW infants, when growth recovery may still be possible.

Although the determinants of stunting are multifactorial—encompassing maternal nutrition, infant feeding practices, recurrent illness, sanitation, and poverty, evidence suggests that well-designed nutrition and health interventions can substantially reduce growth faltering. Scaling up proven interventions such as exclusive breastfeeding, micronutrient supplementation, and improved complementary feeding has been shown to reduce stunting by 20–36% (Bhutta et al., 2013). Zambia has embraced this evidence through multi-sectoral strategies, including the Scaling Up Nutrition (SUN 2.0) initiative and the Most Critical Days Programme (MCDP II), which integrate health, agriculture, and social protection. Yet despite these efforts, national stunting rates remain stubbornly high, raising concerns about the effectiveness, targeting, and cost-efficiency of existing policy instruments (Levin et al., 2025).

Poor maternal nutrition, inadequate infant feeding practices, recurrent infections, and limited access to clean water, sanitation, healthcare, and education interact to sustain chronic

malnutrition (UNICEF, 2024; ZDHS, 2018). Although evidence-based interventions such as micronutrient supplementation, exclusive breastfeeding, and improved complementary feeding can reduce stunting by 20-36% when scaled effectively (Bhutta et al., 2013), sustained progress requires coordinated, multi-sectoral approaches that also address the underlying determinants, maternal health, WASH, and household food security. Recognizing this complexity, Zambia's SUN 2.0 and MCDP II integrate health, agriculture, and social protection to strengthen nutrition outcomes, yet stunting levels remain unacceptably high (Levin et al., 2025).

One major gap in the evidence base concerns the effectiveness of postnatal interventions targeted specifically at LBW infants. While the biological vulnerability of LBW infants is well documented, there is limited causal evidence particularly from SSA on whether enhanced postnatal care can mitigate long-term growth deficits. In 2014, Zambia introduced revised Essential Newborn Care (ENC) guidelines that standardized and strengthened postnatal care for LBW infants. These guidelines emphasize closer follow-up, growth monitoring, early feeding support, and timely management of illness, moving beyond survival-oriented care toward interventions designed to promote healthy growth and development. Whether these policy changes translate into measurable improvements in child growth and health outcomes remains an open and policy-relevant question.

The introduction of ENC by the Government of Zambia was a response to the elevated risks faced by LBW infants in a way to strengthen the country's newborn health framework. The ENC guidelines explicitly recommend intensified postnatal interventions for infants weighing below 2,500 grams at birth, including Kangaroo Mother Care, early initiation and support of breastfeeding, supplementary feeding, growth monitoring, and micronutrient supplementation (Ministry of Health (MoH), 2014). Crucially, the ENC guidelines institutionalized a national eligibility rule linking enhanced postnatal support to the 2,500-gram birthweight threshold, creating a sharp policy cutoff. While these interventions are widely

promoted, existing evaluations have largely relied on descriptive or correlational approaches, limiting inference about causal impacts and resource efficiency (Kyei et al., 2012).

This study addresses that gap by examining whether LBW-targeted postnatal interventions under Zambia's ENC policy improved child growth and broader nutrition and health outcomes. Specifically, we assess whether enhanced postnatal care for infants just below the 2,500-gram birthweight threshold led to improvements in height-for-age z-score (HAZ), weight-for-age z-score (WAZ), and weight-for-height z-score (WHZ). By focusing on children born near the LBW cutoff, we isolate the causal impact of eligibility for enhanced care, rather than confounding differences in household or maternal characteristics.

Establishing such causal evidence is particularly important in policy environments characterized by binding budget constraints. Despite a strong investment case for nutrition, progress in reducing stunting in Zambia remains constrained by the complexity of multi-sectoral implementation, limited fiscal space, and uncertainty about which intervention packages deliver the highest returns. Evidence from low- and middle-income countries shows substantial inconsistency in how governments prioritize nutrition interventions under budget constraints, underscoring the need for credible causal evidence to guide resource allocation (Manorat et al., 2020; Sodjinou et al., 2014).

Our study makes two main contributions to the literature. First, we provide the first causal evidence from SSA on the long-term impacts of LBW-targeted postnatal interventions on child growth outcomes. Using a Regression Discontinuity Difference-in-Differences (RD-DiD) design, we exploit the sharp birthweight eligibility threshold and the timing of the ENC policy rollout to credibly identify impacts, net of pre-existing trends and concurrent policies. This methodological approach advances the health economics literature by demonstrating how administrative cutoffs embedded in health policy can be leveraged to evaluate early-life interventions in low-resource settings.

Second, we extend the analysis beyond linear growth to examine broader nutrition and health spillovers, including underweight, wasting, thinness, and recent illness. This allows us to assess whether the benefits of enhanced postnatal care operate through multiple pathways such as improved feeding practices, disease prevention, and early treatment—and whether gains in survival-oriented care translate into meaningful improvements in child well-being. From a policy perspective, our findings provide actionable evidence to inform the prioritization, targeting, and scaling of nutrition investments under budget constraints. By addressing measurement challenges such as heaping birthweight in Demographic and Health Survey (DHS) data and applying a rigorous quasi-experimental design, this study contributes robust evidence to national and global efforts to reduce stunting, improve early-life health, and accelerate progress toward the Sustainable Development Goals.

2.0 Conceptual framework

Figure 2 presents the conceptual framework linking Zambia's 2014 ENC policy to child growth and health outcomes. The framework distinguishes between prenatal determinants of vulnerability, policy-induced postnatal mechanisms, and subsequent child and household-level outcomes, while recognizing the moderating role of health-system and household constraints.

A chain of prenatal factors including structural and socioeconomic conditions, maternal education, household poverty, access to antenatal care, maternal nutrition, and in utero growth conditions jointly determine birth outcomes such as preterm delivery, birth complications, and LBW. These early-life conditions establish baseline vulnerability and strongly predict subsequent growth faltering and long-run human capital outcomes (Currie & Almond, 2011; Aryastami et al., 2017). They also determine which infants fall below the 2,500-gram threshold that defines eligibility for intensified postnatal care under the ENC guidelines. These determinants are assumed to be predetermined with respect to the policy and therefore

unaffected by its introduction, although they may influence responsiveness to postnatal interventions.

Eligibility for ENC-targeted care triggers a package of intensified postnatal interventions designed to mitigate the elevated biological risks faced by LBW infants. These interventions are hypothesized to affect child growth through multiple, complementary pathways. Improved breastfeeding initiation and sustained support, enhanced complementary feeding practices, and targeted supplementary feeding increase dietary adequacy during the critical postnatal growth window, supporting both linear growth and weight gain (Bhutta et al., 2013; Victora et al., 2016). More frequent and higher-quality growth monitoring facilitates early detection of growth faltering and timely corrective actions, while micronutrient supplementation reduces deficiencies that impair skeletal growth and immune function (Black et al., 2013). Strengthened follow-up and clinical care improve early recognition and management of childhood illnesses, reducing infection-related nutrient losses, dehydration, inflammation, and appetite suppression, key pathways linking morbidity to growth failure (Checkley et al., 2008). Together, these mechanisms are expected to improve anthropometric outcomes including HAZ, WAZ, and WHZ, and to reduce morbidity, particularly diarrhoeal disease and other infection-related conditions.

The framework also incorporates behavioural and intra-household spillover mechanisms. Through repeated interaction with the health system and targeted counselling under the ENC guidelines, caregivers, particularly mothers may acquire and internalize improved knowledge and practices related to breastfeeding, complementary feeding, hygiene, care-seeking behaviour, and growth monitoring.

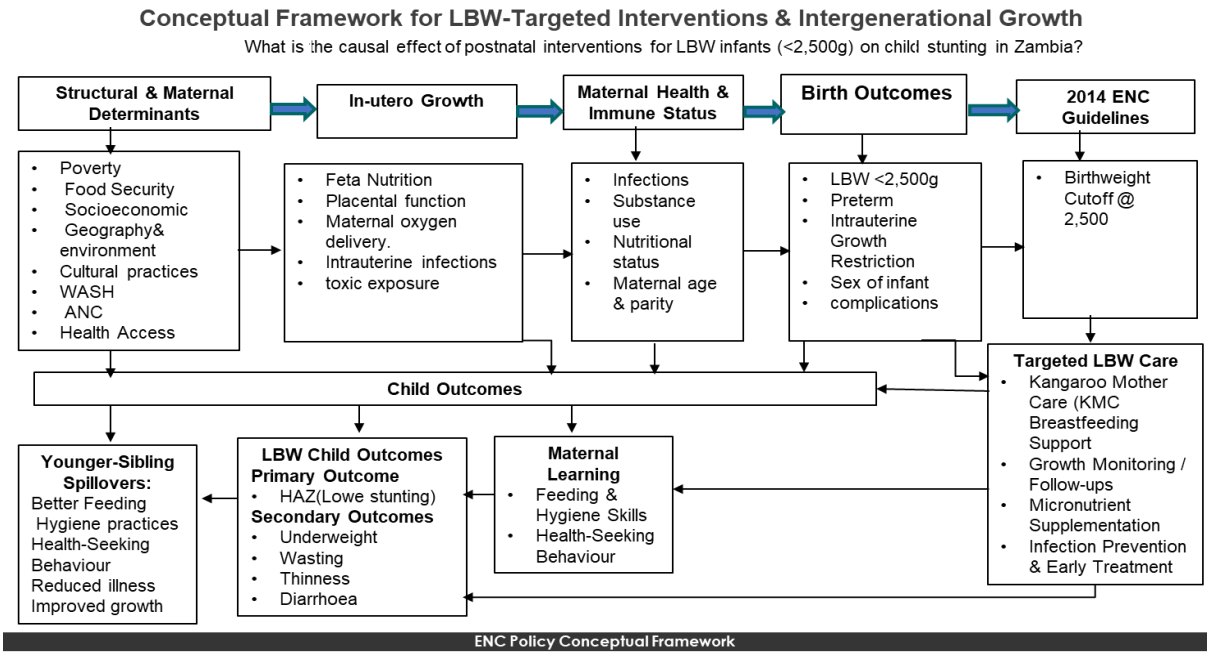


Figure 1: Conceptual Framework for LBW-targeted Postnatal Interventions and Child Growth in Zambia.

Notes: Prenatal factors shape baseline vulnerability and birth outcomes but are unaffected by the ENC policy. The 2,500g cutoff triggers targeted postnatal care, which is the primary channel through which the policy influences child growth. Behavioral spillovers occur through maternal learning and benefit younger siblings.

Such behavioural changes are central to nutrition-sensitive interventions and may persist over time (Ruel & Alderman, 2013). These practices can subsequently be applied to younger siblings, generating spillovers beyond the directly targeted LBW child. Consistent with evidence from early-life health interventions, these spillovers may operate through both learning and reallocation of household resources, improving outcomes even for children who were not LBW at birth (Daysal et al., 2022).

Finally, the framework recognizes that the magnitude and distribution of policy impacts may be moderated by health-system capacity including staffing, supply availability, service quality, and geographic access as well as by household constraints such as poverty, food insecurity, and maternal time allocation. Variation in compliance with recommended practices and intensity of service delivery may attenuate average treatment effects (Das et al., 2018; Miller & Babiarz, 2014). The framework also allows for potential offsetting behaviors, such as substitution between public and private inputs or differential take-up across socioeconomic

groups, which may further shape observed outcomes without overturning the expected direction of effects.

3.0 Data

3.1 Sampling

This study draws on nationally representative cross-sectional data from the 2007, 2013/14, and 2018 Zambia Demographic and Health Surveys (ZDHS). The ZDHS interview women aged 15–49 residing in sampled households and collect detailed information on fertility, maternal and child health, and household characteristics. In each survey wave, all children aged 0–59 months born to interviewed women are included in the children's module, where standardized anthropometric measurements and health indicators are collected.

The unit of analysis was the child aged 0–59 months with non-missing information on birthweight and HAZ. Birthweight serves as the running variable, while child nutritional and health outcomes constitute the primary outcomes of interest. The empirical strategy exploits the introduction of Zambia's ENC guidelines in 2014, which linked eligibility for intensified postnatal care to a birthweight threshold of 2,500 grams. Accordingly, we implement a Regression Discontinuity Difference-in-Differences (RD-DiD) design that compares changes in outcome discontinuities at the 2,500g cutoff before and after ENC implementation.

3.2 Treatment Variable

Treatment is defined by eligibility for enhanced postnatal care at the 2,500g birthweight threshold. As illustrated in Figure 2, the ENC policy generates a discontinuous increase in the intensity and probability of postnatal care for infants weighing below 2,500 grams. Infants just below the cutoff are flagged for closer clinical follow-up, feeding support, caregiver counselling, thermal care, and growth monitoring, whereas those just above the threshold receive standard postnatal care.

Because the DHS does not directly observe treatment intensity or compliance with ENC-recommended practices, the analysis exploits the policy-induced discontinuity at the cutoff as a proxy for treatment assignment. The identifying assumption is that infants born just below and just above the 2,500g threshold are otherwise comparable, such that any post-policy change in outcomes at the cutoff reflects the causal effect of enhanced postnatal care rather than underlying differences in infant or household characteristics. Comparing the magnitude of the discontinuity before and after ENC rollout further removes any pre-existing threshold effects, ensuring that estimated impacts capture policy-induced changes rather than persistent birthweight-related patterns.

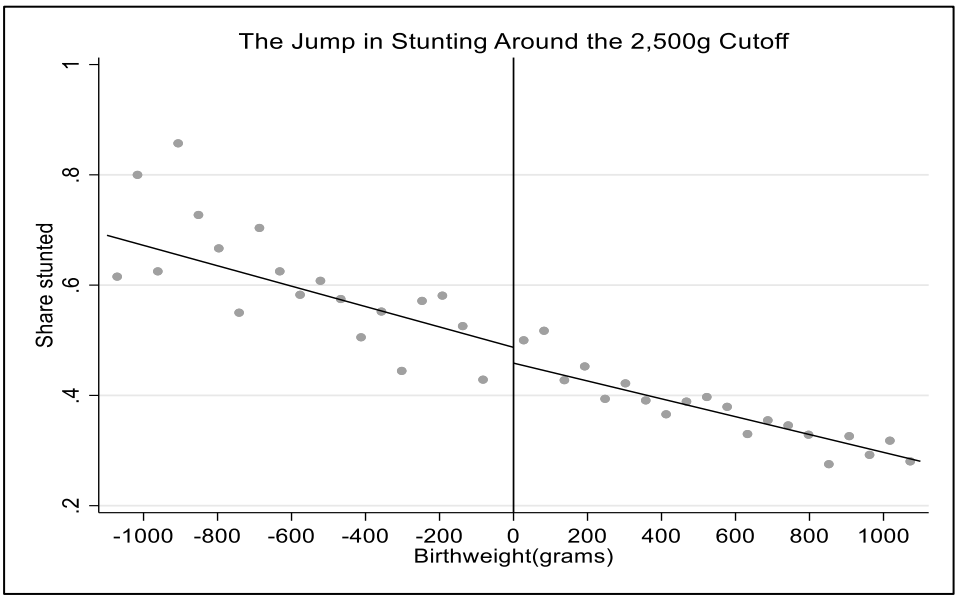


Figure 2: The Discontinuity in Stunting Around the 2500g Cutoff

Notes: the figure plots mean stunting rates by centered birthweight (±1,000g) using 50g bins, with local linear fits estimated separately on each side of the 2,500g cutoff. The observed jump reflects the increase in postnatal care intensity for low-birth-weight infants following ENC implementation.

3.3 Outcome variables

The primary outcome of interest is stunting, defined as a height-for-age z-score (HAZ) below −2 standard deviations from the World Health Organization (WHO) child growth standards. To capture broader nutritional and health effects, we also examine underweight (weight-for-

age z-score < −2), wasting (weight-for-height z-score < −2), thinness (BMI-for-age z-score < −2), and recent illness.

Anthropometric indicators are computed by the ZDHS using standardized height and weight measurements collected during household visits. Stunting reflects chronic growth failure, wasting captures acute malnutrition, and thinness measures low body mass relative to age. Underweight combines elements of both chronic and acute nutritional deficits. Child morbidity is proxied by caregiver reports of diarrhea, defined as the occurrence of three or more loose stools in the two weeks preceding the survey. Together, these outcomes provide a comprehensive assessment of child nutritional status and morbidity in Zambia.

3.4 Descriptive Statistics

Figure 3 documents strong and consistent birthweight gradients across key child health outcomes. For stunting, underweight, wasting, and recent diarrhoea, children born with lower birthweight face systematically higher risks than their heavier counterparts. These gradients are particularly steep in the LBW range between 2,000g and 3,000g, indicating that children born within this interval are especially vulnerable to adverse health outcomes. Lower birthweight in this range is associated with higher susceptibility to infections, feeding difficulties, reduced nutrient absorption, and more rapid weight loss, all of which compromise early-life growth and health.

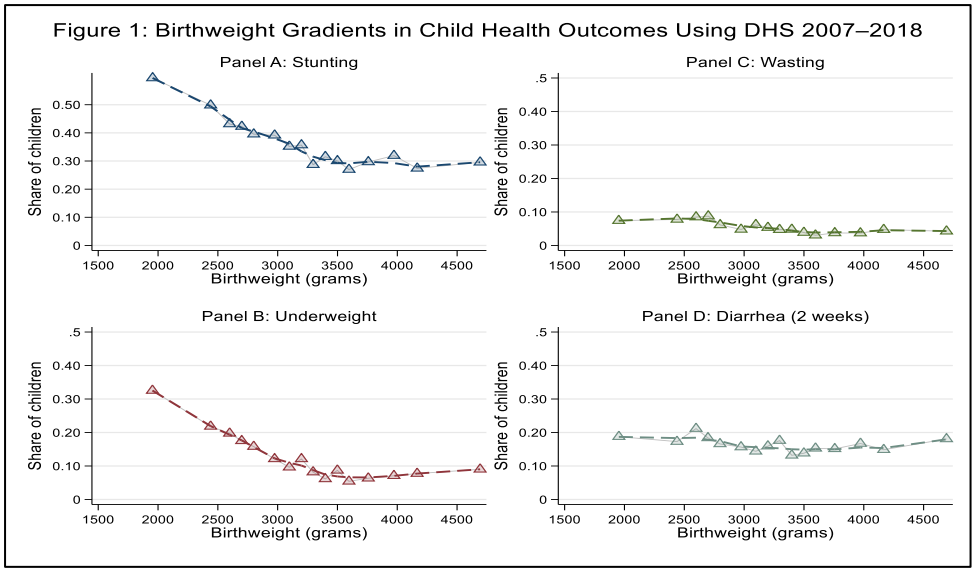


Figure 3: Birthweight Gradient in Child Health Outcomes using DHS 2007-2018

Notes: Figure 1 uses pooled DHS 2007–2018 child data. Birthweight is grouped into 20 survey-weighted quantile bins, with Locally Weighted Scatterplot Smoothing (LOWESS) curves fitted to the binned means. Analysis is limited to children with non-missing birthweight, sampling weights, and outcome measurements.

Panel A shows that stunting declines sharply as birthweight increases. The prevalence of stunting among LBW infants exceeds 50 percent, reflecting compromised fetal growth and heightened vulnerability in early life. Children born with low birthweight begin life with reduced linear growth potential, weaker immune systems, and increased exposure to repeated infections, which cumulatively depress height-for-age outcomes. These pronounced gradients underscore why LBW is a meaningful policy target and provide strong motivation for exploiting the 2,500g threshold within a quasi-experimental framework. Notably, the largest changes in stunting, underweight, wasting, and diarrhoea prevalence occur around the cutoff, precisely where enhanced postnatal care interventions are triggered and where policy effects are most likely to alter long-term growth trajectories.

Table 2 presents descriptive statistics for children born just below and just above the 2,500g cutoff. The analytical sample includes 19,970 children, of whom 1,775 are classified as LBW (treated) and 18,195 as non-LBW (control). Overall, the two groups are highly comparable across observable characteristics, suggesting strong local balance around the

threshold. Gender composition differs modestly, with a slightly higher share of females among LBW infants (54.6 percent) compared to controls (48.8 percent). Socioeconomic characteristics are closely aligned: approximately 43 percent of births occur in urban areas, wealth quintile distributions are similar across groups, and access to piped water and basic sanitation shows only minor differences. For instance, the poorest wealth quintile is only marginally overrepresented among LBW children (20.2 percent versus 18.3 percent).

Table 2. Descriptive Characteristics Near the 2,500g Threshold

Variable	≥2500 g (Control)	<2500 g (Treated)	Total
Sample size (N)	18,195	1,775	19,970
Gender of child (%)			
Female	48.8	54.6	49.3
Male	51.2	45.4	50.7
Place of residence (%)			
Urban	43.4	44.8	43.5
Rural	56.6	55.2	56.5
Wealth index (%)			
Poorest	18.3	20.2	18.5
Poorer	20.6	20.0	20.5
Middle	21.6	21.7	21.6
Richer	21.3	22.3	21.4
Richest	18.2	15.8	18.0
Female education (%)			
No education	7.4	8.8	7.5
Primary	50.4	51.7	50.5
Secondary	37.1	34.9	36.9
Higher	5.1	4.5%	5.0
Access to piped water (%)			
No	68.8	67.9	68.7
Yes	31.2	32.1	31.3
Basic sanitation (%)			
Not basic	73.0	75.7	73.2
Basic	27.0	24.3	26.8
U5 slept under bed net (%)			
No	44.2	47.2	44.5
Yes	55.8	52.8	55.5
Four or more ANC visits (%)			
No	36.9	43.0	37.4
Yes	63.1	57.0	62.6

Note: Figures are survey-weighted percentages unless otherwise indicated. Comparisons between pre-policy and post-policy births (pre = before July 2014; post = July 2014 onward)

Maternal and child health characteristics exhibit small but economically meaningful differences. Mothers of LBW infants are slightly less educated, with 8.8 percent reporting no formal education compared to 7.4 percent among mothers of non-LBW children, and

correspondingly fewer attaining secondary or higher education. Health service utilization also differs modestly: 57 percent of mothers of LBW infants completed at least four antenatal care visits, compared to 63 percent among controls, suggesting that inadequate prenatal care may contribute to low birthweight. Similarly, LBW children are slightly less likely to have slept under a bed net (52.8 percent versus 55.8 percent), potentially reflecting differences in household preventive health practices. While these imbalances are not large enough to threaten comparability near the cutoff, they highlight plausible socioeconomic and behavioral pathways—such as maternal education, antenatal care, and household health environments—through which early-life conditions influence both birth outcomes and subsequent child growth.

Figure 4 examines the distribution of birthweight and assesses the validity of the regression discontinuity design by inspecting potential manipulation around the 2,500g cutoff.

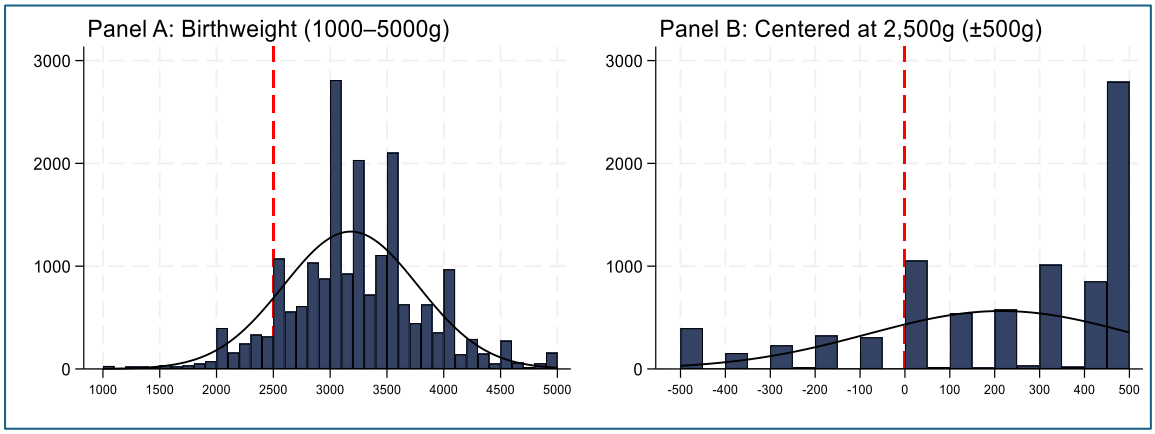


Figure 4: Birthweight Distribution and Heaping Around the 2,500g Cutoff

Notes: Panel A shows the full birthweight distribution (1,000–5,000g), with visible mass points at rounded values. Panel B zooms in around the 2,500g cutoff (±500g). Heaping occurs at multiple rounded values, consistent with non-strategic clinician rounding rather than manipulation.

Panel A reveals clear mass points at rounded values—most notably at 2,000g, 2,500g, 3,000g, 4,000g, and 5,000g—consistent with birthweight heaping arising from routine rounding practices by health personnel. Importantly, heaping occurs at multiple 100g and 500g intervals throughout the distribution and is not unique to the LBW cutoff. Panel B, which focuses on the region surrounding 2,500g, shows a similar pattern: while a mass point is visible at the cutoff,

comparable rounding is evident at neighboring values. This pattern suggests that heaping reflects non-strategic measurement practices by nurses, midwives, and clinicians rather than deliberate manipulation of birthweight records to influence treatment eligibility.

Taken together, the distributional evidence supports the validity of the regression discontinuity design by indicating that birthweight heaping is plausibly random with respect to treatment assignment. At the same time, it motivates the robustness checks implemented later in the analysis to address discrete support and potential measurement error.

4.0 Empirical Strategy

To obtain the exogeneous variation in postnatal care intensity, we exploit the policy rule embedded in Zambia's ENC guidelines, which mandate enhanced postnatal care for infants born with birthweight below 2,500g. We therefore use a local RD-DiD design that compares the discontinuity in child health outcomes at the 2,500g before and after the ENC policy rollout in July 2014.

The identifying intuition is twofold. First, births occurring just below and just after the 2,500g threshold are highly comparable, so any sharp change in outcomes at the cutoff can be attributed to differences in postnatal care intensity rather than underlying child or maternal characteristics. Second, comparing the size of this discontinuity before and after the ENC implementation differences out any pre-existing threshold effects unrelated to the policy. By combining regression discontinuity with a difference-in-differences framework, the RD-DiD design addresses concerns related to endogeneity, reverse causality, measurement error in treatment intensity, and functional-form dependence that often limit standard regression approaches.

Formally, the RD-DiD design identifies the causal effect of the ENC policy on children born close to the low-birth-weight cutoff by isolating the policy-induced change in the

discontinuity at 2,500g. The analysis is grounded in a potential outcomes framework, $Y_i(w, r)$, defined at the LBW cutoff, which is outlined in appendix D.

We estimate the following local linear regression model within the symmetric bandwidth around the 2,500g cutoff:

$$\begin{aligned} Y_i = \alpha + \delta_1 \text{Below2500}_i + \delta_2 \text{Post}_i + \beta(\text{Below2500}_i \times \text{Post}_i) \\ +\gamma_1 x_i + \gamma_2(x_i \times \text{Below2500}_i) + \gamma_3(x_i \times \text{Post}_i) \\ +\gamma_4(x_i \times \text{Below2500}_i \times \text{Post}_i) \\ +\mathbf{X}_{i'}\boldsymbol{\theta} + \epsilon_i, \end{aligned} \quad (1)$$

where Y_i is height-for-age Z-core (HAZ) for child i, Below2500_i is binary indicator and equals to one if child i's birth weight is below 2500g, and zero otherwise. Post_i is binary indicator equal to one if child i was born after the ENC policy implementation (July 2014), x_i is the centered birth weight defined as $BW_i - 2500$. The interaction term $\text{Below2500}_i \times \text{Post}_i$ identifies the RD-DD estimator. The coefficient β captures the causal effect of the ENC policy on child stunting among LBW infants at the cutoff, net of any pre-existing discontinuity at 2,500g. The vector $\mathbf{X}_i$ includes pre-determined covariates including child's sex, birth order, maternal age, education, and household characteristics, which improve precision but are not required for identification.

The specification allows for separate linear trends in birthweight on either side of the cutoff and across policy periods by including interactions between the running variable, the cutoff indicator, and the post-policy indicator. This flexible structure ensures that the estimated treatment effect is not driven by differential slopes in the relationship between birthweight and child outcomes. In the framework, δ_1 measures any pre-policy discontinuity in HAZ at the LBW threshold while δ_2 reflects common changes in outcomes across cohorts born after the ENC rollout. The same framework applies to other outcome variables.

5.0 Estimation results

5.1 Effects of LBW-Targeted Postnatal Care on Child Stunting

Table 4 reports local linear RD–DiD estimates at the 2,500g birthweight cutoff, using a triangular kernel and a bandwidth of 250g. This baseline specification does not apply donut exclusions, heaping corrections, or jittering to address mass points in the birthweight distribution. All models adjust for predetermined child, maternal, and household covariates, with standard errors clustered at the primary sampling unit level.

Across all age groups considered, children aged 6–23 months, 24–59 months, and the pooled sample of 6–59 months, the estimated RD–DiD coefficients are negative, indicating a directional reduction in stunting among infants just below the LBW threshold in the post-policy period relative to the pre-policy period. For children aged 6–23 months, the point estimate implies a 29-percentage-point reduction in stunting. However, the estimate is statistically insignificant. Similar patterns emerge for older children and the pooled sample.

Taken together, these results provide no statistically robust evidence of a discontinuous improvement in stunting at the 2,500g cutoff attributable to the rollout of the ENC policy under the baseline local linear specification. While the consistency in the sign of the estimates across age groups is suggestive, the lack of precision precludes strong causal claims. Overall, the findings indicate that any policy-induced effect on stunting is weak and not reliably distinguishable from zero in this baseline framework.

Table 4. Local Linear RD–DiD Estimates for Stunting at the 2500 Cutoff (Bandwidth = 250g)

	1	2	3
Outcome	Age 6–23m	Age 24–59m	Age 6–59m
Stunting	-0.290	-0.362	-0.258
	(0.340)	(0.373)	(0.269)
N	523	505	1,028
R^2	0.1415	0.1080	0.0779
Heaping correction	No	No	No
Donut RD	No	No	No

Notes: Local linear RD-DiD estimates using a 250 bandwidth and triangular kernel. No jittering and no donut were applied. All models are adjusted for baseline covariates. SEs clustered at Primary Sampling Unit (PSU) level.

Across robustness checks that apply donut RD only, heaping correction via jittering only, and both adjustments jointly, the RD-DiD point estimates for children aged 6-23 months remain consistently negative, indicating directional improved stunting outcomes for infants just below the LBW cutoff. Although these estimates are not statistically significant, their stability in sign across alternative treatments of the running variable suggests that the baseline findings are not driven by mechanical mass points or heaped observations at the 2,500g threshold. Importantly, diagnostic checks indicate that birthweight heaping appears random rather than strategically manipulated around the cutoff, supporting the validity of the RD design. The full set of robustness results for the 6-23 months age group is reported in Appendix A.

5.2 Broader Nutritional and Health Outcomes

Table 5 presents RD–DiD estimates at the 2,500g cutoff for secondary outcomes—including underweight, wasting, thinness, and recent diarrhoea—among children aged 6–23 months. As in the baseline stunting analysis, estimates are obtained using a triangular kernel and a 250g bandwidth, without donut exclusions or heaping corrections.

The RD–DiD estimate for underweight is negative and relatively large in magnitude, implying a 34.4-percentage-point reduction in underweight prevalence among infants just below the LBW threshold in the post-policy period. However, the estimate is imprecise and not statistically significant and therefore does not provide robust evidence of a discontinuous policy effect.

For wasting and thinness, the estimated coefficients are also negative but smaller in magnitude and statistically insignificant, suggesting no detectable improvements in acute malnutrition outcomes associated with ENC eligibility at the cutoff. In contrast, the point estimate for diarrhoea is positive, indicating a directional increase in reported diarrhoeal

incidence in the post-policy period, though this estimate is likewise imprecise and statistically insignificant. Overall, the results in Table 5 reveal no statistically significant discontinuities in nutritional or morbidity outcomes at the 2,500g cutoff among children aged 6–23 months.

Table 5: Local Linear RD-DiD Estimates for Child Nutrition Outcomes (Ages 6-23 Months, Bandwidth =250g)

	1	2	2	3
Outcomes	Underweight	Wasting	Thinness	Diarrhea
Coef	-0.344	-0.109	-0.111	0.175
	(0.263)	(0.216)	(0.216)	(0.288)
N	525	522	523	546
R^2	0.1226	0.0519	0.0403	0.0518
Donut RD	No	No	No	No
Heaping correction	No	No	No	No

Notes: Local linear RD-DiD estimates using a 250 bandwidth and triangular kernel. No jittering and no donut were applied. All models adjusted for baseline covariates and ages 6-23 months. SEs clustered at Primary Sampling Unit (PSU) level.

5.3 Robustness Checks

The study conducted diagnostic tests including the McCrary density test, covariate balance checks, and placebo thresholds, with bandwidth selection based on the Imbens-Kalyanaraman method and sensitivity analyses across varying bandwidths(Gelman & Imbens, 2019). First, we re-estimated at 150h, 200h, 250h, and 300h, using local linear p=1 as the main specification and quadratic p=2 only as a check, with bias corrected confidence intervals throughout. This probes the balance between bias and variance and, given discrete and heaped birthweights, verifies that estimates are not driven by mass points or local curvature.

Table 6: Placebo Local Linear RD-DiD estimates for Stunting at the 3000G Cutoff (Bandwidth=250g)

	1	2	3
Outcome	Age 6–23m	Age 24–59m	Age 6–59m
Stunting	-0.037	-0.208	-0.145
	(0.190)	(0.211)	(0.149)
N	1,484	1,515	2,999
R^2	0.0801	0.0580	0.0355
Heaping correction	No	No	No
Donut RD	No	No	No

Notes: Local linear RD-DiD estimates using a 250 bandwidth and triangular kernel centered at the 3000g placebo cutoff. No jittering and no donut were applied. All models are adjusted for baseline covariates. SEs clustered at Primary Sampling Unit (PSU) level.

We then conducted placebo RD-DiD tests by re-centering the design at 3,000g, where no treatment rule or program eligibility threshold applied. As expected, we find no evidence of discontinuities in stunting at the placebo cutoff across age groups, as shown in table 6. For children aged 6-23 months, the placebo estimates are small, close to zero, and statistically insignificant, despite the relatively large sample size within the placebo bandwidth window. This null placebo results support design specificity, suggesting that the RD-DiD specification is not mechanically generating discontinuities at arbitrary birthweight thresholds or rounded heap points, and thereby reinforcing the interpretation of the main 2,500g results.

To address concerns related to birthweight heaping and mass points at the cutoff, additional specifications were estimated and are reported in Appendix A. These include: (i) donut RD designs excluding observations within ±10g of the cutoff; (ii) heaping-correction specifications applying ±20g jittering to heaped values; and (iii) combined specifications implementing both donut exclusions and jittering. Across all specifications, the estimated effects for children aged 6–23 months remain small, statistically insignificant, and qualitatively like the baseline results, indicating that the findings are not driven by rounding or digit preference.

Appendix C further presents graphical diagnostics, including histograms and density plots before and after heaping corrections, which confirm that birthweight heaping is systematic but non-strategic. Simulation-based jittering smooths mass points without altering the underlying distribution, reinforcing the conclusion that heaping does not drive the main results.

Table 7: Local Linear RD-DiD estimates for Stunting at the 2500g cutoff, Birth Card-only Birthweight (Bandwidth=250g)

	1	2	3
	Age 6–23m	Age 24–59m	Age 6–59m
Stunting	-0.148	-0.536	-0.271
	(0.361)	(0.443)	(0.318)
N	415	350	765
R^2	0.1159	0.1252	0.0679
Heaping correction	No	No	No
Donut RD	No	No	No

Notes: Local linear RD–DiD estimates using a 250g bandwidth and triangular kernel, based on card-only birthweight. No jittering and no donut were applied. All models are adjusted for baseline covariates. SEs clustered at Primary Sampling Unit (PSU) level.

Finally, we assessed the sensitivity of the results to potential recall bias in reported birthweight by restricting the sample to children with birth card-recorded birthweights, excluding observations based on maternal recall. As shown in Table 7, the RD-DiD estimates remained negative and statistically insignificant across all age groups and are comparable in magnitude to the baseline results. This suggested that the main findings are not driven by recall error or selective misreporting of birthweight, and that measurement differences between card-based and recalled birthweights do not materially affect the identification strategy.

6.0 Limitations of the Study

This study relies on the Zambia Demographic and Health Survey (ZDHS) data, which is cross-sectional rather than panel. As a result, the same mother or child cannot be followed over time to directly observe the impact of early-life interventions on later health outcomes. In addition, ZDHS data cannot observe actual ENC service delivery or facility-level rollout intensity. From a policy and identification perspective, the ZDHS data does not capture how exactly the ENC policy was implemented across health facilities, and the DHS does not collect facility-level data. Moreover, other concurrent maternal and child health interventions, such as the Scaling Up Nutrition (SUN 2.0) program or routine immunization campaigns, may have overlapped with ENC rollout, making it difficult to isolate the policy's independent effect on stunting outcomes. However, the empirical strategy focusses on local randomization around the 2,500g cutoff, and no other intervention in Zambia uses this threshold for eligibility, making the ENC

policy the only program that discontinuously changes at this cutoff across clinics and hospital nationwide.

The measurement of birthweight in DHS data is problematic. DHS relies on either health records or on maternal recall to record a child's birthweight at the time of the survey. Mothers often report birthweight from memory or provide approximate figures, particularly when written records are unavailable. This introduces recall bias and digit preference, whereby birthweights are rounded to multiples of 100g. Such heaping can lead to misclassification of infants into LBW or non-LBW categories. However, the observed heaping appears broadly distributed across multiple rounded values and not concentrated exclusively at the 2,500g cutoff, suggesting that rounding behaviour is largely non-strategic rather than targeted manipulation around the eligibility threshold.

To address discreteness and heaping near the cutoff which violate the assumptions of RD, we used a three-part strategy: (i) simulation-based jittering to smooth mass points in the running variables as a robustness (ii) local linear RD estimation with a triangular kernel and bias-corrected confidence intervals, incorporating discrete-support adjustments mass points (Cattaneo et al., 2024; Kolesár & Rothe, 2018); and (iii) donut RD specification excluding observations at 2,500g and within ±10/±15/±20 grams of the cutoff to mitigate bias from heaped observations (Barreca et al., 2011; Barreca et al., 2016). Across these approaches, the results remain qualitatively unchanged, supporting the robustness of the conclusions.

7.0 Conclusion and policy implications

This study provides an impact evaluation of Zambia's 2014 Essential Newborn Care (ENC) policy by exploiting the low-birth-weight eligibility threshold at 2,500g within a regression discontinuity–difference-in-differences framework. Across baseline specifications and an extensive set of robustness checks—including alternative bandwidths, donut RD designs, jittering to address birthweight heaping, placebo cutoffs, and restrictions to card-recorded

birthweights, the analysis finds no strong evidence of a discontinuous effect of ENC eligibility on child linear growth or related nutrition and morbidity outcomes at the threshold.

Although point estimates for stunting and underweight are consistently negative for children aged 6–23 months, suggesting a possible directional improvement among LBW infants following policy implementation, these effects are small, statistically insignificant, and imprecisely estimated. As such, they cannot be interpreted as robust causal impacts of the ENC policy. Importantly, these null findings are not driven by modelling choices or data artefacts. Estimates remain stable across alternative treatments of the running variable, age groups, and specification choices, indicating that the absence of detectable effects reflects limited policy-induced changes at the cutoff rather than weaknesses in the empirical design.

At the same time, descriptive evidence documents steep and persistent birthweight gradients in stunting and undernutrition, underscoring that LBW infants remain a highly vulnerable population. Taken together, the results suggest that while low birthweight is a meaningful marker of early-life risk, LBW-triggered postnatal care under the ENC policy, as implemented during the study period—did not generate sufficiently large changes in care intensity to produce measurable improvements in child growth outcomes.

The findings point to important limitations of threshold-based, postnatal-only policy approaches to stunting reduction. The absence of a detectable discontinuity at the 2,500g cutoff suggests that eligibility rules alone are insufficient to induce behavioral changes or service-delivery responses large enough to alter child growth trajectories. Despite formal eligibility for intensified care, the ENC policy does not appear to have generated sufficient increases in coverage, intensity, or continuity of postnatal interventions to produce detectable gains near the threshold.

More broadly, the results highlight the constraints of relying on postnatal interventions to address outcomes whose origins are largely prenatal and cumulative. Growth faltering in

Zambia begins in utero and accelerates during the first two years of life, implying that interventions triggered at birth may arrive too late to offset earlier nutritional and health disadvantages. These findings underscore the importance of policy designs that place greater emphasis on maternal nutrition, antenatal care quality, and sustained support throughout the first 1,000 days, rather than narrowly targeting infants based on birthweight alone.

Finally, the study underscores the central role of implementation and measurement in determining policy effectiveness. The inability to observe ENC service delivery intensity and facility-level rollout limits both targeting and evaluation, while birthweight mismeasurement complicates eligibility assignment. The null effects documented here should therefore be interpreted not as evidence against newborn care investments, but as a call to rethink policy design and delivery mechanisms. Strengthening routine birthweight measurement, improving monitoring of postnatal care intensity, and integrating ENC within broader, multi-sectoral nutrition strategies may be necessary for such policies to achieve meaningful reductions in stunting.

Declarations

- Ethical approval and consent to participate

  Not Applicable
- Consent for publication

  Not Applicable
- Availability of data and material

  All the data used is included in the appendix
- Competing interests

  No competing interest
- Funding

  Not Applicable
- Author's contributions

SS led the study design, gathered and analysed the data, and prepared the initial manuscript draft. JN contributed to the study design and provided critical feedback on the manuscript. CSE also participated in the study design, offered critical revisions and provided a detailed critique of the study. All authors reviewed, provided feedback, and approved the final manuscript

- Author's Information

Sharper Sikota is a Health Economist. His research interests primarily focus on economic evaluation, microeconometrics, and measuring health outcomes. He is particularly interested in causal inference and the application of quasi-experimental methods to evaluate large-scale health programs. He is a Chevening alumnus and a Fulbright Ph.D. scholar in Health Economics.

Lecturers at Kwame Nkrumah University, Department of Economics and Finance, Plot 1583 Munkoyo Street, Kabwe, Zambia. Sikota Sharper, Chikumbe Sankwa Evans.

- Acknowledgements

I wish to acknowledge the full sponsorship I received from the Chevening to pursue MSc International Public Health at LJMU. I am thankful to all members of staff at LJMU Public health Institute, and I am particularly thankful Rose Khatri for her guidance, encouragement, and mentorship.

References

Alderman, H., Behrman, J. R., & Puett, C. (2017). Big numbers about small children: estimating the economic benefits of addressing undernutrition. *The World Bank Research Observer*, *32*(1), 107-125.

Aryastami, N. K., Shankar, A., Kusumawardani, N., Besral, B., Jahari, A. B., & Achadi, E. (2017). Low birth weight was the most dominant predictor associated with stunting among children aged 12–23 months in Indonesia. *BMC Nutrition*, *3*(1), 16.

Barham, T., Macours, K., & Maluccio, J. A. (2013). Boys' cognitive skill formation and physical growth: Long-term experimental evidence on critical ages for early childhood interventions. *American economic review*, *103*(3), 467-471.

Barreca, A. I., Guldi, M., Lindo, J. M., & Waddell, G. R. (2011). Saving babies? Revisiting the effect of very low birth weight classification. *The Quarterly journal of economics*, *126*(4), 2117-2123.

Barreca, A. I., Lindo, J. M., & Waddell, G. R. (2016). Heaping-induced bias in regression-discontinuity designs. *Economic inquiry*, *54*(1), 268-293.

Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., Webb, P., Lartey, A., & Black, R. E. (2013). Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The lancet*, *382*(9890), 452-477.

Cattaneo, M. D., Idrobo, N., & Titiunik, R. (2024). *A practical introduction to regression discontinuity designs: Extensions*. Cambridge University Press.

Gelman, A., & Imbens, G. (2019). Why high-order polynomials should not be used in regression discontinuity designs. *Journal of Business & Economic Statistics*, *37*(3), 447-456.

Hoddinott, J., Alderman, H., Behrman, J. R., Haddad, L., & Horton, S. (2013). The economic rationale for investing in stunting reduction. *Maternal & child nutrition*, *9*, 69-82.

Kolesár, M., & Rothe, C. (2018). Inference in regression discontinuity designs with a discrete running variable. *American economic review*, *108*(8), 2277-2304.

Kyei, N. N., Chansa, C., & Gabrysch, S. (2012). Quality of antenatal care in Zambia: a national assessment. *BMC Pregnancy and Childbirth*, *12*, 1-11.

LCMS. (2022). Living Conditions Monitoring Survey.

Levin, A., Sharper, S., & Pantazis, A. (2025). Determinants, Impact and Optimal Resource Allocation of Zambia's Scaling Up Nutrition Program. *Maternal and Child Health Journal*, 1-10.

Manorat, R., Rana, Y., Borces, K., Becker, L., & Flory, A. (2020). How are countries planning for costs of nutrition data and information systems? *Gates Open Research*, *4*, 60.

Miguel, E., & Kremer, M. (2004). Worms: identifying impacts on education and health in the presence of treatment externalities. *Econometrica*, *72*(1), 159-217.

Sodjinou, R., Bosu, W. K., Fanou, N., Deart, L., Kupka, R., Tchibindat, F., & Baker, S. (2014). A systematic assessment of the current capacity to act in nutrition in West Africa: cross-country similarities and differences. *Global Health Action*, *7*(1), 24763.

UNICEF. (2024). *Child Malnutrition*. Retrieved May from https://data.unicef.org/topic/nutrition/malnutrition/

ZDHS. (2018). Zambia Demographic and Health Survey