Health Economic Perspectives of Pediatric Malnutrition: Determinants of Innovative Progress

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Abstract

Despite some improvements in recent years, extreme poverty and malnutrition remain a critical concern for developing countries. Malnutrition, and more specifically pediatric malnutrition, is a reality affecting millions of children, particularly in South Asia and Africa. It causes increased mortality and morbidity, decreased physical and intellectual development, poor productivity and a number of negative economic outcomes. Health economics data clearly demonstrate that interventions are effective and efficient, but more data are needed to measure that efficiency. Initiatives to address microdeficiencies have focused on vitamin A, iodine, zinc, iron and folate. Iodine is often used as a best practice example. Two main institutions lead the efforts to address malnutrition throughout the world: the UN with its UN Millennium Development Goal project, and the Copenhagen Consensus. We consider micronutrient deficiencies, particularly in iodine, corresponding interventions, their effects and health economic data. We discuss how developing public/private partnership could boost the effectiveness of interventions by combining the competencies of both sides: credibility, national and international buy-in, experience of public institutions, commercial competencies, high penetration rate, and product knowledge of private industry.

Introduction

Despite some reductions in world income poverty in recent years, malnutrition remains widespread. Recent estimates [1] suggest that ‘maternal and child malnutrition is the underlying cause of 3.5 million deaths annually, 35% of the disease burden in children younger than 5 years, and 11% of the total global DALYs’ (disability-adjusted life years). Malnutrition is a critical parameter to understand when trying to evaluate the overall state or
progress of a society in health and well-being because malnutrition is often
the origin of a series of negative downfalls at human, health and economic
levels.

Malnutrition, the underlying cause of death for at least 30% of children in
the world, is a problem of such magnitude that the UN included it in the UN
Millennium Development Goal project. In 2000, world leaders came together
at UN Headquarters in New York to adopt the United Nations Millennium
Declaration, committing their nations to a new global partnership to reduce
extreme poverty and setting out a series of time-bound targets – with a dead-
line of 2015 – that have become known as the Millennium Development Goals
[2]. Two of the eight goals are to eradicate extreme poverty and malnutri-
tion, and reduce child mortality. Other goals, such as cure major diseases or
improve maternal health, heavily depend on improvement of the malnutrition
situation. So far, child deaths declined from 12.6 million in 1990 to around 9
million in 2007 and the percentage of underweight children declined from
31% in 1990 to 26% in 2007. However, rising food prices and the state of
the global economy might erode these results, and it is highly questionable
whether the targets to halve between 1990 and 2015 the proportion of people
who suffer from hunger and to reduce by two thirds the mortality of children
under 5 years of age will be met [3].

The Copenhagen Consensus 2008, is a group of 8 world-renowned econo-
mists, including 5 Nobel Laureates who were asked to assign a fictive amount
of USD 75 billion over a period of 4 years to the ten most pressing challenges
facing the world today. The criteria used included the cost-benefit ratio, as
well as feasibility and sustainability of the interventions. Table 1 shows the
interventions mentioned, and table 2 shows the attribution of the financial
resources. They ranked micronutrient supplements (vitamin A, zinc, iodine,
iron and folate) for children as the top international development priority
[4].

<table>
<thead>
<tr>
<th>Solution</th>
<th>Challenge</th>
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<tbody>
<tr>
<td>1 Micronutrient supplements for children (vitamin A and zinc)</td>
<td>malnutrition</td>
</tr>
<tr>
<td>2 The Doha development agenda</td>
<td>trade</td>
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<tr>
<td>3 Micronutrient fortification (iron and salt iodization)</td>
<td>malnutrition</td>
</tr>
<tr>
<td>4 Expanded immunization coverage for children</td>
<td>diseases</td>
</tr>
<tr>
<td>5 Biofortification</td>
<td>malnutrition</td>
</tr>
<tr>
<td>6 Deworming, other nutrition programs in school</td>
<td>malnutrition</td>
</tr>
<tr>
<td>7 Lowering the price of schooling</td>
<td>education</td>
</tr>
<tr>
<td>8 Increase and improve girl’s schooling</td>
<td>women</td>
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<tr>
<td>9 Community-based nutrition promotion</td>
<td>malnutrition</td>
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<td>10 Provide support for women’s reproductive role</td>
<td>women</td>
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The objectives of this article are first to demonstrate that malnutrition is a problem of great magnitude and that in particular micronutrient deficiencies can be effectively addressed. Second, we will discuss the role of public/private partnerships. And third, we will discuss the criteria for such interventions, their outcome, and whether there are some innovative approaches.

Macro-/Micronutrient Deficiencies

For a long time, hunger in the world was principally addressed by shipping food to developing countries. In 1990, some analyses revealed that some of these interventions had a poor efficacy in decreasing malnutrition. Addressing hunger does not necessarily resolve nutrient deficiencies: large volumes of bulky foods do not necessarily bring the density of nutrients, particularly vitamins and minerals, required for the normal growth and development of children.

Natural sources of food and diversity in diet provide most bio-available forms of nutrients but they are also higher cost items, and most poor people cannot afford them and have limited opportunities to diversify their meals. In addition, during periods of increased needs or acute vulnerability, everyday foods simply do not offer the necessary density of nutrients, including vitamins and minerals. Children under 5 are particularly vulnerable because of their physiological needs and susceptibility to infections.

According to the WHO definition, macronutrient deficiencies, also referred to as protein-energy malnutrition (PEM), are a nutritional deficiency resulting from either inadequate energy (caloric) or protein intake and manifesting

<table>
<thead>
<tr>
<th>Solution</th>
<th>Yearly cost in million USD</th>
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<tbody>
<tr>
<td>1 Micronutrient supplements for children (vitamin A and zinc)</td>
<td>60</td>
</tr>
<tr>
<td>2 The Doha development agenda</td>
<td>0</td>
</tr>
<tr>
<td>3 Micronutrient fortification (iron and salt iodization)</td>
<td>286</td>
</tr>
<tr>
<td>4 Expanded immunization coverage for children</td>
<td>1,000</td>
</tr>
<tr>
<td>5 Biofortification</td>
<td>60</td>
</tr>
<tr>
<td>6 Deworming and other nutrition programs at school</td>
<td>27</td>
</tr>
<tr>
<td>7 Lowering the price of schooling</td>
<td>5,400</td>
</tr>
<tr>
<td>8 Increase and improve girls’ schooling</td>
<td>6,000</td>
</tr>
<tr>
<td>9 Community-based nutrition promotion</td>
<td>798</td>
</tr>
<tr>
<td>10 Provide support for women’s reproductive role</td>
<td>4,000</td>
</tr>
<tr>
<td>11 Heart attack acute management</td>
<td>200</td>
</tr>
<tr>
<td>12 Malaria prevention and treatment</td>
<td>500</td>
</tr>
<tr>
<td>13 Tuberculosis case finding and treatment</td>
<td>419</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18,750</strong></td>
</tr>
</tbody>
</table>
in underweight and slow growth. These two parameters are the most widely used indicators of nutritional status in children less than 5 years of age [5]. Pediatric malnutrition affects first and foremost children under the age of 2, but young children less than 5 years of age, adolescents, and children with HIV/AIDS and TB are also vulnerable.

Malnutrition may be followed by developmental disability of varying degree, including reduced physical and/or mental ability, often associated with reduced strength, impaired cognitive function, reduced occupational activity [6]. In developing countries – mainly in Asia and sub-Saharan Africa – 146 million children under the age of 5 are underweight (1 in 4 children) and 60 million children under the age of 5 are wasted (almost 1 in 10 children). Most recent estimates for India suggest that nearly one half of all children aged 0–3 years are underweight and about 40% are stunted [7, 8].

Although severe malnutrition is associated with higher risk of death in children under 5, mild and moderate malnutrition accounts for the heaviest public health burden. Interventions to address malnutrition and the associated loss in economic productivity have demonstrated the effectiveness of breastfeeding in addressing a large part of the PEM issue. Following these results, WHO and UNICEF recommend exclusive breastfeeding during the first 6 months of life and continuation of breastfeeding beyond this age.

It is reported that the most critical micronutrients missing in developing countries are vitamin A, zinc, iodine, iron, and folate [5]. The Copenhagen Consensus placed interventions addressing these deficiencies on top of the list in particular due to their low cost of intervention (tables 1 and 2).

UNICEF estimates that 100–140 million children (mainly in South Asia and sub-Saharan Africa) are still deficient in vitamin A, despite supplementation efforts in many countries. Vitamin A deficiency in newborn babies, infants, and children accounts for about 6% of deaths of the children under 5 years, 5% of the under the age of 5 years DALYs and 1.7% of total DALYs lost [1].

An estimated 2 billion individuals worldwide suffer from iron deficiency, of whom more than half live in South Asia. Progress has been very difficult, although policy efforts are intensifying considerably. Iron fortification has a very high benefit-cost ratio, estimated as 8.7:1 [9]. The cost of iron fortification varies according to the iron compound used and the food vehicle but can be USD 0.10–0.12 per person per year. Fortification, however, requires that there exists a product that is purchased by a target population regularly and in sufficient quantities to convey the iron requirement [5].

Zinc deficiency is hard to measure, but tends to be correlated with iron deficiency and low animal food intake. IZiNCG [10] estimates that 20% of the world's population is at risk of deficiency based on food intake patterns. Zinc deficiency accounts for about 4% of under the age of 5 years DALYs and 1% of total DALYs lost [7]. Cost-effectiveness results for zinc supplementation suggest that its therapeutic use in diarrhea is highly cost-effective. A study [11] suggests that the incremental cost of zinc as part of case management is USD
0.47 per course of treatment, leading to an average cost of USD 73 per DALY gained, and USD 2,100 per death averted.

Concern over folate is relatively new. Although diets based on unrefined grains and beans (such as those in many rural areas of developing countries) tend to have good folate content, small studies from India and China find high incidence of birth defects, perhaps related to refined rice as the main staple. There are approximately USD 8 billion lifetime costs associated with birth defects related to births in a single year in the US alone [12].

Iodine deficiency affects mainly the development of the brain, and causes major losses in cognitive development, having significant economic impact in the affected regions. Prior to 1993, an estimated 633 million individuals suffered from iodine deficiency [13]. In 1993, the WHO and UNICEF recommended universal iodization of the salt to achieve elimination of iodine deficiency disorders. Salt iodization costs around USD 0.05/person per year, with a benefit:cost ratio in the order of 30:1 [5].

There is an increased dissociation between micronutrient deficiencies, and possibly an emerging bias in favor of programs that address micronutrient deficiencies relative to those that address PEM [14, 15]. One wonders whether this is driven by the cost-effectiveness of micronutrient interventions or whether it is determined by the technical nature and ease of implementation of micronutrient deficiencies (relative to PEM). Interventions that address PEM are complicated to plan and implement, and require community and household participation in order to be successful – unlike micronutrient interventions that can often be implemented top-down, e.g. via food fortification at source [16, 17]. Indeed, relatively little is known about which interventions reduce PEM among children and what the costs of these interventions are. In contrast, there is a good deal of evidence on interventions that address micronutrient deficiencies [5].

However, it is not always clear what the best way to address micronutrient deficiencies is, and there is an ongoing debate to choose between fortification and supplementation. Fortification refers to the addition of extra nutrient(s) to staple foods (e.g. cereal, milk, salt, condiments, etc.) in an industrial or manual fashion. Double and triple fortification is sometimes possible, meaning that to a single staple two or three nutrients are added. Supplementation, on the other hand, refers to the enrichment of a diet with extra nutrient(s) isolated from the staples. It can be in the form of a tablet, fluid, or other.

Fortification requires central production facilities with adequate safety standards, good distribution and that the components used do not affect the stability, color, taste or smell of the product aimed to be fortified. Fortification tends to have a lower unit cost than supplementation and hence is preferable if feasible, particularly if the deficiency is of importance across a wide range of population groups and if the fortification has no undesired negative effects for the nondeficient population – such as fortification with iron in malaria-endemic regions. Such undesired effects need to be taken into account in
cost-effectiveness and cost-benefit analyses as this has been neglected in the past, e.g. in iodine. Fortification can be more effective in reaching hard-to-reach populations, especially when using staple foods with high penetration rates.

Supplementation, on the other hand, usually requires a specific infrastructure such as field workers and health centers, for a wide distribution. Supplementation can be more complex to put in place for financial reasons, and because it involves a change in food intake habit. Supplementation tends to be used if a subpopulation is of particular interest and if the micronutrient is more costly and needs only to be taken twice a year (e.g. vitamin A).

For many if not all nutrients, one needs to consider the region, the target population and their cultural preferences and the cost-effectiveness. The resulting strategy will then be the most favorable mix of fortification and supplementation [18].

**Macroeconomics**

Beyond the ethical factor, malnutrition has a number of negative effects on economic growth. It leads to higher mortality and morbidity, higher health care costs, lower levels of education for children, causing a loss of economic output and an overall lower productivity. A number of studies concur to prove the importance of addressing malnutrition from an economic point of view [4, 8] and estimate the economic losses for societies attributable to malnutrition to be in the order of billions of dollars.

Horton [19] reports a productivity loss of children of mothers with goiter to be on average 10.3% and productivity loss associated with anemia to be 5%. A recent review confirms the association between malnutrition and reduced economic productivity [20].

There is a strong relationship between economic growth and nutritional factors, as revealed by the results of econometric procedures, despite some criticism expressed concerning methodology. The growth rate figures vary from 0.4 to 5% [8], which can partly be explained by varying nutritional status of countries. Fogel and Robert [21] go further and believe that the approximate contribution of nutrition to economic growth probably errs on the low side. The impact of nutrition on economic growth would appear to operate directly, through nutrition’s effect on labor productivity, as well as indirectly, through improvements in life expectancy.

Nutrition is widely accepted as a critical contributor to physical and mental health, well-being of a society, and economic productivity and growth. It is also recognized that factors to be taken into account to address malnutrition include nutrition itself, as well as economic growth and poverty alleviation. It might even be argued that, in the medium to long run, non-nutritional interventions, such as improving agricultural productivity, expanding female
schooling, and bringing piped water and electricity to rural areas, have larger effects on the reduction of child malnutrition than nutritional supplementation or fortification programs [7]. A study [22] estimated the contribution of various factors to reducing child malnutrition (between 1970 and 95) to be as follows:

- 43.0% women's education
- 19.3% health environment
- 26.1% national food availability
- 11.6% women's status

These findings have been reported in similar results, but a problem with nearly all of the studies is that the unit costs of the non-nutritional interventions (such as sanitation or electricity coverage) are not compiled, so it is not possible to know whether improved sanitation access or electricity coverage delivers more nutritional improvements per dollar of investment than community nutrition programs [7].

However, the income-malnutrition relationship is modest. When gross national product per capita in developing countries doubles, nutrition does improve, but the changes in underweight rates are much more modest decreasing from 32 to 23% [8]. A possible explanation is that the growth indicator GDP does not adequately reflect the income distribution within a given population.

But even if economic productivity and growth contribute substantially to addressing malnutrition, there is a danger of losing sight of explicit nutrition goals by driving towards broader economic goals, whose effects on malnutrition are complex to measure. Because of the belief that interventions focused on non-nutrition will also address malnutrition, the resources allocated for malnutrition remain insufficient: the direct nutrition allocations in the global funds account for less than 1% of the other global funds [23]. Another issue is the composition of 61 Millennium Development Goal indicators, whereby only two are measuring nutrition, and this being only quantitative data [2]. Micronutrient deficiencies and their impact may not be evaluated with these tools despite their very positive cost-benefit ratio (see also table 3) [24].

Despite the striking evidence, it remains questionable whether more political attention and more substantial resources will be dedicated to specific malnutrition interventions.

**Public-Private Partnership**

Fortification of salt with iodine has been one of the longest-standing micronutrient interventions, and is often quoted as a model to follow for other micronutrient fortification programs. A worldwide effort has dramatically raised the proportion of people consuming iodized salt from less than 20% in 1990 to about 70% in 2000. Experience over the past two decades shows
that the success of the Universal Salt Iodization program is based on [adapted from 25]:

- A supportive political and regulatory environment
- The formation of multi-sector coalitions and transparent partnerships involving international organizations, private producers, national governments and civil society
- Financial sustainability
- Communication efforts with the target populations
- Technical improvements
- Monitoring and evaluation

However, currently 31% of developing-world households still do not consume iodized salt and are therefore not protected [26]. Still, 38 million children are born every year at risk of lifelong brain damage associated with iodine deficiency [13]. Low coverage remains a problem particularly in South Asia (India, Pakistan, and Bangladesh) and some sub-Saharan African countries [26, 27]. It appears that more data are needed to understand the reasons for the lack of penetration of the iodized salt programs, and how to remedy it. One aspect to consider is the food staple used for supplementation, so far limited to salt for iodine supplementation. Condiments may be attractive alternative food vehicles to deliver micronutrients to populations in countries where rice is the dietary staple, and in countries where centrally processed rice is not consumed by rural populations who produce their own rice. Certain condiments e.g. Maggi cubes have a penetration rate of up to 90% in urban areas and 70% in rural areas in Central and Western Africa and reaching out to 50–90% of the hard to reach groups.

Table 3. Summary of health economic impact: if 1 DALY = USD 1,000 [24]

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Benefit:cost</th>
<th>Cost-effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fortification of staples</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt iodization</td>
<td>30:1</td>
<td></td>
</tr>
<tr>
<td>Flour fortification – iron</td>
<td>8:1</td>
<td></td>
</tr>
<tr>
<td>Flour fortification – folic acid</td>
<td>46:1</td>
<td></td>
</tr>
<tr>
<td>Sugar/oil fortification – vitamin A</td>
<td>50:1</td>
<td>USD 17–22/DALY saved</td>
</tr>
<tr>
<td>Double-fortified salt (additional</td>
<td>2:1 to 5:1</td>
<td></td>
</tr>
<tr>
<td>benefit for iron)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Home fortification</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Sprinkles’ – effect of iron</td>
<td>37:1</td>
<td></td>
</tr>
<tr>
<td>‘Sprinkles’ – effect of zinc</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Food-based approach</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fortified complementary food</td>
<td>2:1 to 1:1¹</td>
<td>USD 500–1,000/DALY</td>
</tr>
<tr>
<td>Ready-to-use therapeutic food</td>
<td>25:1</td>
<td>USD 41/DALY</td>
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¹ Estimates for complementary food underestimates: exclude productivity gains.
In order to address these 31% of households not consuming iodized salt, some critical competencies can be coordinated and put at play:

- In-depth knowledge of specific populations’ eating habits and cultural preferences
- Identification of minimal possible nutritional changes to add iodine in diet – intelligent fortification taking into account the fact that behavioral changes in habits are less likely to be long-term successes
- Experience in various food vehicles (salt, flour, condiments, etc.)
- Manufacturing inventiveness and strength: quality control on new products, volume production
- Market insight driving adapted pricing, distribution and communication strategy

Such competencies reside predominantly in the private food industry. Public-private partnerships could combine and leverage the long-term experience of public institutions in malnutrition interventions with the industry’s competencies in market knowledge, food vehicle and local implementation. Such partnerships could increase the efficiency of malnutrition intervention programs considerably.

Interventions with rather immediate effects have a higher chance of adoption than measures that demonstrate their effects beyond a political term (iodine interventions produce effects within a rather short period of time). However, more research is needed for the result evaluation of concise intervention programs including health economics analysis in order to demonstrate clear clinical outcome data, cost structure and finally the benefits for public health [28]. To develop pediatric malnutrition initiatives and support private/public collaborative programs, there is clearly a need to better analyze and quantify the efficiency of nutritional and non-nutritional interventions.

**Conclusions**

Innovative fortification (double or triple fortifications, home or biofortification) with several micronutrients (e.g. iron and iodine) should lower current malnutrition intervention costs and most probably be even more cost-effective than current single fortifications.

The iodine fortification case is a success story with improvement possibilities addressing pediatric malnutrition. Lessons learnt may be transferred for optimal intervention design not only for other micronutrients but also for other forms of malnutrition, and here in particular for lowering the high infant mortality rate due to unsuitable breast milk substitutes. As public-private partnership is crucial in the implementation of iodine deficiencies and other micronutrient deficiencies, this model may also be valid for breast milk promotion in order to achieve the highest public health benefit and best possible cost-benefit results.
Health economics data (the proven cost-effectiveness and the extraordinary cost-benefit ratio) are strong arguments complementing the burden of disease and other arguments in favor of investment in malnutrition and further recognition of this challenge by all actors involved including governments, NGO's, international organizations and the food industry.

More coordinated effectiveness research needs to be undertaken in the area, in particular on the effectiveness and costs of interventions or programs and their outcome on costs and on the health burden in a given region and country [29].

References

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Discussion

Dr. Mao: We talked about nutrition, now we are discussing malnutrition or undernutrition, and nutrition deficiency, including macro- or micronutrition. We have already learned that every 3 s a child under 5 dies due to malnutrition. In terms of health economics, if you picked two top actions which today could prevent or decrease malnutrition, what would they be?

Dr. Spieldenner: This is exactly the question governments ask, and they often hear that it needs more research and investment provide an answer. Looking at the presented evidence I would chose a nutritional intervention and a non-nutritional intervention, the latter being female education. It has been shown that this measure is very effective in improving the nutritional status of children. The nutritional intervention is more complex as macronutrient deficiencies are the bigger problem, but micronutrient deficiencies can be addressed very cost effectively. This is why I would choose triple fortification (iron, iodine, vitamin A) in a common and accessible product that is distributed all over a country.

Dr. Cai: I have one comment and one question. The comment: you mentioned that China is very successful in supplementing iodine. I have to say that in some areas we are supplementing too much, and we find thyroid disease may be related to that, but so far has been no evidence and we are trying to do a study right now. My question is: how much GDP can reduce malnutrition significantly?

Dr. Spieldenner: Exactly, in China iodine deficiency is most probably not so much of a problem on a national level but probably more so on a regional level such as in the North and in the mountain regions. The same may apply to malnutrition in general, and research into this is very valuable in order to develop the appropriate responses. The higher the relative household expenditure on nutrition, the more likely it is that GDP growth helps to address the issue of malnutrition. Zimbabwe has a GDP per capita of USD 286, which makes it one of the poorest countries in the world, and people have to spend up to 90% of their household income on food. In such a context, GDP growth would have a considerable impact on malnutrition.
China has a GDP per capita of USD 9,000, but this does not essentially reflect the problem of malnutrition as the family income distribution measured by the GINI index is a better indicator. Therefore, tailor-made programs to address malnutrition in rural areas with very low income will be beneficial in addressing malnutrition overall, most probably more than a rise in the overall GDP growth. It would be helpful to know the household expenditure on nutrition in poor and rural areas in China to develop targeted programs.

**Dr. Akbar:** My first question is: do you think that only GDP growth can solve the problem of malnutrition in a developing country like Bangladesh, because even if there is a GDP growth, without a mechanism of equal distribution the resources will not reach the poor rural population. And my second question is: how far has the developed world contributed to reach the MDG goals so far?

**Dr. Spieldenner:** To answer your second question, it is not up to me to judge or to evaluate the work of international organizations in that field, but going through the literature and the different websites of the international organizations it did not become clear to me where all the efforts were put together for each individual country. And I do not believe that the Millennium Development Goals will not all be reached by all countries. I am doubtful about some goals in India and in Bangladesh. And to your first question on GDP growth in Bangladesh, I think that you are right and that family income distribution is the better indicator for a relationship between malnutrition and economic development. But every measurement on a national or international scale has its limitations, and this is one of the reasons why more regional and local studies are needed.

**Dr. Cooper:** Perhaps just to follow on from my colleague in Bangladesh, in South Africa we have had a democratic government for the last 15 years. We have had quite impressive economic growth, around about 2–3% a year as opposed to the higher rate in India and China. But although there has been a growth particularly in the black middle class, the numbers of people living in poverty haven’t changed, the levels of unemployment have if anything increased, compensated to some extent by a better social net in terms of child support grants, but the question is are there macroeconomic policies that perhaps one should be pushing at a national and international level that would ensure some reduction in the GINI coefficient because South Africa certainly has one of the highest in the world.

**Dr. Spieldenner:** There may be a particular situation in South Africa. The very high GINI index may partly be due to the millions of refugees coming from Zimbabwe and other neighboring countries and immediately falling below the poverty line. This is more an epidemiological point of view rather than a macroeconomic point of view, but it may explain some of the disparities.

**Dr. Cooper:** It’s a bit complicated, but it is still a major problem within what one might call the South African population.

**Dr. Spieldenner:** It really depends on what indicators you look at. Macroeconomic policy success is measured with its own indicators, and these indicators are not essentially the best indicators to measure and to monitor what they were not originally made for. Why should a government change its macroeconomic policy if the country has a good GDP growth, although other indicators such as schooling and education rates are most probably better indirect indicators for macroeconomic policies to address malnutrition.

**Dr. Haschke:** I think it’s relevant to talk about famine. There are factors which you cannot predict, for example flooding, earthquake or war, in which case you can’t do anything in terms of prevention. But there are other areas in the world where problem of famine comes at regular intervals. Our measures usually are to intervene and help, and we know that these measures are very ineffective, a lot of money is wasted, and
after a certain while everything returns to normality, malnutrition stays. Is there any model or are you aware of any population-based or even community-based activity where this is done in a preventive way? What would it cost to prevent through certain measures a population from famine versus helping once it has happened.

*Dr. Spieldenner:* Engaging in a behavioral change for prevention is very difficult, in particular for people who are poor and have to struggle every day. Only a system with clear direct incentives such as assistance with profitable farming while preserving the environment and producing the healthiest products possible is a possible pathway, and here the food industry plays a crucial role in engaging in such incentives ideally together with governments.

*Dr. Singhi:* You presented your argument as to convince politicians that if you improve the health you improve wealth and the availability of more resources, but I think that we really do not have a direct evidence for this yet. Is there any model which has clearly shown that investing money in nutritional intervention has resulted in increased GDP or personal income?

*Dr. Spieldenner:* Yes, there is evidence. Micronutrient deficiencies are rather well researched. However, not many longitudinal studies with a long-term follow-up of nutritional interventions have been carried out.

*Dr. Singhi:* I think most of these are estimates and extrapolations, that’s why I am asking if we have any direct measures.

*Dr. Spieldenner:* Of course, one part is economic modeling, but there are also interventional data supporting the modeling, particularly in micronutrient deficiencies.