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More Information

1

World Population Growth and Food Supply

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Rapid technological change since the end of World War II has combined with the inelastic demand for food to generate declining real agricultural prices. Consumers have been the ultimate beneficiaries of agricultural innovation, while farmers have had to continually grow in size and become more efficient to offset price declines. To shelter their farmers from these price declines, governments in high-income countries have adopted various support and protective trade policies, which often contributed further to low prices. This long-term decline in real prices has periodically been interrupted by price spikes that were mostly caused by crop failures due to poor weather.

From the beginning of 2006 to the end of 2008, the world witnessed the largest surge of commodity and food prices since the early 1970s, and it seems unlikely that prices will soon return to the lower levels of the early part of this decade. This price surge has again raised the age-old Malthusian question of whether food production can keep pace with growing demand. Historically, the main driver of production has been technological progress; the drivers of consumption have been population growth, which increases the number of mouths to feed, and income growth, which increases the quality and quantity of food consumption per capita. Changing diets that accompany both increased incomes and increased urbanization generally involve more meat consumption and hence more grain consumption per person. Aging of the population, which is happening faster in higher income countries, may have the opposite effect on diet and the quantity of grain consumed.

Two new and significant factors in the growth of grain and oilseed consumption since the early 2000s have been the increase in petroleum prices and the implementation in a number of countries of policies that have stimulated biofuel production in pursuit of environmental and farm support objectives (FAO 2008b; OECD 2008). These changes have increased both the profitability of investments in biofuel capacity and the use of existing capacity, resulting in more grains and oilseeds being used as feedstock for biofuel production. More fundamentally, the growth of the biofuel

Table 1.1. *Exponential growth rates in area, yield, and production of grains and oilseeds*

	1960–70	1970–80	1980–90	1990–2000	2000–7
Grains					
Yield	2.7	1.9	2.1	1.22	1.59
Area	0.5	0.9	−0.5	−0.32	0.44
Production	3.3	2.8	1.6	0.89	2.03
Consumption	3.3	2.6	1.7	0.94	1.70
Grains and Oilseeds					
Area	1.6	1.3	−0.03	0.18	0.79
Production	4.0	3.0	2.0	1.29	2.32
Consumption	4.1	2.9	2.0	1.31	2.05

Source: USDA FAS (2010).

industry has resulted in a much stronger link between fuel and food markets that can contribute both to the higher level and the higher volatility of food prices (Meyers and Meyer 2008).

Examination of grains and oilseeds world markets indicates that the rate of production growth has been slowing since the 1970s (Table 1.1), although the new millennium saw a rebound partly in response to higher commodity prices. A comparison of growth rates in yield over each decade from 1960–2007 indicates a slowdown in yield growth rates in the 1970s, a partial recovery in the 1980s, and then a significant decline from 1990 onward.[1] According to the Intergovernmental Panel on Climate Change (IPPC), natural disasters may be becoming more frequent and extreme due to climate change (Parry et al. 2007, 299); hence, adverse weather may have contributed to a reduction in average yields. Beginning in 1980, grain acreage also declined until the late 1990s, slowing production growth to less than 1 percent per annum during the 1990–2000 period and then rebounding.

Consumption growth has generally corresponded with production growth since the 1960s (Table 1.1). This typical pattern reveals the time-series tendency of production and consumption to change synchronously. In years of bumper crops or substantial land expansion, production may temporarily outpace consumption and build buffer stocks. Conversely, declining land use or adverse weather may lead to lagging production and falling buffer stocks. Not surprisingly, since the 1980s consumption growth rates for both grains and total grains and oilseeds have declined, which suggests that weakening growth in population has not been completely offset by the consumption-boosting effects of income growth (Alexandratos 2008). Sustained reduction in buffer stocks is the hallmark of an imbalance in supply and demand in which consumption

[1] A significant share of the decline in the 1990s was due to the restructuring and reform in the former Soviet Union. Nevertheless, grain production growth would have been slower than in earlier decades.

outpaces production. Such reductions in grain stocks laid the foundation for the price shocks of 2006–8. The price surge and the emergent world food crisis captured headlines and stimulated a wide range of analytical activity and policy discourse (Meyers and Meyer 2008). The crisis caused and continues to cause hardship in many developing countries, led to social unrest in scores of these countries, added 75 million people to the number of undernourished, and reversed progress toward the Millennium Development Goals (MDG) hunger target (FAO 2008a). It also raised questions about the capacity of the global food system to sustain its past success in expanding food and fuel security for a growing part of the world population.

This chapter begins the quest for answers to these food and fuel security questions by first studying population growth projections, then the implications for food demand growth, and finally grain and oilseed supply projections from several sources. Obviously, growth in demand and supply for foodstuffs cannot be viewed in isolation from food prices and income growth. Higher incomes both stimulate demand and change demand patterns, and prices influence the supply as well as the level and composition of consumption. Thus, supply and demand growth is analyzed relative to the expectation of the effect of supply–demand pressures on prices and potentially necessary developments on the supply side to keep pace with likely demand growth.

Population Growth Dynamics and Projections to 2050

World population is projected by the U.S. Census Bureau (USCB) to reach 9.5 billion persons by 2050, which is roughly a 42 percent increase over the population in 2008 (USCB 2008), although the medium variant[2] update issued by the United Nations (UN) in early 2009 was 9.15 billion (UN 2009) and revised by the USCB to 9.28 billion in June 2010 (USCB 2010). This 9.5 billion would not yet be a steady-state population, because world population is expected to peak and begin to decline in about 2070. However, it has been the pattern of population projections that rates of growth are adjusted downward in nearly every projection update, so this peak population could occur sooner than current projections suggest.

Although world population continues to increase, rates of population growth have been declining for decades as incomes grow and education becomes more universal (Table 1.2). Both income growth and education are well-established factors that increase the marriage age of women and reduce the number of children per family, which more than offset the increased life expectancy at birth and reduce population growth rates. Only in Africa, the poorest continent, was the population growth rate still increasing until 1983, when it reached 3.09 percent year over year before starting

[2] The medium variant assumption is that the total fertility rate (TFR) will decline from 2.56 children per women in 2005–10 to 2.02 in 2045–50.

Table 1.2. *Population growth rates, historical and projections in 10-year increments*

Region	1960–70	1970–80	1980–90	1990–2000	2000–10	2010–20	2020–30	2030–40	2040–50
World	2.06	1.82	1.73	1.42	1.21	1.10	0.89	0.73	0.58
Developing	2.50	2.20	2.08	1.68	1.44	1.30	1.05	0.85	0.68
Developed	0.97	0.74	0.55	0.42	0.25	0.15	0.05	−0.11	−0.08
Africa	2.55	2.70	2.84	2.48	2.29	2.11	1.88	1.69	1.52
North America	1.73	1.43	1.33	1.37	1.05	0.95	0.84	0.71	0.59
South America	2.70	2.38	2.06	1.64	1.33	1.09	0.84	0.60	0.37
Europe	0.82	0.55	0.38	0.11	−0.03	−0.12	−0.25	−0.34	−0.45
Oceana	2.10	1.58	1.55	1.43	1.43	1.21	0.98	0.75	0.57
Asia	2.39	2.04	1.87	1.47	1.21	1.06	0.80	0.58	0.39
China	2.59	1.81	1.57	1.00	0.60	0.61	0.21	−0.05	−0.21
India	2.21	2.14	2.05	1.83	1.66	1.41	1.19	0.95	0.71

Source: USCB (2008).

to decline (USCB 2008). In the aggregate of developed countries, population is forecasted to decline after 2030; Europe already began this decline in 1999. In China, which has mandated a reduced family size with its one-child policy, the population growth rate has been declining from the developing-country level in 1960 and is projected to become negative in 2033 and reach the developed-country level by 2050.

Another important aspect of global population growth is its regional distribution and that distribution's change over time. From 1970 to 2010, 63 percent of world population growth was in Asia and 21 percent in Africa (Table 1.3). From 2010–50 the growth in Asia will be about 51 percent of the world total and Africa 40 percent. In 1970, Africa accounted for about 10 percent of world population, but because it has the fastest population growth rate, by 2010 it is projected to be 15 percent and by 2050 almost 22 percent of the total. Meanwhile, the European population, which has been declining (negative population growth) since 1999, dropped from about 18 percent of world population in 1970 to 10 percent in 2010 and is forecasted to be less than 7 percent in 2050. The share of Asia remains close to 60 percent throughout this period, whereas North America and South America remain relatively steady at 8 and 6 percent, respectively (Table 1.3).[3]

In summary, between 2010 and 2030 there are expected to be 1.5 billion more mouths to feed in the world and an additional 1.16 billion by 2050. The result is 2.67 billion additional persons, or approximately two more Chinas over the next 40 years. Additionally, the fastest growing parts of the world are the lower income

[3] Figures assume no population change due to immigration or other displacement.

Table 1.3. *Regional shares in population and population changes, in millions*

	Asia	Africa	N. America	S. America	Europe	Oceana	World
Change 1970–2010	1992.5	650.6	217.5	207.2	71.2	16.0	3155.1
% of total	63%	21%	7%	7%	2%	1%	100%
Change 2010–50	1353.9	1056.5	193.8	132.9	−79.9	14.8	2672.1
% of total	51%	40%	7%	5%	−3%	1%	100%
Share of World							
% in 1970	58.1	9.9	7.7	5.6	17.7	0.5	100
% in 2010	60.4	14.8	7.8	5.8	10.6	0.5	100
% in 2050	57.7	21.7	8.7	5.6	6.8	0.5	100

Source: USCB (2008).

regions, where per capita consumption will also be growing and dietary patterns changing as incomes increase. As is explored further in many of the chapters, this is the challenge for agriculture in the decades ahead.

Potential Income and Demand Growth

As a first approximation to the growth in demand for food, we can theorize that, if there were no change in per capita consumption in any country, food demand would grow at a slower rate than population simply because the populations with lower per capita consumption levels also tend to have higher population growth rates (Alexandratos 1999). In reality, per capita consumption does grow with income, which is especially true in low-income populations for which calorie intake and dietary quality are inadequate. At higher income levels, when people have obtained an adequate diet, the income effect becomes very small. The percent growth in demand for food for a 1 percent growth in income is the income elasticity of demand. We can illustrate this concept by comparing the calculated growth in demand for food with no change in per capita consumption (or no income effect) compared to scenarios where the income elasticity of demand for food is 0.2 or 0.4, meaning that food consumption would grow by 2 or 4 percent for every 10 percent growth in income, assuming no other changes.[4]

This calculation is:

$$\text{Food demand growth} = \text{population growth} + (\text{income elasticity} * \text{income per capita growth})$$

The calculation requires a projection of the growth in income per capita for which we use the projected growth in real gross domestic product (GDP) per capita. By applying the different income elasticities and using the world population growth rates from the

[4] "No other changes" means there are no changes in prices or other factors that may influence food demand.

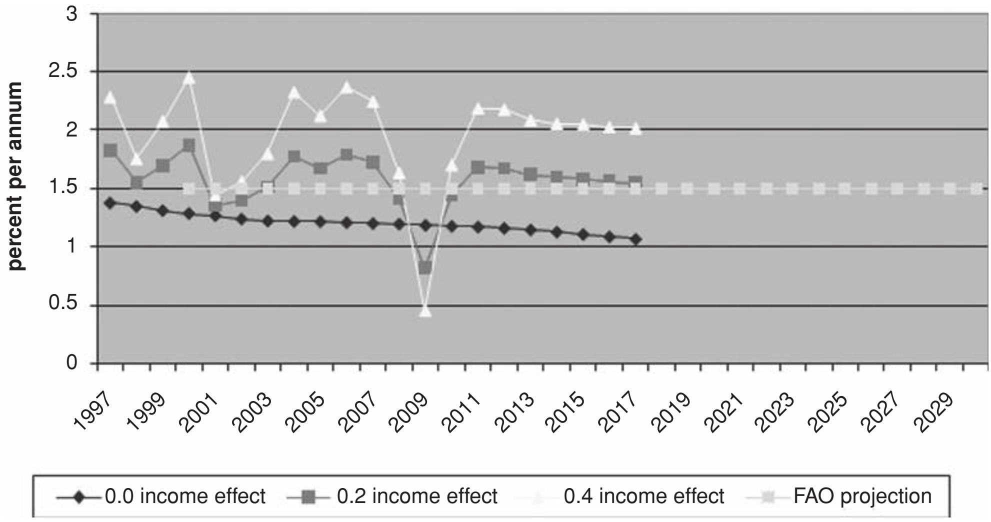

Figure 1.1. Calculated Food Demand Growth Rate Compared with FAO Long-Term Projections. *Source:* GDP growth rates are IHS Global Insight projections used in the FAPRI (2009) baseline.

previous section, we can obtain food demand growth rates that range from about 2 percent per annum for the higher income elasticity to about 1 percent per annum when there is no income effect or no change in per capita consumption (Figure 1.1). To determine which of these rates may be closest to a recent long-run projection of food demand growth, we use the Food and Agriculture Organization (FAO) projection for growth rate of demand for all commodities and all uses. For the period 2000–30 they estimate an average growth rate of 1.5 percent per annum, which is virtually identical to the middle calculation from 2017 onward (Figure 1.1). Because population growth rates are declining, it makes sense that this food demand growth is higher than 1.5 percent per annum before 2017 and likely to decline further in the remaining years.[5]

We do not want to dwell too much on food demand growth without speaking of supply and price conditions, but a reference point is useful when discussing potential growth in supply. When looking at supply growth, we focus not on food in general but on grains and oilseeds, because they are the basic commodities from which most foods derive. When incomes grow, individuals tend to shift from direct consumption of grains to meats, which consume grain as a feedstuff. This shift comprises much of what is reflected in the income effect represented by income elasticity, because more grain is needed per capita with the addition or increase of meat in the diet.

[5] This global illustration greatly oversimplifies the process actually used in doing such projections. Generally, projections of demand growth must be done in more disaggregated ways and preferably country by country (Alexandratos 1997).

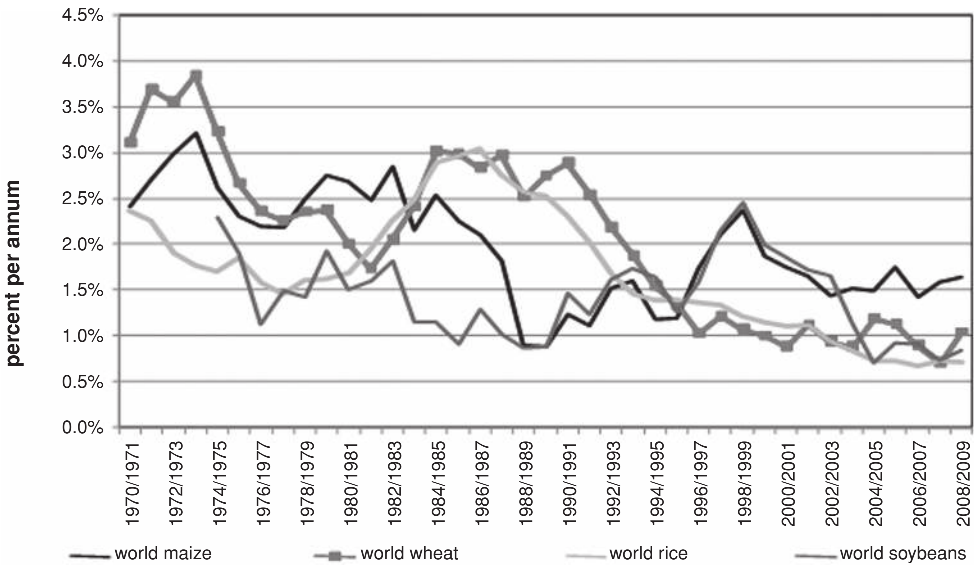

Figure 1.2. Exponential Growth Rates for Yields the Previous 10 Years. *Source:* Calculated from the USDA FAS (2010).

Supply Projections for Cereals from Different Sources

We have discussed the declining growth rates in production that have characterized the last two decades. Several factors contributed to this relatively slow production growth, but the key market factor was declining real prices for an extended period that reduced market incentives to invest and produce. The decline was interrupted only by short-lived price surges in short crop years in 1988/89 and 1995/96 (Meyers and Meyer 2008). In short, grain acreage declined (Table 1.1), and yield growth rates slowed simultaneously.

In addition to low prices, another important contributing factor in slowing yield growth rates, especially for rice and wheat (Figure 1.2), is the diminishing national and international public investment in agricultural research and development (R&D). Such investment has slowed in both developing and developed countries since the 1990s. The international research investments of the 1960s were deliberate policies to enhance agricultural productivity in developing countries and resulted in the high-yielding Green Revolution wheat and rice varieties that spurred yield growth and enhanced multiple cropping opportunities with shorter growing seasons. Along with continuing public and private agricultural R&D in industrial countries, these improved technologies supported grain yield growth of 2.4 percent and production growth of 3.1 percent annually from 1960–80. Although yield growth remained relatively high in the 1980s, grain acreage declined. Grain acreage peaked in 1981, and some land moved into oilseeds. As a result, total land in grains and oilseeds grew by less than 0.2 percent per annum from 1981–2007. Since 1990, yield and production growth have been slowing for both grains and oilseeds.

It has been well established in numerous documents of the World Bank, FAO, and International Food Policy Research Institute (IFPRI) that investment in agricultural development has been lagging, especially in developing countries. The World Bank *World Development Report 2008* (IBRD 2007) shows that developing countries have "suffered from neglect and underinvestment over the past 20 years. While 75 percent of the world's poor live in rural areas, a mere 4 percent of official development assistance goes to agriculture in developing countries. In Sub–Saharan Africa, a region heavily reliant on agriculture for overall growth, public spending for farming is also only 4 percent of total government spending" (World Bank 2007). Pardey et al. (2006) found that growth in public agricultural R&D spending, which was critical to the Green Revolution, declined by more than 50 percent in most developing countries from 1980 onward and even turned negative in high-income countries beginning in 1991. There were important exceptions in China and India (IBRD 2007), but national governments and international organizations have neglected these investments despite the high rates of return that were demonstrated in past R&D projects.

It is noteworthy that corn and soybean yield growth rates have been significantly higher than for wheat and rice (Figure 1.2) since the Green Revolution's effects diminished in the mid-1980s. This trend reflects the role of private investments in corn and soybean germplasm research and biotechnology development, as well as the commercialization of that research.

In response to the commodity price surge since 2006, grain area and production have been increasing. The most recent 10-year projections of future supply have been conducted in this context. These projections were also completed within the context of the public R&D deficiency, because even if urgent action were taken to reverse the investment path for agriculture, it is a long-term endeavor.

The first comparison of grain and oilseed production projections is from three of the best known annual global market assessments. One is by the Food and Agricultural Policy Research Institute (FAPRI), which is a collaboration of the University of Missouri–Columbia and Iowa State University and the University of Arkansas's global rice market analysis. The second assessment is by the U.S. Department of Agriculture (USDA), and the third is conducted jointly by the Organisation for Economic Cooperation and Development (OECD) and FAO. These were completed at somewhat different times of the year: USDA was in December 2007 (USDA 2008), FAPRI was in March 2008 (FAPRI 2008), and OECD was in May 2008 (OECD/FAO 2008). Some of their differences are due to different release dates and the information available at publication, but in any case the implications of these three projections are quite similar.

Grains and oilseeds experienced significant growth in production in the middle part of this decade, primarily in response to rapidly rising prices. The rates of growth in grain (except for rice) and oilseed production from 2000–7 were significantly higher than those of the previous decade, with coarse grains growing nearly three times as

Table 1.4. *Comparison of growth rates for grains and oilseeds production, percent per annum*

Crop	1990–2000	2000–7	FAPRI 2007–17	USDA 2007–17	OECD 2007–17
Rice	1.61	1.02	0.88	0.73	0.89
Wheat	0.78	1.08	0.99	0.92	0.97
Coarse grains	1.04	2.96	1.46	1.53	1.46
Total grains	1.07	1.96	1.21	1.16	1.17
Oilseeds	4.01	4.29	2.30	2.89	2.22

Sources: FAPRI (2008); OECD/FAO 2008; USDA (2008) historical figures. Used 3-year average of production.

fast and total grains growing nearly twice as fast (Table 1.4). From 2007–17, projected production growth rates are not as high as in the recovery period 2000–7, but all grain production growth rates remain somewhat higher than in the 1990s.

Finally, we compare these 10-year projections to long-term projections conducted by FAO (FAO 2006) and by IFPRI (Rosegrant et al. 2009). For FAO, the long-term projections use different types of modeling systems than the 10-year projections, and they essentially assume constant real prices such as we illustrated in the demand growth exercise of the previous section. Their long-term projections were completed without including the use of grains and oilseeds for biofuel feedstock. In contrast, IFPRI does estimate prices, includes biofuel feedstock demands, and analyzes alternatives under different assumptions of investment in technology to enhance productivity. Their long-term estimates also take into account water and land resource constraints in the analysis. In any case, looking at the longer term is helpful to gauge how it differs from the 10-year outlook. We use the FAPRI results for comparison and find a rather consistent outlook. In the 2000–30 period, production growth rates are projected to be lower than in the 2000–17 period of the FAPRI analysis (Table 1.5). When the

Table 1.5. *Comparison of growth rates for grains and oilseeds production, percent per annum*

Crop	FAPRI 2000–17	FAPRI 2007–17	FAO 2000–30	FAO 2030–50	FAO 2000–50	IFPRI 2000–50
Rice	1.02	0.88	0.8	0.2	0.50	0.44
Wheat	1.16	0.99	1.1	0.5	0.90	0.79
Coarse grains	2.21	1.46	1.4	0.8	1.10	1.16
Total grains	1.53	1.21	1.2	0.6	0.90	0.92
Oilseeds	3.06	2.30	2.2	1.6	1.96	Na
Population	1.18	1.15	1.0	0.5	0.80	0.87

Sources: FAPRI (2008); FAO (2006); Rosegrant et al. (2009).

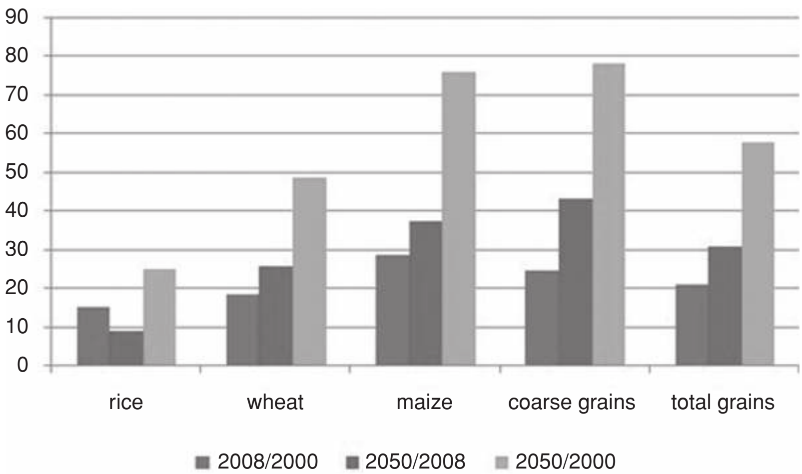

Figure 1.3. Projected Grain Production Increase to 2050, Percent. *Source:* USDA 2000–8 estimates (USDA 2008), IFPRI 2000–50 projection (Rosegrant et al. 2009).

production recovery period up to 2007 is removed and we look at the 2007–17 period only, the differences in growth rates are much smaller. FAO projects that the rates of growth in the 10-year FAPRI projection would continue to 2030. Longer term production growth is slightly lower.

Comparing FAO and IFPRI and looking only at the 2000 to 2050 summaries, there is sufficient evidence to conclude that the assessments are very similar. IFPRI analysis projects slightly higher growth rates in grain production, especially coarse grains, which reflect the growth of biofuel feedstock demand at least through 2020 and a slightly higher rate of population growth. Using IFPRI's growth rate results, which are slightly higher, these figures would result in an increase in total grain production of 58 percent from 2000 to 2050 (Figure 1.3). However, world grain production was quite flat during the late 1990s and early 2000s and then grew by more than 20 percent from 2003 to 2008 as prices increased and policy incentives became more favorable. So, from the current 2008 levels to 2050, the projected total production growth is 30 percent for total grains, closer to 40 percent for coarse grains and maize, and somewhat lower for wheat and rice (Figure 1.3).

Regional patterns of production are important as well. Production growth in areas closer to population and consumption growth centers results in lower transportation costs and reduced losses of quality and quantity associated with transportation. The historical path shows again the declining rates of growth up to 2001, but regional differences are revealing. The rate of production growth increased in industrial countries and Latin America, slowed most in developing regions, and was increasingly negative in transition countries (former Soviet Union and East European countries). As in the past, future cereal production growth is projected to be higher in developing than industrial or transition countries (Table 1.6). In the projection period 2000–30, the small increase in the world cereal production growth rate is due to major