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'Meat or wheat for the next millennium?' Plenary Lecture

Alternative futures for world cereal and meat consumption

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Fundamental changes in the global structure of food demand will lead to an extraordinary increase in the importance of developing countries in global food markets. Economic growth in developing countries is changing consumption patterns, with slower growth (and in many countries actual declines) in *per capita* food consumption of grains and rapidly growing *per capita* and total meat consumption, combined with induced growth in cereal feed consumption. The present paper examines the hypothesis, suggested by some researchers, that high-meat diets in developed countries limit improvement in food security in developing countries. These analysts argue that reduced meat consumption in developed countries would release cereals from livestock feed to food for poorer populations, thus improving food security in developing countries. Using the International Food Policy Research Institute (Washington, DC, USA) global food projections model, the international model for policy analysis of agricultural commodities and trade (see Rosegrant *et al.* 1995), we first analyse the implications for future global cereal and meat supply and demand resulting from changes in global income, population growth and other structural changes, then simulate alternative scenarios to examine the effect of large reductions in meat consumption in developed countries on food consumption and food security in developing countries. The paper shows that while the long-term prospects for food supply, demand and trade indicate a strengthening of world cereal and livestock markets, the improvement in food security in the developing world will be slow, and changes in the dietary patterns in developed countries are not an effective route to improvement in food security in developing countries.

Meat consumption: Cereal consumption: Global food model: Dietary patterns

Fundamental changes are occurring in the global structure of food demand, driven to a large extent by economic growth in the developing countries (including: Latin America and the Caribbean, Sub-Saharan Africa, West Asia and North Africa (WANA), Asian developing countries, the remaining (non-'developed') countries of the world). Rising incomes and rapid urbanization, particularly in Asia, are changing the composition of food demand. Direct *per capita* food consumption of maize and coarse grains is declining as with increasing incomes consumers shift to wheat and rice. When incomes rise further and lifestyles change with urbanization, a secondary shift from rice to wheat takes place. Growth in incomes in developing countries is driving strong growth in *per capita* and total meat consumption, which in turn induces strong growth in feed consumption of cereals, particularly maize. At the same time, growth in *per capita* meat and cereal consumption in developed countries (including: Australia, Canada, Eastern Europe, EU, other Western European countries, former Soviet Union, Israel, Japan, New Zealand, South Africa, USA) has slowed dramatically as these countries have reached very high levels of meat consumption in the past decades. These

Abbreviations: IMPACT, international model for policy analysis of agricultural commodities and trade; RMD, reduced meat demand; WANA, West Asia and North Africa

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trends will lead to an extraordinary increase in the importance of developing countries in global food markets.

Concurrent with these fundamental shifts in long-term demand, strong concerns have been raised that high-meat diets in the developed countries constitute a severe limitation on growth in cereal consumption and food security in developing countries. In developed countries, production of 1 kg poultry meat requires about 2 kg grains, 1 kg pigmeat requires 4 kg grains, and production of beef in feedlots utilizes as much as 7kg grain/kg meat production. As a result of the high rate of conversion of grains to meat, some analysts have argued that a reduction in meat consumption in developed countries, either through voluntary changes in dietary patterns, or through policies such as taxes on livestock, would release cereals from livestock feed to food for poor people in developing countries (for example, see Brown, 1995; Seager, 1995). Would a reduction in meat consumption in developed countries improve food security in developing countries?

The present paper examines the implications of the fundamental changes in the structure of food demand for long-term global cereal and meat supply and demand using the global food projections model of the International Food Policy Research Institute (Washington, DC, USA), the international model for policy analysis of agricultural commodities and trade (IMPACT; see Rosegrant *et al*. 1995). Alternative scenarios are then simulated with IMPACT to examine the effect of large reductions in meat consumption in developed countries on food consumption and food security in developing countries. We first summarize historical trends in demand and production for cereals and meats; describe IMPACT; and present the baseline projections of cereal and meat demand and supply using IMPACT. We then explore the implications of scenarios that postulate large reductions in meat consumption in developed countries.

Historical trends in cereal and meat demand

Cereal feed and food use

Table 1 summarizes trends in cereal utilization for feed and food since 1961, and Table 2 shows trends in *per capita* demand for cereals. The global utilization of cereals as feed increased at 2·69%/year over the period 1961–94, but the growth in feed use of cereals has declined steadily over time, from 5·49%/year in 1961–71, to 0·88%/year in 1981–94. Growth in feed demand in developing countries has been much faster than that in developed countries, but from a considerably smaller base. The share of developing countries in total cereal feed demand has grown from about 13% in 1961–71 to 25% in 1981–94. Maize accounts for 54% of feed use, other coarse grains 30%, wheat 15%, and rice less than 1%, as of 1992–94. The decline in growth in feed use, particularly in developed countries, is due to slowing growth in livestock production and increased efficiency in the feeding of livestock. The key factors in the improvement in feeding efficiency in the developed countries appear to be the shift in the composition of meat production from beef to poultry (which uses less cereal per unit meat produced), the use of animal growth hormones, and other technological changes that improve feeding efficiency. In Western Europe, an additional factor is the substitution of other feeds (cassava (*Manihot* spp.), oilmeals and maize-gluten feed) for cereals due to policy-driven high cereal prices.

Table 1. Trends in total cereal feed and food consumption by region 1961–1994*

	1961–71	1971–81	1981–94	1961–94
Cereal feed use				
Average annual utilization (x10^6 t)				
Developed countries†	308·7	423·9	457·6	400·4
Developing countries†	44·6	86·4	150·9	99·3
World	353·3	510·3	608·4	499·7
Annual growth rate (%/year)				
Developed countries	5·18	1·39	–0·16	1·90
Developing countries	7·87	7·00	3·99	6·06
World	5·49	2·30	0·88	2·69
Cereal food use				
Average annual utilization (x10^6 t)				
Developed countries	146·8	149·6	161·0	153·4
Developing countries	327·3	450·8	633·5	485·6
World	474·1	600·3	794·5	639·0
Annual growth rate (%/year)				
Developed countries	0·12	0·42	0·68	0·43
Developing countries	3·65	3·30	2·20	2·97
World	2·53	2·57	1·89	2·29

* The basic data were obtained from Food and Agriculture Organization (1997).
† For details, see p. 219.

Table 2. Trends in *per capita* cereal food consumption by region, 1961–1994*

	1961–71	1971–81	1981–94	1961–94
Per capita cereal food use				
Average annual utilization (kg *per capita* per year)				
Developed countries†	141·6	131·7	130·5	134·4
Developing countries†	137·1	149·1	165·3	151·8
World	138·5	144·4	156·8	147·5
Annual growth rate (%/year)				
Developed countries	–0·90	–0·39	0·03	–0·38
Developing countries	1·14	1·07	0·20	0·75
World	0·48	0·74	0·22	0·46

* The basic data were obtained from Food and Agriculture Organization (1997).
† For details, see p. 219.

Global cereal food consumption also increased at a decreasing rate, averaging 2·29%/year in 1961–94, but the slowdown in growth was smaller than that for feed (Table 1). In contrast with trends for cereal feed use, average annual cereal food consumption in the developing countries is substantially higher than that in the developed countries. Developing countries accounted for 69% of direct food consumption of cereals in 1961–71, and 80% in 1981–94. In *per capita* terms, cereal food consumption in the developed countries decreased slightly from 141·6kg/year in 1961–71 to 130·5kg/year in 1981–94. In the developing countries, *per capita* food consumption increased from an average 137·1 kg/year in 1961–71 to 165·3kg/year in 1981–94. The rate of growth in *per capita* cereal food consumption in

developing countries has slowed considerably over the time periods shown. In 1992–4, wheat accounted for 43 % of the cereal food consumption, rice 39 %, maize 12 % and other coarse grains 10 %.

Meat demand

In 1961–94, total and *per capita* meat consumption in the world increased at a decreasing rate, but in the developing countries both total and *per capita* meat consumption accelerated from a very low base level (Table 3). Over the whole period, meat consumption grew at an average rate of 1·9 %/year in the developed countries, and at 4·7 %/year in the developing countries. Developing countries accounted for only 29 % of the consumption of meat in 1961–71, but this share increased to 41 % in 1981–94. The difference in meat consumption is even larger on a *per capita* basis, with a person in the developed countries consuming an average of 76 kg/year in 1981–94, compared with a consumption of only 17 kg/year for a person in the developing countries. Pigmeat accounts for 40 % of the global meat production, beef for 29 %, poultry for 25 %, and sheep and goat meat for about 5 %. These patterns, however, have changed in recent years. In the developed countries, *per capita* demand for beef and pigmeat has actually declined since the late 1980s, while *per capita* poultry demand has grown at a strong 2·2 %/year from 1981 to 1994. With growth in poultry consumption offset by declining beef and pigmeat consumption, *per capita* consumption of meat was virtually constant for developed countries as a whole.

In contrast, growth in total meat demand remains very rapid in developing countries, with a *per capita* demand growth rate of 2·9 %/year for all meats from 1981 to 1994. Growth was again fastest for poultry, with *per capita* demand growth of 5·5 % and total demand growth of an extraordinary 7·6 %. Growth in pigmeat *per capita* consumption was also very rapid at 4·3 %/year, while beef was relatively slow at 1·1 %/year from 1981 to 1994.

Table 3. Trends in total and *per capita* meat consumption by region, 1961–1994*

	1961–71	1971–81	1981–94	1961–94
Total meat consumption				
Average annual utilization (x10^6 t)				
Developed countries†	59·66	79·24	94·20	79·10
Developing countries†	23·96	36·07	65·77	44·28
World	83·62	115·31	159·96	123·38
Annual growth rate (%/year)				
Developed countries	2·72	1·71	0·71	1·86
Developing countries	3·80	4·18	4·69	4·73
World	3·02	2·48	2·36	2·92
Per capita meat demand				
Average annual utilization (kg *per capita* per year)				
Developed countries	57·61	69·93	76·46	68·66
Developing countries	10·05	11·93	17·01	13·39
World	24·47	27·82	31·55	28·26
Annual growth rate (%/year)				
Developed countries	1·88	1·05	0·14	1·08
Developing countries	1·79	2·37	2·90	2·58
World	1·36	1·02	0·89	1·16

* The basic data were obtained from Food and Agriculture Organization (1997).
† For details, see p. 219.

Trends in cereal area, production and yield

Growth trends in area harvested, production and yield for wheat, rice, maize and other grains are summarized in Table 4, for the periods 1967–82 and 1982–94. The two sub-

Table 4. Annual growth (%/year) in cereal crop area, production and yield by region, 1967–1994*

	1967–82			1982–94		
	Area	Production	Yield	Area	Production	Yield
Wheat						
Developed countries†	–0·12	1·73	1·87	–1·38	–0·03	1·35
Developing countries†	1·45	5·39	3·88	0·42	2·94	2·52
World	0·48	2·88	2·40	–0·59	1·20	1·80
Maize						
Developed countries	0·64	3·05	2·33	–0·26	0·69	1·01
Developing countries	0·65	3·46	2·80	1·36	3·66	2·27
World	0·64	3·20	2·52	0·77	1·93	1·16
Paddy rice						
Developed countries	–0·23	–0·14	0·09	–0·28	0·34	0·61
Developing countries	0·81	3·21	2·38	0·21	2·03	1·81
World	0·78	2·96	2·17	0·20	1·94	1·74
Other grains						
Developed countries	0·52	1·32	0·79	–1·63	–0·78	0·85
Developing countries	–0·87	1·20	2·08	0·12	0·03	–0·09
World	–0·15	1·28	1·43	–0·79	–0·52	0·26
All cereals						
Developed countries	0·23	1·92	1·69	–1·27	0·01	1·30
Developing countries	0·48	3·36	2·87	0·46	2·34	1·87
World	0·37	2·61	2·24	–0·24	1·27	1·51

* The basic data were obtained from Food and Agriculture Organization (1997).
† For details, see p. 219.

periods roughly divide the period of 1967 to 1994 into a peak-Green Revolution period and a post-Green Revolution period. The contribution of area expansion to growth in production of cereals declined dramatically during the latter period. In developed countries as a group, the area harvested of each of the cereals actually contracted, with a decline in wheat area of 1 ·4%/year in 1982–94.

In developing countries, wheat and rice area continued to expand after 1982, but at much slower rates. Wheat area grew at only 0·4 %/year, less than one-third the rate of growth from 1967 to 1982, while rice area was down from 0·8 %/year to 0· 2%/year. However, the growth rate in maize area in developing countries doubled to 1·4 %/year after 1982, and other coarse grains showed a slight increase after a decline in the previous period (Table 4).

The pattern of growth of cereal yields also shows a significant slowdown after 1982, but hardly the stagnation in yields claimed by some observers (Brown & Kane, 1994). In developing countries, growth in wheat yield declined fro m3· 9%/year in the first sub-period to 2·5 %/year in the second, while in the world as a whole, growth in wheat yield slowed from an annual rate of 2·4 % to 1·8 %. Growth in maize yield in developing countries dropped from 2·8 %/year in 1967–82 to 2· 3%/year thereafter. Globally, growth in maize yield declined from 2·5%/year to 1·2 %/year. The growth in rice yield in developing countries was 2·4 %/year in 1967–82, and 1 ·8%/year in 1982–94. Global growth in rice yield dropped from 2·2 %/year to 1·7 %/year. Only yields for other coarse grains could be characterized as truly stagnant, with a global growth in yield of 0·3 %/year after 1982.

In the developed world, the slowdown in growth of crop area, yield and production was primarily policy-induced, as North American and European governments drew down c ereal stocks and scaled back farm-price support programmes in favour of direct payments to farmers. The economic collapse and subsequent struggles with economic reform in the formerly centrally-planned economies in Eastern Europe and the former Soviet Union further depressed crop production for developed countries as a whole.

The slowdown in growth of cereal production in developing countries since the early 1980s has been caused by declining world cereal prices and by factors related to the increasing intensification of cereal production. Much attention has been focused on the technological reasons for the slowdown of growth in yield. The use of high levels of inputs and the achievement of relatively high cereal yields in parts of Asia have made it more difficult to sustain the same rate of yield gains, as farmer yields in these regions approach the economic optimum yield levels. At the same time, increased intensity of land use has led to increasing input requirements in order to sustain current yield gains. Less attention has been paid to the crucial role of cereal prices in the drop in growth rates in yield and production. Between 1982 and 1995, real world wheat prices declined by 28 % , rice prices by 42 % , and maize prices by 43 % . The declining price of cereals has caused a direct shift of land out of cereals and into more profitable cropping alternatives, and has slowed the growth in input use, and therefore yields. Probably more important in the long run, declining world prices have also caused a slowdown in investment in crop research and irrigation infrastructure, with consequent effects on growth in yield (Rosegrant & Svendsen, 1993; Rosegrant & Pingali, 1994). Perhaps the most remarkable aspect of growth in wheat, maize and rice yield in the developing world since the 1980s is not that growth was slower than in the previous period, but that growth has been as high as it was in the face of steeply declining real cereal prices.

Trends in livestock numbers, production, and yield

Table 5 summarizes trends in the number of livestock slaughtered, meat production, and yield (carcass weight per animal slaughtered). The most striking development shown here is the rapid expansion in production of poultry in all country groups. In 1982–94, poultry production expanded at an average rate of 5·1 %/year on a global basis. Growth in production was an extraordinary 8· 4% (from a relatively low base) in developing countries, 5· 4% in the USA, and 2·9 % in developed countries as a whole. Growth in poultry production after 1982 was driven mainly by growth in numbers, which accounted for 64% of the growth in production in developed countries, 83 % of the growth in production in the USA, 90 % of the growth in production in developing countries, and 86% of the growth in global production. Nevertheless, growth in yield was also a significant factor during the 1982–94 period and, at 1·0%/year in developed countries and 0·8 %/year in developing countries, substantially faster than in the 1967–82 period.

Production of beef has grown slowly in developed countries since 1982, with the decline in numbers offsetting the growth in yield. However, in developing countries, bee fproduction grew at 3· 1%/year after 1982, leading to an overall growth for the world of 1·1 %/year. Of this growth, 65 % was due to growth in numbers of slaughtered stock. Pigmeat production also grew slowly in developed countries, but, like poultry, showed phenomenal growth in production in 1982–94 in developing countries, from a relatively small initial base of production. Globally, production of pigmeat grew at 3· 3%/year, with more tha n 80% of this growth coming from numbers slaughtered.

International Food Policy Research Institute's global food projections model

Global food projections have been made using the global food projections model of the International Food Policy Research Institute, IMPACT. IMPACT covers thirty-seven countries and regions (which account for virtually all world food production and consumption), and eighteen commodities, including all cereals, soyabeans, roots and tubers, meat sand dairy products. The model is specified as a set of country-level supply and demand equations. Each country model is linked to the rest of the world through trade. Demand is a function of prices, income and growth in the population. Growth in crop production in each country is determined by crop prices and the rate of growth in productivity. Future growth in productivity is estimated by its component sources, including management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector

Table 5. Annual growth (%/year) in the number of livestock, production and yield by region, 1967–1994*

	1967–82			1982–94		
	No.‡	Productio	Yield§	No.‡	Production	Yield§
Beef						
Developed countries†	0·27	1·52	1·25	–0·68	0·01	0·69
Developing countries†	2·42	2·53	0·11	2·48	3·11	0·61
World	1·04	1·82	0·78	0·71	1·10	0·39
Pigmeat						
Developed countries	2·07	2·46	0·37	0·14	0·47	0·33
Developing countries	3·14	4·79	1·60	5·27	6·75	1·41
World	2·50	3·21	0·69	2·65	3·25	0·58
Poultry						
Developed countries	4·72	5·11	0·37	1·88	2·94	1·03
Developing countries	6·78	7·33	0·52	7·47	8·37	0·82
World	5·40	5·75	0·32	4·34	5·05	0·68
Sheep and goat						
Developed countries	–0·01	0·05	0·06	0·10	0·27	0·17
Developing countries	2·48	2·45	–0·04	3·43	3·88	0·43
World	1·33	1·21	–0·11	2·19	2·37	0·18
All meat ll						
Developed countries	–	2·45	–	–	0·90	–
Developing countries	–	4·16	–	–	5·92	–
World	–	2·99	–	–	2·96	–

* The basic data were obtained from Food and Agriculture Organization (1997).
† For details, see p. 219.
‡ Based on the number of livestock slaughtered.
§ Based on the carcass weight (kg) per animal slaughtered.
ll Production growth only is shown. Yield growth for 'all meat' does not correctly measure productivity growth because of the increasing share in production of lighter-weight poultry

agricultural research and development, agricultural extension and education, markets, infrastructure and irrigation.

Food security: projection of number of malnourished children

In order to explore food security effects, we also project the number of malnourished preschool children in developing countries. IMPACT generates projections of the percentage and number of malnourished preschool children (0–5 years old) in developing countries. A malnourished child is one whose weight-for-age is more than 2 SD below the weight-for-age standard set by the US National Center for Health Statistics (Administrative Committee on Coordination/Sub-committee on Nutrition, 1992 *b*) and adopted by many United Nations agencies in assessing the nutritional status of persons in developing countries. The projected numbers of malnourished children are derived from an estimate of the functional relationship between the percentage of malnourished children, the average *per capita* energy availability of food, and other non-food determinants of child malnutrition including the state of health (proxied for by the percentage of public expenditures spent on health, education, and social security), education (proxied for by the percentage of females undertaking secondary schooling), and sanitation (proxied for by the percentage of the population with access to safe drinking water). The analysis employed a fixed-effect model on pooled cross-section time-series data from sixty-one developing countries covering the years 1980, 1985 and 1990 (Administrative Committee on Coordination/Sub-committee on Nutrition, 1992*a*). The estimated functional relationship, used to project the percentage of malnourished children, is as follows:

$$\%MAL_t = 0{\cdot}69 - \underset{(-5{\cdot}9)}{0{\cdot}00014}KCAL_t - \underset{(-6{\cdot}6)}{0{\cdot}004}SOCEXP - \underset{(-1{\cdot}1)}{0{\cdot}0005}SCH - \underset{(-0{\cdot}6)}{0{\cdot}0002}WATER + \underset{(9{\cdot}9)}{0{\cdot}00009}(DUMM \times KCAL_t);\ R^2\ 0{\cdot}72,$$

where %*MAL* is percentage of malnourished children, *KCAL* is *per capita* energy availability (kcal), *SOCEXP* is percentage of social expenditures in total public expenditures, *SCH* is percentage of females with secondary education, *WATER* is percentage of households with access to clean water, and *DUMMY* is dummy for South Asia (a dummy or proxy variable is an artificial variable constructed such that it takes the value unity whenever the qualitative phenomenon it represents occurs, and zero otherwise) and *t* is time. The values in parentheses represent *t* statistics. This percentage value is then applied to the projected population of children 0–5 years of age to compute the number of malnourished children:

$$NMAL_t = \%MAL_t \times POP5_t,$$

where *NMAL* is the number of malnourished children, and *POP5* is the number of children 0–5 years old in the population.

Projected *per capita* energy availability for food is made up of two components. One component (which accounts for about 70–90% of the total *per capita* energy, depending on the country) is derived from projected *per capita* food consumption of commodities included in the model and converted to kilocalories using the 1992–4 Food and Agriculture Organization (1997) estimates for each commodity as benchmarks. The second component of energy comes from commodities outside the model (such as sugar, fish, vegetables and fruits), whose energy contribution is projected using the base year energy contribution and the specified income elasticity of demand for energy from these sources.

Model revisions

The basic methodology of IMPACT is described in detail in Rosegrant *et al*. (1995). The results presented here are generated from a revised and updated version of IMPACT. The new version of IMPACT incorporates additional features in its structures and input data that improve its projections capability on both the supply and demand sides. Modifications of model structure are reflected primarily in the supply and demand equations. The marginal contribution of further expansion of irrigated area (as part of the national government development agenda) is incorporated into the area function through potential increases in cropping intensities, and into the yield function through the addition of a yield differential between irrigated and non-irrigated crops, that represents the improvement that will be realized with the conversion of farm areas into irrigated ecosystems. With the inclusion of the effect of irrigation expansion as a separate variable, the non-price growth variables incorporated in the area and yield equations in the original version of IMPACT were adjusted downward. They now reflect primarily the impact of the continuation of investments on research and extension.

The demand side of IMPACT incorporates the dynamic adjustment of income elasticities with respect to growth in income. Adjustments have been made also to some of the elasticities, based on recent studies and surveys. In addition to the modifications in the model structure, the baseline data on which the projections are made have been updated from 1990 to 1993. Updating the baseline information of the model enables it to reflect more accurately the most likely trends of commodity markets, incorporating the effects of policies implemented from the late 1980s to the present. The revised IMPACT also includes the November 1996 revised population projections from the United Nations (1998), and updated information on investment in agricultural research.

Baseline projections of global cereal and meat supply and demand, 1993–2020

Projected demand for cereals

In the present section and in the following sections, we present the results of the baseline scenario, which incorporates our best estimates of underlying growth in population and income, growth in crop area and livestock numbers, rates of technological change in crop and livestock yields, and price relationships for supply and demand. Changing patterns of demand are apparent in both the projected *per capita* food demand for cereals shown in Table 6, and the projected total demand for cereals (Table 7). *Per capita* consumption of all cereals will be virtually constant on a global basis, with declining consumption of cereals at higher income levels balancing the increasing demands of lower-income countries. Global growth in *per capita* food demand for wheat will slow down slightly compared with recent trends, but growth is significantly faster than that for other cereals. Strong growth in income and the relative shift in diets from rice to wheat will drive continued growth in *per capita* food demand for wheat in China and Southeast Asia. Growth in *per capita* food consumption of wheat in India and the rest of South Asia will be driven by solid growth in income, but will remain flat in Latin America and in WANA. For developing countries as a group, annual *per capita* wheat demand is projected to increase by 6% from 62kg *per capita* in 1993 to nearly 66kg *per capita* in 2020, whereas for the developed countries as a group *per capita* wheat consumption is projected to be virtually constant (Table 6).

On a global basis, *per capita* food demand for maize and other coarse grains will continue to be stagnant or declining, as consumers shift to wheat and rice. In developing countries, maize consumption will decline by 10% from 22 kg *per capita* in 1993 to less than 20kg *per capita* in 2020, and in the developed countries the drop will be from 12 kg *per capita* to 11 kg *per capita* (8 %). The increase in *per capita* food demand for other coarse grains in developing countries is mainly due to Sub-Saharan Africa, where these grains are the primary cereal staple. For the world as a whole, food consumption of other coarse grains is stagnant at 17 kg *per capita* (Table 6).

Per capita demand for rice is projected to decline over time, as rapid growth in income in Asia continues to drive the diversification of diets that has gained momentum during the past two decades. Although India will show some growth in *per capita* food demand for rice, from 78kg to 83 kg (7%), *per capita* consumption in China will drop from 96 kg to 92kg (4%). Similar rates of decline are projected for the other Asian regions. Developing countries as a group are projected to reduce rice food consumption from 72 kg *per capita* in 1993 to less than 68kg *per capita* in 2020 (6 %). With rice consumption remaining stagnant in the USA and other developed countries, global *per capita* rice consumption will decline slightly.

Table 7 shows the projected levels of total demand for cereals in 1993 and 2020. Total cereal demand is projected to grow by 71 $\times 10^6$ t, or 40 % over 1993. Projected growth in total cereal demand will be slower than that in the past, due to both the changes in the diet structure described previously and the continued gradual slowdown in growth in the population. Sub-Saharan Africa and other South Asia (mainly Pakistan) comprise the most rapid rate of growth in food demand for wheat and for all cereals, mainly driven by accelerated growth in the population. WANA also shows strong growth in food demand for rice and for all cereals. Relatively rapid growth in food demand for wheat in Southeast Asia is the product of high growth in income and moderate growth in population.

Table 6. *Per capita* food demand (kg/year) for cereals, 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Wheat		Maize		Milled rice		Other grains		All cereals	
	1993	2020	1993	2020	1993	2020	1993	2020	1993	2020
China	82·62	86·65	25·84	18·62	95·80	92·30	9·48	8·11	213·74	205·68
India	54·62	64·12	8·39	7·37	77·50	82·96	22·68	20·48	163·19	174·93
Other South Asia*	72·94	87·74	6·28	6·53	77·13	72·43	2·76	2·82	159·11	169·52
Southeast Asia	13·81	17·91	12·87	11·37	141·24	139·12	1·14	1·04	169·06	169·44
Latin America	49·35	49·77	44·84	43·58	26·92	29·51	6·51	5·90	127·62	128·76
West Asia and North Africa	158·82	156·10	14·77	11·83	20·37	21·19	21·54	20·73	214·07	209·95
Sub-Saharan Africa	12·72	14·98	39·39	38·46	16·65	19·10	43·07	46·47	111·83	119·01
Developing countries†	62·08	65·55	22·06	19·83	71·81	67·52	15·65	16·83	171·60	169·73
Developed countries†	98·15	98·20	11·83	10·90	12·00	11·74	22·16	19·52	144·14	140·36
World	70·38	71·42	19·71	18·22	58·06	57·51	17·15	17·31	165·30	164·46

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Table 7. Total cereal demand (x10^6 t), 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Wheat		Maize		Rice		Other grains		All cereals	
	1993	2020	1993	2020	1993	2020	1993	2020	1993	2020
China	111·2	150·0	91·5	179·4	125·0	146·1	16·6	21·5	344·3	497·0
India	56·9	96·7	9·7	18·5	77·4	117·5	23·3	30·6	167·3	263·3
Other South Asia*	23·0	48·0	2·6	4·8	24·3	39·7	1·0	1·9	50·8	94·3
Southeast Asia	6·8	12·5	19·4	35·6	73·6	102·3	0·9	1·4	100·7	151·8
Latin America	27·4	40·3	69·3	110·4	14·4	22·5	17·7	29·6	128·8	202·8
West Asia and North Africa	73·4	125·9	15·8	26·9	8·2	14·6	29·8	55·4	127·1	222·9
Sub-Saharan Africa	6·9	16·6	26·3	53·1	9·6	22·6	27·6	60·9	70·4	153·1
Developing countries†	312·2	501·1	249·4	453·3	341·4	475·5	118·5	203·6	1021·5	1633·5
Developed countries†	240·1	264·1	276·8	330·5	17·8	19·2	216·8	243·8	751·5	857·7
World	552·2	765·3	526·2	783·8	359·2	494·8	335·3	447·4	1773·0	2491·3

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Driven by the rapid growth in demand for feed, maize will show the largest increase in total demand, 258×10^6 t, constituting more than one-third of the projected overall increase in global cereal demand. Nearly two-thirds of the increase in maize demand will come from developing countries, with China increasing its maize demand by 79×10^6 t. Demand for maize for feed is projected to grow at about 3 %/year in China and India, and at 2·8 %/year in developing countries as a group. This fast growth is due to the rapid expansion of the livestock industry, especially in the more-rapidly-growing developing economies, where consumption of meat will expand dramatically. Overall cereal feed demand in the developing world is projected to increase at 2·6 %/year for the period 1993–2020. Feed demand for all cereals in the developed world is projected to grow at 0·7 %/year, slightly higher than the growth rate prevailing since 1982.

Global wheat demand will increase by 213×10^6 t, representing approximately another one-third of the increase in total global cereal demand. Of the increase in wheat demand, 86 % will come from the developing world, where growth in both population and income are higher than those in the developed economies. China and India will each account for an increase of about 40×10^6 t in wheat demand. Less well recognized is the importance of WANA in global wheat demand. In this region, wheat demand is projected to grow by over 50×10^6 t in 1993–2020, a 72 % increase.

Rice demand will grow more slowly than that for wheat and maize, because of changing consumption patterns and the limited role of rice in animal feed. Overall rice demand is expected to increase by 136×10^6 t, with the most significant increases in India (40×10^6 t), Southeast Asia (29×10^6 t), and China (21×10^6 t). Overall demand for other coarse grains is projected to increase by 112×10^6 t.

Projected area and yield growth for cereals

How will this growth in demand be met? As shown in Table 8, very little incremental production will come from expansion of cereal crop area. Area harvested of wheat in developed countries will stabilize after the significant post-1982 drop resulting from declining cereal prices, policies to remove land from production, and the economic collapse in much of Eastern Europe and the former Soviet Union. However, growth in area will contribute little to future growth in production of wheat, with an annual growth rate for the world of 0·1 %, and only slightly higher growth rates in developing countries. Globally, only about

7×10^6 ha is projected to be added to the total wheat area of 22 $\times 10^6$ ha in 1993 (Table 8). Rice area will also be virtually stagnant, with an increase of only 4×10^6 ha projected to 2020, of which $\times 10^6$ ha will be in Sub-Saharan Africa. Area devoted to maize will increase slightly faster, with a projected expansion of 1 $\times 10^6$ ha, nearly half of which will be in Sub-Saharan Africa. The area of other coarse grains will increase by 1×10^6 ha, most of which will be again in Sub-Saharan Africa. Total cereal area is projected to increase by only 4 $\times 10^6$ ha between 1993 and 2020. More than half this expansion will be in Sub-Saharan Africa, where crop yields are very low.

The projected slow growth in expansion of crop area places the burden to meet future cereal demands on growth in crop yield. Table 9 shows the projected growth rates in annual yield for cereals. Although growth in yield will vary considerably by commodity and country, in general there is a projected continued decline in the rates of growth in crop yields compared with the already reduced rates of the 1982–94 period (see Table 4). The growth rate in yield for all cereals is projected to decline from 1·5%/year in 1982–94 to 1·0%/year in 1993–2020. For developing countries as a group, wheat yields are projected to grow at 1·3%/year (compared with 2·5%/year since 1982), maize yields at 1·4%/year (compared with 2·3%/year in 1982–94), and rice yields at 1·1%/year (compared with 1·8%/year; Tables 4 and 9).

For developed countries, growth rates in yield for all cereals are projected to decline between 1993 and 2020, as compared with the growth rates between 1982 and 1994. The growth rate in yield for wheat is projected to decline from 1·4%/year to 0·9%/year, for maize from 1·0%/year to 0·9%/year, and for other grains from 0·9%/year to 0·7%/year. Only the growth rate in yield for rice will recover slightly from 0·6% to 0·7%/year.

Projected demand for livestock

As shown in Table 10, *per capita* demand for meat will grow rapidly in developing countries, particularly in China and East and Southeast Asia. China's *per capita* meat demand is projected to grow 82% to 60kg in 2020, from 33kg in 1993. This level of meat consumption is substantially higher than that projected for Japan (49 kg *per capita*), and is closing the gap in the consumption levels of developed countries, where *per capita* meat consumption is projected to increase only slightly, from 78 kg to 83kg (7%). *Per capita* demand for beef and poultry will more than double in China, but the biggest absolute increase will be in pigmeat; the 1993 consumption of pigmeat was

Table 8. Cereal crop area (x10^6 ha), 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Wheat		Maize		Rice		Other grains		All cereals	
	1993	2020	1993	2020	1993	2020	1993	2020	1993	2020
China	29·9	29·	21·0	22·5	30·9	29·	6·9	6·8	88·6	89·0
India	24·3	25·	6·0	6·2	41·8	43·	27·3	27·5	99·4	102·4
Other South Asia*	9·3	9·8	1·7	1·8	14·4	14·	1·4	1·3	26·7	27·7
Southeast Asia	0·1	0·2	8·5	8·8	38·2	39·	0·4	0·4	47·2	48·7
Latin America	8·3	9·8	27·8	31·9	6·8	7·5	4·9	5·7	47·9	54·9
West Asia and North Africa	28·6	29·	2·4	2·7	1·5	1·7	23·1	25·1	55·6	59·0
Sub-Saharan Africa	1·1	1·5	20·1	27·2	6·1	8·3	35·2	50·9	62·4	87·9
Developing countries†	102·2	106·	88·2	101·9	141·7	146·	99·5	118·1	431·6	473·4
Developed countries†	118·2	120·	47·0	50·0	4·4	4·0	98·9	99·1	268·5	273·2
World	220·4	227·	135·1	151·9	146·1	150·	198·3	217·2	700·0	746·6

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Table 9. Projected growth rates in annual yield (%/year) for cereals, 199 –2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Wheat	Maize	Rice	Other grains	All cereals
China	0·91	1·40	0·72	0·42	1·00
India	1·56	1·81	1·43	0·88	1·45
Other South Asia*	1·48	1·85	1·55	0·70	1·53
Southeast Asia	0·37	1·88	1·29	0·55	1·39
Latin America	1·65	1·39	1·68	1·05	1·43
West Asia and North Africa	1·73	1·43	1·82	1·69	1·69
Sub-Saharan Africa	1·37	1·81	1·75	1·52	1·63
Developing countries†	1·33	1·40	1·11	1·14	1·21
Developed countries†	0·91	0·85	0·71	0·69	0·86
World	1·10	1·05	1·08	0·73	1·03

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

already twelve times that of beef, and five times that of poultry. For developing countries as a whole, *per capita* meat demand is projected to increase 43 % from 21 kg to 30 kg. For the USA and for all developed countries, *per capita* consumption of beef and pigmeat will decline, while poultry consumption will continue to increase, although not as rapidly as in the 1980s.

With continued growth in the population and rapid growth in per capita demand, the total demand for meat will grow very rapidly in developing countries, as shown in Table 11. Led by the very fast growth in demand in South-east Asia, Sub-Saharan Africa and China, total meat demand in developing countries will grow at 2·9 %/year to 2020, compared with the 0·5 %/year for the developed world. In 1993, developing countries accounted for 47 % of world meat consumption; in 2020, they are projected to account for 63 % of the meat demand, an increase of 112 %. Asia is projected to account for 42 % of the world demand for meat in 2020. China alone is projected to consume 28 % of the global meat consumption in 2020, up from 20 % in 1993.

Projected production of livestock

Most of the growth in livestock production will also take place in the developing countries, albeit at slower rates than during the 1982–94 period (Table 12). The rate of growth in production for all meat is expected to decline from 5·9 %/year in the 1982–94 period to 2·7 %/year in 1993–2020 in the developing world, and from 0·9 %/year to 0·7 %/year in the developed countries in the same periods. In absolute terms, China and the rest of Asia will show the greatest growth in production, in particular in pigmeat and poultry. Growth in production is more evenly distributed among the different meats for WANA, Latin America, and Sub-Saharan Africa.

Projected world food prices and international trade

The world food price implications of these projected outcomes are summarized in Table 13. The baseline projections results of IMPACT indicate that food production in the world will grow fast enough for real world prices of food to be falling, but at much slower rates than in the past two decades. Over the 27-year period, world wheat prices are projected to decline by only 10 %, compared with the 28 % drop between 1982 and 1995. Rice prices will fall by only 8 %, maize prices by 2 %, and coarse grain prices by 14 %. These price declines are extremely small compared with the rate of decline in prices over the last several decades. Moreover, projected real cereal prices will be

Table 10. *Per capita* food demand (kg/year) for all meat products, 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Beef		Pigmeat		Sheep and goat		All poultry		All meat	
	1993	2020	1993	2020	1993	2020	1993	2020	1993	2020
China	2·07	4·41	24·51	43·06	1·20	1·41	5·02	10·72	32·80	59·60
India	2·61	4·02	0·45	0·68	0·69	0·84	0·51	0·94	4·26	6·48
Other South Asia*	3·70	5·12	0·04	0·05	2·52	2·90	1·15	1·89	7·41	9·96
Southeast Asia	2·57	4·61	6·68	10·24	0·38	0·41	5·45	8·52	15·08	23·78
Latin America	22·22	27·11	7·49	9·51	1·01	1·19	15·20	21·24	45·92	59·05
West Asia and North Africa	6·22	7·34	0·13	0·14	5·40	6·20	7·96	10·03	19·71	23·71
Sub-Saharan Africa	4·09	5·48	1·19	1·46	1·65	1·80	1·91	2·36	8·84	11·10
Developing countries†	5·25	7·36	9·03	12·80	1·51	1·86	5·03	7·67	20·82	29·69
Developed countries†	25·21	25·76	29·38	29·35	2·83	3·16	20·30	24·68	77·72	82·95
World	9·84	10·67	13·71	15·78	1·81	2·09	8·54	10·73	33·90	39·27

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Table 11. Demand ($x10^6$ t) for all meat products, 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Beef		Pigmeat		Sheep and goat		All poultry		All meat	
	1993	2020	1993	2020	1993	2020	1993	2020	1993	2020
China	2·4	6·4	28·8	61·4	1·4	2·0	5·9	15·3	38·6	85·0
India	2·4	5·1	0·4	0·9	0·6	1·1	0·5	1·2	3·8	8·3
Other South Asia*	1·1	2·6	0·01	0·02	0·7	1·5	0·3	0·9	2·1	5·0
Southeast Asia	1·2	3·0	3·1	6·7	0·2	0·3	2·5	5·7	7·0	15·6
Latin America	10·3	17·9	3·5	6·3	0·5	0·8	7·0	14·0	21·2	38·9
West Asia and North Africa	2·3	4·7	0·05	0·09	2·0	4·0	2·9	6·4	7·3	15·2
Sub-Saharan Africa	2·1	5·7	0·6	1·5	0·8	1·9	1·0	2·5	4·5	11·6
Developing countries†	22·4	46·6	38·6	81·1	6·4	11·8	21·5	48·6	88·9	188·2
Developed countries†	32·2	35·8	37·5	40·7	3·6	4·4	25·9	34·3	99·3	115·2
World	54·6	82·4	76·1	121·9	10·1	16·2	47·4	82·9	188·2	303·3

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Table 12 Projected annual growth rates (%/year) of meat production, 1993–2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Beef	Pigmeat	Sheep and goat	All poultry	All meat
China	3·56	2·77	1·52	3·59	2·92
India	2·84	2·16	2·12	3·51	2·76
Other South Asia*	2·75	1·24	2·44	2·58	2·61
Southeast Asia	3·23	2·99	2·09	3·17	3·08
Latin America	1·96	2·27	2·15	2·49	2·19
West Asia and North Africa	2·28	1·72	2·50	2·60	2·48
Sub-Saharan Afric	3·69	3·38	2·46	3·54	3·40
Developing countries†	2·59	2·73	2·17	3·01	2·73
Developed countries†	0·62	0·36	1·11	1·16	0·70
World	1·53	1·76	1·78	2·09	1·78

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Table 13 Real world prices of meat and cereals, baseline scenario, 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	World prices (US$/t	
	1993	2020
Beef	2023	1768
Pigmeat	1366	1209
Sheep and goat	2032	1842
Poultry meat	1300	1157
Wheat	148	133
Maize	126	123
Rice (standard	275	252
Other coarse grains	122	105

Table 14 Net trade for cereals and meat (x10^6 t), 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	Cereals		Meat	
	1993	2020	1993	2020
China	–0·94	–46·18	0·85	0·77
India	1·28	–7·07	0·11	–0·05
Other South Asia*	–4·54	–21·07	0·00	–0·75
Southeast Asia	–3·18	–5·39	0·14	0·52
Latin America	–16·04	–12·96	0·61	0·22
West Asia and North Africa	–38·21	–74·65	–1·40	–3·77
Sub-Saharan Africa	–11·58	–24·86	–0·10	–0·66
Developing countries†	–93·86	–226·06	–0·61	–5·42
Developed countries†	93·86	226·06	0·61	5·42
World	0·00	0·00	0·00	0·00

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

particularly strong through the year 2010. Aggregate cereal prices are projected to be constant through 2010, wheat prices will drop only by 2%, other coarse-grain prices will decline by 7%, maize prices will be constant, and rice prices will increase by 7%. It is only after 2010 that the continued decline in the rate of growth in the population, combined with declining income elasticities of demand for cereals, will combine to reduce the growth in demand enough to cause cereal prices to drop more sharply. Livestock prices will also remain relatively strong throughout the projections period. Beef prices are projected to drop by 13%, pigmeat prices by 11%, sheep and goat prices by 9%, and poultry prices by 11%.

This slow decline in prices will be accompanied by rapidly-increasing world trade in food, with the primary impetus for expanded trade resulting from the developing world's increase in food imports from the developed world. Table 14 shows that the projected net cereal imports of developing countries will increase by 140%, from 94×10^6 t in 1993 to 226×10^6 t in 2020. Wheat imports will sho the biggest absolute increase, more than doubling from 63×10^6 t in 1993 to 12×10^6 t in 2020. The biggest increases in wheat imports are projected to be in WANA (up by 2×10^6 t), other South Asia (increasing by 1×10^6 t, of which Pakistan accounts for 1×10^6 t) and China, which will increase wheat imports from $\times10^6$ t in 1993 to about 20×10^6 t in 2020.

The increase in exports of maize from developed countries to developing countries is the highest in percentage terms, with a more than threefold increase from 18×10^6 t in 1993 to 6×10^6 t in 2020. It should be noted that trade among developed countries causes the aggregate exports of maize (and other commodities) from developed countries to be lower than the exports of some individual developed countries. Japan, for example, is a major importer of maize, at 1×10^6 t in 1993. Exports of other coarse grains and rice from developed countries also increase to 2020, although the latter increase is small.

A major beneficiary of increased cereal import demand from the developing world will be the USA, which is projected to increase its cereal exports by more than 50%, from 8×10^6 t in 1993 to 13×10^6 t in 2020. Wheat exports from the USA are projected to increase by 2×10^6 t and maize exports by 2×10^6 t. Another important development for international cereal markets is the projected shift of Eastern Europe and the former Soviet Union from importers of 27×10^6 t in 1993 to exporters of 3×10^6 t in 2020. Removal of food subsidies and other price-distorting policies, combined with sharply lower incomes, have already resulted in falling *per capita* cereal consumption in these regions. Improvements in feeding efficiency in the livestock industry and a projected gradual recovery in

incomes will cause growth in production to outstrip growth in demand.

The developing countries are projected to increase their meat imports from $0{\cdot}6\times10^6$ t in 1993 to 5×10^6 t in 2020. Most of the increase during this period will take place in Sub-Saharan Africa (Table 14), which will see growth of almost 600 % to approximately 1×10^6 t. WANA will more than double its imports of meat over this period, importing $3{\cdot}8\times10^6$ t in 2020, up from $1{\cdot}4\times10^6$ t in 1993. At the same time, Southeast Asia will increase its exports of meat by more than 270 %, from $0{\cdot}14\times10^6$ t to $0{\cdot}52\times10^6$ t, while exports from Latin America will drop almost 65 % from $0{\cdot}61\times10^6$ t to $0{\cdot}22\times10^6$ t. Exports from China will also drop, and India will become a small net importer of meats in 2020 under the baseline scenario.

Food security: malnutrition of preschool children

What is the impact of these global supply and demand developments on food security in the developing countries? Table 15 shows the projected number of malnourished preschool children (less than 5 years of age) under the baseline scenario. It can be noted in Table 15 that, despite the availability of food on a global level to meet effective demand at slowly-declining world prices, there will be a worsening of food security in many developing countries, particularly in Sub-Saharan Africa, and only relatively slow improvement in other regions. In Sub-Saharan Africa, the baseline projection foretells only a slight improvement in *per capita* food and energy availability; thus the percentage of the preschool population who are malnourished remains virtually unchanged. The implication is a substantial increase (41 %) in the absolute number of malnourished children, from twenty-seven million to thirty-eight million, because of the rapid rate of population expansion in the region. Although India shows significant progress in reducing malnutrition, it is projected to remain the home of forty-nine million malnourished children, approximately one-third of the world's total. For developing countries as a group, it is projected that the number of malnourished children will decline by only 21 %, from 185 million in 1993 to 147 million in 2020.

Table 15. Number (million) of malnourished children under 5 years of age, 1993 and projected 2020 (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

	1993	2020
Latin America	10	6
Sub-Saharan Africa	27	38
West Asia and North Africa	8	6
India	76	49
Other South Asia*	24	19
Southeast Asia	16	11
China	24	16
Developing countries†	185	147

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Impact of reduced meat demand in developed countries: alternative scenarios

As noted in the introduction, many analysts have argued that a reduction in meat consumption in developed countries would enable the release of cereals for human food consumption, and generate significant improvements in nutritional status in the developing countries. In order to examine the effects of reduced meat demand in developed countries, we compare the baseline results with the results of two alternative scenarios. The first alternative scenario, which we will call reduced meat demand (RMD)-I, simulates a progressive and dramatic reduction over time in *per capita* meat demand in developed countries. This scenario is implemented by setting the initial income elasticity of demand in developed countries at 0·0 and imposing a linear reduction in the income elasticity of demand over time so that each developed country reaches an income demand elasticity of –1·0 for livestock products (beef, pigmeat, sheep and goat meat, and poultry meat) in 2020; i.e. for every 1 % change in *per capita* income in developed countries, there will be a 1 % decrease in meat demand. The resulting projected *per capita* meat demand in developed countries as a whole in 2020 is approximately half the *per capita* meat demand in 1993.

In the second alternative scenario, RMD-II, the reduction in meat demand is combined with a compensating increase in cereal consumption in developed countries. This compensating effect is simulated by increasing the income elasticities of demand over time for direct human consumption of wheat, rice, maize and other coarse grains in developed countries in order to maintain the same level of projected energy consumption in 2020 as in the baseline scenario. In the following sections, we examine the impact of these alternative scenarios on world prices and demand for cereals and meat, on *per capita* consumption of food and energy, and on the number of malnourished children in developing countries.

Projected world prices

The primary means by which reduced meat demand in developed countries can affect food consumption in developing countries is the price mechanism. Reduced demand for meat will directly reduce the world price of meat, making meat more affordable for consumers in developing countries. This reduced meat demand and drop in meat prices will also cause a direct reduction in meat production in both developed and developing countries, which will reduce the demand for cereals for animal feed. Reduced feed demand for cereal will in turn cause a drop in prices of cereals, inducing an increase in food demand for cereals.

The impact of the alternative scenarios on world prices of cereal and meat is shown in Table 16. The pattern of 1993–2020 price changes relative to the baseline scenario, however, varies from commodity to commodity. As would be expected under the reduced meat demand scenarios, projected real meat prices are considerably lower in 2020 than under the baseline scenario. For the RMD-I scenario, 2020 prices for beef, pigmeat, sheep and goat meat, and

poultry are lower by 31, 22, 23 and 23% re spectively. Meat prices under RMD-II are just slightly higher than under RMD-I.

The effects of reduced meat demand in developed countries on cereal prices are, however, much less pronounced. Under RMD-I, the fall in global demand for maize and coarse grains as livestock feed results in projected 2020 maize and coarse-grain prices being respectively 11 and 10 % lower than in the baseline scenario. The impacts are still smaller on global wheat and rice prices, which are 5 % and only 1% lower respectively in 2020 than under the baseline. Under RMD-II, with the additional pressure on cereals demand arising from increased cereal consumption in developed countries, there is an actual increase in the real wheat price compared with the baseline projection, and rice prices remain virtually unchanged. Maize and other coarse-grain prices are 10 and 7 % below baseline projections (Table 16).

The price impact on cereals is smaller than might be expected, because a large share of the market adjustments to the reduction in meat demand are worked out through changes in the livestock supply, demand, and international markets rather than through changes in cereals markets. This will be shown in greater detail when we describe changes in cereal demand and supply (pp. 230–232). Moreover, the price effects on wheat and rice, which are the primary food staple cereals in developing countries, are particularly small because of the small share of these crops that is used for animal feed. Reduced demand for maize and other coarse grains for livestock feed in developed countries does not t ranslate into reduced prices for rice and wheat in developing countries.

Projected per capita *demand for cereal and meat*

Table 17 summarizes projected *per capita* food demand for meat under the alternative scenarios. Under the RM scenarios, *per capita* meat demand in the developed countries is projected to be 39kg in 2020, compared with the 83 kg projected under the baseline scenario. The lower meat consumption in the developed countries and the resulting decline in world meat prices induce increased meat consumption in the developing countries. Under RMD-I, average *per capita* meat demand for developing countries as a group in 2020 increases from the 2 9·7kg in the baseline to 33· 5kg, a 13 % increase. Projected *per capita* and total meat demand in developing countries under RMD-II is virtually identical to that under RMD-I.

In contrast to the outcomes in *per capita* meat consumption under the RMD scenarios, the projected increase in *per capita* food consumption of cereals in the developing countries is small compared with the baseline projection for 2020 (Table 18). As was shown in Table 16, real world prices for cereals decline only slightly relative to the baseline, and demand for these commodities is relatively price-inelastic (i.e. the price elasticities of demand for these cereals are low), so there is only a small increase in *per capita* food consumption of these commodities. Under RMD-I, *per capita* food consumption of cereal for food is 2·5 kg, or 1· 5% higher, in 2020 than in the baseline scenario. Under RMD-II, *per capita* cereal consumption is only 0·5 kg higher than in the baseline scenario in developing countries. Thus, there is essentially no improvement in cereal consumption in developing countries when the reduction in meat demand in developed countries is accompanied by an increase in cereal consumption to maintain energy

Table 16 Projected real world prices (US$/t) of major commodities under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
Commodity	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Beef	2023	1768	1214	1223
Pigmeat	1366	1209	942	947
Sheep and goat	2032	1842	1416	1424
Poultry meat	1300	1157	894	900
Wheat	148	133	126	135
Maize	126	123	109	111
Rice	286	252	249	251
Other coarse grains	122	105	94	98

Table 17 Projected *per capita* food demand (kg/year) for meat under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
Region	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Developing countries*	20·8	29·7	33·5	33·4
Developed countries*	77·7	83·0	38·6	38·7
World	33·9	39·3	34·4	34·4

* For details, see p. 219.

levels in the developed countries. *Per capita* cereal demand for food in developed countries in the RMD-I scenario increases by 1·8 kg, or 1·3 %, in 2020 relative to the baseline scenario. The exogenously imposed increase in cereal consumption in RMD-II causes a 30 kg *per capita* (21 %) increase in cereal demand for food in developed countries relative to the baseline 2020 projections.

Projected demand, production and trade for cereal and meat

Table 19 summarizes projected demand, production, and trade for meat, and Table 20 shows food, feed and total demand, production and trade for cereal under these scenarios. In developing countries, total demand for meat (which consists only of food demand) is projected to reach 212×10^6 t in 2020, 13 % higher than the baseline projection, in both RMD scenarios. In contrast to demand, production of meat in developing countries falls by 12 % under the RMD scenarios relative to the baseline scenario. The lower meat prices resulting from the reduction in meat demand in developed countries, while benefiting consumers in developing countries, also reduce the incentives and incomes of livestock producers in developing countries. With demand increasing and production declining, relative to the baseline prediction, there is a huge increase in meat imports into developing countries by 2020 under this scenario, from 5×10^6 t under the baseline scenario to 51×10^6 t, or nearly one-third of total meat demand.

As can be seen also in Table 19, the exogenous reduction in meat demand in the alternative scenarios results in a dramatic drop in meat demand in developed countries in 2020, from a baseline projection of 115×10^6 t to only 53×10^6 t. The drop in meat production in developed countries, induced by more rapidly falling meat prices, is, however, not nearly as dramatic. The RMD scenario projects a decline in meat production in developed countries of 16×10^6 t, or 13 %, as compared with the baseline projection. Why is the drop in meat production in developed countries much smaller than the drop in demand? Specification of the autonomous downward shift in meat demand in developed countries (implicitly due to changes in dietary preferences) causes meat prices to decline. As meat prices decline, meat production (supply) in both developed and developing countries falls and demand in developing countries increases. Supply, demand and prices equilibrate at a global level, with production declines in developed countries accounting for only part of the adjustment to the autonomous demand shift. To illustrate the adjustment dynamics, although perhaps through oversimplification, this outcome can be viewed as a partitioning of the 62×10^6 t decline in developed countries' meat demand (relative to the baseline) into a 16×10^6 t drop in developed countries' production, a 22×10^6 t fall in developing countries' production and a 24×10^6 t increase in meat demand in developing countries.

As a result of these supply and demand adjustment dynamics, feed demand for cereals in developed countries

Table 18. Projected *per capita* food demand (kg/year) for all cereals under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
Region	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Developing countries*	171·6	169·7	172·3	170·2
Developed countries*	144·1	140·4	142·2	174·4
World	165·3	164·4	166·8	171·0

* For details, see p. 219.

Table 19. Projected demand, production, and trade in meat (x10^6 t) under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Developing countries*				
Total demand	89	188	212	212
Production	88	183	161	161
Trade	–1	–5	–51	–51
Developed countries*				
Total demand	99	115	53	53
Production	100	120	104	104
Trade	1	5	51	51
World				
Total demand	188	303	265	265
Production	188	303	265	265
Trade	0	0	0	0

* For details, see p. 219.

drops far less than would be expected from looking only at the isolated effects of a decrease in meat demand in developed countries. As Table 20 shows, feed demand in developed countries under RMD-I is projected to be 38×10^6 t less (9%) than that in the baseline scenario. Total demand for cereals in developed countries will drop by 42×10^6 t, or 5%, as compared with the baseline projection. Under RMD-II, total cereal demand in developed countries in 2020 will actually be higher than that in the baseline scenario, because the exogenously-imposed increase in cereal consumption to offset the decline in meat consumption will be greater than the drop in feed demand.

Total demand for cereals will also drop slightly in developing countries under RMD-I as compared with the baseline projection, with the 1×10^6 t increase in food demand offset by a 3×10^6 t decline in feed demand because of the fall in meat production. Developing countries' production falls by 27×10^6 t compared with the 2020 baseline because of lower cereal prices, and cereal imports increase by 1×10^6 t. Under RMD-II, food demand for cereals is virtually identical to that of the baseline scenario, but feed demand and production remain below the baseline projection.

Projected energy availability and child malnutrition

The previous discussion shows that cutting meat consumption by half in developed countries would result in increases in developing countries of about 13% in *per capita* meat consumption and 1·5% in *per capita* cereal consumption. Tables 21 and 22 summarize the effects of these changes in consumption on projected total energy availability and proportion of malnourished preschool children in developing countries. In these estimates, the projected growth in social expenditures, women's access to education, and access to clean water are kept at the same rates as in the baseline projections. The changes in malnutrition of children shown in Table 22 are therefore fully attributable to the changes in energy availability due to changes in food consumption resulting from reductions in meat consumption in developed countries.

In the RMD-I scenario, the improvement in projected daily *per capita* energy availability in developing countries due to reduced meat consumption in developed countries is projected to be only 167kJ (40kcal) *per capita* (1·4%) in 2020, increasing from an average of 11·8 MJ (2818 kcal) *per capita* in the baseline projection to 12·0MJ (2858kcal) *per capita* in RMD-I. The gains in energy consumption vary from country to country, with the greatest benefits going to those developing countries that consume a relatively larger amount of meat in their diets. Thus, China will increase energy consumption by 177kJ (65kcal) (2·1%) and Latin America by 259kJ (62kcal; 2%) compared with the baseline projection. In India, where meat consumption accounts for only 1% of energy consumption, energy consumption increases by only 75 kJ (18 kcal) *per capita* (0·6%). When reduced meat consumption in developed countries is compensated for by increased cereal consumption (RMD-II), the already small improvements in energy consumption in developing countries are cut by half, to an average of 84kJ (20 kcal) *per capita*. In India and other South Asian countries, energy consumption in RMD-II is actually lower than that in the baseline scenario because the increase in wheat prices reduces wheat consumption, thus eroding the improvements in meat, maize and other coarse-grain consumption.

The fundamental reason that the impact on developing countries of dietary patterns in developed countries is small was shown previously; reduced meat consumption in developed countries simply does not lead to large increases

Table 20 Projected demand, production, and trade (x10^6 t) in cereal under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Developing countries*				
Food demand	734	1076	1092	1077
Feed demand	194	409	376	375
Total demand	1022	1634	1617	1600
Production	928	1407	1380	1394
Trade	–93	–226	–237	–206
Developed countries*				
Food demand	184	195	198	242
Feed demand	442	519	481	477
Total demand	752	858	816	864
Production	845	1084	1052	1069
Trade	93	226	237	206
World				
Food demand	918	1270	1290	1319
Feed demand	636	928	857	852
Total demand	1773	2491	2433	2464
Production	1773	2491	2433	2464
Trade	0	0	0	0

* For details, see p. 219.

in meat and cereal consumption in developing countries. In fact, some of the increase in meat consumption is due simply to the substitution of meat products for milk, eggs, fats, and oils brought about by the diversification of diet. Finally, the large reduction in meat prices and loss of production in developing countries (together with smaller reductions in cereal prices and production) results in a decline in growth in income in agriculture, which further dampens demand growth for food. The order of magnitude of these effects in the RMD-I scenario can be illustrated for the case of China. The increase in meat demand in China boosts energy consumption by 230 kJ (55 kcal) *per capita*, and increased cereal consumption adds 96 kJ (23 kcal) *per capita*. Consumption of potatoes, sweet potatoes, (*Ipomoea batatas*) and cassava increases slightly (because of declines in prices), adding 21 kJ (5 kcal) *per capita*. Substitution in consumption from milk, eggs, and fats and oils to meats reduces energy consumption by 33 kJ (8 kcal) *per capita*. A reduction in growth of *per capita* income of 0·25 %/year due to slower growth in the value of agricultural production reduces the energy consumption from other commodities (including fish, sugar, fruits, and vegetables) by 42 kJ (10 kcal) *per capita*. The net effect of these changes is the 77 kJ (65 kcal) increase in consumption relative to the baseline projection, as shown in Table 21.

Table 22 summarizes the effects of increased energy consumption on the projected number of malnourished children under 5 years of age. Following directly from the small energy effects, reduced meat consumption in the developed world has only a small impact on the number of malnourished preschool children in the developing countries. Under the RMD-I scenario, the number of malnourished children in developing countries in 2020 declines by 3·6 million children, or 2·5 %, to 142·9 million children, compared with the baseline projection of 146·5 million malnourished children. Under the RMD-II scenario, there is a reduction of

Table 21. Projected daily *per capita* energy availability (MJ (kcal)/d) under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
Region	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Latin America: MJ	11·4	12·8	13·1	13·0
kcal	2730	3054	3116	3101
Sub-Saharan Africa: MJ	9·2	9·9	10·1	10·0
kcal	2199	2372	2414	2393
West Asia and North Africa: MJ	12·6	13·3	13·4	13·3
kcal	3030	3179	3205	3183
India: MJ	10·0	11·7	11·8	11·7
kcal	2397	2795	2813	2793
Other South Asia*: MJ	9·6	11·0	11·0	11·0
kcal	2297	2619	2637	2617
Southeast Asia: MJ	10·6	11·8	11·8	11·8
kcal	2525	2808	2828	2821
China: MJ	11·2	12·9	13·2	13·1
kcal	2680	3087	3152	3134
Developing countries†: MJ	10·6	11·8	12·0	11·9
kcal	2523	2818	2858	2839
Developed countries†: MJ	13·5	14·1	13·4	14·2
kcal	3223	3379	3204	3385
World: MJ	11·2	12·2	12·2	12·3
kcal	2684	2919	2920	2938

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

Table 22. Projected number (million) of malnourished children under 5 years of age under alternative scenarios (Data generated using the international model for policy analysis of agricultural commodities and trade; see pp. 222–223)

		2020		
Region	1993	Baseline	Reduced meat demand-I	Reduced meat demand-II
Latin America	10·1	6·2	5·9	6·0
Sub-Saharan Africa	27·4	38·1	36·9	37·5
West Asia and North Africa	7·6	6·3	6·1	6·2
India	76·0	48·5	47·9	48·6
Other South Asia*	23·8	19·5	19·2	19·5
Southeast Asia	16·1	11·0	10·8	10·9
China	24·4	16·8	16·1	16·3
Developing countries†	185·3	146·5	142·9	145·0

* Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka.
† For details, see p. 219.

only 1·5 million in the number of malnourished children in developing countries compared with the baseline, and there is a slight worsening of malnutrition in India, because of the reduction in wheat consumption described previously.

Conclusions

The present paper examined the future evolution of global cereal and meat demand, supply and trade, and assessed the impact of a decline in meat consumption in developed countries on food security in developing countries. The long-term prospects for food supply, demand and trade indicate a strengthening of world cereal and livestock markets. World prices of these commodities will decline much more slowly than in the past several decades. The stronger price picture is the result of the continued gradual slowing in the rate of growth in both production and demand. On the production side, with the exception of Sub-Saharan Africa and parts of Latin America, there will be virtually no growth in crop area. Growth in crop yield, therefore, will account for nearly all growth in production, but in most countries and regions the gradual slowdown in crop yields that began in much of the world in the earl y1980s will continue. Livestock production will grow considerably faster than crop production, but will also slow down relative to the growth in production in the past decade.

Countering the continued gradual slowing of production will be a matching decline in the growth rate in food demand. Rates of growth in population will be declining throughout the projections period, particularly in developing countries. Rising incomes and rapid urbanization, particularly in Asia, will change the composition of demand. These trends will lead to an extraordinary increase in the importance of developing countries in global food markets. A full 8 2% of the increase in global cereal consumption, and approximately 90% of the increase in global mea tdemand between 1993 and 2020 will come from the developing countries. By 2020, developing countries will a ccount for 6 5% of global cereal demand an d 62% of global meat demand.

Despite the relatively favourable global outlook, the improvement in food security in the developing world will be slow, with the number of malnourished children projected to decline from 185·3 million in 1993 to only 146·5 million in 20 2 0 (21%). Moreover, changes in the dietary patterns in developed countries are not an effective route to improvement in food security in developing countries. A decline in consumption of livestock products in the developed countries has virtually no impact on food security for developing countries. As would be expected, there will be more livestock products available in the global market, leading to lower prices in developing countries, where consumers shift consumption to include more meat. The reduced demand for feed for maize and other coarse grains also causes a decline in prices of these commodities, but there is little impact on prices of wheat and rice, the main staple foods in most developing countries and, therefore, little gain in consumption of these staples. The overall effect on energy consumption in developing countries, therefore, is very small. Consequently, the projected number of malnourished preschool children in the developing countries will show very little reduction relative to the baseline results.

Reduction in meat consumption in developed countries may improve the health of people in these countries, but it will not have a major impact on better nutrition of the poor in developing countries. As was shown by Rosegrant *et al*. (1995) significant progress on malnutrition in developing countries will require: economic growth that generates employment and reduces inequality and poverty; investments in agricultural and rural development; investments in agricultural research and technologies and in health and education; the development of infrastructure such as irrigation, domestic water supply, good roads, communications and effective markets, in order to increase agricultural productivity, household incomes and food security.

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