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GLOBAL FOOD DEMAND AND THE CONTRIBUTION OF LIVESTOCK AS WE ENTER THE NEW MILLENNIUM

by

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Abstract

People in developed countries currently consume about 3 to 4 times as much meat and fish, and 5 to 6 times as much milk products per capita as in developing Asia and Africa. Meat, milk, and fish consumption per capita has barely grown in the developed countries as a whole over the past 20 years. Yet poor people everywhere clearly desire to eat more animal protein products as their incomes rise above poverty level and as they become urbanized. Growth in per capita consumption and production has in fact occurred in regions such as developing Asia, and most particularly China. Per capita consumption of animal proteins and use of cereals as feed in Asia have both grown in the 3 to 5 percent per annum range over the past 20 years. By 2020, according to IFPRI's IMPACT model projections, the share of developing countries in total world meat consumption will expand from 47 percent currently to 63 percent. Of the global total projected increase in meat consumption, 40 percent is from pork, 30 percent is from poultry and 24 percent is from beef. The latter helps mitigate the otherwise much larger decline in real beef prices expected through 2020. Projected annual growth in meat consumption in China of 3.2 percent per annum through 2020--up from 8.3 percent per annum from the early 1980's to the early 1990's, drives these results.

A rapidly expanding supply of feedgrains will be essential to achieving the desire production increases for livestock products without undue upwards pressure on grain prices, especially in view of the role of monogastrics and the relative increase in industrial production in developing countries. IMPACT projections under various technical and economic assumptions suggest that there is enough production supply response in world systems to accomplish these production increases smoothly. Sensitivity analysis of the impact of restrictions on China's ability to produce more feedgrains illustrates that in a system of linked global markets for cereals and livestock products, such restrictions are not effective at lowering Chinese livestock consumption, which is driven by global trade in manufactures, although they do lower Chinese livestock production. The resulting imbalance raises world feed costs by one-third in 2020 over anticipated levels, encourages increased livestock exports from Latin America, discourages livestock exports from the U.S., and reduces meat and cereals imports and consumption in the poorer countries of Africa and Asia.

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Introduction

Food products of animal origin have played a key role as suppliers of human food calories and protein in virtually all parts of the world since the beginnings of recorded history. Over the last couple of centuries, progressive economic differentiation between North and South in the world, and within parts of the South, have led to the present pattern where the "developed" countries--principally the industrial countries of North America, Europe, Japan and a few others--typically consume three to four times the meat and fish and five to six times as much milk per capita as in the developing countries of Asia and Africa. However, this is all about to change.[1]

Recent trends in global consumption of food products of animal origin

In the first half of the 1990s, people in the developed countries directly consumed 78 kg of meat and 22 kg of fish per capita as food, with higher amounts in the U.S. and lower amounts in some of the European countries. The corresponding figures in Sub-Saharan Africa were 9 kg of meat and 8 kg of fish per capita. In developing Asia, people ate 18 kg of meat and 11 kg of fish, compared to 46 kg of meat and 9 kg of fish in Latin America. (FAOSTAT 1997; Westlund 1995).

At 100 kg liquid milk equivalents (LME)/capita/annum, milk consumption levels at the present time are much higher in Latin America than elsewhere in the developing world, in part due to a long tradition of large stock-raising, but also due to high levels of urbanization, similar to the developed countries. Three Latin Americans out of four live in towns, as in the developed countries, and unlike China, a few other parts of Asia, and most of Sub-Saharan Africa, where the reverse proportion holds. Even so, consumption of milk products in Latin America is still about forty percent less than in the developed countries on average, even though it is four times higher than in Africa, and about three times higher than in developing Asia.

While the consumption of animal products is generally high in developed countries--and especially the U.S.-- at the present time, it is quite low in most of the developing world. This can be seen in detail in Table 1, where average figures for the early 1970s are compared to the early 1980s and 1990s. China and India account for nearly 40 percent of the world's population, yet the consumption of all animal products combined, including fish and milk, represented only 6 percent of caloric intake in the early seventies, increasing to 15 percent for China in the 1990s and remaining at 7 percent in India, the latter largely for cultural and religious reasons. Similarly, animal products accounted for between 15 (India) and 28 percent (China) of human digestible protein intake in those countries in the early 1990s. These figures may be compared to 28

percent of caloric intake and 64 percent of protein in the U.S. in the early 1990s.

Table 1--Percent of food calories and protein from animal products, 1973-1993

	Percent of calories from animal products			Percent of protein from animal products		
Region	1973	1983	1993	1973	1983	1993
			(percent)			
China	6	8	15	12	14	28
India	5	6	7	12	14	15
Other East Asia	7	11	15	21	29	38
Other South Asia	8	7	9	19	19	22
Southeast Asia	6	6	8	22	23	25
Latin America	16	17	18	39	42	46
WANA	10	11	9	21	25	22
Sub-Saharan Africa	7	7	7	21	23	20
Developing world	8	9	11	19	21	26
Developed world	28	28	27	55	57	56
United States	31	29	28	68	66	64
World	15	15	16	34	34	36

Source: FAOSTAT 9/17/97.
Notes: "Animal products," using the FAO definition, includes meat, dairy and egg products, and freshwater and marine animal products. Calculated from three year moving averages. WANA is Western Asia and North Africa.

The low average consumption figures for the developing world are further accentuated by the fact that average total caloric intakes of food in those countries are already much lower than in the developed countries. Finally, the low average figures mask considerable variation across individuals. There is little reason to suspect that increased calories and protein from animal sources would be harmful to the vast majority of people in developing countries; on the contrary, it would probably help solve some major nutritional deficiencies. Meat, fish, eggs, and dairy products provide protein of high biological value which is

often a good compliment to the limiting amino acids in the plant foods consumed so heavily in the diet of persons in the developing countries (Latham 1997).

Furthermore, there is considerable value in diversity of diets for nutritional purposes as well as palatability. Micronutrient deficiencies (such as vitamin A and iron) in countries where diets consist primarily of bulky starchy staples (such as rural China) can in part be dealt with through greater use of foods of animal origin. Animal products also provide a more concentrated form of calories, which can be useful in areas where bulky and low caloric value foods in the diet produce satiation before nutritional needs are met (Latham 1997). Animal products have historically been the major means used around the world to diversify caloric sources away from an over-reliance on starchy staples.

The data on caloric and protein intake in Table 1 show that there has been very little increase in the shares of total human calories and protein derived from animal products over the last twenty-some years in the already-diversified developed countries: 1 percent for calories and 2 percent for protein. Both shares have in fact fallen in the U.S., and remained static in the developed countries as a whole. However, the increase in the shares of animal products in China and other East Asian countries have been dramatic, of the order of 250 percent over twenty years, from a low base.

East Asia is in fact the only part of the world where livestock consumption is becoming relatively much more important over time, and the effect there is so important that it will drive world livestock markets for the next twenty years at least, as will be shown below. Furthermore, all the results that follow conservatively assume that India will preserve its preference for vegetarian or non-beef diets for religious and cultural reasons. If this should change for any reason, the effect on world meat markets of the increased demand from the sub-continent would be major.

Table 2 shows which animal products are increasing most in demand. From the early 1970s to the early 1990s, consumption per capita of poultry virtually doubled in the developed countries, and milk and pork consumption increased marginally. In the developing countries, most of the increase in consumption of livestock products came from milk (+11 kg/capita/annum), pork, (+5 kg/capita/annum), and poultry and eggs (each + 3 kg/capita /annum). Over the twenty year period, beef consumption fell 2 kg/capita in the developed countries and rose 1 kg/capita in the developing countries.

Table 2--Annual per capita human food consumption (kg) and percent of calories from selected livestock products, 1973 and 1993

	Developed Countries		Developing Countries	
Commodity	1973	1993	1973	1993
Beef	26	25	4	5
	(3%)	(3%)	(1%)	(1%)
Mutton and goat	3	3	1	1
	(1%)	(1%)	(0%)	(0%)
Pork	26	29	4	9
	(4%)	(5%)	(2%)	(3%)
Poultry	11	20	2	5
	(1%)	(2%)	(0%)	(1%)
Eggs	13	13	2	5
	(2%)	(2%)	(0%)	(1%)
Milk and products excluding butter	188	195	29	40
	(9%)	(9%)	(2%)	(3%)
Four meats	67	78	11	21
	(10%)	(11%)	(3%)	(6%)
Four meats, eggs, and milk	268	285	42	65
	(20%)	(21%)	(6%)	(9%)

Sources: FAOSTAT 12/10/97 and Rosegrant *et al.* 1997. When 1993 observations differed slightly between original FAO data and Rosegrant *et al.* because of rounding, the Rosegrant *et al.* figure was chosen to maintain consistency.

Notes: "Four meats" includes beef, pork, mutton and goat, and poultry. Percentages of total food calories consumed directly by humans accounted for by the item and location shown are given in parentheses. Values are three year moving averages centered on the year shown; percentages are calculated from three year moving averages. Throughout this report the term "food" will be used to distinguish direct food consumption by humans from uses of animal products as feed, fuel, cosmetics, or coverings.

Per capita consumption levels are in fact far more likely to change in developing countries than in developed ones. First, consumption levels per capita are so much lower in developing countries than in developed ones that satiation is not yet a factor. There is widespread empirical evidence that meat demand in developing countries increases more rapidly than disposable income (Ahmed and Gruhn 1995). Second, urban populations in developing countries are currently growing at 3.5 percent per annum, compared to 0.75 percent in the developed countries (United Nations 1995). Urbanization is thought to be the key non-income factor explaining the growth of animal protein consumption. Finally, income per capita in some regions of the developing world, such as China and much of the rest of Asia, have grown rapidly to date (6 to 9 percent per annum above inflation), whereas 3 percent is considered to be the maximum sustainable real growth rate in many developed countries.

Furthermore, changes in per capita consumer behavior in developing countries are likely to have much larger global impact than changes in the developed world. First, the developing countries have a much larger share of the world's population, about 77 percent in the early 1990s. Second, they have much higher overall population growth rates: 1.9 percent per annum currently, compared to 0.4 percent per annum in the developed world (United Nations 1996).

The differential capacity for growth in consumption of animal products between developed and developing countries shows up clearly for meat in Table 3. For beef, for example, growth of 0.1 percent per annum in total consumption in developed countries implies a notable decline in per capita consumption in those countries of the order of 0.3 percent per annum, given an average population growth of 0.4 percent. Yet in developing countries, a 3.1 percent per annum growth rate in total beef consumption from the early 1980s to the early 1990s is still consistent with a 1.2 percent annual *increase* in per capita consumption of beef in those countries. These differences between developed and developing are even stronger for pork and poultry.

Note that these increases in meat consumption occurred over a period when cereals prices were falling faster than meat prices. Real cereals prices fell 38-46% (depending on the grain) between the early 1980s and early 1990s while real meat prices fell only 23-35% (calculated from price data in Table 13). The price of beef rose from 21 times to 25 times the price of maize and from 6.6 times to 9 times the price of rice. The price of pork rose from 14 times to 17 times the price of maize and from 4.4 times to 6.2 times the price of rice.

Table 3--Past and projected consumption trends of various meats, to the year 2020

Region	Annual growth of consumption 1982-1993	Projected annual growth of consumption 1993-2020	Total consumption			Per capita consumption		
			1983	1993	2020	1983	1993	2020
	(percent per year)		(million MT)			(kg)		
Developed world								
Beef	0.1	0.3	32	32	35	27	25	25
Pork	0.9	0.2	34	38	40	29	29	29
Poultry	3.3	0.9	19	26	33	16	20	24
Meat	1.2	0.5	88	99	113	74	78	81
Developing world								
Beef	3.1	2.8	16	22	47	5	5	7
Pork	6.1	3.0	20	39	85	6	9	13
Poultry	7.4	3.1	10	22	50	3	5	8
Meat	5.3	2.9	50	89	194	15	21	31

Sources: Annual growth of meat consumption 1982-1993 is the compound growth rate from regressions fitted to FAO annual data (FAOSTAT 12/10/97). Total and per capita meat consumption 1983 and 1993 are calculated from FAOSTAT 12/10/97. Projections are from Rosegrant *et al.* 1997. When 1993 observations differed slightly between the two sources because of rounding, the Rosegrant *et al.* figure was chosen to maintain consistency.

Notes: "Consumption" is direct use as food, uncooked weight bone-in. "Meat" includes beef, pork, mutton and goat, and poultry. Metric tons and kilograms are three year moving averages centered on the year shown. WANA is Western Asia and North Africa.

Projections of meat consumption to the year 2020

Presently, there are no reliable disaggregated estimates of milk or fish consumption on a global scale for more than a few years into the future.[2] About the best available for milk, given data problems, is an estimated growth rate for total dairy products production and consumption in developing countries of about 2.5 percent per annum through the year 2010 (Alexandratos 1995). This is consistent with a per capita growth rate of roughly 0.6 to 0.7 percent. A similar exercise for fish suggests that consumption in the developing countries will grow from 9.3 kg/capita in 1988/90 to 13.7 kg/capita in 2010, consistent with a 1.8 percent per capita growth rate per annum (Westlund 1995).

For meat, we are fortunate that there is a major global modeling effort, running to the year 2020, to draw insights from, and these can be disaggregated by major country grouping and major animal group. The body of work in question is the IMPACT model estimated at the International Food Policy Research Institute (last revision May 1997).[3] The main strengths of this model for present purposes are that it was built with a great deal of detail to the developing countries, the livestock sector is relatively disaggregated by product, the links between cereals feed markets and livestock markets are carefully specified, and both feed and meat prices are endogenously determined, which is very unusual for these models. This allows the model to simulate much more closely the real-world livestock system, where livestock production is closely tied to the availability and cost of feed, yet consumption can be satisfied by trade, with repercussions for prices and quantities of cereals and livestock products all over the world.

Recent levels of consumption of major meats in the developed world and the developing countries are shown for the early 1980s and 1990s in Table 3, as are IMPACT model projections of meat consumption and actual and projected rates of growth of consumption by major product. In the developed world, only poultry consumption has grown at a high rate (3.3% p.a.) since the early 1980s, and this rate is likely to fall to 0.9 percent from now until 2020 (or approximately 0.5 percent per capita per annum). On the other hand, consumption of all meats soared in the developing countries since the early 1980s, especially in the cases of pork and poultry (here collectively referred to as the "monogastrics"). Demand is projected to continue for these items at about 3 percent per annum through 2020.

Comparison of total meat consumption levels in the center portion of Table 3 to figures per capita in the right-hand portion underscore a fundamental point often lost in debates on meat consumption in developed countries. This is that the low consumption levels per capita in developing countries need to be measured against the fact that 7 out of 10 people in the world live in those countries, and this proportion is increasing every year. Thus whereas the

developed countries as a group ate more meat in total and for each major meat species than did developing countries in the early 1980s, this had changed for pork by the early 1990s, and was no longer true for all meats in the late 1990s. By 2020, the developing countries will eat 70 percent more meat than the developed countries, although their per capita consumption is projected to be only 38 percent of developed country levels, compared to 20 percent in the early 1980s.

The locus of this blockbuster change in world meat consumption patterns can be seen in Table 4. Meat consumption in China--accounting for over a fifth of the world's population--grew at 8.3 percent per annum from the early 1980s to the early 1990s, followed by the rest of developing Asia at 5.4 percent. This can be compared to 1.8 percent in the U.S. and even less in Europe. Growth of consumption in developing countries is expected to remain around 3 percent through the period to 2020, whereas it will only grow at 0.5 percent in the developed world as a whole, with little growth per capita. Meat consumption per capita in the developing countries is expected to double by 2020, led by poultry and pork. By the early 1990s, the Chinese were eating on average about the global average amount of meat per capita, up from about half the global average in the early 1980s. By 2020, the Chinese are projected by IMPACT to consume 63 kg of meat per capita, which is beginning to approach the 1992-94 average for the developed countries of 78 kg.

Table 5 provides detail for production of principal meat types by major region. China is the only major region examined where the share of beef in total meat production increased from the early 1980s to the early 1990s, although at 5 percent in the latter period, it is still much lower than just about anywhere else in the world. On a global scale, the share of beef in total meat fell from 33 to 27 percent, even though aggregate production of beef increased by a total of 16 percent from the early 1980s to the early 1990s.

Recent and projected trends in meat production

Meat production growth rates from the early 1980s to the early 1990s exceeded consumption in our country groupings only in vegetarian India and in the meat-satiated U.S. In the other country groupings, the reverse is true, as shown by comparing Tables 4 and 6. More than four-fifths of the total actual increase in world meat production since the early 1980s has been in developing countries; China alone accounted for almost half of the increase in world production, as suggested by the figures in

Table 4--Past and projected consumption trends of meat, to the year 2020

Region	Annual growth of meat consumption 1982-1993	Projected annual growth of meat consumption 1993-2020	Total meat consumption			Per capita meat consumption		
			1983	1993	2020	1983	1993	2020
	(percent per year)		(million MT)			(kg)		
China	8.3	3.2	17	39	89	16	33	63
India	3.1	3.0	3	4	8	4	4	7
Other East Asia	5.4	2.6	2	4	8	22	44	70
Other South Asia	5.4	3.3	1	2	5	6	7	10
Southeast Asia	5.4	3.6	4	7	18	11	15	28
Latin America	3.2	2.2	15	21	38	40	46	57
WANA	2.6	2.7	5	7	15	20	20	23
Sub-Saharan Africa	2.1	3.4	4	5	11	10	9	11
Developing world	5.3	2.9	50	89	194	15	21	31
Developed world	1.2	0.5	88	99	113	74	78	81
United States	1.8	0.6	25	31	37	107	118	114
World	2.8	1.8	139	188	306	30	34	40

Sources: Annual growth of meat consumption 1982-1993 is the compound growth rate from regressions fitted to FAO annual data (FAOSTAT 9/17/97). Total and per capita meat consumption 1983 and 1993 are calculated from FAOSTAT 9/17/97. Projections are from Rosegrant *et al.* 1997. When 1993 observations differed slightly between the two sources because of rounding, the Rosegrant *et al.* figure was chosen to maintain consistency.

Notes: "Consumption" is direct use as food, uncooked weight bone-in. "Meat" includes beef, pork, mutton and goat, and poultry. Metric tons and kilograms are three year moving averages centered on the year shown. WANA is Western Asia and North Africa.

Table 5--Production of beef, pork, poultry, and share of beef in location total meat production, 1983 and 1993

	Beef		Pork		Poultry		Share of beef in total location meat production	
Region	1983	1993	1983	1993	1983	1993	1983	1993
			(million MT)				(percent)	
China	0.3	2.5	14.1	29.5	1.3	6.0	2	5
India	1.0	2.5	0.3	0.4	0.1	0.5	32	31
Other East Asia	0.2	0.3	0.7	2.1	0.2	1.0	18	16
Other South Asia	0.5	1.1	0.0	0.0	0.2	0.3	30	24
Southeast Asia	0.5	1.1	1.8	3.3	1.3	2.6	13	11
Latin America	9.1	11.0	3.3	3.4	3.5	7.4	54	50
WANA	0.9	1.6	0.0	0.0	1.4	2.5	23	21
Sub-Saharan Africa	2.2	2.1	0.3	0.6	0.6	0.9	48	41
Developing world	14.7	22.0	20.5	39.3	8.6	21.0	28	22
Developed world	32.3	32.6	34.8	36.8	17.2	26.4	35	32
United States	10.7	9.8	6.7	7.7	5.9	12.5	43	34
World	47.1	54.6	55.3	76.1	25.8	47.4	33	27

Sources: FAOSTAT 12/9/97 and Rosegrant *et al.* 1997. When 1993 observations differed slightly between original FAO data and Rosegrant *et al.* because of rounding, the Rosegrant *et al.* figure was chosen to maintain consistency.

Notes: "Meat," used in the calculation of the last two columns, includes all meats reported by FAOSTAT 12/9/97. Values are three year moving averages centered on the year shown, and refer to carcass weights. WANA is Western Asia and North Africa.

Tables 6 and 7. By the early 1990s, China produced more meat in aggregate than did the Unites States, a fact many in the U.S. may find surprising.

Total world meat production is projected to increase 63 percent by 2020 over the levels of the early 1990s, which themselves were 31 percent over the levels of the early 1980s, as shown in Table 8. By 2020, China alone is projected to account for almost 30 percent of world meat production, at levels comparable to total production in the developing world (including China) in the early 1990s. Latin America is also projected to see major increases in production, adding an extra 21 million metric tons to world production by 2020. Finally, as if more were needed to make the point, the developing countries as a group are projected to increase their current market share of just under half of world meat production to 59 percent in 2020.

Actual increases in production since the early 1980s have largely followed the geographic and species evolution of consumption, as can be seen by comparing Tables 4 and 6, and again 3 and 8 above. Although the monogastrics have accounted for most of the production increases world-wide since the early 1980s, beef production in developing countries has also grown at the respectable rate of 2.8 percent per annum, and is projected to continue at 2.4 percent, even as the rate of growth of monogastrics slows down as the base that is growing becomes larger. Together, beef and pork production in the developing countries is projected to amount to 20 kg per capita in 2020, which may be compared to 54 kg consumption per capita in the early 1990s in developed countries.

Sensitivity of projections to assumptions about China

Clearly China plays a preponderant role in influencing world consumption trends for meats. Although the IMPACT model was developed with China very much in mind, it is fair to ask if these startling results are driven by overly optimistic assumptions in the model. Key assumptions concern changes in feed conversion ratios over time, rates of growth of cereals yields, and rates of growth (or decrease) in cropped acreage, all of which are controversial issues for China.

These key assumptions were tested in a special "pessimistic scenario" for China in the IMPACT model, discussed in further detail in the section on feed issues below. The pessimistic scenario assumes three "bads" for domestic production of livestock in China. First, a steady secular increase in feed conversion ratios is introduced, to account for the growth of industrial production of monogastrics in China, leading to a 62 percent increase in China in feed needs per kg of meat by 2020. Second, the rate of decline of

Table 6--Past and projected production trends of meat, to the year 2020

Region	Annual growth of meat production 1982-1993	Projected annual growth of meat production 1993-2020	Total meat production			Per capita meat production		
			1983	1993	2020	1983	1993	2020
	(percent per year)		(million MT)			(kg)		
China	8.3	3.1	17	39	89	16	34	62
India	3.3	2.7	3	4	8	4	5	6
Other East Asia	4.5	2.5	1	4	7	20	31	57
Other South Asia	4.6	2.6	2	2	4	6	7	8
Southeast Asia	5.4	3.1	4	7	16	10	16	25
Latin America	2.7	2.1	17	22	38	44	48	58
WANA	3.8	2.5	4	6	11	17	19	18
Sub-Saharan Africa	1.6	2.1	3	4	8	9	8	7
Developing world	5.2	2.7	51	88	182	15	21	29
Developed world	1.2	0.8	92	100	124	77	78	89
United States	2.3	1.1	24	31	41	105	118	128
World	2.8	1.8	143	188	306	30	34	40

Sources: Annual growth of meat production 1982-1993 is the compound growth rate from regressions fitted to FAO annual data (FAOSTAT 12/9/97). Total and per capita meat production 1983 and 1993 are calculated from FAOSTAT 12/9/97. Projections are from Rosegrant *et al.* 1997. When 1993 observations differed slightly between the two sources because of rounding, the Rosegrant *et al.* figure was chosen to maintain consistency.

Notes: "Meat" includes beef, pork, mutton and goat, and poultry, carcass weights plus fifth quarter. Metric tons and kilograms are three year moving averages centered on the year shown. WANA is Western Asia and North Africa.

Table 7--Location shares of total world production of meat, 1983 and 1993

	Beef		Pork		Poultry		Meat	
Region	1983	1993	1983	1993	1983	1993	1983	1993
				(percent)				
China	1	4	26	40	5	11	12	21
India	2	2	1	1	1	1	2	2
Other East Asia	1	1	1	1	1	1	1	1
Other South Asia	1	1	0	0	1	1	1	1
Southeast Asia	1	2	3	4	5	6	3	4
Latin America	19	21	6	4	14	17	12	12
WANA	2	2	0	0	5	6	3	3
Sub-Saharan Africa	5	4	0	1	2	2	3	3
Developing world	31	38	37	51	33	46	36	47
Developed world	69	62	63	49	67	54	64	53
United States	23	21	12	10	23	25	17	16

Source: FAOSTAT 12/9/97.

Notes: "Meat" includes all meats reported by FAOSTAT 12/9/97. Values are calculated from three year moving averages centered on the year shown, and include carcass weight. WANA is Western Asia and North Africa.

Table 8--Past and projected production trends of various meats, to the year 2020

Region	Annual growth of production 1982-1993	Projected annual growth of production 1993-2020	Total production			Per capita production		
			1983	1993	2020	1983	1993	2020
	(percent per year)		(million MT)			(kg)		
Developed								
Beef	0.4	0.8	32	33	40	27	25	29
Pork	0.9	0.4	35	37	41	29	29	30
Poultry	2.8	1.2	17	26	37	14	20	27
Meat	1.2	0.8	92	100	124	77	78	89
Developing								
Beef	2.8	2.4	17	22	42	4	5	7
Pork	6.1	2.8	21	39	84	6	9	13
Poultry	7.4	3.0	9	21	46	3	5	7
Meat	5.2	2.7	51	88	182	15	21	29

Sources: Annual growth of meat production 1982-1993 is the compound growth rate from regressions fitted to FAO annual data (FAOSTAT 12/9/97). Total and per capita meat production 1983 and 1993 are calculated from FAOSTAT 12/9/97. Projections are from Rosegrant *et al.* 1997. When 1993 observations differed slightly between the two sources because of rounding, the Rosegrant *et al.* figure was chosen to maintain consistency.

Notes: "Meat" includes beef, pork, mutton and goat, and poultry, carcass weights plus fifth quarter. Metric tons and kilograms are three year moving averages centered on the year shown. WANA is Western Asia and North Africa.

cropped cereal area in China, due to growing urban and industrial use of land, is assumed to increase by one-fifth. Third, the rate of growth of cereals yield in China is assumed to decrease by one-fifth, assuming a lack of investment in irrigation and agricultural research.

These changes in China-specific assumptions in a large model such as IMPACT play out through backwards and forwards effects in both feed and meat markets in each of the 37 country groupings in the model; resulting price changes elicit changes in production, consumption, and trade patterns that--as in the real world--reverberate throughout the world system until a new set of market-clearing world prices is achieved. Thus the impact of the "pessimistic scenario" depends not only on the parameter estimates used for China, but also on the structure of the whole model. The "pessimistic scenario" results serve primarily to show how sensitive (or insensitive) the main conclusions are to assumptions.

As explored in more detail in the next section, the main impact of the pessimistic assumptions is felt through the assumed secular increase in the feed ratio. The other two assumptions work to lower the capacity of China to produce more feed grain. The consequent rises in meat prices elicit adjustments in consumption patterns, higher world feed grain and meat prices, and increased imports of feed grains and meat. The net effect is to lower projected world meat consumption and production by 7 million metric tons by 2020, or about 2.3 percent. Chinese meat production falls 6 million metric tons, implying that less than 1 million metric tons of production decreases are spread throughout the rest of the world.

Projected consumption of meat in developed countries in 2020 falls about 1 million metric tons or less than 1 percent. In China it falls 2 million metric tons, or about the same percentage as for the world as a whole. The other four million metric ton decrease in consumption comes from developing countries other than China, where higher meat and feed grain import prices slow down the growth in meat consumption. *The implications of this fundamental insight should not be overlooked: in a system of global markets, the impact of slowing down production increases in livestock for China is felt primarily in reduced livestock consumption in other developing countries, where consumption per capita is still quite low.*

The expansion of livestock production is intimately connected to feed issues in real life, and feed assumptions in the IMPACT model. Therefore it seems relevant to explore the bases for assumptions about the relationship of livestock production to feed availability. These questions involve issues such as the conditions under which systems can produce enough grain to meet the need for cereals in feed rations, the technical scope for substituting things other than cereals into feed rations, the availability of those other materials, and the scope

for increasing the efficiency of use different kinds of feed through technical changes of different kinds. The next section will lay out how the IMPACT model handled the feed issue and explore the extent to which cereal-based feed supplies appear to be an issue.

Can the world produce enough cereals at reasonable price levels to meet emerging demands for feed?

Since the answer to this question is not independent of whether future food supplies will be adequate, the full details of this question go beyond the scope of the present paper. However, the projections to 2020 given above using IFPRI's IMPACT model provide insight into the issue, since the IMPACT model links food and feed projections with meat projections. Consumption increases in the model cannot be projected unless feed is forthcoming in sufficient amounts to meet production needs. Therefore the larger question can be addressed in part by looking at the assumptions that the IMPACT model makes about cereals feeds and their relation to demand and supply pressures for both food and feed. Particular attention is devoted to China, where size and structural change will be key to understanding future world food and feed markets.

Cereals feed demand in IMPACT is driven by livestock production, cereals feed ratios, own and cross-price relationships among feed crops, and an exogenously specified "efficiency parameter" that can be used to model exogenous technical progress or other secular changes affecting feed demand. Price and technical parameters are independently specified for each country or country grouping from independent studies or other data. The huge number of parameters mandates simplifying approaches. IMPACT therefore takes cereals as the limiting component of feed rations and models the interaction between feed supplies and livestock supplies through cereals markets, based on the situation existing during the early 1990s baseline period.[4]

The baseline "feed conversion ratios" in IMPACT are taken from the total amount of all cereals used as feed in the country in question during the early nineties divided by the total amount of meat produced in the same period. This provides the equivalent to the weighted average of cereals fed for each kg of meat produced, where the weights are the share of each kind of meat produced in the early 1990s in total meat production.[5] Priors about changes in the relationship between feed and livestock production can be entered through the country-specific "efficiency parameter."

The ratio between total cereals feed use and total meat production in the early 1990s was 1.92 to 1 in China and 4.82 to 1 in the US. The averages for developing and developed countries, respectively, were 2.42 to 1 and 5.0 to l. Note that a significant amount of cereals feed use in the developed countries was probably for egg and dairy production, although all cereals feed use is

ascribed here to meat. This and the greater use of natural pastures, household wastes, roots and tubers, and by-products for feeding in developing countries explains why their cereals feed ratios are lower than in the developed countries.

An increased allowance for the fact that China's burgeoning livestock production is likely to be increasingly comprised of poultry and swine produced under industrial conditions is embodied in secular decreases in cereals feed efficiencies in China under the "pessimistic scenario," such that the cereals feed conversion ratio in China increases steadily to reach 3.1 to 1 by the year 2020, a level intermediate between developed and developing countries currently.

On the cereals feed supply side, the IMPACT model is not out of line with a variety of projections for Chinese aggregate cereals production made by staff of diverse institutions (Fan and Sombilla 1997; Anderson *et al.* 1997). Rosegrant *et al.*'s projections for 2010 can be compared to the results from 5 competing models for China that are prominent in the literature, detailed in Table 9. Each of the models has a different approach to the issues. The very detailed study by Simpson *et al.* is from the animal science perspective of feed balance sheets. Huang *et al.* is based on parameters from detailed econometric estimation from Chinese data. The USDA and World Bank models are closer in spirit to IMPACT, while OECF is a limited partial equilibrium model of China, estimated in Japan. Both Huang *et al.* (Chinese Academy of Social Sciences) and World Bank are more optimistic than IMPACT about China's future grain production, whereas the other sources are less optimistic.

The Rosegrant "pessimistic scenario" explored above is on the pessimistic side of the eight scenarios. Even so, implementation of the pessimistic scenario in IMPACT, which imposed a steady secular rise of a total of 62 percent over 27 years in the feed conversion rate for China, a one-fifth increase in the rate of decrease of cropped area in Chinese cereals, and a one-fifth decrease in the rate of growth of Chinese cereal yields, had little effect on Chinese meat consumption patterns. It did raise world maize prices by one-third in the model, and reduced the meat available elsewhere in Africa and Asia.

Past and projected trends in use of cereals as feeds are shown in Table 10. Cereals feed use from the early 1980s to the early 1990s outstripped cereals production growth in all developing regions except for WANA, which has traditionally imported its meat. The reverse was true in most of the developed countries (but not the U.S.). The rate of growth of production exceeded the rate of growth of feed use for the world as a whole during this period, because of the preponderant role of developed countries in feeding cereals to animals.

Table 9--Alternative projections of grain production in China

Study		2010	2020	2025
			(million MT)	
Rosegrant *et al.* baseline		443	477	
Rosegrant's pessimistic scenario		419	440	
Simpson *et al.*	Economy robust	428		467
	Economy sluggish	421		437
Huang *et al.*		486	570	
ERS/USDA		403		
World Bank		483		
OECF		389		

Sources: Fan and Agcaoili-Sombilla 1997 for all except "Rosegrant *et al.* baseline" which was updated to reflect Rosegrant *et al.* 1997, and "Rosegrant's pessimistic scenario" which is from data supplied by the authors. Updated figures were adjusted as specified in Fan and Agcaoili-Sombilla 1997 to ensure comparability. Original sources are as follows: Rosegrant, Agcaoili-Sombilla, and Perez 1995; Simpson, Cheng, and Miyazaki 1994; Huang, Rozelle, and Rosegrant 1997; ERS/USDA 1996; Mitchell and Ingco (World Bank) 1993; Overseas Economic Cooperation Fund 1995. Rosegrant's pessimistic scenario is from personal communication with Mark Rosegrant.

Notes: All values were adjusted to reflect differences in the definition of grain in the original sources. Rosegrant's pessimistic scenario assumes a secular annual increase in feed conversion in China to reflect the industrialization of production over time, a 20% increase in the rate of decrease of cropped area, and a 20% decrease in the rate of increase in cereal yield in China.

Table 10--Past and projected trends in use of cereal as feed, to the year 2020

Region	Annual growth rates			Total cereal use as feed				Per capita cereal use as feed	
	Cereal production 1982-93	Cereal use as feed 1982-93	Projected cereal use as feed 1993-2020	1983	1993	2020	China pessimistic 2020	1993	2020
	(percent per year)			(million metric tons)				(kg)	
China	2.0	5.8	3.2	40[a]	73	171	259	62	120
India	3.2	3.5	3.0	2	4	8	8	4	6
Other East Asia	-2.0	6.7	2.5	4	11	22	20	115	183
Other South Asia	2.1	1.5	2.9	1	2	4	4	7	8
Southeast Asia	2.4	8.6	2.9	6	15	32	32	32	49
Latin America	0.7	2.5	1.9	38	54	90	88	118	137
WANA	3.9	1.8	2.1	23	34	60	59	92	94
Sub-Saharan Africa	4.1	5.3	2.3	2	2	4	4	4	4
Developing world	2.3	4.3	2.6	126	194	390	474	45	62
Developed world	0.2	0.1	0.7	453	443	536	512	346	386
United States	0.0	1.0	0.9	132	159	199	171	603	622
World	1.3	0.9	1.4	579	637	927	986	115	120

Sources: Production and use 1982-1993 growth are compound growth rates from regressions fitted to FAO annual data (FAOSTAT 12/8/97). Total and per capita use 1983 and 1993 are calculated from FAOSTAT 12/8/97. Projections are from Rosegrant *et al.* 1997 and further data provided by the authors.

Notes: Cereals includes wheat, maize, rice, barley, sorghum, millet, rye, and oats. Metric tons and kilograms are three year averages centered on the year shown. WANA is Western Asia and North Africa. "China pessimistic" assumes a secular annual increase in feed conversion in China to reflect the industrialization of production over time, a 20% increase in the rate of decrease of cropped area, and a 20% decrease in the rate of increase in cereal yield in China.

[a]Simpson, Cheng, and Miyazaki report 40 million MT from USDA ERS data. That figure is used here because it is more consistent with the feed quantities and feed/meat conversion ratios in Rosegrant *et al.* FAOSTAT (9/17/97) reports 49 million MT.

From the early 1990s to 2020, IMPACT projects that cereals feed use will grow at 0.5 percent per annum faster than cereals production in the world as a whole, although the rate of growth of feed use will generally slow down in developing countries. Under the baseline projections, China will need an extra 98 million tons of feeds in 2020 compared to the early 1990s. This projection includes three associated projections. First, there will be a 3.2 percent rate of growth of feed use (down from the observed growth of 5.8 percent per annum from the early 1980s to 1990s). Second, there will be a projected growth rate of total cereals production (not per capita) of 1 percent per annum through 2020 (down from an actual rate of 2 percent from the early 1980s to the early 1990s). Third, China will import 41 million tons of cereals in 2020 (about 8 percent of production). None of these items are historically incongruous.

Under the China pessimistic scenario, feed grain use expands 185 million tons in 2020 over levels observed in the early 1990s. This corresponds to 170 million tons of feed grain imports in 2020, or 29 percent of total grain demand in China in 2020 under that scenario. The pessimistic scenario is deemed feasible by the model, although whether the world system modeled would remain valid under that kind of change is debatable. It is much more likely that the "pessimistic" assumptions underlying this run would crumble, as Chinese authorities and entrepreneurs faced with such unmet grain demand (and rising grain prices) in China found ways to increase supplies more in line with the less pessimistic assumptions of the baseline model. World suppliers would also find better ways to supply China with meat in all probability. For present purposes, the meat consumption predictions of both models (baseline and pessimistic), which are very close to each other, seem robust.

Projected impacts on trade in livestock products

Meat trade, as measured by the difference between net consumption and net production by country in the early 1990s, concerned only a very small share of meat production, as suggested by Table 11. On a global basis and allowing for surpluses in some products and deficits in others, net exports from the developed countries to the developing countries as a whole were only of the order of 600,000 metric tons per annum in the early 1990s. This is equivalent to 0.3 percent of world production during the same period. China was a net exporter of 900,000 tons of meat per annum, compared to the U.S.'s net imports of 100,000 tons of meat. The big player was West Asia-North Africa (WANA), which had net imports of 1.4 million tons in the early 1990s. Although countries may have exported one meat and imported others, and otherwise have been more involved in world meat trade in a way not measured here, it is safe to say that livestock consumption in the early 1990s was largely from production originating within the same country or country grouping used for analysis.

Table 11--Total meat production, consumption, and net trade, 1993 and 2020

	Consumption		Production		Net Exports (Imports)	
Region	1993	2020	1993	2020	1993	2020
	(million MT)		(million MT)		(million MT)	
China	39	89	39	89	0.9	-0.4
India	4	8	4	8	0.1	-0.4
Other East Asia	4	8	4	7	-0.7	-1.6
Other South Asia	2	5	2	4	0.0	-0.9
Southeast Asia	7	18	7	16	0.1	-1.8
Latin America	21	38	22	38	0.6	0.6
WANA	7	15	6	11	-1.4	-3.3
Sub-Saharan Africa	5	11	4	8	-0.1	-3.4
Developing world	89	194	88	182	-0.6	-11.5
Developed world	99	112	100	124	0.6	11.5
United States	31	37	31	41	-0.1	4.7
World	188	306	188	306	0.0	0.0

Source: Rosegrant *et al.* 1997.
Notes: Net exports (imports) are defined as production minus consumption, subject to rounding error. Metric tons are three year averages centered on the year shown and refer to carcass weights. WANA is Western Asia and North Africa.

IMPACT projections suggest that this will change. Developed countries will export a net of 11.6 million metric tons of meat to developing countries in 2020. Beef will account for 46 percent of these net exports by weight, followed by poultry at 30 percent by weight, as shown in Table 12. By value, beef will account for an even larger share, given a more than 50 percent projected price premium. Beef exports will primarily come from the

Table 12--Net exports (imports) of various meats by location in 1993 and projected to the year 2020

	Beef		Pork		Poultry		Sheep/Goat	
Region	1993	2020	1993	2020	1993	2020	1993	2020
	(million MT)							
China	0.1	-0.2	0.7	-0.2	0.1	0.0	0.0	0.1
India	0.1	-0.2	0.0	-0.2	0.0	-0.1	0.0	0.0
Other East Asia	-0.4	-0.9	0.0	-0.1	-0.3	-0.6	0.0	-0.1
Other South Asia	0.0	-0.5	0.0	0.0	0.0	-0.3	0.0	-0.1
Southeast Asia	-0.2	-1.6	0.2	-0.2	0.1	0.1	0.0	0.0
Latin America	0.7	1.8	-0.2	-0.2	0.1	-1.0	0.0	0.0
WANA	-0.7	-1.6	0.0	0.0	-0.4	-1.0	-0.3	-0.7
Sub-Saharan Africa	0.0	-2.0	0.0	-0.5	-0.1	-0.5	0.0	-0.4
Developing world	-0.4	-5.3	0.7	-1.5	-0.5	-3.5	-0.4	-1.3
Developed world	0.4	5.3	-0.7	1.5	0.5	3.5	0.4	1.3
United States	-0.7	1.2	-0.3	0.4	0.8	3.1	0.0	0.0
World	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Rosegrant et al. 1997.

Notes: Metric tons are three year averages centered on the year shown, and refer to carcass weight. Net export (import) figures may not sum to zero overall because of rounding.

European Community (EC), Australia, and Latin America. Poultry exports will primarily come from the U.S.

The impact of the "pessimistic" scenario for China is most evident in the case of trade (although not shown in Tables 11 and 12). Chinese net imports of meat in 2020 rise from the modest 300,000 tons projected by the baseline IMPACT model to 3.8 million metric tons in the pessimistic scenario. Yet net exports from developed to developing countries only rise 6 percent, to 12.3 million metric tons. U.S. net exports of meat actually shrink by 9 percent, due to the rise in feed prices which encourages the export of feed grain and discourages the export of meat. Latin American net exports rise 1 million tons. Other developing countries in Asia and Africa reduce their imports of meat by 1.8 million metric tons. The increased demand for feed grain and higher meat prices implicit in the pessimistic scenario for China increases feed grain exports to China, primarily from the developed countries, and reduces meat imports in the developing countries other than China, primarily in Africa and Asia.

Impact on meat prices of the shifting locus of meat consumption in the world

Farmers everywhere cannot help but be conscious of the fact that the last two decades have seen serious erosion of the purchasing power of agricultural commodities in terms of manufactured goods. Livestock producers are no exception, as shown in the top half of Table 13. Prices in the table are converted to dollars with a constant purchasing power in terms of manufactured goods in 1990 U.S. dollars. The series show that both crop and livestock farmers have lost ground in terms of unit values of outputs. Cereals prices fell more than those of meat from the early 1980s to the early 1990s, but overall beef prices fell more than those of cereals from the early 1970s to the mid 1990s. Interestingly, exporters of higher end fisheries products have maintained the unit value of their output fairly constant in real terms, after a boom in the early 1980s and a bust in the early 1990s. As of writing (late 1997), feed grain prices have rebounded somewhat from the very low levels shown for 1993-95, however the long run outlook is for a fairly constant low real price over the long term.

The price projections of the IMPACT model are given in the second half of Table 13, compared to commodity price projections published by the World Bank using conventional commodity price projection techniques. The higher prices for beef in the IMPACT projections for 2010 (the only comparable year and commodity) are due to the fact that IMPACT takes into account the market-clearing effect of increased demand in developing countries on world livestock prices, which single-equation commodity price projections cannot. The rapid expansion of demand in Asia will support the

Table 13--Past and projected trends in real prices of selected crop, livestock, and fisheries exports

Year	Wheat	Rice	Maize	Soybeans	Soymeal	Beef	Pork	Poultry	Lamb	Shrimp	Skipjack	Fishmeal
						(constant 1990 US$/MT)						
1970-1972	$232	$524	$215	$476	$415	$5,144	n/a	n/a	$3,248	$12,603	n/a	$750
1980-1982	$236	$534	$169	$384	$338	$3,536	$2,344	$1,474	$3,730	$15,587	$1,029	$615
1990-1992	$135	$288	$104	$234	$195	$2,585	$1,781	$1,139	$2,440	$10,795	$946	$444
1993-1995	$139	$284	$99	$229	$179	$2,060	n/a	$1,100	$2,395	$11,285	$1,132	$367
World Bank projections												
2000	$135	$279	$102	$230	$189	$1,773	n/a	n/a	n/a	$11,610	n/a	n/a
2010	$118	$262	$92	$236	$196	$1,629	n/a	n/a	n/a	$9,850	n/a	n/a
Rosegrant *et al.* projections												
1992-4	$148	$286	$126	$263	n/a	$2,023	$1,366	$1,300	$2,032	n/a	n/a	n/a
2010	$145	$305	$126	$255	n/a	$1,929	$1,330	$1,232	$1,986	n/a	n/a	n/a
2020	$128	$260	$121	$250	n/a	$1,919	$1,288	$1,248	$1,923	n/a	n/a	n/a

Sources: Past data is from ERS 1997, Globefish 1997, IMF 1997, and World Bank 1993. World Bank projections and the Manufacturing Unit Value index used for expressing values in constant 1990 US dollars are from World Bank 1997. Rosegrant *et al.* projections are from Rosegrant *et al.* 1997.

Notes: Wheat is US no. 1, hard red winter, ordinary protein, export price delivered at Gulf ports for shipment within 30 days. Rice is Thai 5% broken, WR, milled, indicative survey price, government standard, fob Bangkok. Maize is US no. 2, yellow, fob US Gulf ports. Soybeans are US cif Rotterdam. Soymeal is any origin, Argentine 45/46% extraction, cif Rotterdam, prior to 1990, US 44%. Beef is Australian/New Zealand, cow forequarters, frozen boneless, 85% chemical lean, cif US port (East Coast), ex-dock. Pork is EC pork, slaughter wholesale price. Poultry is broilers, 12 city composite wholesale price, ready-to-cook, delivered. Lamb is New Zealand, frozen whole carcasses, wholesale price, Smithfield market, London. Shrimp is US, frozen, Gulf brown, shell-on, headless, 26-30 count per pound, wholesale price at New York. Skipjack is Southwest Pacific frozen Skipjack for which the 1980-82 observation is actually from 1983-85 data because earlier years were not available. Fishmeal is any origin, 64-65%, cif Hamburg, nfs. "n/a" indicates that comparable prices for those years are not available.

world beef price over where it would fall otherwise, even though real growth in beef prices is not expected.

The price series in Table 13 also demonstrate that it does not make much sense to debate world food availability in the aggregate sense without looking at the role of prices as a flexible mechanism to reallocate resources to increased production where necessary. The tremendous flexibility of the global production system in meeting expanded demand is hinted at by the more than twofold decline in world maize and soybean prices over 20 odd years, during a period when livestock production expanded by a factor of two.

The impact of the pessimistic production scenario for China on world livestock prices is to raise the projected 2020 world prices of beef, pork, and poultry by 6 to 6.6 percent over the 2020 baseline projected level. On the feed side, soybeans would be only 8 percent above the 2020 baseline projection in 2020, but maize prices would be 32 percent higher than the baseline projection. Even so, at 160 U.S. 1990 dollars/ton, maize in the 2020 pessimistic scenario would still be cheaper in real terms than in the early 1980s. According to IMPACT, the effect of feed production constraints in China coupled with higher growth in demand is to raise world maize prices high enough to elicit increased supply on world markets. China will import more meat and other developing countries will import a little less.

A final concern might be that under pessimistic assumptions about future livestock feed availability in China, the price rises this might induce in world markets for feed grains and meat would be too big for China to sustain over time. In other words, the parameters used to specify the IMPACT model might not hold up under 30 percent price changes (as opposed to 3 percent ones). However there is no evidence that this concern is warranted. The rise in demand for agricultural products in East Asia is powered by rapid export-led industrialization, which suggests that it can be met by imports if necessary; if anything demand is likely to be greater than forecast if China enters the WTO in 1999 (Anderson *et al.* 1997). Overall, the prospects for increased meat consumption in China do not seem to be much diminished.

What can we conclude for the future patterns of livestock production, consumption, and trade?

The first conclusion is that regardless of one's feelings about large projection models, historical trends clearly indicate that major patterns have been afoot with respect to world livestock consumption in the past 15 years. Developing countries, and especially those in East and Southeast Asia, are transforming world livestock markets. The desire to consume animal products appears to be very strong, and to be especially sensitive to increases in income

and urbanization, in addition to responding to the strong population growth currently observed in the developing world.

It is pointless to discuss the contribution of livestock to world food supplies without taking consumption in the developing countries themselves into account. Current livestock consumption levels are low in developing countries, and--on a country average basis at least--there is little ground for thinking that consumption of animal products is likely to be "too high" in developing countries anytime in the next two to three decades.

Some organizations have seen a danger in increased consumption of livestock products in that they project a consequent shortfall in cereals available for direct human consumption. Without attempting to debate the ethical issues, which probably cut in both directions, it seems imperative to better understand the real implications of what is being advocated.

Since the recent and projected rise in livestock consumption has occurred primarily in developing East Asia, and especially China, it would seem likely that some would seek to curb further expansion of livestock production in those areas. In an era of globalization of markets, the analysis cited above shows that this may have quite different effects from those intended. Policies intended to slow the growth of livestock consumption in China are not likely to be very effective at quelling the desire to consume meat in a country whose population is still three-quarters rural (like Africa), meat consumption is still relatively low, but where rapid income growth and urbanization from industrial development is fueling a rapid catch-up in consumption patterns.

Alternatively, policies to slow down the rise in Chinese livestock production could be effective since foreign finance (as in World Bank loans) and government funding of infrastructure investment and research are key to increased production. Lest some be tempted, they should consider the results of the "pessimistic" simulation, which suggests that consumption increases in China will be barely affected by difficulties in producing adequate feed grains domestically. Shortfalls in meat production in China are met by reduced meat imports into Africa and the rest of Asia, and by increased net exports from Latin America. Paradoxically, slowing the Chinese ability to convert resources into feed grain production is also likely to be an efficient way to raise world coarse grains prices, which in turn would be highly problematic to efforts to achieve food security in many poor countries, especially in Africa, which are projected to be net meat and grain importers by both IMPACT and virtually all other models.

Appendix Table 1--Regional classification of countries

Region	Member Countries
Other East Asia	Hong Kong, Macau, Mongolia, North Korea, and South Korea
Other South Asia	Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, and Sri Lanka
Southeast Asia	Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam
Latin America	South and Central America and Carribean
Western Asia and North Africa (WANA)	Algeria, Bahrain, Cyprus, Egypt, Gaza Strip, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates, Western Sahara, and Yemen
Sub-Saharan Africa	Africa south of the Sahara except for South Africa
Developed	Australia, Canada, Eastern Europe, European Union, other western European countries, Israel, former Soviet Union, Japan, New Zealand, South Africa, United States
Developing	All other countries in FAOSTAT
World	All countries included in FAOSTAT

Sources: Regional groupings were chosen based on FAOSTAT 12/10/97, which is consistent with classification in Rosegrant *et al.* 1997.

Note: Data from some small countries were not available in all series in all years. Missing values for very small countries are ignored without note.

Endnotes

1. The categorization of countries in this study follows usual practice at the Food and Agricultural Organization of the United Nations (FAO). Details are found in Appendix Table 1. Unless otherwise indicated, all data used in the present section originated from FAO sources. The reader should know that all data are in fact estimates, especially at such high levels of aggregation. As such, they are constantly under revision as new information becomes available. It is not unheard of for FAO to change its estimates of specific magnitudes several times as better information becomes available, even several years after the event. Wherever possible, we have used the most recent raw data at the time of writing, obtained from the FAO internet web site, and referred to as "FAOStat". This also explains why some of the figures may differ marginally from other estimates published in the literature. Finally, to minimize the effects of annual variation, all actual data are presented as three-year moving averages of annual data, centered around the year listed. Thus "1993" means the average of 1992, 1993, and 1994. As of writing, 1994 is the last year of data not subject to further major revisions. While such data always incorporate a degree of measurement error, the trends are so clear, so uniform, and so large that they surely are robust.

2. This is particularly surprising given the importance of these products to human nutrition and the rapid changes these sectors are undergoing. Rosegrant *et al.* (1997) included milk in their global modeling, but feel that the results are too unreliable, given the lack of strong disaggregated information on underlying parameters, for publication at the present time. FAO estimates of milk and fish consumption by 2010 (Alexandratos 1995) have some modeling input, but are very partial equilibrium estimates with little account taken of links among commodities or the impact of shifting relative prices. FAO estimates of fish consumption (Westlund 1995) basically are straight line projections dependent on assumed GDP and population growth.

3. This is reported on by its principal authors in Rosegrant *et al.* 1995 and Rosegrant *et al.* 1997. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model in its current form divides world agriculture into 37 countries and country groups, and 17 commodities. It uses parameters for production and consumption responses to prices and incomes, and disaggregated estimates of production relationships and their secular evolution over time. Population is assumed to grow exogenously at the rates estimated by the United Nations in its recently revised "middle variant". National income growth is assumed to follow historical trends. Links between agriculture and nonagriculture are partially incorporated. Particular focus in the model was

put on the cereals sector.

4. This approach neglects major non-cereal feed crops such as soybeans and alfalfa. Adding such crops would only alleviate feed constraints, which would only strengthen results offered. Making cereals the binding constraint in feed rations also facilitates consideration of the impact of livestock on non-animal origin human food staple availability.

5. This procedure provides a separate average cereals feed conversion applicable to each of 37 widely varying countries or regions. It also means that the model closely tracks reality in the baseline and near baseline period. However, it has the drawback that changes over time in the shares of different sorts of meat with different cereals feed requirements may introduce an error in feed requirements that could be serious if production shifts from range fed ruminants to intensively fed swine, say. It also assumes that non-cereals feeds keep up with cereals feed as production expands. This could be a problem where production systems are shifting from low cereal use systems (as in backyard poultry or swine) to industrial feedlots.

References

Ahmed, R., and P. Gruhn. 1995. Selected issues in the supply of and demand for red meat and poultry products in developing countries. In *Supply of livestock products to rapidly expanding urban populations*, ed. R. T. Wilson. Proceedings of the Joint FAO/WAAP/KAAS Symposium, Hoam Faculty Club, Seoul National University, Seoul, Korea, 16-20 May. Rome: Food and Agriculture Organization of the United Nations.

Alexandratos, N., ed. 1995. *World Agriculture: Towards 2010*. Rome: Food and Agriculture Organization of the United Nations.

Anderson, K., B. Dimaranan, T. Hertel, and W. Martin. 1997. Asia-Pacific food markets and trade in 2005: a global, economy-wide perspective. *Australian Journal of Agricultural and Resource Economics*. 41 (1) March, 19-44

ERS (US Department of Agriculture Economic Research Service). 1996. *Long term projections for international agriculture to 2005.* ERS Staff Paper No. 9612, August. Washington, D.C.

ERS (US Department of Agriculture Economic Research Service). 1997. World agriculture: Trends and indicators\World and regional data. <http://mann77.mannlib.cornell.edu/data-sets/international/89024/14/World.wk1>. Accessed 12/1/97.

Fan, S., and M. Agcaoili-Sombilla. 1997. Why projections on China's future food supply and demand differ. *The Australian Journal of Agricultural and Resource Economics* 41 (June): 169-190.

FAO (Food and Agriculture Organization of the United Nations). 1997. *The state of world fisheries and aquaculture*. Rome.

FAOSTAT (Food and Agriculture Organization of the United Nations, FAOSTAT database). 1997. <http://faostat.fao.org/default.htm>. Accessed September and December 1997.

Globefish (Fish Marketing Information Service of the Food and Agriculture Organization of the United Nations). 1997. Skipjack price series, 1983-1997. Rome.

Han, I. K. 1995. World production and consumption of animal products: common features and future developments. In *Supply of livestock products to rapidly expanding urban populations*, ed. R. T. Wilson. Proceedings of the Joint FAO/WAAP/KAAS Symposium, Hoam Faculty Club, Seoul National

University, Seoul, Korea, 16-20 May. Rome: Food and Agriculture Organization of the United Nations.

Huang, J., S. Rozelle, and M. W. Rosegrant. 1997. *China's food economy to the 21st century: Supply, demand, and trade*. 2020 Vision Discussion Paper No. 19. Washington, D.C.: International Food Policy Research Institute.

IMF (International Monetary Fund). 1997. *International financial statistics yearbook*. Washington, D.C.

Latham, M. C. 1997. *Human nutrition in the developing world*. FAO Food and Nutrition Series, No. 29. Rome: Food and Agriculture Organization of the United Nations.

Mitchell, D., and M. Ingco. 1993. *The world food outlook*. Washington, D.C.: International Economics Department, World Bank.

Overseas Economic Cooperation Fund, Research Institute of Development Assistance. 1995. Prospects for grain supply-demand balance and agricultural development policy. September. Tokyo, Japan.

Phelan, J. A., and J. Henriksen. 1995. Global issues in the supply of livestock food products to urban populations. In *Supply of livestock products to rapidly expanding urban populations*, ed. R. T. Wilson. Proceedings of the Joint FAO/WAAP/KAAS Symposium, Hoam Faculty Club, Seoul National University, Seoul, Korea, 16-20 May. Rome: Food and Agriculture Organization of the United Nations.

Rosegrant, M.W., M. Agcaoili-Sombilla, and N. Perez. 1995. *Global food projections to 2020: Implications for investment*. 2020 Vision Discussion Paper No. 5. Washington, D.C.: International Food Policy Research Institute.

Rosegrant, M. W., M. A. Sombilla, R. V. Gerpacio, and C. Ringler. 1997. Global food markets and US exports in the twenty-first century. Paper presented at the Illinois World Food and Sustainable Agriculture Program Conference "Meeting the Demand for Food in the 21st Century: Challenges and Opportunities for Illinois Agriculture," May 28, Urbana-Champaign.

Simpson, J. R., X. Cheng, and A. Miyazaki. 1994. *China's livestock and related agriculture: Projections to 2025.* Wallingford, UK: CAB International.

United Nations. 1995. *World Urbanization Prospects: The 1994 Revision*. New York.

United Nations. Department for Economic and Social Information and Policy Analysis. Population Division. 1996. *World population prospects*: *The 1996 Revision*. ST/ESA/SER.A/145.

Westlund, L. 1995. Apparent historical consumption and future demand for fish and fishery products--exploratory calculations. Paper presented at the International Conference on Sustainable Contribution of Fisheries to Food Security, December 4-9, Kyoto, Japan.

World Bank. 1993. *Price prospects for major primary commodities, 1990-2005,* volume 2. Washington, D.C.

_____. 1997. *Commodity markets and the developing countries*, August. Washington, D.C.