

Chronic undernutrition: Retrospect and prospects

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Introduction: Some basics

- (Human) nutrition refers to the provision and utilization of essential nutrients necessary to support human life and health
- Nutrients are components of food needed by the human body. Generally, we divide these into two categories:
 - Nutrients that we need “a lot”: Macronutrients such as carbohydrates, fats, proteins
 - Nutrients that we need in “small” quantities. Micronutrients such as vitamins and minerals
- Being malnourished can take two forms:
 - “Too little”. Being undernourished.
 - “Too much”. For example, consuming too many calories and becoming obese

Introduction: Some basics

- Historically, in developing country contexts, discussions of undernutrition focused on conditions of marasmus and kwashiorkor
 - Marasmus: Emaciation; loss of muscle mass and subcutaneous fat
 - Kwashiorkor: A consequence of severe protein deficiency; physical manifestation is infants and young children with distended stomachs
- Starting in the 1970s, attention switched to:
 - Micronutrient deficiency (not the focus of this lecture)
 - Using anthropometry, the measurement of body size and gross body composition, to assess nutritional status

Introduction: Some basics

- The core idea underpinning anthropometry as it relates to undernutrition is that prolonged or severe nutrient depletion eventually leads to retardation of linear (skeletal) growth in children and to loss of, or failure to accumulate, muscle mass.
- Distinguish between acute undernutrition (wasting) as measured by weight for height and chronic undernutrition (stunting) as measured by height for age (HAZ).
- Chronic undernutrition in young children is the focus of this presentation
- Globally, ~165 million children are stunted

Introduction: Structure

Part I

- Consequences of chronic undernutrition

Part II

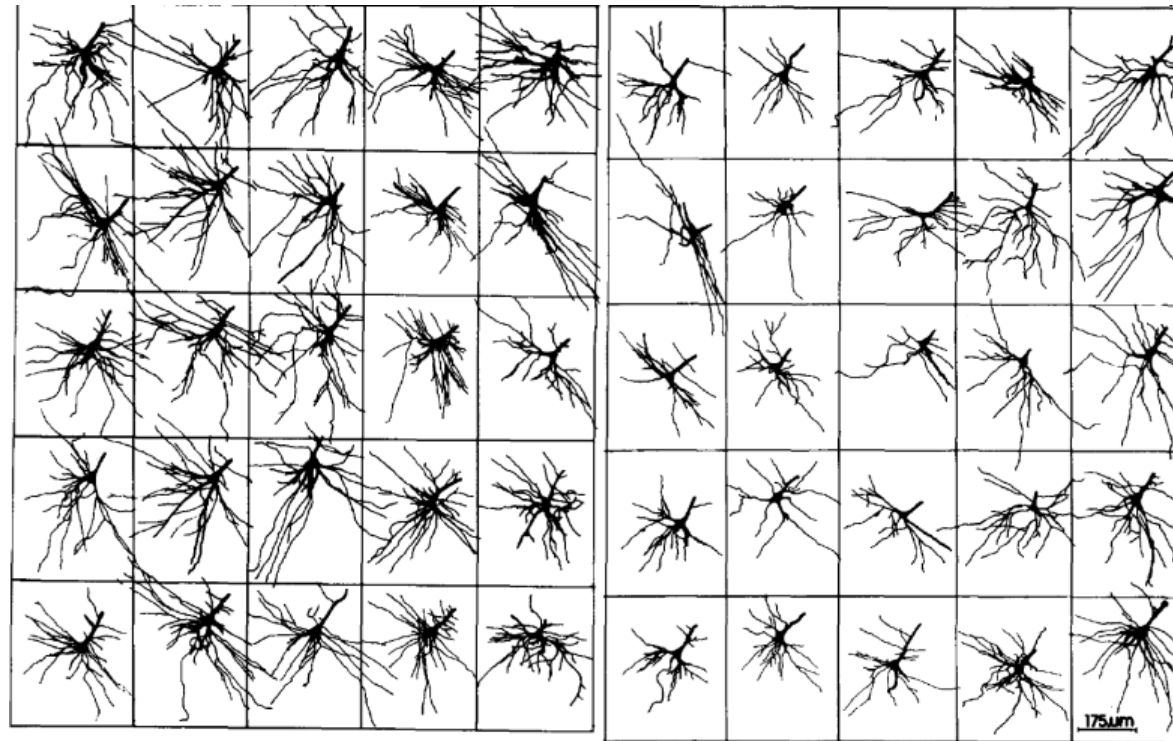
- Current state of knowledge
 - Conceptual frameworks
 - Stylized facts
 - Gaps and puzzles

Part III

- Possible lines of research and their implications

Consequences of chronic undernutrition: Motor cortex dendrites by child nutritional status

Well nourished
children



Undernourished
children

Figure 3. Pyramidal cell drawings from (A) well-nourished and (B) malnourished infants. On the left side pyramidal cells from (A) normal dendritic

Cordero et al, 1993

Neurological consequences of chronic undernutrition

- In the brain, development of axonal and dendritic systems is complete by 24 months.

In children who are chronically undernourished:

- Dendrites in the motor cortex and the occipital lobe (responsible for the processing of visual information) are shorter, having fewer spines and greater numbers of abnormalities; consequently, chronic malnutrition leads to delays in the evolution of locomotor skills
- There is reduced dendrite density in the hippocampus. This adversely affects spatial navigation and memory formation
- There is reduced production of glia cells (cells in the brain responsible for producing myelin); reduced myelination of axon fibers slows the speed at which signals are transmitted across neurons
- There is a decrease in the number of neurons in the locus coeruleus which plays a role in signalling the need to inhibit the production of cortisol. Thus early-life chronic undernutrition diminishes the ability to exhibit down regulation and handle stressful situations.

Consequences of chronic undernutrition

- The biomedical literature tells us that chronic undernutrition can lead to cognitive impairments. Do these have functional consequences? Are the magnitude of these meaningful?
- Consider the “INCAP” studies; longitudinal data collection that begins with a randomized village level nutrition supplementation trial in Guatemala between 1969 and 1977. Some villages randomized to receive a high calorie and high protein supplement; other villages receive placebo drink. All villages receive extensive primary health care
- A series of follow up studies have traced participants into early/mid adulthood (ages 25-42y)
- Very detailed data collection both at the time of the initial intervention and subsequently

Consequences of chronic undernutrition

- Look at relationship between HAZ at age 2y and outcomes across the life course (Hoddinott et al, 2013)
- Use instrumental variables to account for the endogeneity of HAZ, specifically the randomized intervention

Consequences of chronic undernutrition in Guatemala: Schooling and cognitive skills

Outcome	Unit	Impact of ↑ 1SD in HAZ	P value
Age Start School	Years	-0.21	0.068
Age left school	Years	0.54	0.025
Highest grade attained	Grades	0.78	0.003
SIA z score (25-42y)	SD	0.28	0.003
Raven's z score (25-42y)	SD	0.25	0.002

Consequences of chronic undernutrition in Guatemala: Marriage and fertility

Outcome	Unit	Impact of ↑ 1SD in HAZ	P value
Age at first marriage	Years	0.40	0.185
Partners' age	Years	1.39	0.006
Partners' highest grade attained	Grades	1.02	0.001
Partners' height	cm	1.01	0.046

Outcome	Unit	Impact of ↑ 1SD in HAZ	P value
Age at first birth	Years	0.77	0.043
Number of pregnancies	Number	-0.63	0.003
Number of living children	Number	-0.43	0.032

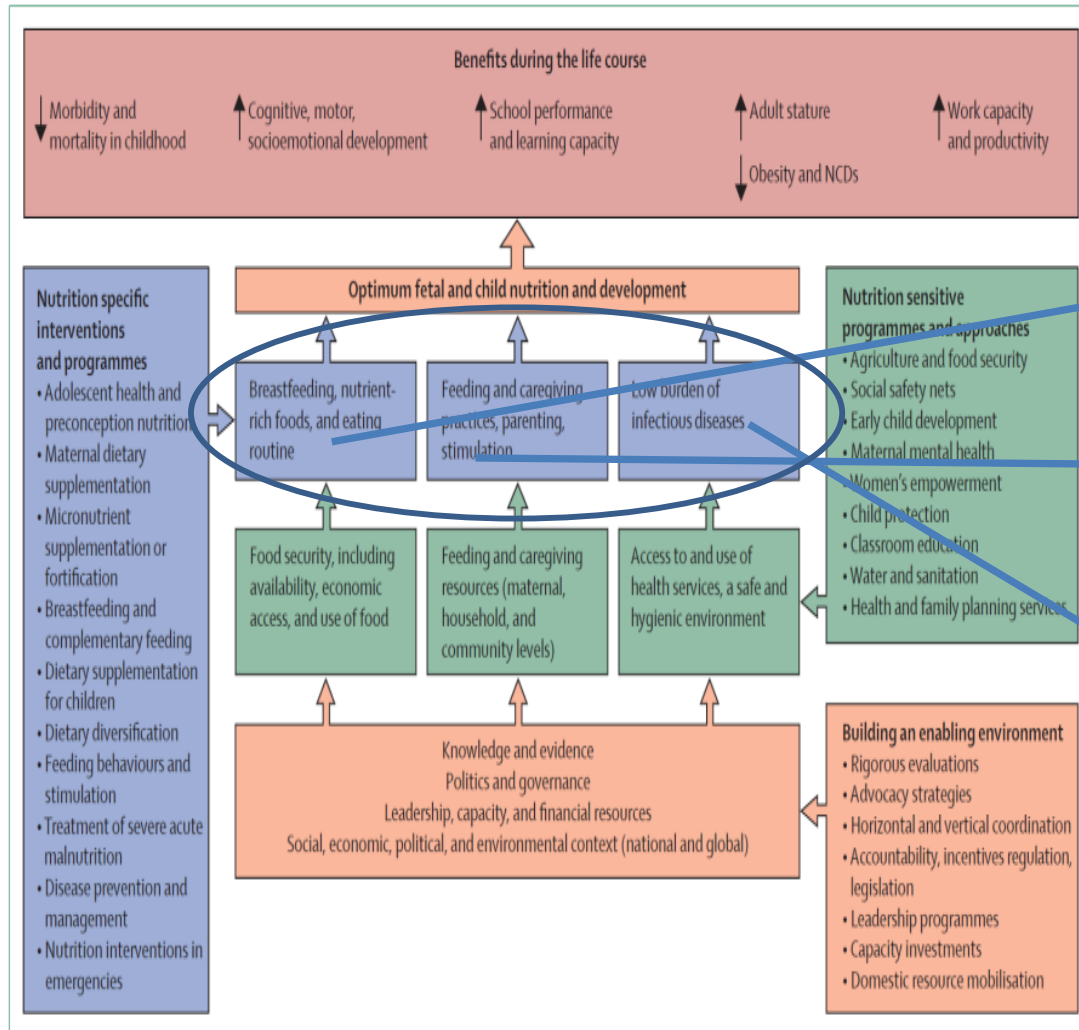
Consequences of chronic undernutrition in Guatemala: Labor market

Outcome	Unit	Impact of ↑ 1SD in HAZ	P value
Men			
Wages	%	14	0.080
Likelihood of operating own business	Percentage points	4	0.279
Women			
Wages	%	5	0.745
Likelihood of operating own business	Percentage points	11	0.010

Consequences of chronic undernutrition in Guatemala: Consumption and poverty in adulthood

Outcome	Unit	Impact of ↑ 1SD in HAZ	P value
Per capita household expenditure	%	21	0.001
Poverty	Percentage points	-10	0.014

Current state of knowledge: Conceptual frameworks



The nutrition production function

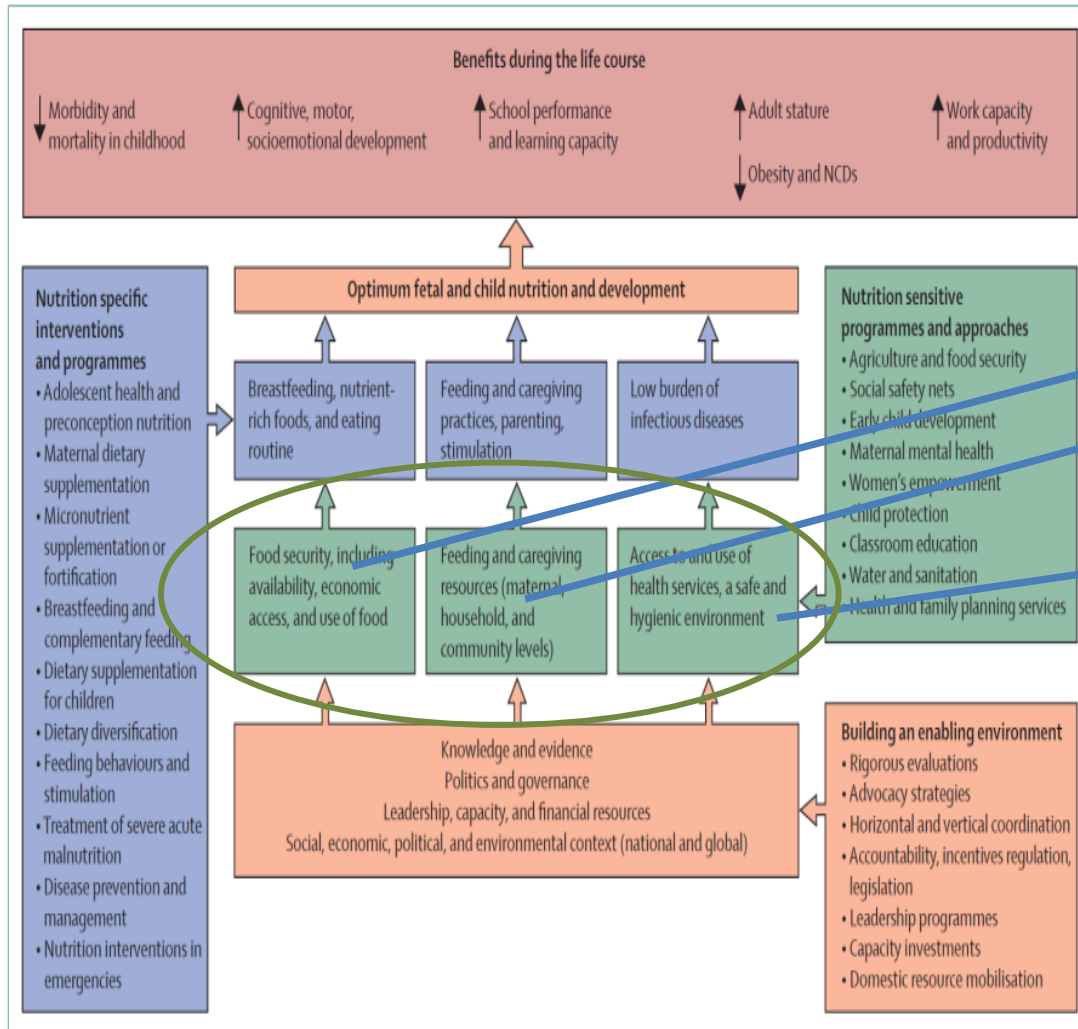
$$H_c = H(\text{nutrient intake,}$$

Time input, technology of child care,

Health inputs incl genetic endowments)

Black et al, 2013

Conceptual frameworks



Reduced form demand function for nutritional status

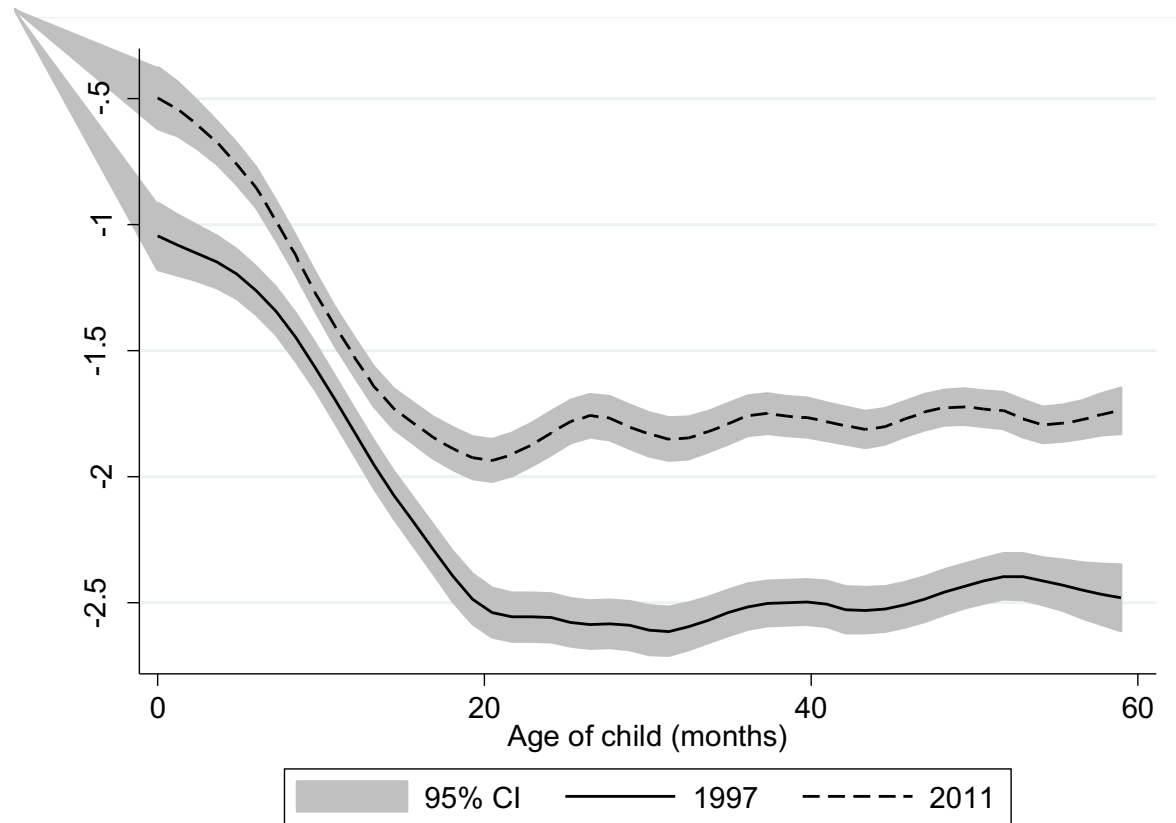
$$H_c = H(\dots)$$

- Incomes or assets, prices,
- maternal schooling,
- Health services, health environment)

Stylized facts: Wealth, health care, sanitation and maternal schooling

- Wealth is associated with improved HAZ (Black et al, 2013).
- Using DHS data from 2000 and 2014, Headey, Hoddinott and Park (2017) find that increases in assets account for about 20 percent of the reduction in stunting across six countries
 - Improvements in health care (% mothers receiving 4+ ANC visits; child being born in a health center) also contribute
 - Improvements in maternal schooling and reductions in open defecation play a role but the magnitudes of these effects are small

Stylized facts: Age profile of chronic undernutrition Bangladesh 1997 and 2011



Headey et al, 2015

Gaps and puzzles

- But this stylized fact raises a critical issue; why does HAZ deteriorate so badly between 6 and 24 months
- Story #1: “It is all about food availability.” Energy is needed for growth; when energy is lacking growth faltering occurs
 - This is consistent with another component of the 1970s revision. “The great protein fiasco” (McLaren, *the Lancet* 1974). Protein deficiency is over-rated as a source of nutrition deficiency. Supplements such as Incaparina (used in the INCAP intervention) are costly and unnecessary. “Lack of energy rather than protein is the crux of the matter”
- Headey and Hoddinott (2016) combine DHS and agricultural productivity data to look at the association between rice yield growth and HAZ in Bangladesh between 1996 and 2011. They find no effect.

Gaps and puzzles

- Story #2: “Its all about income.”
- Manley, Gitter and Slavchevska (2013) report a meta-analysis of the impact on HAZ of 17 social protection interventions that increased household incomes by 8 – 250%
- Average impact across these many programs:

Romansh: Nagut

Italian: Niente

French: Rien

German: Nichts

Gaps and puzzles

- Story #3: But Headey and Hoddinott is associational (though with lots of controls), Manley et al is built out of a heterogeneous set of studies
- So consider an RCT in southern Bangladesh (Khulna and Barisal) reported in Ahmed et al (2016):
 - Multiple treatment arms: Monthly cash transfers equivalent to 25% of hh income; Food basket (rice, pulses, fortified vegetable oil) of equivalent value; ½ food, ½ cash payment; Food plus nutrition behavior change communication (BCC)
 - RCT runs for 24 months
 - All payments made to mothers of children <2y at baseline
 - High quality BCC; 48 meetings over two years

Gaps and puzzles

- Impact on children's diets:
 - Small effects of food+BCC on consumption of eggs and animal source foods
 - Small effect of cash on egg consumption
- Impact on nutritional status:
 - Nagut, Niente, Rien, Nichts, Nothing

Gaps and puzzles

- Story #4: Surely the nutritionists have a good idea what to do
- Bhutta et al (2013) identify the 10 best bet direct nutrition interventions:
 - These have a powerful effect in terms of reducing acute undernutrition (and therefore infant and child mortality); reduction of severe wasting is estimated to be 61%
 - These have only a limited effect on chronic undernutrition, reducing it by around 20%

Lines of research and their implications

- One starting point may be to re-focus attention on the nutrition production function
- Both in nutrition and economics, the “food” component of this is often thought of in terms of energy (and micronutrients)
- The logic is that energy (think “calories”) is needed for cellular growth; absent sufficient energy over protracted periods of time during the first two years of life, growth falters
- But this view might be incomplete

Lines of research: Advances in metabolomics

- Rapid advances are occurring in metabolomics – the study of small molecule chemicals that are the consequence of metabolic processes.
- Improvements in our understanding of mTORs (mechanistic target of rapamycin) is an example
- mTORs are catalytic proteins. They signal (or regulate) cellular processes such as growth and differentiation (anabolic processes). This signaling process integrates information about the availability of nutrients (food sources, oxygen, and growth factors).
- There are two types: mTORC1 (mechanistic target of rapamycin complex 1) and mTORC2. mTORC1, when activated, regulates growth in:
 - Chondral plates (ie part of the bone where growth takes place)
 - Skeletal muscle growth
 - Myelination of nervous system

Lines of research: Advances in metabolomics

- Metabolomic work has also focused attention on choline, an essential nutrient
- Choline is needed for the synthesis of phosphatidcholines; this synthesis is needed for bone formation and cell membrane formation.
- Choline also appears to play a role in neurotransmitter synthesis which plays a role in the transmission of chemicals across synapses in the brain
- In addition, cow's milk (in addition to being an important source of animal-source protein, amino acids, calcium, iron, and vitamin B-12) stimulates the secretion of insulin-like growth factor I (IGF-I), the hormone that stimulates bone and tissue growth

Lines of research: Advances in metabolomics

- A review by Semba et al (2016a) shows that amino acids are essential for the activation of mTORC1. So when these are absent:
 - The body represses protein and lipid synthesis and cellular growth
 - Bone growth is restricted
- Essential amino acids cannot be synthesized from scratch within the human body; these must be obtained via diet. The best sources are animal source foods (meat, poultry, fish, eggs). Plant sources also contain these, but typically in much lower concentrations.
- Eggs are an excellent source of choline. Flesh foods (beef, chicken) are another source as are groundnuts, though the latter contain much less choline than eggs

Lines of research: Three examples consistent with advances in metabolomics

- Example #1: Biochemical analysis
- Semba et al (2016b) analyze serum blood samples from Malawi. These show that stunted children lack all essential amino acids.
- Semba (2016c) find that in Malawi, children with low serum choline concentrations are more likely to have experienced linear growth failure

Three examples

- Example #2: Consider a second RCT (in north Bangladesh, Rangpur) reported in Ahmed et al (2016):
 - Multiple treatment arms: Monthly cash transfers equivalent to 25% of hh income; Food basket (rice, pulses, fortified vegetable oil) of equivalent value; ½ food, ½ cash payment; Cash plus nutrition BCC
 - RCT runs for 24 months
 - All payments made to mothers of children <2y at baseline
 - High quality BCC; 48 meetings over two years
- Impact of the cash, food and cash&food treatment arms on child diet:
 - Some small effects of cash on improving diet quality
- Impact of the cash, food and cash&food treatment arms on child anthropometry:
 - Nagut, Niente, Rien, Nichts, Nothing

Three examples

- Impact of cash+BCC on child diet:
 - 10.9 percent ↑ in consumption of dairy products
 - 22.8 percent ↑ for flesh foods (meats, poultry, fish)
 - 24.6 percent ↑ for legumes and nuts
 - 36.0 percent ↑ for eggs
- Impact on chronic undernutrition:
 - ↑ HAZ by 0.25SD
 - ↓ Stunting by 7.3 percentage points

Three examples

- Example #3: Puentes et al (2016). Revisit INCAP data from the 1960s and 1970s. Look at data on child diets; use randomized intervention and food prices as instruments to estimate nutrition production function
- Impact on child growth (additional cm per 3 month period) of adding 100 kcal per day from all food sources: 0.23cm
- Impact on child growth (additional cm per 3 month period) of adding 10g per day of protein: 1.08cm
- In the treatment group, the protein came from the dried milk powder found in the Incaparina, described by McLaren (1974) as “costly and unnecessary”

Moving forward

- Given that chronic undernutrition “matters”, what should future work focus on?
- Shift away from the current emphasis on reduced forms and towards estimating production functions:
 - What children eat, not just how much they eat, with particular attention to animal source foods
 - *As well as ..* Hygiene and sanitation (Dean Spears work, work on environmental enteropathy etc)
- Pay more attention to the substitutability of inputs; what does the production function look like (Leontief or Cobb-Douglas or something else)
- A better understanding of the production function will permit the design of improved interventions
- Our evidence base of the long term effects is limited and unrepresentative. More and better follow up studies would be of considerable value

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