

WORLD AGRICULTURE IN A DYNAMICALLY CHANGING ENVIRONMENT: IFPRI'S LONG-TERM OUTLOOK FOR FOOD AND AGRICULTURE¹

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The sharp increases in food prices that occurred in global and national markets over the 2006 to 2008 period sharpened the awareness of policy-makers and agricultural economic analysts of the stresses facing global food systems and the ecosystems that support them. The rapid increases in prices of key food commodities such as maize, wheat, rice and soybeans have mirrored the increases in prices of energy products, and strengthened the perception that energy and agricultural markets are becoming more closely linked (Schmidhuber, 2006). In the period 2002 to 2008, the international market prices of basic grain commodities more than doubled, while the prices of wheat and rice tripled. Although this might present different impacts on the consumer price indices in different countries – owing to the different shares of these commodities in total consumption – it represents a significant and sharp change in market conditions. While many see the reversal of historically declining real prices of agricultural commodities as an opportunity for agricultural producers in both developed and developing countries, others remain concerned about the implications of high food prices and increased volatility in food markets for the welfare and well-being of vulnerable populations, who consist mostly of net consumers of these products and who largely reside in the poorest regions of the developing world (Evans, 2008; FAO, 2008).

The nearly fourfold increase in oil prices over the same period led to second-round price effects on the wide range of goods and services that depend significantly on fossil fuels as inputs to production, including agricultural ones. Looking into the future, a number of researchers project the continued elevation of world prices for agricultural goods to above historical trends, despite a levelling off in the short term from the current highs. The medium-term projections generated by

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the joint Organisation for Economic Co-operation and Development (OECD)/FAO modelling effort show that a prevailing tightness remains in most major agricultural markets, keeping price levels significantly above historical trends (OECD/FAO, 2008). The world market price projections of the International Food Policy Research Institute (IFPRI) show that world grain prices will increase a further 30 to 50 percent over the period 2005 to 2050, while meat prices in the same period will increase an additional 20 to 30 percent beyond the levels seen in 2007/2008 (von Braun, 2008).

The underlying factors that led to the rapid increases in food prices up to 2008 have been widely discussed in the policy literature and are varied – in both nature and relative strength in driving market dynamics across various commodities. In both the published literature and the press, a number of factors have been attributed to the rapid increase in food prices, ranging from the rapid increase in production of first-generation, food-based biofuels (Oxfam International, 2008; Runge and Senauer, 2008), to the increase of cereal and meat demand in East and South Asia and the increase in speculative activity in food markets. Several comprehensive discussions of this issue have appeared in recent literature (Headey and Fan, 2010; Headey, 2010), which seeks to assess the relative merit of each of these factors while providing an overview of the global macroeconomic picture and the relative decline of the United States dollar in relation to other currencies (Abbot, Hurt and Tyner, 2008). The steady decline in the global level of cereal stocks, resulting from the private sector taking over the operation of cereal stocks from governments and adopting a more “just-in-time” management orientation (Trostle, 2008), has also been cited as a factor that reduced the ability of national governments to stabilize consumer and producer prices (OECD, 2008). Most authors, however, do not isolate a single cause as being to blame for the current world food situation, but cite a complex interaction among several coincident factors.

The challenges and increased stresses that face global food production and distribution systems in the decade starting in 2010 are particularly acute and pressing for sub-Saharan Africa, where persistent levels of food insecurity already exist. For example, roughly 33 percent of the population of sub-Saharan Africa lives with insufficient food supplies (FAO, 2005) and an even greater proportion – 43 percent – lives below the international dollar poverty line (Dixon, Gulliver and Gibbon, 2001). Myriad constraints lie in the way of Africa’s benefiting from higher producer prices of agricultural commodities on the world market, and include the fact that most of sub-Saharan Africa’s agricultural production relies on rainfed cultivation and receives lower input levels of improved seed technology and fertilizer applications than agriculture in other regions. Additionally, the area affected by land degradation within the region is expanding, thereby causing a

decline in soil fertility that reduces yield levels and increases the difficulty in maintaining sufficient production levels, especially given the lack of technological innovation and fertilizer use (FAO, 2005).

This chapter examines the key environmental, technological and socio-economic drivers that underpin the global world food situation, and evaluates the potential role of alternative policy interventions that might address these. It discusses these policy interventions in terms of the role they can play in enhancing market stability, food security and human well-being in the face of the increasing stresses that continue to face global agricultural markets and food systems. Specifically, it looks at the role that biofuels might play in raising food prices, and the role that agricultural technology investments might have in counteracting these effects. Based on this analysis, the chapter concludes with some final recommendations for both policy intervention and further research.

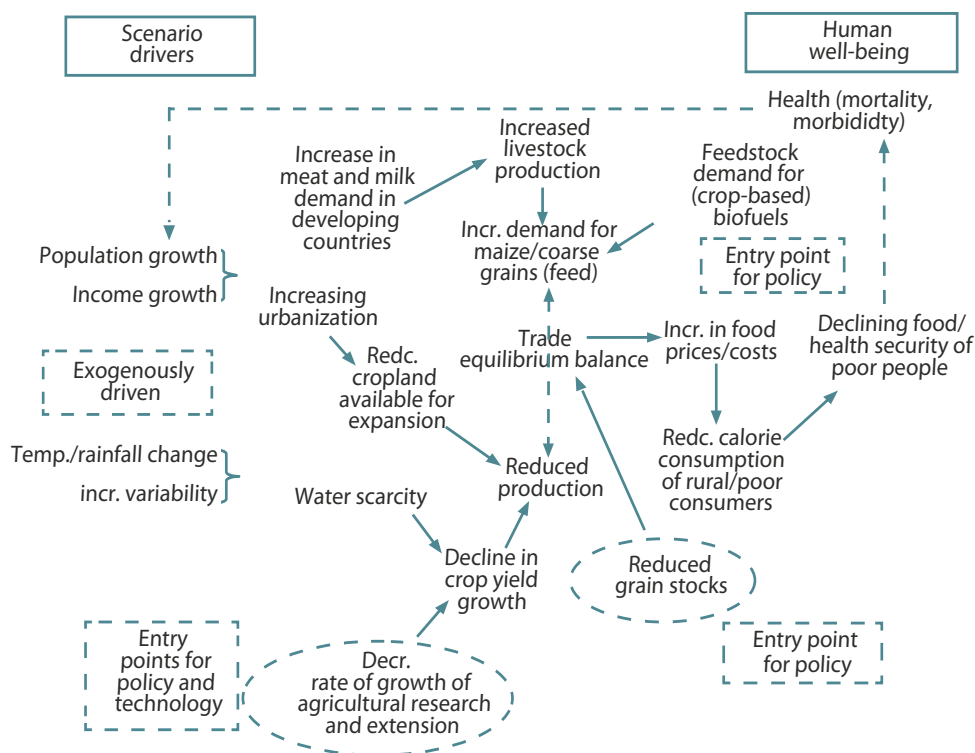
Drivers of change in food systems

The upward pressure on key commodity prices mentioned in the previous section can be accounted for by a number of underlying factors or drivers of change that are diverse in nature. These drivers range from environmental to socio-economic and from slow- to fast-moving, and affect outcomes differently in the short and long terms. In addition, underlying factors driving the long-term trends in food supply and demand have also contributed towards a tightening of global food markets during the past decade. These trends are driven by both environmental and socio-economic changes, as well as by agricultural and energy policies, including those that encourage biofuel production from agricultural feedstocks. Figure 2.1 illustrates the interactions among the various key drivers of change in global food systems, and their linkages to other components of the food economy and to important outcomes of human well-being, such as nutrition. Although Figure 2.1 does not include all the factors of importance, it incorporates the main elements of global environmental and economic change in food production and consumption systems that are addressed in this chapter.

Socio-economic change in the form of increasing growth in population numbers and total income, is among the major drivers that change the economic behaviour of consumers in terms of their demand for food and energy products. Urbanization, which is related to these demographic changes, also has an impact on consumption patterns and the transformation of consumer preferences for food, fibre and energy products. These changes in consumption and consumption preferences introduce increased stresses into the demand side of food and energy systems, while other environmental factors might restrain the supply side of food systems from responding readily – as a result of either resource scarcity or degraded

land and water quality. Reduced investments in crop and energy technology, over time, can also lead to a longer-term slowdown in the expansion of supply, which eventually leads to higher prices as demand begins to grow faster.

Figure 2.1
Interrelationships among key drivers of change in food systems, and their connection to human well-being



Source: Authors.

Taking these factors into account, as illustrated in Figure 2.1, a variety of entry points for policy or technological intervention present themselves. These offer a menu of options for policy-makers to consider when deciding how best to cope with the current stresses on food or energy systems, or how to mitigate the severity of such stresses in the future. The following subsections discuss some of these components and drivers of the food system in more detail, putting them into the context of food and energy supply and demand systems.

Socio-economic factors

Both demographic growth and socio-economic change – in the form of overall income growth, rates of urbanization or changes in the incidence of poverty in the population over time – are key factors that determine observed patterns of food consumption and nutrition outcomes. Since the oil crisis in the 1970s, there has been notable socio-economic progress and growth in various regions of the world, in terms of human welfare. Despite population growth, the number of malnourished people in developing countries has declined over time – albeit at various rates. According to *The State of Food Insecurity in the World 2006* report (FAO, 2006a), a decrease of 37 million from 1970 to 1980 was followed by a decrease of almost 100 million between 1980 and 1990, but then by a decrease of only 3 million in the period 1990 to 1992, which was set as the baseline for the 1996 World Food Summit. Food has become more affordable, as it is now less than half as expensive in real terms as it was in 1960. This decline in the cost of food can be attributed to a large increase in food production – even in per capita terms, the world now produces 40 percent more food than it did 40 years ago (MEA, 2005). Nonetheless, these positive trends might be reversed in the future, if the major tipping points of climate change and accompanying degradation of land and water resources intensify.

The main socio-economic factors that drive increasing food demand are population increases, rising incomes and increasing urbanization. Global population is set to increase from approximately 6 billion in 1995 to 8 billion in 2025, with more than 98 percent of this increase occurring in developing countries, according to the United Nation's (UN) medium-variant projections (UN, 2004). In addition, 84 percent of the population increase from 1995 to 2025 in developing countries is expected to occur in urban areas. Incomes, measured by gross domestic product (GDP) per capita, are expected to grow strongly in recently industrialized nations, and most rapidly in East Asia and the Pacific, according to the projections of growth used by a number of key policy centres (World Bank, 2007a; UNEP, 2007). Based on the rates used in IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) projections in its most recent world food situation report (von Braun, 2008), per capita GDP in China is expected to increase by 5.2 percent per year from 1995 to 2025, while those in the Republic of Korea, Thailand and India grow at approximately 4.5 percent per year. In general, growth rates in Asia will be the highest, ranging from 2.1 to 5.2 percent per year, while Eastern European incomes will rise by 4.1 percent per year. On the other hand, rapid population growth in sub-Saharan Africa is projected to depress per capita growth rates to approximately 0.8 to 1.7 percent per year.

The combination of rising income and increasing urbanization is also changing the nature of diets. Rapidly rising incomes in the developing world have led to increased demand for livestock products. In addition, it has been shown that urbanized populations consume fewer basic staples and more processed foods and livestock products (Rosegrant *et al.*, 2001). Diets with a higher meat content put additional pressure on land resources for pasture and coarse grain markets for feed, including maize. As a result of these trends, it is predicted that by 2020 more than 60 percent of meat and milk consumption will occur in the developing world, and the production of beef, meat, poultry, pork and milk will at least double from their 1993 levels (Delgado *et al.*, 1999).

Increasing urbanization compounds the pressure on adjacent areas to meet the demand of large, concentrated populations. While urbanized areas themselves do not require large portions of land, the terrestrial and water resources necessary to support their populations can overwhelm existing rural-urban linkages. Many developing countries with large land endowments find it easier to convert forest and other land cover to agricultural production than to disseminate yield-enhancing technologies, especially where extension services are limited or non-existent. It is estimated that an additional 120 million ha of cropland will need to be converted to agriculture to meet food demands in developing countries over the next 30 years, with seven countries in Latin America and sub-Saharan Africa providing most of the additional land potential (FAO, 2006b).

These agricultural land requirement projections assume that 70 percent of food needs will be met through yield enhancements (FAO, 2006b). However, agricultural research dedicated to productivity enhancement of staple crops has declined over the years. As the United States of America and other developed regions shift their research focus to reflect consumer preferences for processed, organic and humane products, the diffusion of more relevant yield-enhancing technology in developing countries has slowed (Alston and Pardey, 2006). Only one-third of global, public agricultural research in the 1990s was in developing countries, more than 50 percent of it in Brazil, China, India and South Africa (Alston and Pardey, 2006). Therefore, better technology diffusion and more public money dedicated to developing country research programmes are critical to meeting growing food needs.

Environmental drivers

Population and income growth increase the pressure on natural resources to meet domestic, agricultural and industrial demand. Many large water basins, including the Yellow River and the Ganges, are expected to pump relatively less water for irrigation over the next 20 years, owing to unfavourable competition from other

sectors. As a result, compared with 1995 levels, irrigated cereal yields in water-scarce basins are expected to decline by 11 to 22 percent by 2025 (Rosegrant, Cai and Cline, 2005).

Climate change and increasing demand for water resources will have an impact on growing conditions, significantly affecting food production in the future. Integrated assessment models have shown that climate change effects on temperature and rainfall will have positive yield effects in cooler climates, while decreasing cereal yields in low-latitude regions, where most developing countries are located (Easterling *et al.*, 2007). Specifically, owing to global warming, developing countries face declines of 9 to 21 percent in overall agricultural productivity, while the effects on industrialized countries will range from a 6 percent decline to an 8 percent increase, depending on the offsetting effects that additional atmospheric carbon could have on rates of photosynthesis (Cline, 2007). As a result of these differentials in predicted production capabilities, some regions will benefit from increased yields, while others will be forced to import increasing amounts of food to meet demand. Fischer *et al.* (2005) estimate that cereal imports will increase in developing countries by 10 to 40 percent by 2080. Although this prediction covers a large variation, the combined effects of rapid population growth, lower yields and increasing reliance on trade policy for food imports could leave an additional 5 to 170 million people malnourished in 2080 – depending on the projection scenario – with up to 75 percent of them in Africa (Schmidhuber and Tubiello, 2007). Parry, Rosenzweig and Livermore (2005) have shown that the regional variation in the numbers of food-insecure people is better explained by population changes than by climate impacts on food availability. A recent report released by IFPRI (Nelson *et al.*, 2010) looks at a wide range of scenarios illustrating the complex interplay between climate and socio-economic outcomes that leads to future outcomes for food and agriculture to 2050, and the critical role that productivity growth plays in offsetting the negative impacts. As a result, economic and other development policy, especially that pertaining to agricultural research and technology, will be critical in influencing future human well-being.

Policy-based drivers

In addition to the socio-economic and environmental processes described in the previous subsections, other factors can help create the kind of tight market environment that was observed in 2006 to 2008. These include the decline in cereal stocks, and unilateral trade actions by individual countries (such as India), as they both restrict supply in the market. For example, world wheat stocks-to-use ratios have declined from more than 40 percent in 1970 to 20 percent today – below the

oil crisis level. Maize stocks-to-use ratios have declined from their 45 percent peak in the 1980s to about 12 percent, a level also previously seen only during the world oil crisis (Abbot, Hurt and Tyner, 2008). There have also been increasing levels of private capital invested in grain (and other commodity) markets, in search of portfolio diversification and in response to the recent poor performance of the stock market. In addition, unfavourable macroeconomic developments (such as the United States dollar devaluation) can further complicate the situation for some consumers. The thorough overview of these issues given by Headey and Fan (2010) illustrates the importance of various country-level policy decisions (over grain reserve and trade policies, for example) in creating the conditions that led to the spike in food prices, and their implications for institutional design. In this assessment, production shocks and productivity trends played less of a role in explaining the surge in food prices seen in 2006 to 2008 than other important policy drivers did. Looking to 2050 and beyond, however, the role of yield growth and productivity improvements in enabling production to meet future demands while “saving land” in the process becomes more critical.

A closer look at productivity growth finds that yield growth rates for major grains have been declining in recent decades (World Bank, 2007b) and have dropped by roughly 50 percent since their highs during the 1960s and late 1970s. One of the causes of this decline is no doubt a fall in the growth of public agricultural research and development (R&D) spending, in both the developing and the developed world (World Bank, 2007b). At the global level, R&D spending growth has declined by 51 percent in real terms in the two decades since the 1980s, with the decline occurring mainly in the developed world while the developing world has taken a larger share of the world’s agricultural research spending than the developed world since the 1990s (Alston and Pardey, 2006). This is especially troubling as both FAO and IFPRI project that future production growth will depend more heavily on yield improvements than area expansion, as has been found in past assessments of global agricultural futures, such as the Millennium Ecosystem Assessment (MEA, 2005). In fact, some regions, such as East Asia, Europe and North America, will need to increase production as the agricultural area shrinks.

Characterizing the drivers of change

Given the rather complex interplay of factors described in this chapter and the wider literature, it is useful to try and separate the slower-acting, long-term drivers of change from the faster-moving ones that might have more of an impact in the short term. Population and income growth both tend to act relatively slowly and steadily over time, evolving in a rather predictable fashion – given the nature of

the drivers that underlie demographic and economic growth, and past experience. There are also long-term shifts in climatic conditions at play, which also tend to unfold more gradually over time than do the shorter-term manifestations of climatic variability such as weather events that occur within the cyclical progression of seasons. Another slow-moving change is the gradual slowing of crop yield growth relative to the rate of food demand growth, which is driven by socio-economic changes.

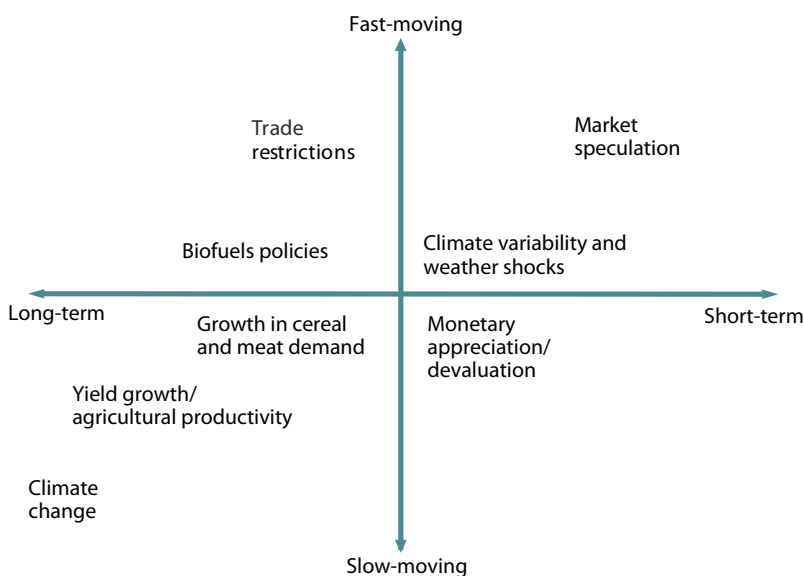
In contrast to these slow-moving drivers of change are the faster-moving ones, which can take the form of sudden climatic and environmental shocks that cause seasonal losses of harvest. Although food demand tends not to surge upwards over short periods, there have been relatively rapid increases in the demand for energy, especially for transportation, which manifest themselves in the increasing demand for fossil-based fuels and renewable substitutes such as biofuels. The demand for biofuels, such as ethanol and biodiesel, tends to be strong when fossil-based fuel prices are high and national fuel policies push for increased levels of blending to reduce the cost of fuel imports. This has been the case in a number of countries around that world, and is a major determinant in the rapid expansion of biofuel production observed over the past six years.

It is worthwhile to consider the characteristics of these various drivers of change, to develop a better understanding of their relative importance in explaining the tightening of market conditions observed in global food markets in recent times. Despite some of the fairly comprehensive overviews and discussions of high food prices – in terms of their causes and consequences – relatively little effort has been made to distinguish their dynamic characteristics of change, to identify their relative importance in explaining short-term versus long-term phenomena. Such a distinction is helpful, not only in allowing identification of the most urgent issues to be addressed from a policy point of view, but also in identifying which issues are more temporary in nature and which might persist into the future, preventing market and food system characteristics from returning to a stable equilibrium, or causing prices to rise even further later on.

While Figure 2.1 shows how the various drivers of change interact with each other and where the critical feedback loops might be, it does not identify the type of distinguishing characteristics that can explain short- and longer-lived effects on food systems. Figure 2.2 does more to make this distinction. It shows where some key drivers of change lie in relation to each other and in terms of their dynamic characteristics, which are a combination of the speed with which they act and the degree to which they explain short- or long-term phenomena. At the end of the spectrum containing the fast-acting drivers that help to explain short-term effects, market speculation stands out as a factor that might explain the “bubbles”

that can form in markets as a result of expectations about short- to medium-term trends, which can reverse themselves fairly rapidly on the basis of economic conditions and fast-changing market information. This type of activity has been cited as a factor in the spikes that developed in some markets and were contrary to the indicators provided by the supply and demand fundamentals that usually determine price formation (von Braun *et al.*, 2008). Other authors (Headey and Fan, 2010) are more cautious of attributing the influence of speculative activity to the rise in food prices up to 2008, given the lack of econometric evidence from the available data.

Figure 2.2
Characteristics of the drivers of change in food systems



Source: Authors.

At the other end of the spectrum, among the relatively slow-moving phenomena that play a part in determining the long-term evolution of food systems and the performance of the underlying ecosystems that support them, is climate change, which encapsulates the changes in long-term means of temperature, precipitation and even atmospheric carbon content that affect crop growth potential and the characteristics of key agro-ecological systems. Climate change as a phenomenon should be distinguished from the effects of climate variability and extreme weather incidents that are currently occurring in many

regions and that act over a far quicker time scale. These types of weather shocks drive the supply side of the food equation and lead to sudden drops in output that can push up market prices, whereas sudden surges from the demand side of the equation (such as those due to growth in crop-based biofuel production) might tighten market conditions and contribute to similar price increases.

Other drivers of supply and demand change that operate on a slower-moving trajectory are growth in demand for key consumer food products such as cereals and meat, which also have implications for feed demand, and trends for crop yield growth, which determine how well the supply side can adjust to increases in demand. Changes in demand for food and fibre products tend not to surge as rapidly as those for energy-intensive products, such as petroleum for transport, but represent a component of food system change that will continue to keep prices at an elevated level into the future, as cited by OECD in its projections of agricultural production and prices to 2017 (OECD/FAO, 2008), and in longer-term projections (IAASTD, 2009).

Entry points for policy

Given these various drivers, several possible entry points for policy intervention that might address the current global food situation can be considered. As shown in Figure 2.1, these entry points are on both the supply and the demand sides. On the demand side, policies that govern the use of food-based feedstocks for biofuel production could be altered, so that the overall quantities from food and feed sources are substituted by other non-food feedstocks or feedstock conversion technologies. Other policies that might affect direct food and feed use of grains would rely on the alteration of consumer preferences for food products (including meat), and are not as straightforward to address within the analytical framework discussed in this chapter. Therefore, attention should focus on the use of food crops in first-generation biofuel production.

From the supply side, a number of interventions can be considered. The first is boosting the output of cereals by raising yields over time, through policies that accelerate the improvement of crop technologies so that higher growth rates of yield are realized. This can be done directly through improved seed technologies, which might enhance the productivity and hardiness of plant varieties, or through the expansion of area under irrigated production, which typically has a higher yield than rainfed alternatives. Improved seed technologies can even reduce the loss in productivity that occurs when irrigated crops become water-logged or subject to increased salinity and submergence, thus allowing the expansion of irrigated area to raise overall production levels further. Through analytical work supported by IFPRI (Rosegrant *et al.*, 2009), the comprehensive Strategy

and Results Framework of the Consultative Group on International Agricultural Research (CGIAR) demonstrates that these kinds of intervention across the range of mandate commodities supported by CGIAR research could have profound and multiplicative effects on future food outcomes.

Another supply-side intervention would be improving the management of grain storage, so that there are sufficient quantities of grain on hand to provide an adequate buffer when shocks in either production or supply cause prices to spike. This has been discussed at length in the recent literature, without a great deal of analysis. Considerable attention is paid to this aspect of policy in the analytical framework presented in the following section.

Quantitative outlook to 2050

This section presents some forward-looking outlooks for food production and consumption that are based on IFPRI's IMPACT model (Rosegrant *et al.*, 2001; 2005; Rosegrant, Cai and Cline, 2002), and outlines the implications observed for long-term food security. These simulations will help identify the impact of policy-based and socio-economic drivers on the evolution of agricultural prices, and the role that technological interventions and investments can play. They will also help to illustrate the types of entry point that are possible for helping to stabilize food prices and improve human well-being outcomes in the face of the various drivers of change discussed so far.

The model

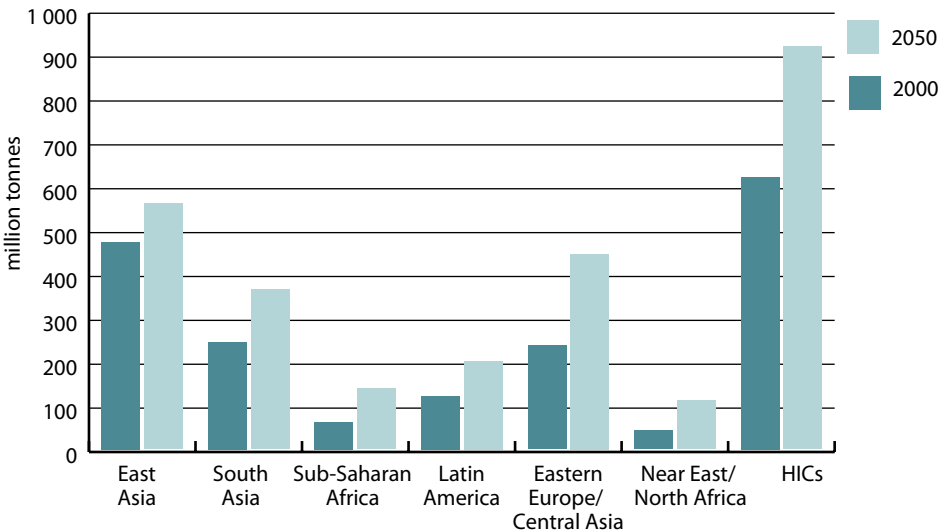
To examine the potential impact of biofuel production growth on country-level and domestic agricultural markets, a partial equilibrium modelling framework is adopted to capture the interactions between agricultural commodity supply and demand, and trade, at the global level. The model used is IMPACT, which was developed by IFPRI for projecting global food supply, food demand and food security to 2020 and beyond (Rosegrant *et al.*, 2001). IMPACT is a partial equilibrium agricultural model for crop and livestock commodities, including cereals, soybeans, roots and tubers, meats, milk, eggs, oilseeds, oilcakes/meals, sugar/sweeteners, and fruits and vegetables. It is specified as a set of 115 country and regional sub-models, within each of which supply, demand and prices for agricultural commodities are determined. The model links the various countries and regions through international trade, using a series of linear and non-linear equations to approximate the underlying production and demand functions. World agricultural commodity prices are determined annually at levels that clear international markets. Growth in crop production in each country is determined by crop and input prices, the rate of productivity growth, investment in irrigation,

and water availability. Demand is a function of prices, income, and population growth. IMPACT contains four categories of commodity demand: food, feed, biofuel feedstocks, and other uses.

Baseline model projections

Production growth: The profile of cereal production over time is presented in Figure 2.3, which shows steady trends of output growth to 2050. Cereal production is projected to grow steadily across all seven regions, with North America and Europe leading in production volume. When looked at on a per capita basis, however, the trends present a somewhat more static picture in terms of how the various regions are projected to maintain production levels relative to their populations (Figure 2.4). North American, European and Central Asian regions make significant increases in production relative to their own population growth, and are able to provide the surpluses needed to supply the food and feed needs of the rest of the world. The Near East and North African region is able to increase its per capita production levels over the production period, as is Latin America and the Caribbean. In contrast, the South and East Asian regions decrease their per capita production over time, as does sub-Saharan Africa.

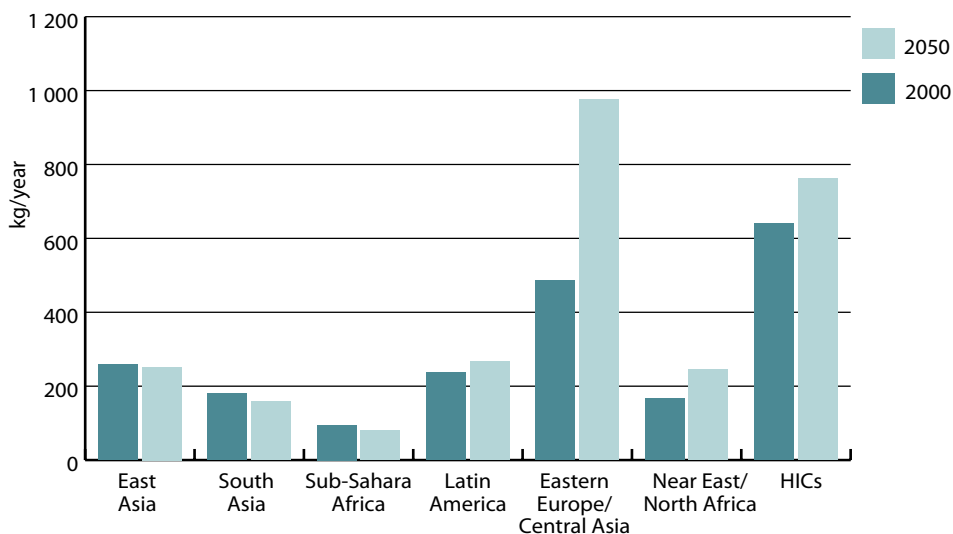
Figure 2.3
Total cereal production to 2050



HIC = high-income country.

Source: Projections from von Braun, 2008.

Figure 2.4
Per capita cereal production to 2050



Source: Projections from von Braun, 2008.

Table 2.1
Total feed and food demand for cereals

Region	Total demand			Food demand			Feed demand		
	2000 (million tonnes)	2050 (million tonnes)	Change (%)	2000 (million tonnes)	2050 (million tonnes)	Change (%)	2000 (million tonnes)	2050 (million tonnes)	Change (%)
East Asia and Pacific	493	662	34	335	366	9	101	204	102
South Asia	244	421	73	217	359	66	3	12	266
Sub-Saharan Africa	83	239	189	64	185	188	7	18	156
Latin America and Caribbean	132	237	79	63	88	40	49	110	126
Eastern Europe and Central Asia	233	264	13	79	80	1	108	123	14
Near East and North Africa	88	178	102	56	102	83	23	58	147
High-income countries ^a	545	737	35	112	146	30	322	398	24

^a United States of America, Canada, EU15, Switzerland, Norway, Cyprus, Israel, Japan, Republic of Korea, Singapore, Australia, New Zealand, Persian Gulf Region.

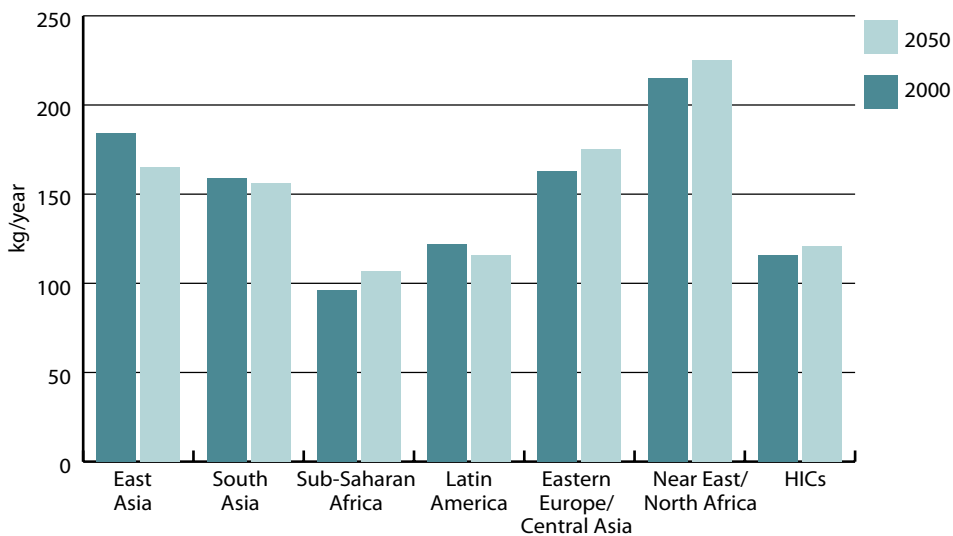
Source: Projections from von Braun, 2008.

Demand growth: Over the 50-year period, total food demand for cereals is projected to increase in all regions, with North America, Europe and East Asia leading all other regions in total volume. Table 2.1 shows how the total demand for cereals is divided into its largest two components: food and feed uses. Regarding food use, the region that shows the strongest demand growth for cereals is sub-Saharan Africa, although other regions such as South Asia, East Asia and the Pacific, and Latin America exceed it in terms of food consumption volume. The Near East and North Africa has similar food demand growth for cereals to South Asia, and the regions with the lowest levels of growth are Eastern Europe and Central Asia, and East Asia and the Pacific. Regarding feed uses of cereals, the North American and European regions lead the world in total volume of feed consumption, followed by East Asia, Latin America and the Caribbean, and the Near East and North Africa.

The patterns of food demand in per capita terms provide a more comparable basis for examining the changes in consumption patterns across regions (Figure 2.5). Regarding the demand for cereals, East and South Asia fall in per capita cereal consumption, while most of the rest of the world rises. In terms of the demand for meat (Figure 2.6), which is the main driver of feed demand for cereals, East Asia far outstrips other regions, in keeping with its rapid growth in per capita income compared with other developing and developed regions. Other regions that show large increases in per capita consumption of meat are North America and Europe; these have far higher levels of consumption compared with South Asia and sub-Saharan Africa, which grow steadily from relatively low levels owing to their steady income growth over the period.

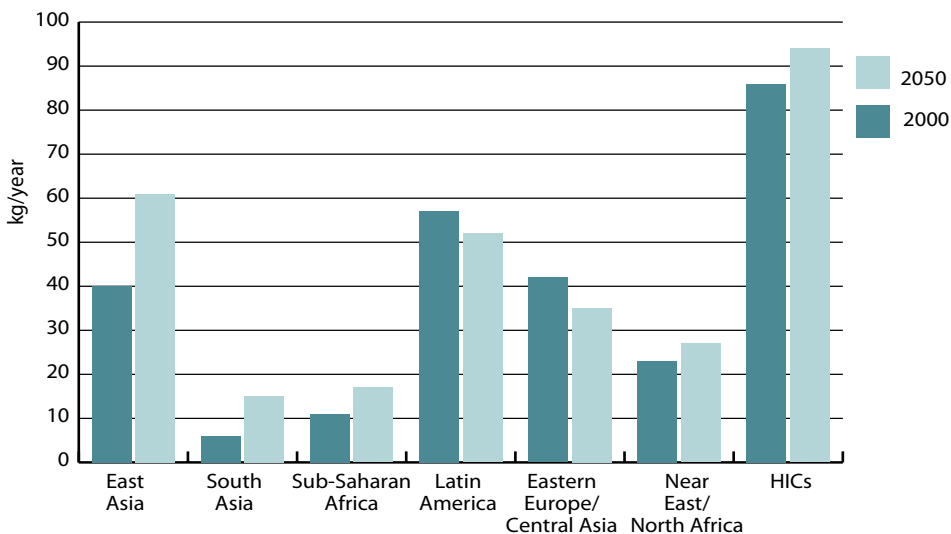
Long-term trends in malnutrition: Given the patterns of supply and demand that have been highlighted, the IMPACT model infers a trend in levels of malnourished among the most vulnerable demographic of the population – those aged zero to five years. The determinants of malnutrition are derived primarily from four key indicators: per capita calorie availability; access to clean drinking-water; rates of secondary schooling among females; and the ratio of female-to-male life expectancy. The links between malnutrition and these determinants were established by Smith and Haddad (2000), who used the determinants as explanatory variables to account for changes in levels of child malnutrition across the developing world between 1975 and 1995. According to their work, a greater share of the reduction in child malnutrition levels over this period can be attributed to improvements in female schooling and access to clean water than to calorie availability alone. This finding is in line with the four-pillar concept of food security that underlies FAO's conceptual framework, in which availability is only one of the factors that accounts for food security status among vulnerable populations and must be evaluated along with access, utilization and stability.

Figure 2.5
Per capita cereal food demand to 2050



Source: Projections from von Braun, 2008.

Figure 2.6
Per capita meat demand to 2050



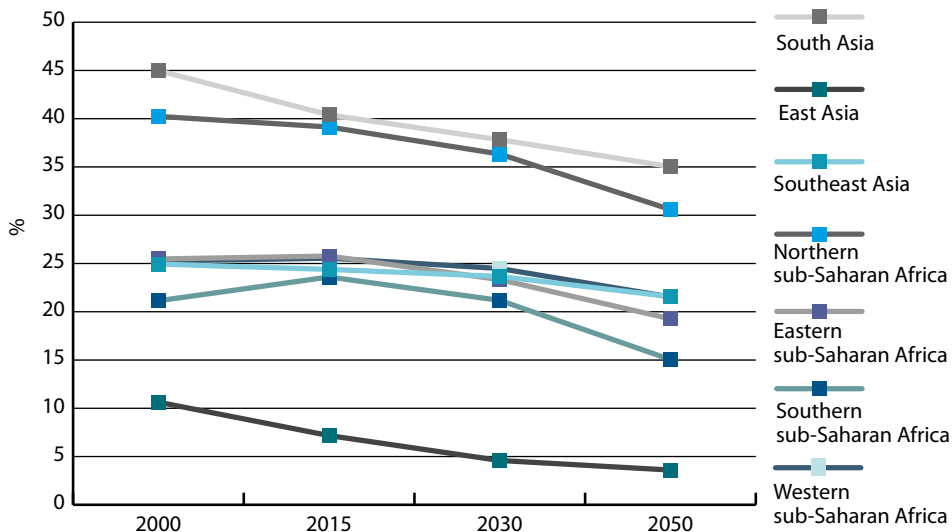
Source: Projections from von Braun, 2008.

The methodology used for tracking child malnutrition in IMPACT therefore covers aspects of availability, access and utilization, where the concept of access is grounded in the price response of consumption to market conditions, and utilization is influenced by access to clean water, which is a major determinant of human health and the body's ability to absorb and utilize available and accessible nutrients. This methodology is implemented through an analytical relationship that computes changes in the prevalence of malnutrition in the population aged zero to five years as a function of per capita calorie availability (generated endogenously by the model), as well as exogenous projections of schooling rates among females of secondary school age, the share of population with access to clean water, and the ratio of female to male life expectancies. The influence of each of the four explanatory factors on under-five malnutrition is determined by the statistical coefficients derived by Haddad and Smith's work (2000).

The baseline trends for malnutrition are illustrated in Figures 2.7 and 2.8, which show variation in the rates of change in malnutrition. The decline in malnutrition prevalence is steeper in Asia than sub-Saharan Africa in the period up to 2025, after which a number of African subregions also show steady declines (Figure 2.7). The South Asia region has the highest overall levels of prevalence, but is able to make significant reductions by 2050, compared with Southeast Asia and western sub-Saharan Africa, which are able to decrease the overall levels of prevalence only slightly. East Asia, which begins with the lowest levels, is able to draw these levels even further down in the longer term, to achieve single-digit prevalence rates, which no other region can match. The complete picture of child malnutrition emerges when total numbers of malnourished are examined. Figure 2.8 shows the Asian region as a whole to be the most aggressive in reducing its overall levels of malnutrition, which remain the highest in the world, even in 2050 and even compared with sub-Saharan Africa, which sees an overall increase in numbers before the acceleration of increases in production and per capita income levels allows it to reduce its numbers. In total numbers, however, the count of malnourished children in sub-Saharan Africa remains nearly the same in 2050 as in 2000, although this figure represents a smaller share of the overall population in 2050. This picture helps to illustrate the challenge that remains in combating hunger and improving human well-being outcomes in the developing world in the long term, given the impending pressures that environmental and policy-driven shocks will have on the world food system.

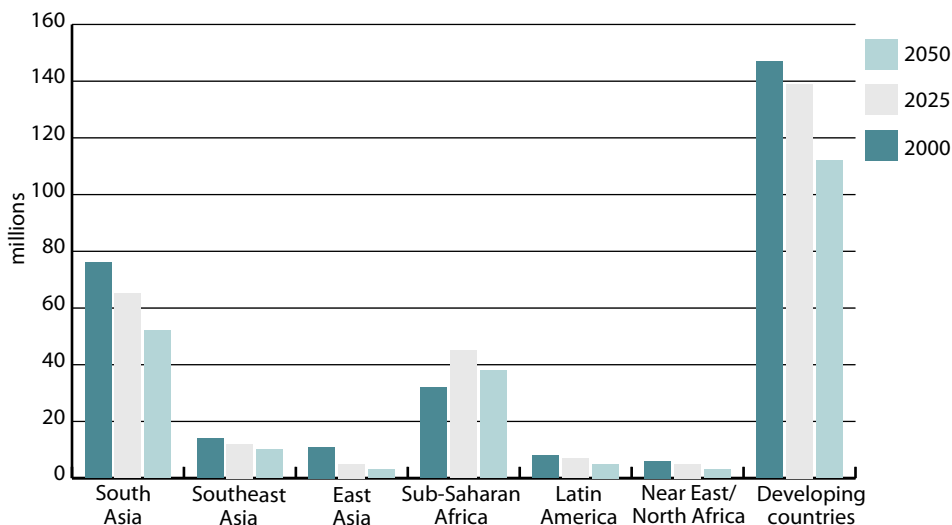
The following sections provide greater details about the nature of these challenges and their implications for future food security.

Figure 2.7
Prevalence of preschool child malnutrition in Asia and Africa (children aged 0 to 5 years)



Source: Projections from von Braun, 2008.

Figure 2.8
Total numbers of malnourished preschool children in the developing world (children aged 0 to 5 years)



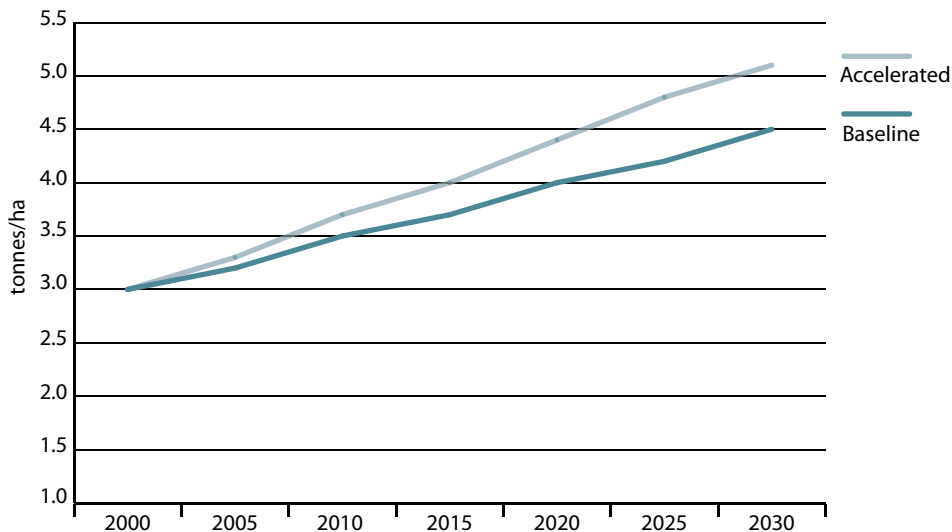
Source: Projections from von Braun, 2008.

The role of biofuels

Given the complex nature of the various drivers of change, and the way in which they interact within global agricultural and non-agricultural markets, it is not easy to isolate the effect of biofuels from that of other important factors. Nonetheless, using IMPACT, Rosegrant *et al.* (2008) set up a simple counterfactual experiment designed to show the contrasting impact on cereal prices that the observed historical trends of biofuels growth would exert if the global growth in biofuel production levels were reduced for the period 2000 to 2007, when most of this rapid growth was realized. The objective of this experiment was to see how much global cereal prices would have deviated from their observed baseline levels if biofuel production levels between 2000 and 2007 had remained on the same trajectory as in 1990 to 2000. The simulation results show a growth rate in average grain prices that is 30 percent lower than the actual rate of increase in world prices for 2000 to 2007. Other authors have carried out similar experiments to measure the effect of biofuels on market prices, although the choice of methodology (and scenario design) has a considerable impact on the measured impacts. As Headey and Fan (2010) point out, a study of the effects of United States maize policies on market prices (based on the Food and Agricultural Policy Research Institute [FAPRI] model) show that the combined effects of biofuel subsidies and tax credits amount to a level of support of 20 percent for maize prices in the United States of America, while the support to soybeans is an even more significant 73 percent (Meyers and Meyer, 2008). The analysis of McPhail and Babcock (2008) (using the international agricultural markets model from the Centre for Agriculture and Rural Development [CARD]) shows that the combined effect of subsidies provide a level of support to maize prices of 16 percent, although this study (and that using the FAPRI model) does not fully outline the effect of the tariff imposed on Brazilian ethanol, which other studies of trade liberalization's effect on biofuel impacts have shown to have had a significant influence on outcomes (Al-Riffai, Dimaranan and Laborde, 2010).

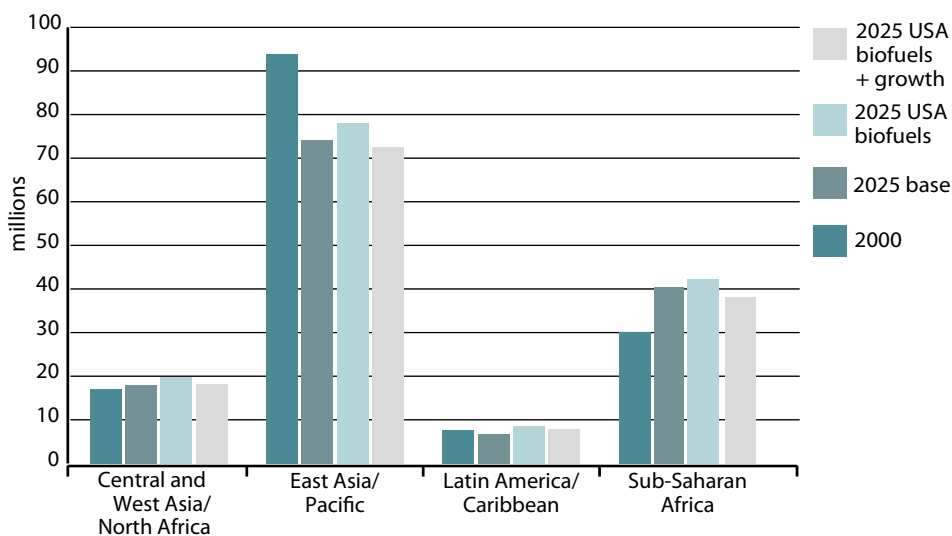
The implications of renewable fuel targets: Specific policies, such as the renewable fuel targets set by various countries for meeting blending and replacement rates of fossil fuels over a given time horizon, can also be examined. For example, the United States of America sets a target for first-generation biofuel production of 15 billion gallons by 2022, under the Energy Independence and Security Act. The additional production of maize feedstock needed to meet this target requires a higher level of yield growth, shown in Figure 2.9, to offset the impacts that it would otherwise have on food security; the average growth in cereal yields would have to increase from 1.3 to 1.8 percent a year (for the period 2000 to 2030) to counteract the implied trends in malnutrition. This translates into

Figure 2.9
Additional global cereal yield growth needed to offset impact of United States biofuels target



Source: Projections from von Braun, 2008.

Figure 2.10
Trends in child malnutrition to 2025 under the baseline case



Source: Projections from von Braun, 2008.

an additional 1 percent of yield growth in the developing world and 0.5 percent in the developed world for 2000 to 2030 – presuming that higher yield gains can be made in less developed countries, where there might still be significant opportunities for closing yield gaps that could be exploited. The impact of this offsetting yield increase is shown in Figure 2.10, which shows the increases in malnutrition in 2025 resulting from the United States policy being offset by the additional cereal yield growth.

These scenarios illustrate the biofuels impact on global food prices fairly clearly, and lead to immediate implications for food security and human well-being. To illustrate how specific technological innovations can ameliorate the situation and reduce the pressure that crop-based biofuel production growth places on global food systems, further simulation-based experiments can be carried out, as described in the next subsection.

Yield-enhancing technologies and policies

An important policy intervention for alleviating the trade-offs that arise from the competing demands for land area to produce food, feed, fibre and fuel needs is technology, especially productivity-boosting technologies. Enhancing the yields of food, feed or fibre products per unit area of land has the effect of not only increasing the overall availability of these products (and lowering their market prices as a result), but also increasing the availability of land for non-agricultural uses, such as forestry, wildlife habitat or the provision of fuel from plantation-style biofuel systems. Increasing the yields of biofuel production systems, through improvements in the productivity and energy yield of the underlying conversion technologies, could also have a land-saving effect, increasing the area available for growing food and feed products, or for non-agricultural uses.

Some of these effects have been noted in recent global assessments of future trade-offs between food, feed and energy needs and the health of the environment and ecosystems. In MEA (2005), the scenario with the highest levels of technology adoption and high income growth (the “global orchestration” scenario) also had the highest levels of biofuel production. This arose from greater investments in increasing agricultural productivity, which reduced the competition for food-producing land, thereby making more land available for biofuel plantations and resulting in lower prices for both food and biofuel products. Conversely, the scenario with the lowest levels of income growth and technology adoption (the “Order from strength” scenario) also had the greatest competition for land under food production – owing to lower agricultural productivity and investments – and lower biofuels production, resulting in higher food and energy prices. The assessment scenario results also showed forest land decreasing because of higher

levels of biofuel production, and more extensive agricultural land-use patterns also resulting in a similar encroachment on forest land. Both of these results underscore the persistent trade-offs between maintaining ecosystem health and meeting the demands for food, feed and fuel that exist in all of the scenarios considered. Although there are differences in the ways in which various drivers of change evolve under these scenarios – through increased demand for food, feed, fibre or fuel – they all involve competition for land uses and some encroachment on land that would otherwise remain unmanaged.

The fourth Global Environmental Outlook (GEO4) of the United Nations Environment Programme (UNEP) was similar to the MEA global assessment, and showed that increased emphasis on meeting targets for greenhouse gas reductions (under the “sustainability first” or “policy first” scenarios) could lead to increased biofuel production and decreases in area under forest (UNEP, 2007). In parallel with the global orchestration case in MEA, these GEO scenarios also embodied higher rates of income growth and technology adoption, thereby making agricultural growth more intensive and less extensive in nature, and allowing more land for non-agricultural uses (including biofuel production). In a similar way, both food and energy prices tended to be lower under these high-growth scenarios, owing to the higher production of food and energy products. At the same time, the area of land vulnerable to erosion risk also increases as a result of biofuel production, particularly under the policy first scenario, which pays less attention to soil conservation and improved land management than the sustainability first scenario does.

Other, more biofuel-specific scenarios examine the impact of biofuel production growth on food prices, through demand-side effects and the land-saving impact of increased technology growth, which affects the supply side of the agricultural market equation. As in the IMPACT-based simulations (Rosegrant *et al.*, 2001), the “business-as-usual” or “reference” scenario describes slowly declining rates of growth in agricultural research (and extension), following the same trends as observed in the past. As an alternative to the reference scenario, a case in which levels of agricultural knowledge, science and technology (AKST) are enhanced can be used. In this “high AKST”² variant, levels of investments in agriculture for the period 2005 to 2050 are elevated. These accelerated investments in agricultural technologies lead to increased growth in crop yields and livestock numbers. A further variant of this considers the implications of even more aggressive growth in agricultural R&D together with advances in other complementary sectors that

2. AKST refers to the broad conceptualization of agricultural technology and capital used in the recent International Assessment of Agricultural Science and Technology for Development (IAASTD) global assessment. Various scenarios embodying differing levels of AKST were quantified, using a number of models including IMPACT. The high AKST case described in this chapter was one of these scenarios.

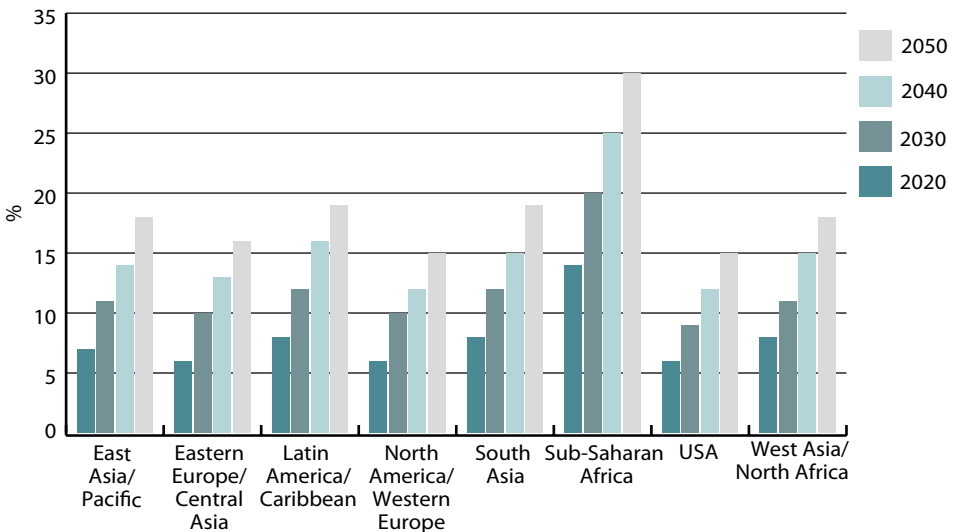
provide key infrastructure and social services. Such sectors include investments in irrigation infrastructure (represented by accelerated growth in irrigated area and efficiency of irrigation water use, and accelerated or reduced growth in access to drinking-water) and changes in investments in secondary education for females, which is an important indicator for human well-being.

Implications for malnutrition

In the scenarios described in the previous subsection, the increase in crop prices resulting from expanded biofuel production is accompanied by a net decrease in availability of and access to food. Under the two biofuel scenarios, calorie consumption is estimated to decrease across regions, compared with baseline levels.

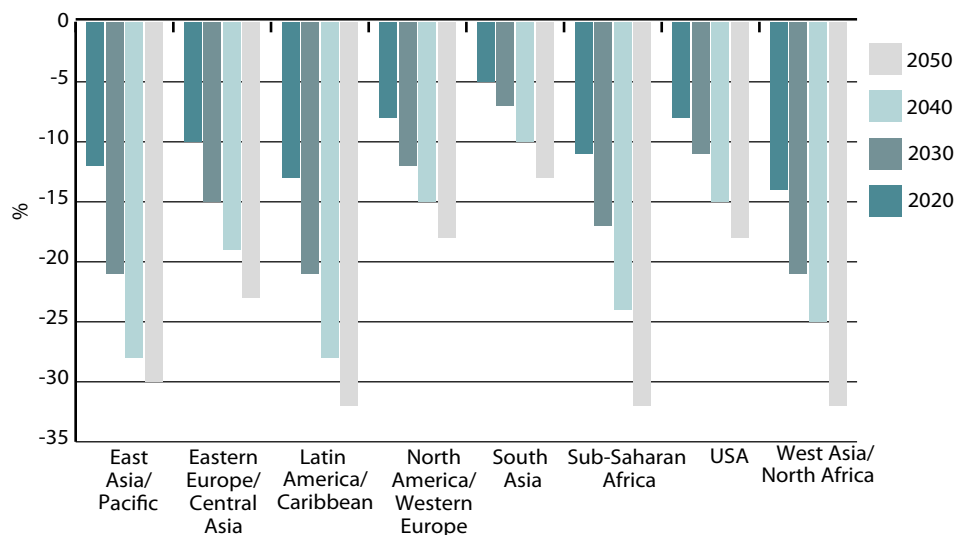
In the high AKST scenario, food security status and human well-being levels increase significantly owing to reductions in the prices of important tropical staple crops such as cassava and maize. Figure 2.11 shows how calorie availability is greatly enhanced over time by the acceleration in yield and production growth realized under high AKST levels. The effect is particularly strong in sub-Saharan Africa, where improvements in maize and cassava yields have a large impact on calorie availability, given the compositions of diets in the region and the fact that maize and cassava are important starch foods.

Figure 2.11
Increases in calorie availability under high AKST scenario compared with biofuel expansion under baseline technology levels



Source: Projections from von Braun, 2008.

Figure 2.12
Decreases in numbers of malnourished children under high AKST scenario compared with biofuel expansion under baseline technology levels



Source: Projections from von Braun, 2008.

Under high AKST, there is a significant reduction of malnourishment in small children over time, as a result of increased calorie availability in various regions (Figure 2.11) and other improvements in socio-economic conditions embedded in the high AKST scenario assumptions. Figure 2.12 shows that the level of malnourishment among small children drops strongly over time, in sub-Saharan Africa, North Africa and Latin America. The poorer regions of West Asia and North Africa benefit from enhanced access to water, better female schooling rates and lower food prices as much as the tropical regions do, owing to the poor state of social services in some of these regions. The rates of change are much faster in these regions, even compared with East Asia and the Pacific or South Asia, and the benefits appear to progress more strongly than even the improvement in calorie availability. This illustrates the importance of socio-economic factors other than food availability alone in determining malnutrition rates, and how the pillars of food security – availability, access, utilization and stability – interact to produce an effect that may be greater than the sum of the individual components. Although not all of the components of food security can be captured within the modelling framework described here, availability and access (which are closely connected to food prices) are well captured. Some elements of utilization are captured through the relationship between access to clean water and level of

malnutrition, according to the empirical work of Smith and Haddad (2000), who found that 43 percent of the decrease in child malnutrition between 1975 and 1995 was due to female schooling, which was the leading determinant, followed by calorie availability (accounting for 26 percent).

The challenge of climate change

In addition to the scenarios presented in the previous subsection, which are driven by energy policy, the accounting of future food balances must also be reconciled with the added challenges that climate change will bring to the global food system. It must be said that the ultimate impacts of climate change – in terms of both magnitude and regional specificity – remain somewhat uncertain, and there is a wide spectrum of modelling results showing different degrees of impact for the same regions of the world. A great part of the uncertainty regarding results from different global circulation models results from the fact that each model presents different interactions among the atmosphere, the ocean and terrestrial systems, and the divergences in model results increase with time. The Intergovernmental Panel on Climate Change (IPCC) tried to portray the wide variance in model results in its third and fourth assessment reports, while many authors choose to take the more extreme of the examples to illustrate the types of impact that are plausible from climate change. Deviations in reported climate change impacts also result from different ways of translating the outputs of coupled (atmospheric-terrestrial) climate models into impacts on crop yield potential, and of translating these shifts in productivity into total production, consumption, price and trade effects in the various economic equilibrium models used.

At the heart of the challenge lies the reconciliation of biophysical modelling results, which are run at a relatively microlevel-scale of resolution, with the workings of an aggregate-level, market equilibrium-driven policy model such as IMPACT, which has to take the average of crop level effects across space. The marriage of these two elements – biophysical process-driven elements and economic equilibrium-driven mechanisms – is complex, and is the subject of continuing research among a number of research groups employing both partial and general equilibrium methods of economic market modelling. IFPRI's work has not fully attributed the possible effects that carbon fertilization could have on future crop yields, owing to the uncertainty that still exists in quantifying this result for various agronomic zones where on-the-ground reality could differ significantly from carbon fertilization experiments in the laboratory. Therefore, in this chapter's discussion of IFPRI results for climate change impacts, the reader should be aware that the methodology employed to account for climate change shocks within the modelling framework is still under revision.

Notwithstanding these difficulties, some results showing the overall magnitude of climate change impacts on global agricultural markets can be used to begin discussions of the implications for both national and household-level economic effects.³ For this, the results from the more extreme “A2” climate scenario are used. This is the socio-economic scenario with greater emphasis on fossil-based fuels and less cooperation and (clean) technology sharing across the globe. This type of outcome is similar to those of the less favourable MEA and GEO4 scenarios in terms of portraying a less harmonious, cooperative and purely growth-driven kind of geopolitical atmosphere. More recent work by IFPRI (Nelson *et al.*, 2010) shows results from a scenario with more convergent socio-economic characteristics and balanced energy consumption patterns, the “A1b” scenario, which is used in this chapter to show contrast in the outcomes.

Table 2.2
Simulated impacts on yield in 2050 from various climate change scenarios

Crop and region	Change from yields with climate as in 2000 (%)					
	CSIRO		NCAR		MIROC	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
<i>Maize</i>						
Developing regions	-2.0	+0.2	-2.8	-2.9	-5.3	-3.5
Developed regions	-1.2	+0.6	-8.7	-5.7	-12.3	-29.9
<i>Rice</i>						
Developing regions	-14.4	-1.3	-18.5	-1.4	-11.9	+0.1
Developed regions	-3.5	+17.3	-5.5	+10.3	-13.3	-12.8
<i>Wheat</i>						
Developing regions	-28.3	-1.4	-34.3	-1.1	-13.4	-10.4
Developed regions	-5.7	+3.1	-4.9	+2.4	-11.6	-9.0

Sources: CSIRO and NCAR results from Nelson *et al.*, 2009, based on the A2 Special Report on Emissions Scenarios (SRES) scenario; MIROC results from Nelson *et al.*, 2010, based on A1b SRES scenario-based climate outputs.

Using recent IFPRI studies based on a variety of climate models, Table 2.2 shows the simulated effects of climate outcomes on crop yields for three major cereal commodities of key importance for food and feed uses. The model results from the Australian modelling group in the Commonwealth Science and Industrial Organization (CSIRO) tend to give “drier” outcomes than the United States model based at the National Center for Atmospheric Research (NCAR). This contrast shows up in the results (reported in Nelson *et al.*, 2009) in Table 2.2, where the

3. This subsection reflects improvements in modelling made since the Expert Meeting by presenting a wider range of scenario results to illustrate the dependence on climate model outputs.

yield impacts on maize, rice and wheat are more negative (or less positive) for the NCAR-based simulations than for the CSIRO outcomes, across both irrigated and rainfed systems in developing and more developed regions. To illustrate additional contrast, Table 2.2 includes the yield outcomes from a more recent IFPRI study (Nelson *et al.*, 2010), which simulates grain yields based on outputs from the Model for Interdisciplinary Research on Climate (MIROC). This gives precipitation patterns that are higher, on average, than those from CSIRO, although they also include stronger decreases of precipitation in some important food-growing regions. The differences between the NCAR and the CSIRO results arise mainly from differences in modelling approaches, while the differences from the MIROC model result from differences in the underlying socio-economic assumptions on which the climate models were run. This helps to explain why the differences in outcomes between MIROC and the other two climate models are not as systematic as those observed when comparing the A2-based outcomes of NCAR and CSIRO.

Table 2.3
World prices of selected grains (USD per metric tonne)

	Baseline		NCAR-based scenario		CSIRO-based scenario	
	2000	2050 no climate change (million tonnes)	2050 with climate change (million tonnes)	Change (%)	2050 with climate change (million tonnes)	Change (%)
Cereal						
Maize	95	155	235	51.9	240	55.1
Rice	190	307	421	36.8	406	32.0
Wheat	113	158	334	111.3	307	94.2

Source: Nelson *et al.*, 2009.

Table 2.3 shows the projected impact of climate change on global prices for the same three cereal commodities, limited to the two models that share the same underlying climate scenario. The doubling (NCAR) or near doubling (CSIRO) of the global market price for wheat in 2050, due to climate change, implies strong effects for consumers of wheat products in many developed and developing regions, especially for the more urbanized populations of Asia and sub-Saharan Africa. The strong increases in maize prices (which exceed 50 percent in both models) imply significant impacts on the livestock industry, which relies on maize for feed, and for regions where large numbers of consumers utilize maize as food, such as sub-Saharan Africa. Although the simulated impacts on rice are less pronounced, they are still important for regions that rely on rice as a key food staple and have experienced civil unrest due to increases in the rice price, as has been witnessed recently. Despite the differences in the underlying

climate models, these results show that the impacts of climate change on food market outcomes to 2050 are non-trivial and significant. These increases do not necessarily represent sudden price spikes in 2050, but a gradual accumulation of price pressures building over time in response to the steady and constant tightening of supplies, as the area suitable for crop cultivation declines in various key cereal growing regions of the world. Nonetheless, the differences demonstrate that the pressure on global food supplies would be significantly increased if the environmental drivers embedded in these climate change scenarios were realized, and that responsive policy action and adaptation would have to occur to offset these effects. Such adaptive actions are not embedded in the results presented here, as agents' endogenous technology choices are not fully represented in the model. Adaptations and technology choices would have to be introduced into each scenario to account for the possibility of improved seed variety and other on-farm improvements, which are not endogenous within the framework. Such adaptation-focused scenarios will be included in further work.

Table 2.4
Total numbers of malnourished children, 2000 and 2050

<i>Region</i>	Baseline		NCAR-based scenario		CSIRO-based scenario	
	2000	2050 no climate change (millions)	2050 with climate change (millions)	Change (%)	2050 with climate change (millions)	Change (%)
South Asia	76	52	59	13	59	13
East Asia and Pacific	24	10	15	50	14	40
Eastern Europe and Central Asia	4	3	4	33	4	33
Latin America and Caribbean	8	5	6	20	6	20
Near East and North Africa	3	1	2	100	2	100
Sub-Saharan Africa	33	42	52	24	52	24
All developing countries	148	113	139	23	137	21

Source: Nelson *et al.*, 2009.

As already shown for the yield growth scenarios, the implications of these climate-driven scenarios for child malnutrition outcomes are presented in Table 2.4, which shows the impacts on malnourishment reported by Nelson *et al.* (2009) for the two A2 scenario-based climate outputs from NCAR and CSIRO models. The magnitudes of impacts on the headcount of malnourished children in 2050 are somewhat similar in both models, given that the price impacts of these scenarios were not vastly different. Although the percentage

change in malnutrition is largest in the Near East and North Africa region, the sheer numbers of malnourished children in South Asia and sub-Saharan Africa imply greater overall changes in the headcount of malnourished children in these regions. While South Asia is projected to decrease its number of malnourished children by 24 million under a no-climate-change case for 2050, sub-Saharan Africa is likely to undergo an increase of 9 million to 2050, which increases by a further 10 million with climate change. So climate change represents a reversal of trends for South Asia and a deepening of an existing negative trend for sub-Saharan Africa. However, as already described, IMPACT's method for calculating malnutrition changes resulting from climate outcomes uses only changes in calorie availability, which is only one component of the food security determinants used elsewhere. This demonstrates how important it is to keep the other important socio-economic components of household food security on track (education, and access to water, sanitation and health services), if developing regions are to avoid being seriously derailed by the additional stress that global climate change poses to food futures. The effects of climate on these other non-calorie-based outcomes are not modelled here, but are worth further scrutiny, as the provision of services by climate-strained economies could be a significant factor in determining future welfare outcomes for vulnerable populations.

Implications for food security

This section discusses the implications of the scenario results in the context of the current global food situation, particularly the implications for household-level welfare.

Price changes in food and energy markets influence households, directly through market prices, or indirectly via the costs of production or transportation of other marketed goods. Net sellers and net buyers are affected differently, and although net sellers gain from price increases, their gains may not be enough to offset the negative impacts that net buyers undergo. FAO data show that in some of the poorest countries, a relatively small share of households are net sellers of the staple foods that are experiencing the strongest price effects. For example, slightly less than 16 percent of all the households in Bangladesh are net sellers of staples, according to data for 2000, compared with slightly more than 40 percent in Viet Nam in 1998 (FAO, 2008). Developing countries such as Madagascar, where almost 51 percent of all households were net sellers in 1993, are unusual, compared with countries such as Guatemala and Malawi, with slightly more than 10 percent in 2000 and almost 12 percent in 2004, respectively.

A recent paper by Ivanic and Martin (2008) shows that the impacts of high food prices had a differential effect on poverty rates and incidence, depending on the net seller or net buyer position of households. This analysis found that a country

such as Viet Nam could (and probably did) experience a net reduction in poverty rates, because increased rice prices put rural households that were net sellers into a much better position than before. Peru too might experience poverty reductions, because increased maize prices would favour rural households that were net sellers. The benefits in Madagascar would arise from maize and dairy prices, and those in Pakistan from rice, dairy and wheat. The impacts therefore vary according to region and commodity, depending on the structure of the national economy concerned, particularly the agricultural economy. Most of the positive benefits that Ivanic and Martin document are in rural areas, while urban households tend to bear the negative impacts of higher prices, across the board. The Ivanic and Martin study also accounts for wage effects, which will be more pronounced (and positive) for rural households that sell their labour within the agriculture sector.

The means by which households adjust their production and consumption in response to economic shocks are shown in Figure 2.13, which illustrates the various dimensions that can be adjusted. Given that a number of expenses may be quasi-fixed, such as rent (especially for urban dwellers), more adjustment has to come from the food consumption side, often leading to poorer diets and lower levels of essential nutrient intake. Households with other assets can disinvest, to the extent possible, to smooth consumption in the short term. Often, however, these disinvestments are not reversed when economic conditions ease, resulting in reduced endowments and enhanced vulnerability to future shocks. The tendency to pull children, especially girls (Schultz, 2002), out of school in times of hardship leads to longer-term effects arising from decreased investments in human capital and reduced earning capacity and productivity in the future.

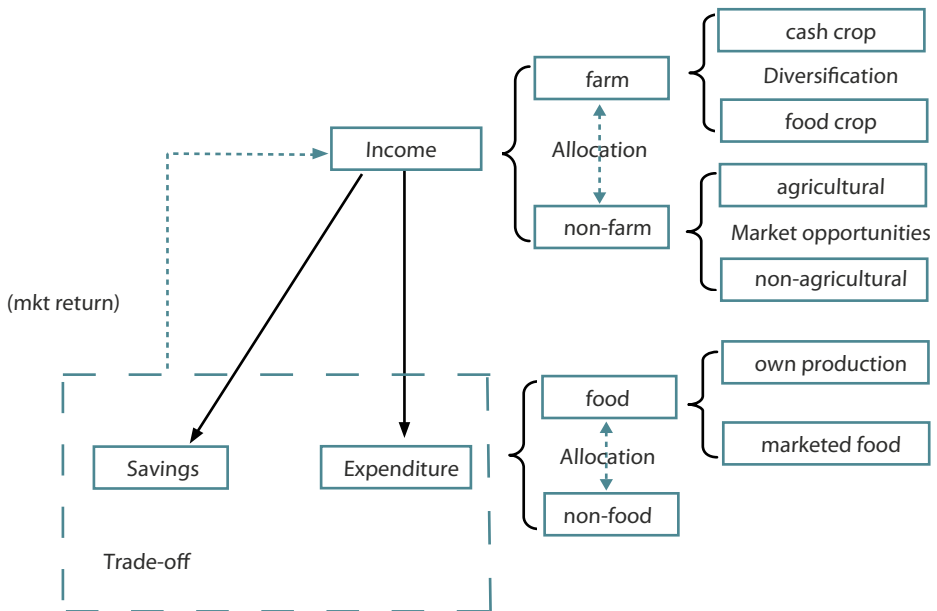
It might be argued that although biofuels cause increases in food prices, they could lower the costs of energy to households, thereby generating some benefits that would not otherwise occur. The specific outcome depends on the shares of household income going to food and energy purchases, which vary by income level. The available data on household-level expenditure patterns show that households on or below the poverty line tend to spend more than 50 percent of their incomes on food, and a far smaller share on energy (Ahmed, Hill and Wiesmann, 2007).

The evidence and experimental results presented in this chapter give rise to a number of policy recommendations for addressing the world food situation and its implications for current and future levels of human welfare. Some of these recommendations are of a technological nature, while others pertain more to policy-level interventions, at both the national and global levels.

Regarding specific technological interventions for addressing the declines in productivity of key staple crops that have been observed, a wide range of improved crop varieties can be adopted in regions that rely mostly on traditional

lower-yielding varieties. Some varietal improvement is necessary, just to maintain yields at their current levels in the face of increasingly adverse environmental conditions, such as those brought on by elevated temperature levels, decreased rainfall or increased incidence of crop pests and diseases (which often move over space as a result of changes in temperature and rainfall conditions). One agricultural technology that was instrumental in allowing the South Asian green revolution to take off was irrigation, which faces drastic underinvestment in some regions, such as sub-Saharan Africa. However, increases in irrigation would have to be accompanied by corresponding investments in installing adequate drainage facilities, to avoid problems of salinity. In regions with (increasing) levels of soil salinity, improved drainage might also have to be accompanied by the adoption of more salt-tolerant crop varieties, to maintain yields at the levels needed for future supply growth.

Figure 2.13
Elements of household income and expenditure that can be adjusted in times of hardship



Source: Authors.

Policy interventions related to the use of agricultural feedstocks for first-generation, conventional biofuel production include limiting or even avoiding the use of food crops to produce biofuels such as ethanol and biodiesel. A variety of policy instruments support biofuel production, including direct support to biofuel producers and blenders, the setting of national blending targets or mandates, and trade instruments, which might raise the barriers for biofuel imports from some regions (or encourage exports from others). Technology adoption will largely continue to be driven by private industry, but can be helped from the policy level by increased spending on R&D aimed at pushing forward the next generation of conversion technologies and feedstocks. While a number of trade-related policy instruments need to be addressed at the country level, there is also a need for policy (and political) coordination at the global level, to effect multilateral agreements leading towards the liberalization of international trade. Trade policy has a large influence on biofuel trade and prices, through feedstocks and, even more so, the trade of biofuels themselves. In practice, allowing freer trade in ethanol makes it easier to replace gasoline with renewable fuels whenever energy prices rise. In addition, poorly designed tariffs, tax credits, subsidies and mandates can lead to perverse effects, such as the possibility of actually increasing fossil fuel consumption, as noted by De Gorter and Just (2007).

Regarding social protection of the most vulnerable sections of the population, much can be accomplished through policy-driven strengthening of national social safety net programmes that provide relief for those who are most threatened by escalating food prices, while avoiding blanket policies such as price controls, which are easier (and cheaper) for governments to enact but which have the perverse effect of reducing producer responses that could soften the price rises through increased outputs. In this case, the main challenge facing policy is to keep a balance between maintaining producer incentives and avoiding the distortions that could dampen the necessary self-correcting responses, while supporting human welfare through protecting the most vulnerable. The directing of interventions to those most in need requires deliberate and careful policy design, and this is often lacking in indiscriminate food subsidy schemes, which although they might benefit a lot of the poor (especially when they are the main consumers of the targeted staples), may also benefit better-off households that have other degrees of adjustment (or assets) to exploit.

Conclusions

This chapter has explored several key drivers of change in food systems and examined some possible entry points for policy interventions, determining their effects on food prices and other market-driven outcomes. Among the drivers

of change discussed are policy-driven growth in biofuel production, which has played a role in the rapid increase in food prices, along with other factors such as global climate change. The chapter has demonstrated the offsetting impact that supply growth could have on the socio-economic impacts of biofuels, in terms of both price changes and changes in nutrition status. The chapter has also emphasized the need to be aware of all the components of food security – and not merely to focus on food production and output – to maintain progress towards reduced levels of malnutrition and improved human well-being.

Certain policy responses should be avoided when dealing with high prices. These include export bans (akin to a “starve-your-neighbour” policy), import subsidies, restoration of production subsidies, subsidies for the vocal middle class, policing and threatening traders, and attempting to curb food price inflation with macroeconomic policies. On the other hand, three broad policy areas represent desirable and effective tools in fighting the challenges and negative side-effects of high food prices: trade, agricultural growth, and protection of the vulnerable.

The pressures of high food prices can be alleviated by eliminating trade barriers and export bans, and making it easier for international institutions to raise the financing and mobilize the resources needed to effect emergency food imports for the neediest countries. Agricultural growth can be revitalized by expanding aid for rural infrastructure, services, agricultural research and technology. The vulnerable can be shielded from the worst effects of high food prices by expanding food and nutrition-related aid, including safety nets, child nutrition and employment programmes.

In summary, a two-track approach is needed in developing countries. It should include global and national food, health and nutrition security initiatives focusing on the vulnerable, and an agricultural productivity initiative focusing on small farmers.

Combining quantitative experiments with evidence from other studies, the chapter suggests a range of policy interventions that could be instrumental in offsetting the negative impacts of food prices and helping to promote benefits in situations where they exist, to encourage increased investments in the agriculture sector, and to reverse the steadily declining trend of R&D spending and decades of counterproductive agricultural trade and national-level sector policy.

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