

Measurements and Determinants of Early Age Human Capital Development: Evidence from Child Malnutrition in Rural Ethiopia

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Abstract

This study examines chronic child malnutrition as an empirical measure of deficiency in human capital accumulation during early-ages. Using anthropometric data for 300 children under five years of age from rural Ethiopia, the study estimates the prevalence of malnutrition and identifies its socioeconomic determinants using Binary Logistic Regression within a Human Capital Production Function framework. Chronic malnutrition affected 23.7% of children and was significantly associated with household income, landholding, livestock ownership, parental education, and child age. The findings demonstrate that child malnutrition captures multidimensional deficits in early human capital accumulation, supporting its use as a robust indicator for human capital measurement.

Keywords: Human capital; child malnutrition; stunting; human capital measurement; Human Capital Production Function; Ethiopia.

1. Introduction

Human capital has become a central concept in development economics and public policy because of its fundamental role in improving labor productivity, economic growth, poverty reduction, and long-term national competitiveness (Barro, 1991). Since Schultz (1961) first conceptualized investments in education and health as productive investments and Becker (1964) formalized Human Capital Theory, an extensive body of research has demonstrated that investments in human capabilities generate substantial economic and social returns throughout the life course (Becker, 1964; Schultz, 1961). Subsequent research expanded the concept beyond formal education to include health, nutrition, cognitive development, and early childhood development as complementary investments that jointly determine the productive capacities embodied in people (Heckman, 2006; Lucas, 1988; Sen, 1999). The growing recognition of human capital has been accompanied by increasing interest in its measurement. Unlike physical or financial capital, human capital cannot be directly observed or inventoried. It represents an intangible stock accumulated through investments and environmental influences, requiring observable indicators that capture these cumulative effects (OECD, 2001; World Bank, 2019).

Following growing recognition of the importance of human capital, governments and international development partners have substantially increased investments in human capital development. The World Bank's Human Capital Project and Human Capital Index stimulated multisector investments across health, nutrition, education, social protection, water and sanitation, and institutional strengthening. This expansion has heightened the need for robust approaches to measuring human capital and assessing whether these investments are producing meaningful improvements in human capabilities.

Recent international initiatives have significantly advanced human capital measurement. The Human Capital Index combines indicators of child survival, schooling, learning-adjusted schooling, adult survival, and child stunting, recognizing that human capital accumulation begins long before entry into the labor market (World Bank, 2019, 2020).

Among these indicators, child malnutrition occupies a particularly important position because it reflects one of the earliest observable manifestations of deficient human capital accumulation. Chronic undernutrition during pregnancy and early childhood impairs physical growth, brain development, cognitive functioning, school readiness, educational achievement, and future labor productivity.

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(Leslie et al., 1997). Many of these developmental losses are irreversible, particularly during the first 1,000 days of life, making chronic child malnutrition not merely a health concern but also a critical indicator of early human capital deprivation (Black et al., 2013; Heckman, 2006; Victora et al., 2008; World Bank, 2019).

Despite growing recognition of the importance of human capital, relatively little research has explicitly examined chronic child malnutrition as an empirical measure of early human capital. Existing studies have largely treated child malnutrition as a public health or nutrition outcome rather than as an observable manifestation of early human capital accumulation.

This article addresses that gap by repositioning child malnutrition within the broader literature on human capital measurement. Using evidence from rural Ethiopia, the study applies the Human Capital Production Function to examine how multiple interacting determinants influence chronic child malnutrition among children under five years of age. Rather than presenting these findings solely as evidence on nutritional status, the present article interprets them within the framework of human capital measurement. The study makes three principal contributions to the literature on human capital measurement. First, it repositions chronic child malnutrition as an empirical measure of early human capital. Second, it provides empirical support for the Human Capital Production Function. Third, it highlights the policy implications of integrated multisector investments across health, nutrition, education, agriculture, water and sanitation, and household welfare.

Against this background, the present study investigates whether chronic child malnutrition can serve as a robust empirical measure of early human capital accumulation.

Objectives of the Study

The primary objective of this study is to examine chronic child malnutrition as an empirical measure of early human capital accumulation using evidence from rural Ethiopia.

Specifically, the study seeks to:

1. Examine the prevalence of chronic child malnutrition using WHO Child Growth Standards.
2. Assess socioeconomic differentials in chronic child malnutrition.
3. Identify the principal determinants of chronic child malnutrition using a Binary Logistic Regression model based on the Human Capital Production Function.

4. Evaluate whether the empirical findings support the Human Capital Production Function.

5. Demonstrate that chronic child malnutrition provides a robust empirical indicator of early human capital.

This study contributes to human capital measurement, human capital theory, and development policy by repositioning chronic child malnutrition as a measure of early human capital, empirically validating the Human Capital Production Function, and highlighting the need for integrated multisector investments.

The remainder of this paper is organized as follows. Section 2.1 reviews the relationship between child malnutrition and human capital. Section 2.2 develops the Human Capital Production Function. Section 3 presents the methodology. Section 4 reports the empirical findings. Section 5 discusses their implications for human capital measurement and policy. Section 6 concludes.

2. Literature Review

2.1 Child Malnutrition and Human Capital: Conceptual Foundations

Human capital encompasses the knowledge, skills, health, and capabilities that enable individuals to participate productively in economic and social life (Becker, 1964; Schultz, 1961). While early formulations of Human Capital Theory emphasized education and skills as the principal sources of productivity, subsequent research has demonstrated that human capital accumulation begins long before children enter formal schooling. Investments in maternal health, child nutrition, early childhood development, healthcare, and family welfare during the earliest stages of life establish the biological and cognitive foundations upon which subsequent learning, skill acquisition, and labor productivity depend (Cunha & Heckman, 2007; Heckman, 2006; World Bank, 2019).

Among these early investments, adequate nutrition occupies a particularly important role because it directly influences both physical growth and neurological development. During pregnancy and the first 1,000 days of life, rapid brain growth and physical development require sufficient nutritional intake and appropriate healthcare. Nutritional deprivation during this critical period may impair cognitive development, reduce school readiness, lower educational attainment, diminish adult productivity, and increase susceptibility to chronic diseases throughout the life course (Black et al., 2013; Victora et al., 2008). These long-term consequences explain why child malnutrition has increasingly been recognized not only as

a public health concern but also as a major constraint to human capital formation.

The relationship between child malnutrition and human capital extends beyond individual wellbeing to national economic development. Countries with high levels of chronic child malnutrition often experience lower educational performance, reduced labor productivity, diminished innovation capacity, and slower economic growth (Barro, 1991). Conversely, improvements in child nutrition generate long-term returns through enhanced educational achievement, increased workforce productivity, improved earnings, and reduced healthcare costs (Hoddinott et al., 2013; World Bank, 2020). Consequently, reducing child malnutrition has become an integral component of national human capital strategies

and sustainable development policies.

Recognizing these relationships, recent human capital frameworks have incorporated child nutritional outcomes into broader systems for measuring human capital. The World Bank's Human Capital Index includes child stunting as one of its core indicators because chronic malnutrition captures the cumulative effects of health, nutrition, sanitation, education, household welfare, and public policy during early childhood (World Bank, 2020). Unlike educational attainment, which becomes observable later in childhood, chronic malnutrition provides an earlier indication of deficiencies in human capital accumulation and therefore offers an important opportunity for timely policy intervention.

Viewed from this perspective, child malnutrition is not

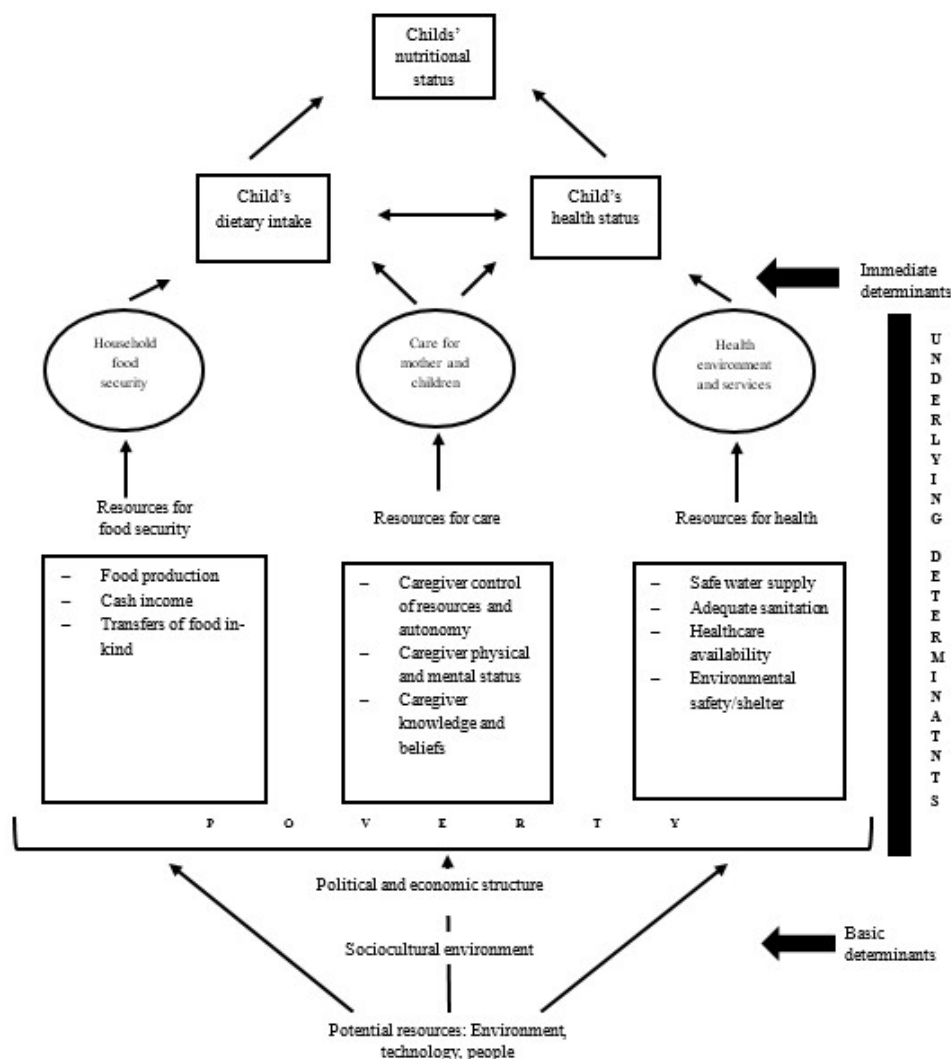


Figure 1. Conceptual Framework for Measuring Early Human Capital through Child Malnutrition

Source: Adapted from Smith and Haddad, 2000 (Smith & Haddad, 2000; UNICEF, 1990).

simply a health outcome requiring nutritional interventions. Rather, it represents an observable manifestation of deficiencies in the broader system responsible for producing human capital. Measuring child malnutrition therefore provides valuable insights into how effectively societies are investing in and protecting early human capital. This perspective provides the conceptual foundation for applying the Human Capital Production Function as the analytical framework developed in the following section. The relationship between child malnutrition and human capital outlined above is summarized in Figure 1. The figure illustrates how multiple socioeconomic, institutional, environmental, and biological determinants jointly influence child nutritional outcomes and, through them, early human capital accumulation. It provides the conceptual foundation for the Human Capital Production Function developed in the following section.

While internationally accepted anthropometric indicators provide observable measures of early human capital outcomes, they do not explain how those outcomes are produced. Understanding the production of early human capital requires an analytical framework capable of integrating the multiple demographic, nutritional, agricultural, socioeconomic, institutional, and environmental determinants that jointly influence children's growth and development. The Human Capital Production Function developed in the following section provides this integrative framework, linking observable nutritional outcomes with the broader system of investments through which early human capital is accumulated.

2.2. Human Capital Production Function as a Framework for Measuring Early Human Capital

2.2.1 Conceptualizing Human Capital through the Production Function

The preceding section established that child malnutrition represents one of the earliest observable manifestations of deficient human capital accumulation. It also demonstrated that nutritional outcomes emerge through the interaction of multiple biological, socioeconomic, institutional, and environmental factors operating throughout early childhood. Figure 1 summarizes these interrelationships by illustrating how determinants operating at different levels jointly influence child nutritional status and, ultimately, early human capital accumulation. The figure further highlights that child malnutrition is not merely a health outcome but an

important indicator through which early human capital can be assessed.

While Figure 1 provides a conceptual representation of these relationships, empirical measurement requires a more explicit analytical framework capable of identifying and analyzing the contribution of multiple interacting determinants. This study adopts the Human Capital Production Function to fulfil that purpose. The production-function approach provides a systematic framework for understanding how investments made by households, communities, governments, and the broader policy environment are transformed into human capital outcomes. Rather than viewing child malnutrition as the consequence of a single determinant, it conceptualizes nutritional status as the cumulative result of complementary investments and environmental conditions that influence children's physical and cognitive development.

The Human Capital Production Function originates from the economics of human capital and household production. Schultz (1961) first argued that expenditures on education, health, and nutrition should be understood as productive investments rather than consumption. Becker (1964) subsequently formalized Human Capital Theory by demonstrating that investments in people's knowledge, health, and capabilities generate long-term economic returns through enhanced productivity and earnings (Becker, 1964). Building on these foundations, Grossman (1972) extended the analysis to health by modelling health status as a durable capital stock produced through investments, behaviours, and environmental conditions (Grossman, 1972). Together, these contributions established the theoretical basis for analyzing human capital as a cumulative product of multiple interacting inputs rather than the outcome of isolated interventions.

Within this tradition, the Human Capital Production Function conceptualizes early human capital as being jointly produced through demographic characteristics, maternal and child health, nutrition, agricultural production, education, household socioeconomic conditions, and institutional and environmental factors. These determinants interact continuously throughout childhood, reinforcing or constraining one another in ways that ultimately influence children's physical growth, cognitive development, learning capacity, and future productivity. Consequently, meaningful measurement of early human capital requires analytical models capable of capturing these multidimensional relationships rather than focusing exclusively on individual risk factors or sector-

specific interventions.

Institutional and environmental conditions constitute the broader enabling context within which human capital is produced. They encompass governance arrangements, public health infrastructure, access to safe water and sanitation, community health services, and the physical environment, including climate conditions and variability, natural resource management, environmental quality, and ecological conditions that influence food security, disease exposure, household livelihoods, and ultimately the accumulation of human capital. Although the present study focuses primarily on child malnutrition, these broader environmental conditions increasingly shape human capital outcomes through their influence on health, nutrition, agricultural productivity, and community resilience.

Accordingly, this study conceptualizes early human capital using the following generalized production function:

Equation (1)

$$HC=f(D,H,N,A,E,S,I)$$

where:

HC = Human Capital

D = Demographic characteristics

H = Maternal and child health

N = Nutrition-related factors

A = Agriculture and household food security

E = Education

S = Household socioeconomic conditions

I = Institutional and environmental conditions

The general production function would have the specific functional form of a multivariate regression equation:

$$HC_i = \beta_0 + \sum_{i=1}^k \beta_i X_i + \varepsilon_i$$

Where:

HC_i is the measure of early age human capital, a binary output variable indicating whether a child is chronically malnourished/stunted; X_i are the socioeconomic factors affecting early age human capital development, stunting in this case; β_0 is the intercept/constant; β_i is the coefficient/parameter and ε_i is the error term.

Evidence from Ethiopian primary schools further demonstrates that educational human capital is jointly influenced by school infrastructure, quality of educational inputs, equity-related factors, teacher qualifications, and school management, highlighting the multidimensional

nature of educational human capital accumulation (Zike, 2026).

The production function does not imply that human capital can be observed directly. Rather, it provides a conceptual structure for identifying the determinants that collectively influence its accumulation. Within this framework, chronic child malnutrition—measured through Height-for-Age Z-scores—serves as an observable indicator of deficiencies in early human capital accumulation. Estimating the relative contribution of the production-function components therefore enables the analysis to move beyond descriptive assessments of malnutrition and towards a broader understanding of how human capital is produced.

The Human Capital Production Function performs two complementary roles in this study. Conceptually, it integrates Human Capital Theory with the multidimensional determinants of child nutritional outcomes. Empirically, it guides the specification of the econometric model used to estimate the contribution of individual determinants to chronic child malnutrition. In doing so, it provides the analytical bridge between the conceptual discussion presented in the preceding sections and the empirical analysis developed in the remainder of the paper.

The following section operationalizes the production function by describing the study area, data sources, anthropometric measurement of child nutritional status using the World Health Organization Child Growth Standards, and the Binary Logistic Regression model employed to estimate the socioeconomic determinants of chronic child malnutrition.

3. Methodology

3.1 Research Design and Analytical Framework

This study employs a quantitative analytical approach to examine child malnutrition as an indicator of early human capital accumulation. Rather than treating chronic child malnutrition solely as a nutritional outcome, the analysis conceptualizes it as an observable manifestation of deficiencies in early human capital formation. Guided by the Human Capital Production Function developed in the preceding section, the study estimates how demographic, health, nutrition, agricultural, educational, socioeconomic, institutional, and environmental conditions jointly influence chronic child malnutrition among children under five years of age.

The empirical analysis is based on the author's Master's research entitled Socioeconomic Determinants of

Child Malnutrition, completed at Haramaya University (Zike, 2004). While the original study investigated the socioeconomic determinants of chronic child malnutrition, the present article reinterprets the findings within the broader framework of human capital measurement. The objective is therefore not merely to identify the determinants of malnutrition, but to demonstrate how child malnutrition provides an empirical indicator through which early human capital can be measured.

Consistent with the Human Capital Production Function, the study adopts a multivariate analytical framework recognizing that child nutritional outcomes are jointly produced through interacting determinants operating at household, community, institutional, and environmental levels. Consequently, the analysis moves beyond single-factor explanations of malnutrition and instead estimates the independent contribution of multiple determinants while controlling for the influence of other explanatory variables. This analytical approach provides a more comprehensive understanding of the processes through which early human capital is accumulated.

The following sections describe the study area, data collection procedures, measurement of child nutritional status using the World Health Organization Child Growth Standards, specification of the explanatory variables, and the Binary Logistic Regression model employed to estimate the determinants of chronic child malnutrition

3.2 Study Area

The empirical study was conducted in the rural areas of Harari National Regional State, one of the regional states of the Federal Democratic Republic of Ethiopia. Harari is located in eastern Ethiopia and is characterized by a mixed farming system in which agriculture constitutes the principal source of livelihood for the majority of rural households. Crop production and livestock rearing are the dominant economic activities, although agricultural productivity is influenced by rainfall variability, land availability, and environmental conditions. These characteristics make the region representative of many rural areas in Ethiopia where household food security, agricultural production, and child nutrition are closely interconnected.

At the time of the study, chronic child malnutrition remained a significant public health and development challenge in rural Harari (UNICEF, 1998). As in many low-income rural settings, children's nutritional status was influenced by a combination of household socioeconomic conditions,

maternal education, access to health services, food security, water and sanitation, environmental health, and agricultural livelihoods. These interrelated characteristics provided an appropriate setting for examining child malnutrition within the broader framework of human capital accumulation.

The study focused on children under five years of age because this period represents the most critical stage of human capital formation. Nutritional deprivation during early childhood has profound and often irreversible consequences for physical growth, cognitive development, educational attainment, labor productivity, and lifetime earnings. Consequently, analyzing the determinants of child malnutrition among this population provides valuable insights into the processes through which early human capital is accumulated.

Although the empirical evidence is drawn from rural Ethiopia, the analytical framework developed in this article is not country-specific. The Human Capital Production Function provides a general framework for understanding how multiple socioeconomic, institutional, and environmental determinants jointly influence early human capital accumulation in many low- and middle-income countries facing similar development challenges.

3.3 Data Sources and Sampling Procedures

The empirical analysis is based on primary household survey data collected from rural households in Harari National Regional State, Ethiopia. The survey was specifically designed to investigate the socioeconomic determinants of chronic child malnutrition among children under five years of age. Information was collected on household demographic characteristics, socioeconomic conditions, agricultural production, maternal education, child health, feeding practices, environmental conditions, and anthropometric measurements required for assessing children's nutritional status.

The study employed a multistage sampling procedure to obtain a representative sample of rural households with children under five years of age. In the first stage, rural administrative units (kebeles) were selected using appropriate sampling procedures to ensure geographical representation. In the second stage, eligible households were identified and selected using systematic sampling techniques (Cochran, 1977). This approach ensured that the sample adequately represented variations in household socioeconomic conditions, agricultural livelihoods, and access to basic services across the study area.

Structured questionnaires were administered to mothers

or primary caregivers by trained enumerators. The questionnaire collected information on household composition, parental education, occupation, income sources, agricultural production, food consumption, child feeding practices, recent illness episodes, utilization of health services, water supply, sanitation, and other socioeconomic characteristics considered relevant to child nutritional outcomes. Anthropometric measurements of eligible children were collected using standardized measurement procedures to ensure consistency and reliability.

Quality assurance measures were implemented throughout the data collection process. Enumerators received comprehensive training on questionnaire administration and anthropometric measurement techniques prior to fieldwork. Survey instruments were pre-tested before the main data collection, and completed questionnaires were reviewed regularly for completeness and consistency. Standardized procedures for measuring children's height and age were applied to minimize measurement errors and improve the reliability of the anthropometric indicators used in the subsequent analysis.

The resulting dataset provided comprehensive information on the demographic, socioeconomic, agricultural, institutional, and environmental determinants specified in the Human Capital Production Function. It therefore offered an appropriate empirical basis for examining child malnutrition as an indicator of early human capital accumulation.

3.4 Measurement of Child Malnutrition

The measurement of human capital requires observable indicators capable of reflecting the cumulative effects of investments in health, nutrition, education, and household welfare. Because human capital cannot be directly observed, empirical analysis relies on measurable outcomes that capture its accumulation during different stages of life. Among children under five years of age, anthropometric indicators have become widely accepted measures of nutritional status and provide valuable information on the biological foundations of early human capital development (de Onis et al., 2007; Pelletier, 1994; World Health Organization, 2006).

This study measures child nutritional status using Height-for-Age Z-scores (HAZ) based on the WHO Child Growth Standards. Height-for-age is the internationally accepted indicator of chronic child malnutrition (stunting) because it reflects the cumulative effects of prolonged nutritional

deprivation, recurrent illness, inadequate childcare, and adverse socioeconomic conditions during early childhood (World Health Organization, 2006). Unlike indicators of acute malnutrition, such as weight-for-height, height-for-age captures long-term growth deficits that are closely associated with impaired cognitive development, reduced educational attainment, lower labor productivity, and diminished lifetime earnings (UNICEF, 1998). Consequently, chronic child malnutrition provides one of the most informative indicators of deficiencies in early human capital accumulation (Black et al., 2013; Victora et al., 2008).

The WHO Child Growth Standards establish an international reference population representing healthy child growth under optimal environmental conditions. Nutritional status is assessed by comparing each child's observed height with the median height of children of the same age and sex in the WHO reference population. The deviation from the reference median is expressed as a standardized Z-score, allowing comparisons across populations and age groups.

The Height-for-Age Z-score is calculated as:

$$HAZ = (X - \mu) / \sigma$$

where:

HAZ = Height-for-Age Z-score;

X = observed height of the child;

μ = median height of the WHO reference population for children of the same age and sex; and

σ = standard deviation of the reference population.

Children whose Height-for-Age Z-score falls below -2 standard deviations from the WHO reference median are classified as stunted, indicating chronic malnutrition, while those below -3 standard deviations are classified as severely stunted (World Health Organization, 2006). These internationally recognized thresholds permit consistent assessment of chronic nutritional deprivation and facilitate comparison across countries and populations.

Within the framework of this study, Height-for-Age Z-scores serve a dual purpose. First, they provide a scientifically robust measure of chronic child malnutrition using internationally standardized anthropometric methods. Second, they function as an empirical indicator of early human capital accumulation because chronic growth failure reflects the cumulative effects of biological, socioeconomic, institutional, and environmental conditions operating throughout early childhood. Accordingly, the measurement

of child nutritional status provides the empirical foundation for analyzing how multiple determinants jointly influence early human capital development.

From a human capital perspective, the significance of Height-for-Age Z-scores extends beyond nutritional assessment. They provide an empirical measure of the cumulative biological and socioeconomic processes through which early human capital is formed, making chronic child malnutrition one of the earliest observable manifestations of human capital deprivation.

3.5 Econometric Model: Binary Logistic Regression

The principal objective of this study is to identify the determinants of chronic child malnutrition and to examine how these determinants collectively influence early human capital accumulation. Because the dependent variable represents a binary outcome—whether a child is chronically malnourished (stunted) or not—ordinary least squares regression is inappropriate. Instead, the study employs Binary Logistic Regression, which estimates the probability that a child experiences chronic malnutrition as a function of multiple explanatory variables while ensuring that predicted probabilities remain bounded between zero and one (Hosmer et al., 2013).

Binary Logistic Regression has become one of the most widely used analytical techniques in epidemiology, public health, nutrition, and development economics because it accommodates dichotomous outcome variables and permits simultaneous estimation of the independent contribution of multiple determinants after controlling for confounding factors. Within the context of this study, the model estimates how demographic characteristics, maternal and child health, nutrition, agricultural production, education, household socioeconomic conditions, and institutional and environmental factors influence the likelihood of chronic child malnutrition.

The logistic model is expressed as:

$$P(Y_i=1)=e^{(\beta_0+\beta_1 X_1+\beta_2 X_2+...+\beta_k X_k)}/1+e^{(\beta_0+\beta_1 X_1+\beta_2 X_2+...+\beta_k X_k)}$$

where:

$P(Y_i=1)$ is the probability that child i is chronically malnourished;

β_0 is the intercept;

$\beta_1, \beta_2, \dots, \beta_k$ are regression coefficients;

$X_1, X_2, \dots, X_k$ represent the explanatory variables included in the Human Capital Production Function.

For estimation purposes, the regression model defined earlier, i.e.,

$HC_i = \beta_0 + \sum_{i=1}^k \beta_i X_i + \varepsilon_i$, is commonly expressed in its logit form as:

$$\ln(P_i/1-P_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon_i$$

where:

P_i denotes the probability that child i is stunted;

$P_i/(1-P_i)$ represents the odds of chronic child malnutrition;

ε_i is the stochastic error term.

The explanatory variables included in the model were selected on the basis of the Human Capital Production Function developed in Section 3 and the established literature on child nutrition and human capital. Collectively, they represent the multidimensional determinants operating at demographic, health, nutrition, agricultural, educational, socioeconomic, institutional, and environmental levels. Estimating these variables simultaneously enables the analysis to isolate their independent effects while recognizing that child nutritional outcomes arise through complex interactions among multiple sectors and household conditions.

Within the broader framework of this article, the Binary Logistic Regression model serves a dual purpose. Statistically, it identifies the determinants associated with chronic child malnutrition. Conceptually, it operationalizes the Human Capital Production Function by estimating how multiple interacting factors contribute to deficiencies in early human capital accumulation. The regression model therefore provides the empirical mechanism through which child malnutrition is interpreted as an observable indicator of early human capital.

3.6 Operationalization of the Human Capital Production Function

Consistent with the Human Capital Production Function presented in Section 3, the explanatory variables included in the Binary Logistic Regression model were selected to represent the principal dimensions through which early human capital is accumulated. Rather than treating child malnutrition as the consequence of a single determinant, the analytical framework recognizes that chronic malnutrition results from the interaction of demographic, health, nutrition, agricultural, educational, socioeconomic, institutional, and environmental conditions operating simultaneously.

The dependent variable is chronic child malnutrition, measured using the Height-for-Age Z-score (HAZ). For the purposes of Binary Logistic Regression, the continuous anthropometric indicator was transformed into a dichotomous variable based on the WHO Child Growth Standards. Children whose Height-for-Age Z-score was below -2 standard deviations from the WHO reference

median were classified as chronically malnourished (stunted) and assigned a value of 1, while children with Height-for-Age Z-scores equal to or greater than -2 standard deviations were classified as not chronically malnourished and assigned a value of 0.

The explanatory variables were selected on the basis of the Human Capital Production Function, previous empirical

Variable	Measurement	Expected Effect	Human Capital Production Function Component
Child age	Months	$\pm$	D
Child gender	Male/Female	$\pm$	D
Birth order	Number	+	D
Maternal education	Years of schooling	–	E
Household size	Number of household members	$\pm$	S
Household income	Household economic status	–	S
Household food security	Food availability/access	–	A
Agricultural production	Crop/livestock production	–	A
Maternal health service utilization	Yes/No	–	H
Child illness	Recent illness episodes	+	H
Breastfeeding practices	Appropriate/Inappropriate	–	N
Dietary diversity	Number of food groups	–	N
Drinking water source	Improved/Unimproved	–	I
Distance to drinking water source	Walking time or distance	+	I
Sanitation facilities	Improved/Unimproved	–	I
Nutrition information and communication	Exposure to nutrition education through health workers, community outreach, or local media	–	I
Physical environmental conditions	Climate conditions, natural resource management, and environmental health	$\pm$	I

Note: (+) indicates an expected increase in the probability of chronic child malnutrition, while (–) indicates an expected reduction.

studies on child malnutrition, and data availability. Collectively, these variables capture the multidimensional determinants of early human capital accumulation and provide the empirical basis for estimating their independent contributions to chronic child malnutrition.

The organization of variables according to the Human Capital Production Function illustrates that child malnutrition is influenced by determinants spanning multiple sectors rather than by isolated household characteristics. Demographic variables capture biological

and household composition effects; health and nutrition variables represent immediate determinants of child growth; agricultural and socioeconomic variables reflect household production and resource constraints; while institutional and environmental variables capture the broader enabling context within which early human capital is produced.

This classification also demonstrates the analytical value of the Human Capital Production Function. Rather than selecting explanatory variables independently, the framework provides a theoretically grounded structure

for organizing and interpreting the determinants of child malnutrition. Consequently, the subsequent regression analysis examines not merely the statistical significance of individual variables but their collective contribution to the accumulation of early human capital.

4. Results

4.1 Prevalence of Child Malnutrition as an Indicator of Early Human Capital

Before presenting determinants, it is important to establish the extent of child malnutrition within the

study population. Because chronic child malnutrition represents an observable manifestation of early human capital deprivation, its prevalence provides an initial indication of the magnitude of human capital deficits affecting children during the critical years of physical and cognitive development. The anthropometric assessment was undertaken using the World Health Organization Child Growth Standards, with nutritional status measured through Height-for-Age (stunting), Weight-for-Height (wasting), and Weight-for-Age (underweight) indicators.

Table 5.1 Prevalence of child malnutrition by indicators.

INDICATORS	NORMAL %	MODERATE %	SEVER %	TOTAL (MODERATE and SEVER)	95% Confidence Intervals.
HFA (stunting)	76.3	15.3	8.3	23.7	(18.8-28.5)
WFH (wasting)	90	9.3	0.7	10.0	(6.6-13.4)
WFA(underweight)	75.3	17.3	7.3	24.7	(19.8-29.6)

Although three anthropometric indicators were examined, the subsequent analysis focuses primarily on Height-for-Age (stunting), as it is the internationally accepted indicator of chronic nutritional deprivation and the anthropometric measure most closely associated with early human capital accumulation.

The results indicate that 23.7% of children were chronically malnourished (stunted), comprising 15.3% who were moderately stunted and 8.3% who were severely stunted. In comparison, 10.0% of children were wasted, while 24.7% were underweight. Among the three anthropometric indicators, stunting is of particular significance because it reflects prolonged nutritional deprivation accumulated during the critical years of physical and cognitive development.

From the perspective of human capital measurement, the prevalence of chronic child malnutrition is especially important. Unlike wasting, which primarily reflects acute nutritional stress, stunting captures the cumulative effects of inadequate nutrition, recurrent illness, poor childcare practices, household poverty, and adverse institutional and environmental conditions. Consequently, chronic child malnutrition provides a robust empirical indicator of deficiencies in early human capital accumulation rather than merely a measure of children's nutritional status.

Comparison with the 2000 Ethiopian Demographic and Health Survey (EDHS) indicates that the prevalence of stunting observed in the present study (23.7%) was

substantially lower than the corresponding estimate reported for Harari National Regional State (37.3%) and considerably below the national average (52.0%) (Central Statistical Authority, 2001). Conversely, the prevalence of wasting (10.0%) exceeded the regional estimate (6.3%), while the prevalence of underweight (24.7%) remained broadly comparable to the regional average (27.1%).

These differences should be interpreted cautiously. Nutritional outcomes are influenced by temporal variations in agricultural production, food security, climate conditions, disease prevalence, household socioeconomic circumstances, and other contextual factors. Furthermore, the EDHS estimates represent regional averages that include both urban and rural populations, whereas the present study focuses exclusively on rural households. Differences in survey coverage and local conditions therefore provide plausible explanations for the observed variations.

From a human capital perspective, however, the principal finding is not the comparison with regional or national averages but the persistence of chronic child malnutrition itself. Nearly one-quarter of the children surveyed experienced chronic growth failure, indicating that substantial deficits in early human capital accumulation remained within the study area. This finding reinforces the central proposition advanced in this article that child malnutrition constitutes a meaningful empirical indicator of early human capital deprivation.

4.2 Socioeconomic Gradient in Early Human Capital Accumulation

The relationship between household socioeconomic status and children's nutritional outcomes provides further evidence that child malnutrition reflects broader processes of human capital accumulation rather than biological variation alone. To examine this relationship, households were classified into poor, middle, and rich socioeconomic groups using a composite asset-based index reflecting

household living standards, housing quality, ownership of productive and household assets, and access to basic amenities. The classification followed the methodology recommended by the World Health Organization for assessing socioeconomic differentials in child health and nutrition.

Table 5.2 presents the mean anthropometric Z-scores for children across the three socioeconomic groups.

Table 5.2. Mean Anthropometric Z-Scores by Household Socioeconomic Status

	Poor	Middle	Rich
WFH (Mean Z-score) NS	-2.07	-0.96	-0.69
HFA (Mean Z-score)*	-3.25	-1.38	-1.04
WFA (Mean Z-score) NS	-1.85	-1.56	-1.08

The results demonstrate a clear socioeconomic gradient in children's nutritional status. Mean Z-scores improved consistently as household socioeconomic status increased across all three anthropometric indicators. The gradient was particularly pronounced for Height-for-Age, where the mean Z-score improved from -3.25 among children from poor households to -1.38 among

middle-income households and -1.04 among children from rich households. The differences in Height-for-Age were statistically significant ($p < 0.05$), whereas the corresponding differences for Weight-for-Height and Weight-for-Age were not statistically significant.

To further examine these differences, multiple comparisons were undertaken for Height-for-Age Z-scores.

Table 5.3 Socioeconomic Gradient

Dependent Variable	Socio-Economic Status (i)	Socio-Economic Status (j)	Mean Difference (i-j)	Standard Error
HFA	Poor	Middle	-1.87*	0.517
		Rich	-2.21*	0.664
	Middle	Rich	-0.34	0.483

The results indicate that the largest and statistically significant differences occurred between poor and middle-income households, while the difference between middle- and high-income households was comparatively small and not statistically significant. This pattern suggests that improvements in household socioeconomic conditions are associated with substantial gains in children's long-term nutritional status, particularly among the poorest households.

From the perspective of human capital measurement, these findings are particularly important. They demonstrate that chronic child malnutrition is not distributed randomly within the population but follows a clear socioeconomic gradient. Children living in poorer households experience substantially greater deficits in long-term physical growth than children living in better-off households. Since Height-

for-Age reflects cumulative nutritional deprivation during early childhood, the observed gradient indicates that early human capital accumulation is strongly influenced by household living conditions and access to productive resources.

These findings also reinforce the conceptual distinction between chronic and acute malnutrition. While socioeconomic differences were less evident for wasting and underweight, they were most pronounced for stunting, the anthropometric indicator used in this study to measure early human capital. This provides additional empirical support for selecting chronic child malnutrition as the principal indicator of early human capital accumulation.

4.3 Determinants of Early Human Capital Accumulation: Evidence from the Binary Logistic Regression Model
While the descriptive analysis presented in the preceding

sections demonstrates the prevalence and socioeconomic distribution of child malnutrition, it does not identify the factors that independently influence children's nutritional outcomes. To address this question, a Binary Logistic Regression model was estimated using the Human Capital Production Function developed in Section 3. The model simultaneously examined the effects of demographic, nutritional, agricultural, socioeconomic, institutional, and environmental variables on the probability of chronic child malnutrition.

The analysis was undertaken in two stages. First, bivariate logistic regression models were estimated to assess the gross effects of individual explanatory variables on chronic child malnutrition. Variables identified as statistically significant were subsequently entered into a multivariate

Binary Logistic Regression model using the Wald procedure to estimate their independent or net effects while controlling for the influence of other explanatory variables (Long & Freese, 2014; Menard, 2002). Prior to estimation, diagnostic tests confirmed that multicollinearity among the explanatory variables was not sufficiently severe to affect the reliability of the regression estimates.

The final multivariate model explained a substantial proportion of the variation in chronic child malnutrition (Pseudo- $R^2 = 0.743$), indicating that the selected explanatory variables collectively provide a strong empirical representation of the Human Capital Production Function. The statistically significant determinants identified in the final model are summarized in Table 5.

Table 5.3 Binary Logistic Regression Results

Explanatory variables	B	S.E	Sig.	EXP(B)
Fertilizer usage:				
No(r)				
Yes	-1.187	0.519	0.022	0.305
Family size (in no. of persons)	0.370	0.101	0.000	1.448
Livestock Unit (in TLU):	-1.158	0.306	0.000	0.314
Duration of breast-feeding (in months):				
<12 months(r)				
>12 months	-1.080	0.413	0.009	0.340
Status of Ecology:				
Bad(r)				
Better	-0.947	0.444	0.033	0.388
Presence of kitchen:				
No(r)				
Yes	-1.154	0.447	0.010	0.314
Type of Cropping:				
Single(r)				
Mixed	2.483	0.702	0.000	11.98
Food shortage:				
<4 months(r)				
>4 months	0.915	0.477	0.055	2.498
R2	0.743			

The statistically significant determinants are interpreted according to the components of the Human Capital Production Function rather than in isolation, thereby emphasizing the complementary nature of early

human capital accumulation.

Rather than interpreting each regression coefficient in isolation, the findings are discussed according to the principal dimensions of the Human Capital Production

Function. This approach emphasizes how multiple complementary determinants jointly influence early human capital accumulation rather than viewing child malnutrition as the consequence of a single risk factor.

4.3.1 Nutrition and Child Care Determinants

Among the nutrition-related variables, duration of breastfeeding emerged as a statistically significant determinant of chronic child malnutrition. Children who were breastfed for more than twelve months were significantly less likely to experience chronic malnutrition than those breastfed for shorter durations, after controlling for other household and environmental characteristics. From a human capital perspective, this finding illustrates the critical importance of early nutritional investments during the first years of life. Adequate breastfeeding contributes not only to children's immediate nutritional status but also to the biological foundations of cognitive development, physical growth, and subsequent learning capacity. The results therefore reinforce the proposition that investments in infant nutrition constitute investments in early human capital accumulation.

4.3.2 Agricultural Production and Food Security Determinants

The regression analysis demonstrates that agricultural production and household food security constitute some of the strongest determinants of chronic child malnutrition. Fertilizer use, livestock ownership, cropping systems, and household food shortages all exhibited statistically significant associations with children's nutritional status. Households utilizing fertilizer and possessing larger livestock assets experienced substantially lower risks of chronic child malnutrition, while prolonged household food shortages significantly increased the probability of stunting. Similarly, agricultural production systems were closely associated with children's long-term nutritional outcomes.

These findings demonstrate that agriculture contributes to human capital through pathways extending beyond income generation. Agricultural productivity determines household food availability, dietary diversity, economic resilience, and the capacity of families to sustain adequate child nutrition throughout the year. Consequently, investments in agricultural development should be viewed not only as economic interventions but also as long-term investments in human capital.

4.3.3 Household and Environmental Determinants

The regression results also identify ecological conditions and the presence of a separate kitchen as significant determinants of chronic child malnutrition. Children living in households located in more favourable ecological conditions experienced significantly lower risks of stunting, while the availability of a separate kitchen was associated with improved nutritional outcomes. These findings highlight the importance of the broader environmental context within which human capital is produced. Ecological conditions influence agricultural productivity, food security, water availability, and disease environments, while household infrastructure reflects environmental health and hygienic conditions affecting child wellbeing. Together, these variables demonstrate that early human capital accumulation depends not only on household behaviour but also on the quality of the physical and environmental conditions surrounding children.

4.3.4 Household Socioeconomic Characteristics

Household family size also emerged as a significant determinant of chronic child malnutrition in the multivariate analysis. Larger household size was associated with a higher probability of child stunting after controlling for the influence of other explanatory variables. This finding suggests that household resource constraints influence children's nutritional outcomes through competition for food, caregiving time, and other household resources. From the perspective of human capital accumulation, the results reinforce the importance of household socioeconomic capacity in supporting sustained investments in children's growth and development.

4.4 Empirical Evidence for the Human Capital Production Function

The empirical findings presented in the preceding sections provide strong support for the Human Capital Production Function advanced in this article. Rather than identifying a single dominant determinant of chronic child malnutrition, the Binary Logistic Regression model demonstrates that children's nutritional outcomes are jointly influenced by multiple interacting factors operating at household, agricultural, institutional, and environmental levels.

The final multivariate model identified significant determinants spanning several components of the Human Capital Production Function, including nutrition (duration of breastfeeding), agriculture and food security (fertilizer

use, livestock ownership, cropping systems, and household food shortages), household socioeconomic conditions (family size), and institutional and environmental conditions (ecological status and household kitchen facilities). Together, these determinants explain a substantial proportion of the variation in chronic child malnutrition observed among children under five years of age.

These findings demonstrate that early human capital is not produced through isolated investments within individual sectors. Rather, human capital emerges from the cumulative interaction of complementary investments and enabling conditions operating simultaneously across households, communities, agricultural systems, public services, and the broader institutional and environmental context. Improvements in child nutritional status therefore depend not only on health and nutrition interventions but also on food security, agricultural productivity, household living conditions, environmental quality, and socioeconomic wellbeing.

The empirical evidence also illustrates the value of the Human Capital Production Function as an analytical framework for understanding early human capital accumulation. By organizing the determinants within a single conceptual model, the production function provides a coherent explanation of how diverse investments jointly influence children's long-term physical growth and development. The framework therefore extends beyond identifying statistically significant variables to explaining the systemic processes through which early human capital is produced.

Perhaps the most important implication of these findings is that chronic child malnutrition should be interpreted not merely as a nutritional or public health outcome but as an empirical manifestation of broader human capital deprivation. Height-for-Age Z-scores capture the cumulative effects of biological, socioeconomic, agricultural, institutional, and environmental influences experienced during early childhood. Consequently, chronic child malnutrition provides a robust empirical indicator through which early human capital can be measured.

4.5 Implications for Human Capital Measurement

Beyond the Ethiopian case study, the findings have broader implications for the measurement of human capital in developing countries. First, they demonstrate that anthropometric indicators—particularly Height-for-Age Z-scores—provide more than measures of child nutritional

status; they capture the cumulative outcomes of multiple investments made during the earliest stages of life. Second, the results illustrate that meaningful measurement of early human capital requires analytical frameworks capable of integrating determinants across multiple sectors rather than focusing exclusively on health or nutrition.

The study also highlights the importance of distinguishing between human capital measurement and human capital production. While anthropometric indicators provide observable measures of early human capital outcomes, the production of human capital depends on a far broader set of interacting determinants spanning agriculture, education, health, household socioeconomic conditions, governance, and environmental factors. This distinction has important implications for both research and public policy. Reliable measurement provides the empirical basis for understanding human capital accumulation, whereas effective policy requires coordinated investments addressing the multiple determinants identified by the Human Capital Production Function.

Finally, the findings reinforce the growing international recognition that investments in early childhood generate substantial long-term returns for individuals and societies. By demonstrating that chronic child malnutrition reflects the cumulative effects of multiple developmental investments, the study provides additional empirical support for integrated approaches to human capital development that extend well beyond the health sector.

Collectively, the empirical findings provide strong support for the central proposition advanced in this article: early human capital is produced through an integrated system of complementary investments rather than isolated sectoral interventions. Chronic child malnutrition, as measured by Height-for-Age Z-scores, therefore provides a scientifically grounded and empirically robust indicator of early human capital accumulation.

5. Discussion

5.1 Child Malnutrition as a Measure of Early Human Capital

The findings of this study demonstrate that chronic child malnutrition extends beyond its conventional interpretation as a public health outcome. Measured using Height-for-Age Z-scores, chronic child malnutrition reflects the cumulative effects of nutritional deprivation experienced during the critical years of physical growth and cognitive development. As such, it provides a robust empirical indicator of early human capital accumulation.

This interpretation is consistent with Human Capital Theory, which conceptualizes human capital as a stock of productive capabilities accumulated through investments made over the life course (Becker, 1964; Schultz, 1961). The results presented in this study suggest that the accumulation of this stock begins long before children enter formal schooling. Nutritional deprivation during the first years of life constrains physical growth, cognitive development, educational readiness, and ultimately labour productivity, thereby reducing the long-term returns to subsequent investments in education and skills.

Unlike conventional measures of human capital that rely primarily on years of schooling or educational attainment, Height-for-Age Z-scores provide an observable measure of the biological foundations upon which future human capital is built. The findings therefore extend the human capital literature by demonstrating that anthropometric indicators can serve as valid measures of early human capital accumulation.

The findings of the present study complement previous research on educational human capital in Ethiopia. While the present study demonstrates that chronic child malnutrition provides a robust measure of early human capital accumulation, evidence from Ethiopian primary schools shows that subsequent human capital development depends on the quality of learning outcomes produced through investments in school infrastructure, educational inputs, teacher qualifications, equity, and institutional management (Zike, 2026). Together, these studies illustrate that human capital is accumulated progressively throughout the life course, beginning with early childhood nutrition and continuing through quality education.

5.2 Evidence for the Human Capital Production Function

The empirical findings also provide strong support for the Human Capital Production Function proposed in this article. Significant determinants emerged across multiple dimensions of the production function, including nutrition, agriculture and food security, household socioeconomic conditions, and institutional and environmental factors. The absence of a single dominant determinant reinforces the proposition that early human capital is produced through the interaction of complementary investments rather than isolated sectoral interventions.

These findings are consistent with Heckman's dynamic model of skill formation, which emphasizes the cumulative and complementary nature of investments made during early childhood (Heckman, 2006). They also support the

World Bank's Human Capital Project, which recognizes nutrition, health, and education as mutually reinforcing investments in human capital development (World Bank, 2019). However, the present study extends these perspectives by demonstrating empirically that chronic child malnutrition provides an observable outcome through which these multiple investments can be measured

5.3 Policy Implications

The findings have important implications for human capital policy. First, they demonstrate that reducing child malnutrition requires coordinated investments extending beyond the health sector. Agricultural productivity, household food security, environmental conditions, and household socioeconomic wellbeing all contribute significantly to children's long-term nutritional outcomes.

Second, the study highlights the importance of integrated approaches to human capital development. Since chronic child malnutrition reflects the cumulative influence of multiple determinants, policies seeking to improve early human capital should promote coordination across agriculture, health, nutrition, education, water and sanitation, and broader development sectors.

Finally, the study has implications for monitoring and evaluation. Height-for-Age Z-scores should be viewed not only as nutrition indicators but also as measures of early human capital. Incorporating anthropometric indicators into national human capital monitoring systems would provide policymakers with a more comprehensive understanding of progress in early childhood development.

5.4 Contribution to the Human Capital Literature

The principal contribution of this study lies in repositioning child malnutrition within the broader human capital literature. Previous studies have established the relationship between child nutrition and subsequent educational attainment, cognitive development, and labour productivity. The present study goes one step further by demonstrating that chronic child malnutrition itself constitutes an empirical measure of early human capital. By integrating Human Capital Theory, the Human Capital Production Function, internationally accepted anthropometric measurement techniques, and multivariate econometric analysis, the study provides a coherent framework linking nutritional assessment with human capital measurement. In doing so, it bridges the disciplines of nutrition, development economics, public policy, and

human capital research.

5.5 Broader Implications for Human Capital Measurement

Although the empirical evidence presented in this study is drawn from rural Ethiopia, the conceptual framework developed has broader implications for the measurement of human capital in low- and middle-income countries. Increasing international attention to human capital has generated substantial investments in health, nutrition, education, social protection, agriculture, water and sanitation, and institutional capacity through initiatives such as the World Bank's Human Capital Project. These investments have simultaneously increased the demand for robust empirical approaches capable of measuring human capital accumulation from the earliest stages of life.

The findings suggest that chronic child malnutrition, as measured through internationally standardized Height-for-Age Z-scores, provides a scientifically grounded indicator of early human capital accumulation because it captures the cumulative effects of multiple complementary investments made during early childhood. Unlike conventional measures that focus primarily on educational attainment or labour market outcomes, anthropometric indicators capture the biological foundations upon which subsequent cognitive development, educational achievement, and productive capacity are built. Consequently, measuring chronic child malnutrition provides an opportunity to assess human capital formation at a stage when interventions are likely to generate the greatest long-term returns.

The Human Capital Production Function proposed in this article also has broader analytical relevance. By integrating demographic, nutritional, agricultural, educational, socioeconomic, institutional, and environmental determinants within a single conceptual framework, it provides a systematic approach for understanding how complementary investments jointly influence early human capital accumulation. This multidimensional perspective moves beyond sector-specific analyses by recognising that early human capital is produced through interactions among households, communities, public institutions, and the wider physical environment.

From a policy perspective, the framework supports the growing international shift towards integrated human capital development strategies. Rather than viewing nutrition, health, education, agriculture, water and sanitation, environmental management, and social protection as independent policy domains, the findings reinforce the

importance of coordinated investments that strengthen the cumulative process of human capital accumulation throughout early childhood. The framework may therefore assist researchers, governments, and development partners in designing more integrated approaches to measuring, managing, and evaluating human capital investments.

Finally, the broader contribution of this study extends beyond the empirical findings from Ethiopia. By repositioning chronic child malnutrition as an empirical measure of early human capital and by proposing the Human Capital Production Function as an analytical framework for explaining its production, the study contributes to the emerging literature on human capital measurement. Future research should examine the applicability of this framework across different countries, institutional settings, and stages of the human capital life course, thereby strengthening the evidence base for integrated approaches to human capital development.

5.6. Limitations of the Study

Like all empirical studies, this research has several limitations that should be considered when interpreting the findings. First, the empirical analysis is based on cross-sectional household survey data collected from rural Harari National Regional State, Ethiopia. Although the analysis identifies statistically significant associations between the explanatory variables and chronic child malnutrition, the cross-sectional design does not permit definitive causal inference.

Second, the study focuses on a single rural region of Ethiopia. While many of the determinants identified are common across low- and middle-income countries, the magnitude and relative importance of these relationships may vary across different socioeconomic, institutional, environmental, and cultural contexts. Consequently, caution should be exercised in generalizing the empirical findings beyond comparable settings.

Third, the empirical data were originally collected to investigate the socioeconomic determinants of child malnutrition. The present article reinterprets these data within the broader framework of human capital measurement. Although this reinterpretation is theoretically grounded in Human Capital Theory and supported by the Human Capital Production Function developed in this study, additional empirical validation using more recent nationally representative and longitudinal datasets would further strengthen the generalizability of the proposed framework.

Despite these limitations, the study makes an important contribution by demonstrating that chronic child malnutrition provides a scientifically grounded and empirically robust indicator of early human capital accumulation. The findings also provide empirical support for the Human Capital Production Function as a multidimensional framework for understanding how complementary investments across nutrition, health, agriculture, education, household socioeconomic conditions, institutions, and the physical environment jointly influence the production of early human capital. Future research should extend this framework across different geographical contexts and stages of the human capital life course.

6. Conclusion

This study examined child malnutrition as a measure of early human capital using empirical evidence from rural Ethiopia. Drawing upon the Human Capital Production Function, WHO Child Growth Standards, anthropometric Z-scores, and Binary Logistic Regression analysis, the study demonstrated that chronic child malnutrition reflects the cumulative influence of demographic, nutritional, agricultural, socioeconomic, institutional, and environmental factors rather than isolated biological or health conditions.

The empirical findings indicate that Height-for-Age Z-scores provide a robust measure of early human capital because they capture the long-term effects of nutritional deprivation during the most critical period of physical and cognitive development. The observed socioeconomic gradient in children's nutritional status, together with the multivariate regression results, confirms that early human capital accumulation is fundamentally multisectoral and shaped by complementary investments operating across households, communities, and public institutions.

Beyond its empirical findings, the study makes a broader conceptual contribution by positioning chronic child malnutrition within the human capital literature. Rather than treating child malnutrition solely as a public health concern, the paper demonstrates that it constitutes a scientifically grounded indicator of early human capital accumulation. This perspective broadens the relevance of anthropometric measurement beyond nutrition and public health, linking it directly to human capital development, economic productivity, and long-term development outcomes.

The study therefore contributes to the growing literature

on human capital measurement by integrating established anthropometric methods with the Human Capital Production Function. It demonstrates that measuring chronic child malnutrition is, in effect, measuring one of the earliest observable outcomes of human capital formation. Future research may extend this analytical framework by examining how educational attainment, learning outcomes, environmental change, and other dimensions of human capital complement anthropometric indicators in measuring human capital accumulation across the life course.

The findings further support the broader human capital tradition initiated by Schultz (1961), Becker (1964), and Grossman (1972), while extending contemporary approaches to human capital measurement through chronic child malnutrition.

Ultimately, measuring early human capital begins with measuring the conditions under which human potential first develops, and chronic child malnutrition provides one of the earliest and most scientifically grounded indicators of that process.

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