Agricultural Research and Policy for Better Health and Nutrition In Developing Countries: A Food Systems Approach

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Abstract

This paper is about the two-way causal relationships between the global food system and health and nutrition. It argues that the global food system begins and ends with health and that the prioritization and implementation of agricultural research and policy should consider health and nutrition effects. An integrated health and food policy approach is likely to be more effective in achieving both health and economic development goals that the current practice of separate sectorial policies. The paper identifies a large number of health and nutrition factors affecting and affected by the food system and suggests research and policies to enhance positive effects and reduce negative ones.

Key Words

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health and agriculture, food policy, global food system, agricultural research, nutrition policy, and health and the food system

Introduction

This paper is about one aspect of the interaction between human health and the global food system. It is about how agricultural research and government policy can alter the impact of the health and nutrition status of individuals and societies on the global food system and how it can alter the impact of the global food system on human health and nutrition. The goal of the paper is to enhance the understanding of how agricultural research and government policy can best improve the health and nutrition of poor people in developing countries.

I believe it is reasonable to argue that the global food system begins and ends with health and nutrition. Health influences the food system as an input through its effect on the human resource and through interactions with natural resources used in food production. The health and nutrition status of the labor force occupied in the food system—and that is a large share of the poor in developing countries—will make a significant impact on the degree of efficiency and effectiveness of the food system and how it ends up serving societies, including the poor. Similarly, health interactions with natural resources such as water-borne diseases in irrigation and other water management systems, can influence the food system both through its impact on farm labor and through the use-efficiency of the resource. That is what I call the beginning of the global food system. Healthy and well-nourished individuals are critical to a well-functioning

global food system. The "end", as visualized here, is the impact of the global food system on people's well-being including their health and nutrition. Since a large share of the people who suffer from poor health and/or poor nutrition is involved directly in the food system, we are dealing with a self-enforcing vicious cycle in which poor health and nutrition leads to low productivity human resources, which, in turn, contributes to deficiencies in the food system, low incomes, and poor health and nutrition.

The global food system is a means to an end, not an end in itself. A global system that leaves a large share of the global population in a state of poor health and nutrition is not a desirable food system. Neither is a global food system that exploits scarce natural resources in an unsustainable manner. Unfortunately, while being very effective in meeting economic demands at falling real prices, the existing global food system is characterized by both of these challenges. Rapidly increasing prevalence of chronic diseases caused, in part, by overweight and obesity continued widespread prevalence of energy and nutrient deficiencies causing the death of more than 5 million pre-school children annually and poor growth and poor health in many more, as well as hunger in millions of adults, unsustainable use of water, soil degradation, and a variety of other insults on the ecology, all contribute to the conclusion that the global food system could do better. Is it all the fault of the global food system? No, but changes in the global food system brought about by agricultural research and government policy can contribute to improvements.

Efforts to improve human health and nutrition through agricultural research and government policy aimed at the global food system, require improved understanding of how health and nutrition influence the global food system, how the food system influences health and nutrition,

and where, in the system, interventions such as government policy and research may be effective. The purpose of this paper is to contribute to such understanding. The next section will present an overview of the current health and nutrition situation, emphasizing those aspects of particular relevance to developing countries and their poor people in the context of the global food system. The paper then proceeds with a schematic overview of the global food system followed by an attempt to identify the most important interactions between health and nutrition, on the one hand, and the global food system, on the other. Potential policy measures and agricultural research that may reduce negative and improve positive interactions between the global food system and human health and nutrition are identified and the paper concludes with a brief summary of the suggested priorities for policy and research to improve human health and nutrition through a more appropriate global food system.

Human health and nutrition: this is where the global food system begins

I argue that the global food system begins with the human health and nutrition situation for two reasons. First, a large share of the world's poor is employed in the food system. Their health and nutrition conditions are of critical importance not only for their own well-being but for their productivity and creativity, which, in turn, will influence the efficiency and effectiveness of the global food system. Thus, good health and nutrition is an important input into the food system. Second, while the global food system plays a key role in the generation of economic growth in virtually every developing country, it is at the same time of critical importance as a means to achieve good health and nutrition for all. While economic growth may be necessary to achieve good health and nutrition, it is not sufficient; the nature of the economic growth matters.

Because of the importance of both quantity and quality of food in the lives of all and because of the large number of poor, unhealthy and malnourished people employed within the food system, the critical importance of food in efforts to assure good health and nutrition, and the large differences in the efficiency and effectiveness in the food systems across communities and countries and therefore apparent opportunities for improvements, I argue that a combined policy focus on that system and the health sector is likely to be more cost-effective to improve human health and nutrition than a focus on other sectors.

The current health and nutrition situation

During the last 50 years, increases in life expectancy and reductions in child mortality rates illustrate dramatic improvements in human health at the global level. However, the health status is very low among low-income countries and poor people. Of the total global disease burden, 92 percent is found in developing countries (Diaz-Bonilla et al., 2002). Furthermore, according to WHO (1999), pre-school children in poverty face a four times higher probability of death than non-poor pre-schoolers. Between 10 and 12 million pre-school children die of preventable causes every year—about half of them from hunger and nutrition-related factors. The large majority comes from poor households. The mortality rate among pre-school children from the poorest quintile of the population of 29 countries, for which data were available from surveys conducted since 2000, was found by WHO (2006) to be 2.5 times that of pre-school children

from the richest quintile[3]. That is slightly higher than 10 years earlier. Similarly, the probability of dying is 2-4 times higher among poor adults than non-poor adults (Diaz-Bonilla et al., 2002).

Stunting among pre-school children is also highly correlated with the wealth of the household. In all of the 47 countries for which data were reported by WHO (2006), the prevalence of stunting was higher in the poorest quintile of the population than in the richest quintile. A simple un-weighted average across the 47 countries showed that the prevalence in the poorest quintile was more than three times (315%) higher than the prevalence in the richest quintile.

Between 70 and 75 percent of the world's poor people reside in rural areas of developing countries. Their health status is poor. The mortality rate among rural pre-school children in the above mentioned 29 countries was 50 percent higher than the mortality rate among pre-schoolers in urban areas during the period since 2000—an increase from 10 years earlier (WHO, 2006). The mortality rate for pre-school children estimated on the basis of the most recent survey in each of 67 developing countries was higher for rural children in all but two countries[4]. A simple average across the 67 countries (without weighing for population size) showed that the mortality rate was 43 percent higher in rural than in urban areas. In three countries, rural mortality rates were more than twice the urban rates. Data for the prevalence of stunting in preschool children in rural and urban areas were available for 56 countries. The prevalence was highest in rural areas in all but one country. On the average (un-weighted across countries), the rural prevalence of stunting among pre-school children was 63 percent higher than the prevalence in urban areas.

[3] The data are from 29 countries (16 from Sub-Saharan Africa, 5 from Asia, 5 from Latin America and the Caribbean, and 3 from the Middle East) that have published the results from demographic and health surveys carried out since 2000 and 10 years earlier (WHO, 2006b).

[4] The probability of dying within 5 years after birth per 1000 live births. The surveys were carried out during the period 1985-2004, with 55 percent carried out during the period 2000-2004.

In 10 countries (18% of the sample), the prevalence of stunting in rural areas was more than twice that of urban areas.

The interaction between the environment and human health is important. Thus, in a recent study, Pruss-Ustun and Corvalan (2006) estimated that modifiable environmental factors, including physical, chemical, and biological hazards, account for 24 percent of the global health burden (measured in terms of "disability adjusted life years" (DALYs)), 23 percent of all premature deaths, and more than one-third (36%) of children's health burden. The diseases with the largest burden attributable to modifiable environmental factors were diarrhea, lower respiratory infections, injuries, and malaria. Although the environmental factors included in the analysis are found in both rural and urban areas, other studies have found strong interaction among human health, the natural environment, and the food system, particularly in low-income developing countries where the food system is closely related to natural resources (Diaz-Bonilla et al., 2002). Furthermore, access to improved water sources is less in rural areas. In 2002, 84 percent of Africa's urban residents had access to improved water sources compared to 45 percent of the rural residents. In Asia, the estimates were 94 percent for urban and 79 percent for rural (WHO, 2006). Thus, it may be hypothesized that the strong causal link between modifiable environmental factors and human health implies a strong causal link between the food system and health.

In addition to poor nutrition and related health problems—which will be discussed below—a large number of diseases and health hazards link human health and the global food system. They include food- and water-borne microbial pathogens causing diarrhea, water-borne diseases such

as malaria, zoonotic pathogens such as salmonella, campylobacter, E.coli, Avian flu, and BSE, HIV/AIDS, Tuberculosis, poisoning from chemicals, pesticide residues in food, parasites, mycotoxins, antibiotics in food causing the risk of antibiotics resistance in human, and more. Some of the diseases and health hazards influence the food system while others are influenced by it. These causal links will be discussed in a subsequent section.

The triple burden of malnutrition

While the above mortality and morbidity rates are influenced by a large number of health factors, malnutrition plays a major role and interacts with many of the diseases mentioned.

Existing malnutrition may be classified into three related but distinctly different problems: energy deficiencies, nutrient deficiencies, and excessive net energy intake. This is what I call "the triple burden of malnutrition". Malnutrition interacts with infectious and chronic diseases, and plays an important role in the resistance to, and severity of, various diseases. Thus, the health effects of malnutrition are complex and an exhaustive treatment of the matter is beyond this paper. Suffice it to briefly present the magnitudes and nature of the triple burden.

Developing countries are increasingly faced with not just energy and nutrient deficiencies and infectious diseases but also excess net energy intake resulting in overweight, obesity, and chronic diseases such as cardiovascular diseases, diabetes, and certain cancers. Thus, all three burdens are important public health problems in developing countries. Because of their impact on labor productivity, income earning and learning capacity, economic growth, and efforts to alleviate

poverty, they are also important development problems. Widespread nutrition problems cause low labor productivity, reduced economic growth, poverty, and large demands for public funds to deal with the resulting health problems. Furthermore, while energy and nutrient deficiencies have traditionally been considered poor people's problems and overweight, obesity, and resulting chronic diseases rich people's problems, such thinking is now out-dated. Overweight and obesity are rapidly becoming an integral part of poverty in all but the poorest countries.

About 800 million people suffer from energy deficiencies and between one-third and one-fourth of all pre-school children in developing countries do not grow to their full genetic potential; they suffer from low weight-for-age, low height-for-age, or both. In spite of promises made by virtually all the world's countries at the World Food Summit in 1996 and reaffirmed 6 years later, to reduce by half the number of people suffering from energy and nutrient deficiencies between 1990 and 2015, the efforts to do so have been minimal and the results dismal. Only about one-third of the countries have managed to reduce the number at all and about half actually experienced an increase during the first half of the 25-year period. While the number of energy-deficient people dropped slightly during the first half of the 1990s, it has increased since then to the current levels—slightly above 800 million or roughly the same as in 1990. Extrapolations to 2015 show no significant reductions. Thus, with business as usual, there will still be about 800 million energy deficient people at the end of the 25-year period during which the number should have been reduced to 400 million.

Some countries, such as China, have made great progress and are expected to exceed the 2015 goal. Because of its population size, China's accomplishments have a great influence on the

global data. If China is removed from the global figures, the rest of the world has seen a significant increase in the number of energy-deficient people from 630 million in 1990 to 673 million as an annual average for the three-year period 2000-2002. Extrapolating to 2015 shows an increase of about 100 million energy-deficient people between 1990 and 2015 instead of the promised reduction from 630 to 315 million—a gap of more than 400 million people. None of the four regions, Sub-Saharan Africa (SSA), West Asia and North Africa (WANA), Latin America and the Caribbean (LAC), and Asia will achieve the World Food Summit goal with business as usual.

The Millennium Development Goal (MDG) of reducing by half the proportion of the population that suffers from energy deficiencies is easier to achieve because of population growth. While the proportion is falling globally and in all regions except WANA, extrapolation of past performance does not lead to the achievement at the global level. However, LAC and Asia are expected to achieve the MDG.

Progress towards achieving the MDG is measured by two indicators: the proportion of the population that suffers from energy deficiencies discussed above and the prevalence of underweight pre-school children. As in the case of energy deficiencies, the prevalence of underweight pre-schoolers is decreasing but the rate of decrease is insufficient to reach the goal by 2015 at the global level (UNICEF, 2006). Two regions—East Asia (dominated by China) and LAC—are expected to achieve the goal. South Asia, home to more that one-half of the world's underweight pre-school children and more than half of low-birth weight babies, Sub-Saharan Africa, where the number of underweight pre-school children is expected to continue to increase

at almost the same rate as the population increase, and WANA, where both the number of underweight pre-school children and their proportion of the population are expected to continue to increase, are almost certain not to reduce by half the proportion of their pre-school children that suffer from underweight by 2015.

Micronutrient deficiencies (primarily iron, vitamin A, iodine, and zinc) affect about 40 percent of the population in developing countries causing severe health problems, particularly among poor women and children. Diets poor in micronutrients can cause, or contribute to, a variety of diseases—blindness, premature death, reduced labor productivity and impaired mental development (UNICEF, 2004). Sufficient micronutrients in the diet can protect against infectious diseases and reduce mortality (Catelo, 2006). Iron deficiencies are particularly widespread in parts of Asia where 50-75 percent of pregnant women and pre-school children suffer from iron deficiency anemia. Micronutrient deficiencies are also widespread in Sub-Saharan Africa. In eight out of 36 countries for which data were available (22 %), 80-85 percent of the pre-school children suffered from iron deficiency anemia and more than half of the pre-school children were affected by iron deficiency anemia in all but three of the 36 countries (IFPRI, 2006). UNICEF (2004) estimates that more than a third of Sub-Saharan Africa's population suffer debilitating effects of micronutrient deficiencies and the annual cost to these countries' economies is estimated to exceed $2.3 billion. The Global Alliance for Improved Nutrition (GAIN, 2006), estimates that micronutrient malnutrition will cause one million pre-school children to die within a year of their estimate.

Increases in overweight and obesity, resulting primarily from excessive energy intake relative to energy expenditures, are taking on epidemic proportions in both rich and poor countries. Two-thirds of the United States population and more than half of the populations of several European countries are overweight or obese and the prevalence is increasing fast, particularly among children and adolescents. The high and rapidly increasing levels of overweight, obesity and related chronic diseases are not limited to high-income countries. The prevalence of overweight and obesity is growing rapidly in many middle-income developing countries and some low-income ones. The growth is particularly noteworthy in China where it is projected that about one-third of the population will be overweight or obese by 2020 (Horton et al., 1999). In high-income countries, the prevalence of overweight and obesity is highest among low-income population groups, while both high and low-income individuals are affected in middle income countries and the prevalence is highest among the relatively well-to-do population groups in low-income countries.

As national income levels increase, it appears that the prevalence of overweight and obesity increases faster among low-income population groups than among the better-off, presumably in part because of a high correlation between income and educational level. On the basis of results from anthropometric surveys in 80 countries carried out in 2000 or later, WHO found that the national prevalence of obesity among women above the age of 15 years increased with increasing national incomes, while the prevalence of stunting in pre-school children decreased (Fig.1). As noted by WHO (2006), countries at the same level of national income may have very different prevalence of stunting and obesity, respectively, implying that factors other than those closely correlated with national incomes are important determinants of both stunting and obesity.

Policy prescriptions are particularly difficult for middle income countries because they show the coexistence of high prevalence of stunting in pre-school children, high and increasing prevalence of obesity in women, and widespread micronutrient deficiencies.

Evidence of negative economic impact of the triple burden of malnutrition is convincing although incomplete. Estimates by Horton (1999) show productivity losses for both energy and nutrient deficiencies between 5 and 17 percent. WHO estimates that 15.9 percent of the global burden of child disease is due to under nutrition. In developing countries, the figure is 18 percent (Gillespie and Haddad, 2003). The World Bank estimates that malnutrition accounts for 20-25 percent of the global health burden (World Bank, 1993). Pelletier et al. (1994) estimated that malnutrition was associated with 51 percent of all child deaths in nine Asian countries. Ross and Thomas (1996) estimated that iron deficiency anemia is associated with 23 percent of all maternal deaths in these nine countries (65,000 deaths). On the basis of findings from a number of studies of the effect of vitamin A supplementation in deficient populations, Beaton et al. (1993) conclude that mortality in pre-school children and pregnant women fell by 27 and 40 percent, respectively, and malaria attacks decreased by 30 percent.

While the importance of overweight and obesity in the increasing prevalence of chronic diseases and the related increase in health costs is well documented, estimates of the economic costs of overweight and obesity in developing countries are still to be done.

The global food system

Characterizing it as a process or set of processes that converts natural and human-made resources and inputs into food, the food system can be represented by a set of physical activities such as primary production, secondary production or processing, exchange activities such as transfer of ownership, transportation, and storage, and consumption. A food system can also be described as a social and economic system within which these and other physical activities take place. In this paper, I think of a food system as one that combines physical activities with economic, social, cultural, and policy factors for the purpose of achieving societal and private goals including improved human health and nutrition. The system is driven by the behavior of a set of actors, including resource owners, farmers, traders, processors, consumers, policy-makers, and officials in government and non-government organizations, who respond to opportunities, challenges, risks, and constraints imposed by bio-physical, socio-economic, cultural, and policy environments. As such, the global food system is a dynamic behavioral system that can be influenced by public policy through incentives and regulations.

A food system may be local, national, regional, or global. A global food system may be a description of a set of national, regional, or local food systems that may be isolated from one another or they may be connected through exchange, i.e. trade. In this paper, the term "global food system" is used to describe a system that connects many national and local systems through trade, information sharing, technology transfer, and other aspects of globalization.

A stylized description of such a system may consist of seven components: health and nutrition, natural (including human) and human-made resources, primary production, secondary production or processing, exchange activities, consumption, and health and nutrition. Except for

exchange activities—which operate between any two of the other components—these components are visualized as being carried out in sequence. Hawkes and Ruel (2006) provide a conceptual framework of the linkages between agriculture and health. Figure 2 gives a more detailed presentation of a food system and attempts to identify the interactions with human health and nutrition.

Interactions between the global food system and human health and nutrition

As shown in Fig.2 , energy and nutrient deficiencies, as well as infectious and chronic diseases, may influence the food system through labor productivity, technology adoption, input and credit application, and utilization of land, water, and other resources. The intuition that the health and nutrition status of workers influence their productivity has been affirmed by a large number of studies. Sick and malnourished people generally produce less than healthy and well-nourished people. Low labor productivity translates into lower wages (if hired labor), lower incomes (if self-employed farmers, traders, or processors), and lower efficiency in the food system. Poor health and nutrition among farmers is also likely to reduce the motivation and incentive to adopt new technology, seek credit, and apply appropriate inputs. In addition to energy and nutrient deficiencies, a large number of diseases, such as HIV/AIDS and TB, may contribute to low labor productivity and reduced motivation and incentives. HIV/AIDS may incapacitate or kill working-age members of farming households, leaving the fields unattended and causing all household members to face abject poverty, hunger, and—when all buffers have been exploited—death. A large increase in the number of orphans, falling life expectancy, and high mortality rates among adults in parts of Sub-Saharan Africa and increasingly in parts of Asia are a

testimony to the tragedy. While policy interventions specific to each disease, i.e. access to antiviral drugs for people affected by HIV/AIDS, are urgently needed, there is also a need to develop integrated policy measures that address both the diseases and their consequences for people's livelihood. In a specific example, strategies should be developed jointly by the health and agricultural ministries, the relevant NGOs, and local communities. Policies, aimed at the global food system, that ignore the implications of health and nutrition as inputs into the system will be less efficient than those that take a more comprehensive approach.

Recent developments in science, including the description of genomes for an increasing number of species and the application of molecular biology, in general, and genetic modification in particular, offer tremendous new opportunities for the application of science to improve the global food system for the benefit of better health and nutrition. The most important health and nutrition impact of technological change in the food system is undoubtedly that which comes about through higher incomes among low-income families that depend on incomes coming from the food system and lower prices for poor consumers. However, technological change in the food system can influence human health and nutrition in a number of other ways (Pinstrup-Andersen, de Londono, and Hoover, 1976). First, the relative price changes among foods will influence the diet composition, which, in turn, will influence the energy and nutrient balance of the diet relative to needs. Priorities in the research that produces new knowledge and technology will influence these relative prices. The most obvious illustration is the tremendous success in research to expand the productivity of rice, wheat, and maize—the so-called Green Revolution. Unit-costs of production of rice and wheat in Asia dropped by around 40 percent. These cost savings reduced rice and wheat prices to the consumers and increased incomes within the food

system. In large measure because research on pulses was not prioritized, the productivity of those food crops did not increase. Asian farmers responded as expected by producing more rice and wheat and relatively less pulses. As mentioned above, rice and wheat prices dropped while the prices for pulses increased. Consumers responded as expected by consuming more rice and wheat and less pulses.

From the point of view of avoiding mass starvation in Asia, which was its overriding objective, the Green Revolution was a thundering success. In addition, it was extremely successful in helping millions of poor farmers and farm workers out of poverty. Having accomplished these goals, the next step from a human health and nutrition point of view would be to emphasize research to reduce unit-costs of production of pulses and other food commodities rich in the micro-nutrients most deficient in the diets of low-income people—namely iron, vitamin A, and zinc. As already mentioned, the health and economic gains from the reduction of these deficiencies are estimated to be very large.

There are essentially five options that could be pursued: 1) industrial fortification, e.g., adding vitamin A to food commodities as part of the processing activities; 2) distribution of nutrient supplements such as vitamin A pills; 3) launching an educational campaign to change consumer behavior in favor of a diet that would meet the energy and nutrient requirements; 4) change the nutrient composition of the foods poor consumers consume through biofortification, e.g., enhance the content of absorbable iron in foods consumed by populations with a high prevalence of iron deficiency anemia, and 5) creating incentives for consumers to change their diets to meet both energy and nutrient needs, such as research to increase productivity and reduce unit-costs of

those foods that could most effectively add the nutrients that are deficient. Price policy, such as commodity or product-specific taxes or subsidies that would change relative prices, would be another potential policy measure.

The choice among the five options will depend on the specific circumstances. While options 1 and 2 may be effective in urban settings and rural areas with good infrastructure, they are likely to be costly and they do not provide a sustainable solution to the problem. They are unlikely to work among the rural poor in most locations because of deficient infrastructure and because most staple foods that could be fortified are not likely to enter into a marketing process where such processing is viable, although small-scale, village-level fortification may be an option in some cases. Distribution of supplements may be a short-term ad hoc solution until a sustainable approach is in place. Option 3 may help in cases where the deficiencies are a result of lack of knowledge rather than lack of income. However, in the case of low-income people, it is likely to be useful only in combination with increasing incomes and only by using new innovative communication approaches made possible by the information and communication revolution in developing countries. In this regard, it is useful to keep in mind that the food system is driven by the behavior of the actors in the system, including consumers and retailers, who do not necessarily prioritize improvements of health and nutrition over other goals.

Biofortification (option 4) offers exciting opportunities for helping to solve deficiencies of specific minerals or vitamins in the diets of people with severe income constraints and where the diet is dominated by one or two staples, such as rice or wheat in most of Asia, maize, cassava, or sweet potato in most of Sub-Saharan Africa, and potatoes in most of the Andes of Latin America.

Research aimed at the enhancement of the content of absorbable iron and vitamin A in rice and vitamin A in sweet potatoes has shown great promise. Ongoing research within the CGIAR is attempting to enhance the content of iron, vitamin A, and zinc in several staple foods. I believe it is reasonable to expect that these, and related research efforts, will be successful in making biofortified foods of that nature available within a reasonable time frame if the appropriate research and development investments continue to be made. The issue then hinges on economics and behavior. Can the biofortified seed be made available to farmers at costs that are less than the expected benefits to the farmers? Must the price of biofortified food be higher than other food for the farmer to be interested and will consumers pay more for biofortified food? The reason for bringing up these questions is not to try to provide answers but to illustrate the importance of behavioral responses to external influences such as public policy and agricultural research. While the global food system can be described as a set of physical activities, failure to recognize its behavioral aspects is likely to lead to disappointing outcomes of policy and research initiatives.

Option 5 provides the ideal outcome—namely, a diversified diet that meets all energy and nutrient requirements. The principal barrier to such a diet is poverty. Thus, the obvious policy choices are for those that would help poor people out of poverty. However, there are many other policy measures that might help low-income people obtain a better diet, such as investment in the development and dissemination of productivity-increasing, unit-cost reducing knowledge and technologies for the food system with emphasis on foods that are most likely to add the nutrients that are deficient in the diet, reducing the costs of distribution through more efficient marketing and processing, price policy, information campaigns that promote good nutrition, and regulation

of promotion and advertising expected to have adverse nutrition effects, such as the promotion of foods high in sugar, sweeteners, saturated and transfat, and low in required nutrients. Policies aimed at dietary changes should take into account the expected impact on both energy deficiency and excess energy intake. Since any one policy measure is unlikely to achieve both reductions in energy and nutrient deficiencies and reductions in excess energy intake, and since both deficiencies and overweight and obesity are prevalent in an increasing number of developing countries—notably middle-income countries—the design and implementation of an appropriate policy package is a serious challenge in those countries.

Another way in which the food system and health interacts is through water-borne diseases and parasites. Water-borne bacteria, viruses and parasites causing diarrhea, malaria and other water-borne diseases may influence the food system through reduced labor productivity and the food system may influence the prevalence of malaria through irrigation and poor water management. Because of the two-way causal link between malaria and water management, effective policy measures should include both the health and the food system aspects. Water contaminated with arsenic, cadmium, or other poisonous metals may cause illness through drinking water or the consumption of contaminated fish. Arsenic poisoning is particularly problematic in South Asia.

A large number of other health factors may influence the food system, e.g. microbial and chemical contamination leading to illness among workers and consumers and transfer of zoonotic pathogens, such as salmonella, Avian Influenza and Mad Cow Disease from animals to humans. As shown in Fig. 2, these factors may also be outcomes of the food system, thus providing a feedback loop contributing to a potential vicious circle.

Low labor productivity caused by the above health and nutrition factors results in lower incomes, reduced demand for food, lower food consumption by the household and individuals within, and a negative nutrition effect. Malnutrition, in turn, will further reduce labor productivity unless the potential vicious circle is broken by public or private action. Lower incomes will also reduce the ability to pay for health services. The economic demand for such services will decrease at a time when it is mostly needed. Free health care at the time and place needed by low-income rural people is, of course, the ideal solution. Rural health care systems that include both preventive and curative measures, are weak or non-existing in many developing countries and their development or strengthening should take a high priority in the allocation of funds by developing country governments and civil society. While international development assistance can help in the short run, rural health care systems are likely to be sustainable only if institutionalized with the national strategies and budget allocations.

In order to support rural health care systems and make them less costly, there is a need for integrated policies for the food system and health to reduce the health risks generated by the food system. Some of the most important in developing countries are shown in Fig 2. They include: microbial contamination such as food borne salmonella and campyabacter contamination of drinking water, crops, and the micro-environment where children are, including open sewer systems, by bacteria from animal manure and human feces; chemical risks such as pesticide poisoning of farmers and farm workers; pesticide residues in food and nitrate poisoning from drinking water contaminated with nitrogen fertilizers or manure; contamination with heavy metals from urban wastes; and zoonotic pathogens transferred from livestock such as avian

influenza, BSE and related Cruzfeldt-Jacob's disease in humans, Lyme disease carried by ticks, E.coli, and salmonella in animal products. Occupational hazards, including accidents in the food system are another important source of poor health which feeds back to labor productivity (ILO, 2000). Toxins and allergens in foods may be natural or introduced through research while research may also remove toxins and allergens.

Negative health effects from the use of chemical pesticides are of particular importance both to poor farmers and farm workers and to consumers. This is a problem where both traditional plant breeding and genetic engineering can be particularly helpful by developing pest resistance in plants. Much progress has already been made in, for example, rice production where the use of chemical pesticides has decreased significantly. The potential of genetic engineering to reduce the need for chemical pesticides to protect plants is illustrated by the Bt-gene introduced in several staple crops such as maize and cotton. For example, when first introduced in China, farmers reduced pesticide use by 80 percent without yield loss. Price policy may also be important. Large price subsidies on pesticides in several Asian countries during the first phase of the Green Revolution resulted in significant overuse of pesticide. Regulative policies that prohibit the use of pesticides considered of great risk to humans would also help reduce the negative health effects. The above are often included in what is popularly referred to as food safety, although the definition of that term is not unique.

The interaction between the food system and health through drugs can have both positive and negative health effects. On the positive side, plants and animals can be used to produce drugs needed to treat important human health problems. This is a dynamic research area at present.

On the negative side, the use of antibiotics in the food system, for example in animal production and in the use of certain marker genes in plant breeding, can contribute to antibiotics resistance in infectious diseases and parasites affecting humans.

Also on the positive side, the food system can develop and produce medicinal plants. This is an illustration of the multifunctional nature of the food system. In addition to food, the system may produce fiber, biofuel, environmental services, medicine, and a variety of other goods and services, each of which may have health and nutrition effects.

Moving to the nutrition aspects of the food system, the most obvious nutrition effect is through the system's provision of food. As illustrated in Fig. 2, household food consumption is influenced by incomes (whether derived from within or outside the food system), prices, the extent of consumption of own production from farming and urban agriculture, and individual and household preferences. The conversion of household food consumption to consumption by individual household members and nutrition is influenced by a number of factors including intra-household decision-making processes, the availability of clean water, sanitary conditions, health care, and the allocation of time—particularly women's time. Three aspects of women's time allocation are of particular importance: time spent in income-earning activities such as farming and non-farm labor, child care, food preparation, and the related energy expenditures[5].

From a policy perspective, it is important to differentiate between food and nutrient needs and economic demand. While needs may play an important role in the economic demand, the latter is determined by consumer behavior and influenced by many factors other than needs such as

[5] A fuller treatment of the interaction between agriculture and nutrition is presented in Pinstrup-Andersen (2005).

purchasing power, relative prices, level of knowledge, competing desires and preferences, and exposure to promotion and advertisement. Consumers, particularly low-income ones, are not likely to express their food demand in terms of nutrients and they may not wish to pay more for more nutritious foods such as those biofortified with absorbable micronutrients. The social value of such nutritionally superior foods may exceed the perceived private value for the consumer. Government intervention may be required to capture the value to society.

Campaigns by some civil society organizations against the use of modern science to improve the food supply, such as irradiation and genetic engineering, along with advertising campaigns by the private sector promoting highly processed foods with high content of fats, sugar, and sweeteners tend to outweigh nutrition education programs promoted by the public sector. Developments in science may soon make it possible for individual consumers to design diets that reduce genetically determined health risks on the basis of knowledge about their genomes. While nutrigenomics is still in its infancy, the development of such individual diets is not as far fetched as it may sound. Widespread dietary modifications in response to the testing for blood cholesterol are a step in that direction. Research to develop functional foods, i.e. foods that have physiological benefits beyond those of basic nutrition (McGill, 2006), is advanced and research is underway to develop food with more desirable nutrient profiles using nanotechnology (Ebbesen, 2006). While many of these science-based dietary changes may be of little relevance to poor consumers, they may be important to low-income farmers and labor in the food system because they open up new opportunities for adding value to agricultural commodities and, in that way, generate incomes among the poor.

Increasing political consumerism attempts to influence not only the individual consumer's behavior but various aspects of the food system, including production and distribution processes. As argued by Micheletti (2006), political consumerism is a response to globalization and the associated weakening of the ability of national governments to regulate and provide incentives to the market and to the lack of effective international institutions. While these civil society activities tend to focus on justice, fairness, food safety, use of modern science, and responsible behavior by private corporations, the nutrition and health effects may be significant. These effects may come about through changes in incomes, relative prices, food safety, and a variety of health risks to workers in the food system.

Rapidly increasing concentration in the supply chain of the global food system, including the development of large supermarkets and supermarket chains, facilitates the impact of political consumerism. Supermarkets may orient their product choice towards the desires expressed by the political consumer, limiting the choice offered to all consumers. The decision by many European supermarkets to exclude legally labeled genetically modified foods and promotion of higher-priced organic foods is a case in point. In fact, the behavior of the increasingly concentrated food distribution system is gradually replacing the role of national governments in providing regulations and incentives within the food system in both high- and low-income countries. The health and nutrition risk of the private sector replacing the government is that efforts to maximize profits are incompatible with health and nutrition goals. Self-regulation by the private sector raises important ethical questions (Pinstrup-Andersen, 2005).

A summary of potential agricultural research and policies

As illustrated above, science and policies aimed at the global food system may contribute to improved human health and nutrition in many ways. In this section of the paper, I will mention some of the most important areas where such contributions can be made. No attempt is made to present an exhaustive list of research and policy priorities.

Health, education, and food system policies aimed at the alleviation of poverty through enhanced human capital should be integrated. As illustrated by the various interactions, an integrated approach is likely to be much more effective that separate sectorial policies. Although urban poverty and associated health and nutrition problems is expanding in virtually all developing countries, the large majority of the poor are still in rural areas. The supply of health care, clean water and improved sanitation in these areas is very limited and should be expanded along with income-generating activities within and outside the food system and primary education. Investments in rural infrastructure, including roads—particularly feeder roads—rural institutions, markets, and agricultural research, as well as policies that give the poor access to productive resources such as land and credit are essential to help the rural poor out of poverty and improve their health, but only if such investments are accompanied by improved access to health care, clean water, and primary education. Policies to eliminate gender discrimination in asset ownership and decision-making should be pursued, with due consideration to the impact on time allocation by women and the associated health and nutrition implications.

Public policies may influence health and nutrition through regulations and incentives aimed at both the food and health system. Such policies may span the spectrum from international trade

and macroeconomic policies through sectorial and technology policies to food safety and transfer policies, school lunch programs, and health care to individuals. As globalization progresses, national policies in one country may affect health and nutrition in others (Pinstrup-Andersen, 2006). This is particularly problematic since globalization has moved faster than the international institutions required to guide it.

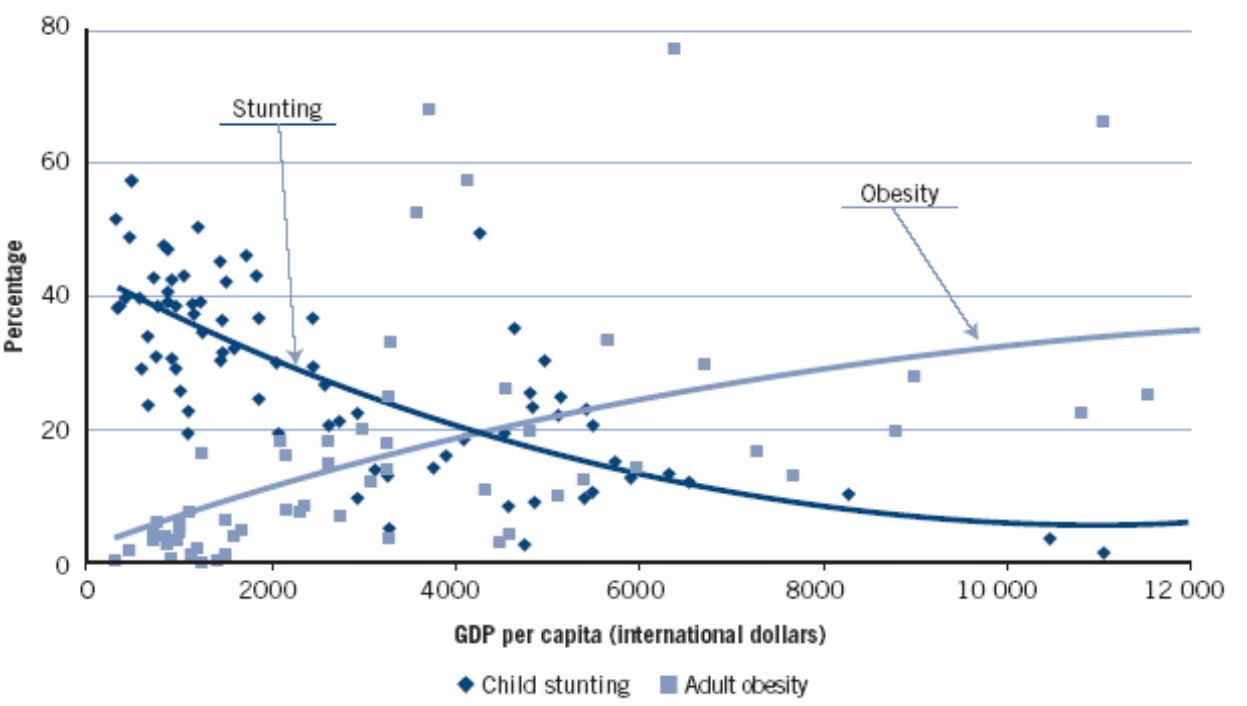
Agricultural research priorities should pay attention to both economic demand for food and agricultural commodities and health and nutrition implications. Commodity priorities should promote enhanced investments of research funds to increase productivity and reduce unit-costs of food commodities with high content of absorbable micronutrients in short supply in the diets of the poor as well as biofortification of basic food staples. Other research priorities include research to reduce the need for chemicals in plant protection through the development of resistant or tolerant plants, research to improve existing knowledge about the transfer of major zoonotic pathogens and how such transfer can be better managed or avoided, research to remove important toxins and allergens from foods, and avoid the development of mycotoxins during production and storage.

Modern science, including molecular biology, offers tremendous opportunities for improving human health both directly through curative and preventive measures and indirectly through improvements in the global food system. Unfortunately, the allocation of research resources is biased towards the development of curative measures for health problems affecting the non-poor. Although recent investments by the Bill and Melinda Gates Foundation is of great importance, opportunities for improving human health and nutrition and reducing child mortality are being

foregone by gross underinvestment in the application of science to solve poor people's health and nutrition problems, including the application of molecular biology to improve the global food system. The new agriculture and health research platform developed by the International Food Policy Research Institute for the Consultative Group for International Agricultural Research is an important step in the right direction.

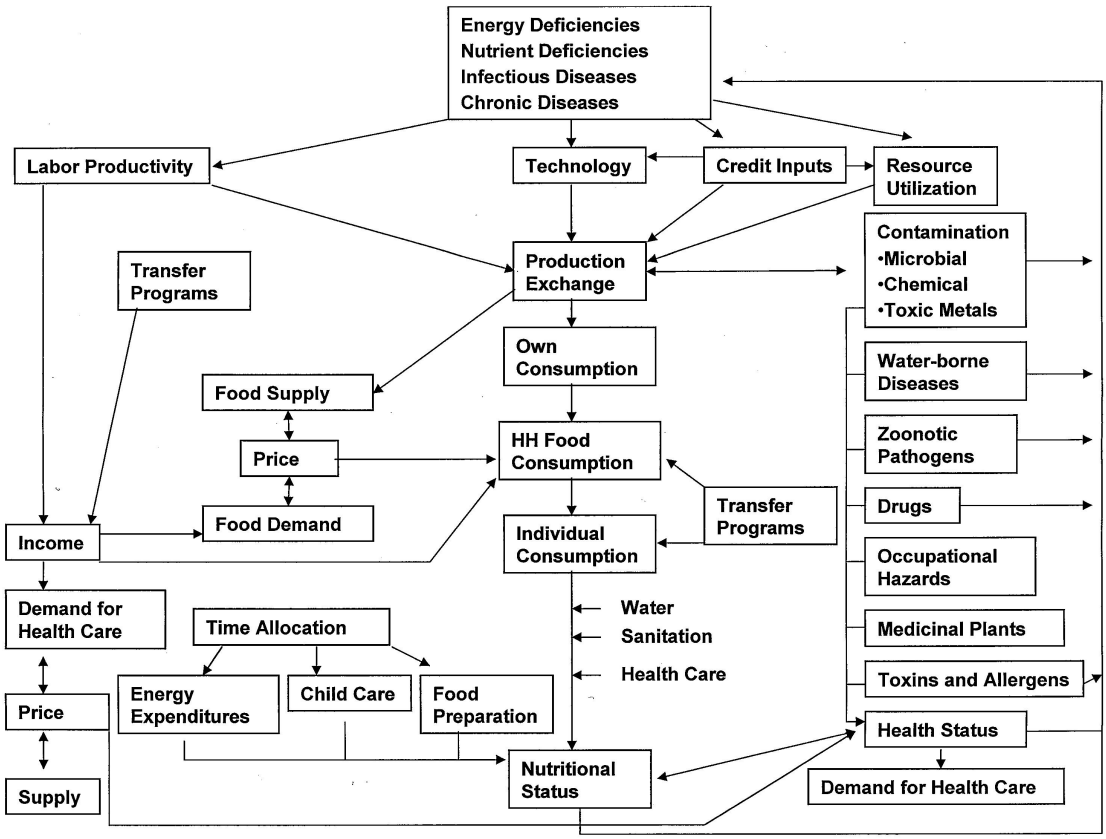
In conclusion, let me clarify that the main message I have tried to communicate in this paper is that the application of science and public policy to the global food system may offer important opportunities for improving human health and nutrition. At the same time, the health and nutrition status of the population is important for a well-functioning global food system. My message is not that farmers and other actors in the food system should reorganize their activities to meet health goals if they conflict with market signals. The food system is part of the private sector which depends on market demand to thrive. Thus, the role of the public sector is to design and implement policies that bridge the gap between societal goals and market signals. If market signals do not reflect health and nutrition goals of society, there is a need for policy intervention.

Figure 1. Undernutrition and obesity by the level of GDP per capita.



Source: WHO, 2006

Figure 2. Illustration of health and nutrition links with the food system.



References

Beaton, G., Martorell, R., Aronson, K.J., Edmonston, B., McCabe, G., Ross A.C., and Harvey, B., 1993. Effectiveness of Vitamin A Supplementation in the Control of Young Child Morbidity and Mortality in Developing Countries. ACC/SCN State-of-the-art Series, Nutrition Policy Discussion Paper No. 13, UN, Geneva.

Catelo, M.A.O, 2006. Understanding the Links Between Agriculture and Health: Livestock and Health. 2020 Vision Focus 13, Brief 9, IFPRI, Washington, DC.

Dawson, A., 2006. Genetics and Tailor-made Diets: Some Ethical Issues. In: Kaiser, M. and Lien, M.E. (Eds.), Ethics and the Politics of Food, 8, Wageningen Academic Publishers, The Netherlands, pp. 309-313.

Diaz-Bonilla, E., Babinard, J., Pinstrup-Andersen, P., and Thomas, M., 2002. Globalizing Health Benefits for Developing Countries. TMD Discussion Paper No. 108, IFPRI, Washington, DC.

Ebbesen, M., 2006. Nanofood: Lessons to be Learnt From the Debate on GM Crops. In: Kaiser, M. and Lien, M.E. (Eds.), Ethics and the Politics of Food, 8, Wageningen Academic Publishers, The Netherlands, pp. 314-319.

GAIN, 2006. A New Way of Development. Global Alliance for Improved Nutrition, http://www.gainhealth.org/gain/ch/EN-EN/index.cfm (accessed June 2006).

Haddad, L., 2000. A Conceptual Framework for Assessing Agriculture-Nutrition Linkages, Food and Nutrition Bulletin 21:4, 367-373.

Hawkes, C. and Ruel, M. T. (Eds.), 2006. Understanding the Links Between Agriculture and Health. 2020 Vision Focus 13, IFPRI, Washington, DC.

Horton, S., 1999. Opportunities for Investments in Nutrition in Low-income Asia, Asian Development Review 17:1-2, 246-273.

ILO, 2000. Safety and Health in Agriculture, 88th Session of the International Labour Conference, Geneva, May – June 2000.

McGill, A.E.J., 2006. Nutrigenomics: A Bridge Too Far, for Now? In: Kaiser, M. and Lien, M.E. (Eds.), Ethics and the Politics of Food, 8, Wageningen Academic Publishers, The Netherlands, pp. 330-333.

Micheletti, M., 2006. Political Consumerism: Why the Market is an Arena for Politics. In: Kaiser, M., and Lien, M.E. (Eds.), Ethics and the Politics of Food, Keynote Papers, Wageningen Academic Publishers, The Netherlands, pp. 23-27.

Pelletier, D.L., Frongillo, Jr., E.A., Schroeder, D.G., and Habicht, J.P., 1994. A Methodology for Estimating the Contributions of Malnutrition to Child Mortality in Developing Countries, Journal of Nutrition 124, 2106-2122.

Pinstrup-Andersen, P., 2006. Food system policies in rich countries and consequences in poor ones: Ethical considerations. In: Kaiser, M. and Lien, M.E. (Eds.), Ethics and the Politics of Food, 9, Wageningen Academic Publishers, The Netherlands, pp. 382-385.

Pinstrup-Andersen, P., 2005. Ethics and Economic Policy for the Food System, American Journal of Agricultural Economics 87:5, 1097-1112.

Pinstrup-Andersen, P., de Londono, N.R., and Hoover, E., 1976. The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy, American Journal of Agricultural Economics 58:2, 131-142.

Prüss-Ustün, A., Corvalán, C., 2006. Preventing Disease Through Healthy Environments: Towards an Estimate of the Environmental Burden of Disease. World Health Organization, Geneva.

Ross, J. S., Thomas, E.L., 1996. Iron Deficiency Anemia and Maternal Mortality. PROFILES 3 Working Notes Series, No. 3, Academy for Educational Development, Washington, DC.

UNICEF, 2006. Progress for Children: A Report Card on Nutrition, No. 4. UNICEF, New York.

UNICEF, 2004. Vitamin and Mineral Deficiency: A Global Progress Report. UNICEF, New York.

Welch, R.M., Graham, R.D., 2000. A New Paradigm for World Agriculture: Productive, Sustainable, Nutritious, Healthful Food Systems, Food and Nutrition Bulletin 21:4, 361-366.

World Bank, 1993. World Development Report: Investing in Health. Oxford University Press, New York.

WHO, 2006. World Health Statistics 2006. World Health Organization, Geneva.