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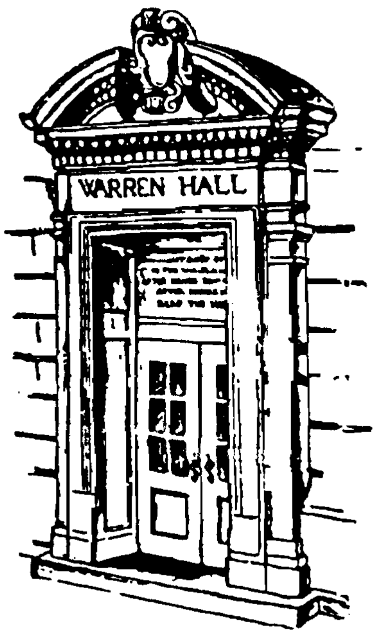

Working Paper

Department of Agricultural, Resource, and Managerial Economics
Cornell University, Ithaca, New York 14853-7801 USA

THE DEMAND FOR FOOD IN A WEALTHIER, MORE POPULOUS WORLD

Thomas T. Poleman

ABSTRACT

This paper focuses on the global demand for food during the next 50 years and offers a simple methodology for quantifying the impact rising incomes will have on per capita demand.

THE DEMAND FOR FOOD IN A WEALTHIER, MORE POPULOUS WORLD*

Estimating the world's human "carrying capacity" has intrigued the minds of men since even before the time, 200 years ago, when Malthus (1798) wrote his famous *Essay on the Principle of Population*, and, as might be expected, their conclusions have varied greatly. In his fascinating survey of the subject, Joel Cohen (1995:402-418) documents no fewer than 66 such inquiries, some serious, others less so, whose verdicts ranged from a half billion persons to an even 1,000 billion (Table 1). Among the more serious, E. G. Ravenstein (1891) in 1890, when global population was of the order of 1.5 billion, reckoned that there remained the potential to support another 4.5 billion. This was in a paper offered to the Geographical and Economic Sections of the British Association, and since much of the potentially productive land envisioned by Ravenstein lay in the tropics, those present went on to debate whether Europeans could survive for prolonged periods in such regions, there "to teach the natives the dignity of labor, and to lead him on to a higher plane of civilization" (Ravenstein 1891:31). Thirty-seven years later, at the first congress of the International Society of Soil Science, Penck (1928:108) calculated that food could be produced for almost 16 billion people; and 50 years after that Roger Revelle (1976:177) put the figure at 40 billion, if a high-starchy-staple-ratio diet of 2,500 calories daily were assumed.

Revelle's estimate was one of a number made in the mid-1970s, a time of heightened interest in agricultural matters because of the just-ended "World Food Crisis." Two others made about the same time are of interest because of the authors' competence and because they spelled out their methodologies in some detail. Colin Clark (1968), for many years Director of the Agricultural Economics Research Institute at Oxford, computed the amount of land per person needed to produce the ingredients of various diets. Using climate as the constraining factor, he calculated that sufficient land existed to support 47 billion people at the dietary level enjoyed in the United States in the 1960s—say, per capita availabilities of 3,250 kcals., of which 39 percent were derived from animal products and 22 percent from the starchy staples—or 157 billion people if the high-starchy-staple-ratio diet experienced by the Japanese people immediately after the war were postulated (Clark 1968:153).

Buringh and his associates (1975) in the Tropical Soil Science Department of the Agricultural University in Wageningen, The Netherlands, based their calculations on soils and their potential and expressed their findings in terms of grain equivalents. They calculated the world's maximum production potential to be of the order of 50 billion metric tons, but reduced this to 32.5 billion tons on the grounds that prevailing dietary patterns required only 65 percent of the cultivated area to be planted to cereals. This being 23 times the actual level of cereal production—1,400 million tons in 1974-76—it followed that the maximum number of people the world could feed was 23 times the then number of 4.1 billion: 93 billion people.

Apart from demonstrating that the world's food producing potential is huge, the usefulness of such calculations is questionable. Of necessity they incorporate heroic assumptions regarding land use, potential yields, and price incentives—assumptions which cannot be verified until long after the conclusions are forgotten. Further, no one seriously argues today that population growth is not amenable to control and that the number of people computed by Revelle, Clark, or Buringh will ever need to be fed. The approach to discussing the world's long-term ability to feed itself should therefore be the inverse of that conceptualized by Malthus. He reasoned that populations would increase to whatever whatever limit was set by the supply of food. Today it is far more realistic to take expected levels of population as the given

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and to consider whether the supply of food can be made to increase sufficiently to sustain them at whatever dietary level their income would warrant.

The first step, then, is to project demand, and the aim of this paper is to offer a simple methodology for doing this. More specifically, I will focus on a simple technique for quantifying the impact rising income will have on per capita demand. For just as rapidly growing population was the principal factor driving the huge growth in demand during the latter half of the 20th century, so rising incomes will be the chief propellant during the first 50 years of the 21st.

Table 1. Selected Estimates of the Number of People the Earth Could Support

Year of Estimate	Principal Author	Billion People	Year of Estimate	Principal Author	Billion People
1679	Leeuwenhoek	13.4	1967	DeWit	79-1,022
1695	King	6.3-12.5	1970	Hulett	1
1741	Sussmilch	4-6.6	1971	Austin & Brewer	40-60
1765	Sussmilch	13.9	1971	Ehrlich	0.5-1.2
1891	Ravenstein	6.0	1973	Muckenhausen	35-40
1898	Fircks	8.1	1973	Lieth & Blaxter	100
1902	Pfaundler	10.9	1974	Revelle	38-48
1917	Knibbs	132	1975	Buringh *et al.*	6.7
1924	East	5.2	1975	Whittaker & Likens	5-7
1924	Pearl & Reed	2	1976	Revelle	40
1025	Wickens	6-12	1978	Eyre & Blaxter	17
1925	Penck	7.7-15.9	1978	Marchetti	1,000
1925	Fischer	6.2	1979	Gilland	7.5
1935	Smith	5.7	1980	Kovda	14
1936	Pearl & Gould	2.6	1981	Mann	<4.5
1937	Hollstein	13.3	1981	Westing	2.0-3.9
1940	Boerman	5.6-13.3	1982	Gates	12
1945	Pearson & Harper	0.9-2.8	1983	Higgins *et al.*	4.-32.8
1946	Mukerjee	7.0-8.6	1984	Farrell *et al.*	6.1
1946	Salter	5	1986	Hardin	300
1947	Fawcett	6.5-10	1986	Calvin	22
1949	Spengler	1.8-7.2	1989	Hudson	9.8-19.3
1952	Darwin	6-10	1990	Chen *et al.*	2.8-5.5
1954	Brown	50	1991	Raven	<5.3
1957	Brown *et al.*	3.7-7.7	1992	Meadows *et al.*	7.7
1958	Clark	28	1992	Tuckwell & Koziol	23.8
1960	Baade	30	1993	Ehrlich *et al.*	much < 5.5
1961	Kleiber	16-800	1993	Heilig	12-14
1964	Fremlin	10^7-10^9	1994	Waggoner	>10
1964	Cepede *et al.*	10	1994	Pimentel *et al.*	3
1965	Schmitt	30	1994	Smil	10-11
1966	Zierhoffer	41	1994	Dutch Scientific Council	11-44
1967	Clark	47-157			

Source: Cohen, Joel E. 1995. *How Many People Can the Earth Support?* New York: Norton.

The Population Component

The population statistics are well known. The world's population remained essentially stable from biblical times to about 1650, when it stood at perhaps .5 billion. It reached 1 billion by 1800 and by 1950 stood at 2.5 billion, two-thirds of whom lived in the developing countries. There followed a half century of population explosion and in 1999 the world's population passed the 6 billion mark, a 2.5-fold increase in just 50 years; of these 6 billion, 90 percent are residents of developing countries. Though the population will continue to grow by about 80 million annually for the next two decades, it seems clear that the great population explosion will draw near to an end in most parts of the world by 2050.

The demographic transition—the process whereby a country's population moves from stability at a low level to a similar state with much higher absolute numbers—is among the best documented trends in recent history, its operation having been demonstrated in literally hundreds of investigations. In England, one of the better documented countries, the transition required almost 200 years, from 1750 to 1950, to run its course, during which time the population rose eight-fold, from 5 million to over 40 million (Figure 1). Even though the transition did not begin in earnest until about 1950 in most of today's developing countries, enough time has passed for it to be evident that it need no longer be such a lengthy process.

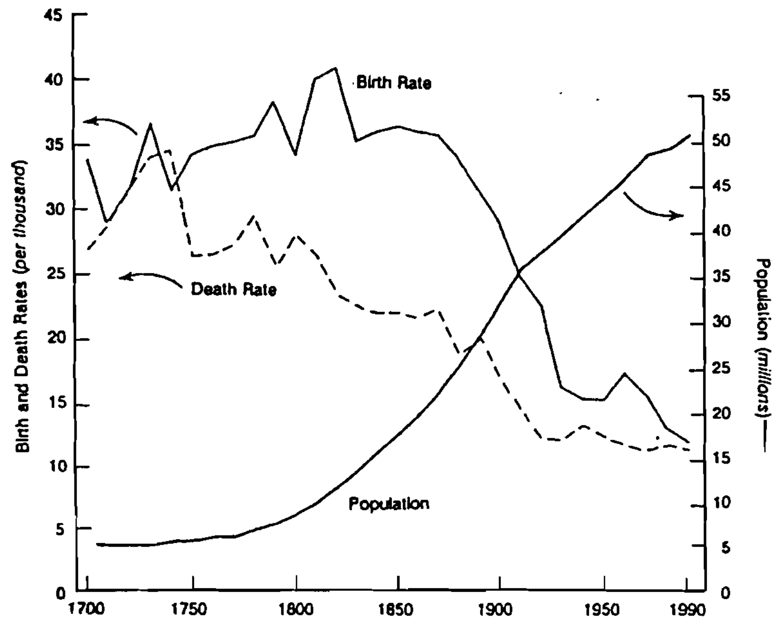
Birth rates are falling with unprecedented rapidity in the economically dynamic countries of Asia's Pacific Rim (Figure 2). In Singapore only 15 years were needed for it to fall from 40 per thousand to less than 20; one-tenth the time required in England. The decline in Hong Kong has been equally dramatic, as has been the drop in China. Even prior to promulgation of China's one-child-per-family target in the late 1970s the rate had dropped within a decade to a little over 20 per thousand.

Less spectacular, but nonetheless steady has been the decline in Latin America. By the early 1990s the birth rate had fallen below 25 per thousand for the region as a whole, whereas it was half again as much in the 1970s. Cuba, of course, has been the pacesetter, but Brazil no longer lags too far behind and the fertility rate in Mexico now stands at about 2.5 children per woman whereas it was almost three times that in 1965 (Dillon 1999).

Most of the world, as a consequence, can look forward to something approaching population stability within the next 50 years. The only exceptions are Sub-Saharan Africa and the Islamic countries of Western Asia and North Africa. In most of the Moslem countries the decline in births has thus far been relatively modest, while it is not an exaggeration to say that it has hardly begun to fall in the heart of Africa.

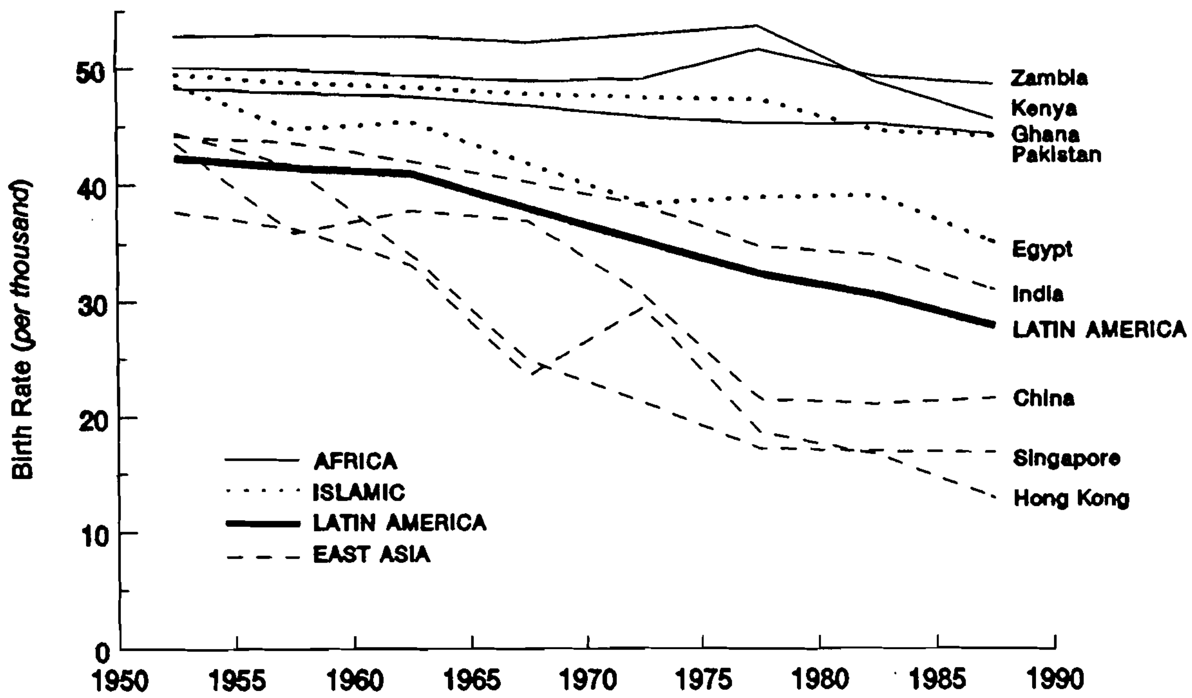
The outlook therefore is for population growth to continue in Africa well after it has been contained elsewhere. The medium variants of the projections prepared by the United Nations, the World Bank, and the U.S. Census Bureau all suggest that after 2025 between a third and a half of global population growth will be concentrated in Sub-Saharan Africa. To this forecast demographers invariably add an important caveat: the AIDS epidemic raging in the eastern and southern parts of the continent. Because AIDS is heterosexually transmitted in Africa and most Africans lack access to preventive measures or medical facilities, many observers fear that its impact on population growth will become increasingly pronounced. Indeed, some go so far as to predict that in such badly afflicted countries as Uganda population trends may switch by 2010 from their present high rate of growth to an actual decrease in numbers.

Figure 1. The Demographic Transition in England, 1700-1990



Adapted from Weeks, J. R. 1992. *Population: An Introduction to Concepts and Issues*. Belmont: Wadsworth Publishing Co.:145.

Figure 2. Birth Rate Declines in Selected Countries and Regions, 1950-55 to 1985-90



Data from United Nations. 1993. *World Population Prospects: The 1992 Revision*. New York: Department for Economic and Social Information and Policy Analysis.

Regional Population Prospects

The most recent UN projections (1999) put the global population in 2050 at between 7.3 billion and 10.7 billion. If future growth follows the path delineated by the medium-variant projection, near stability should be attained at a level of slightly less than 9 billion persons, 90 percent of whom will reside in what are now the developing countries. Today's developed countries will grow not at all, the 100 million increase in the United States being offset by a similar decline in Europe (UN 1999).

Asia will remain the most populous continent, with half again its present population, and East/Southeast Asia and South Asia will each harbor about a quarter of mankind, between 2 and 2.5 billion people. China and India will remain the most populous countries, each having about 1.5 billion inhabitants.

The population of Latin America is projected to level out at rather less than twice its current level: somewhere in the neighborhood of 800 million. The medium projection for Mexico is 147 million, half again what it is today. Rather greater rates of growth are foreseen for the Islamic belt of countries, considerably above what might be expected from the region's income per capita. The literature is surprisingly silent on the reasons for this, but the tenants of the Muslim faith, particularly regarding women's place in society, doubtless play a role.

The great unknown, to repeat, is Sub-Saharan Africa. If the medium variants come to pass, rapid growth will continue well after 2050 and not stabilize until it reaches about 2.3 billion, four times its 1995 level.

If such numbers give weight to the pessimism of modern-day Malthusians, they tell only part of the story. The demand for agricultural products reflects not just the number of mouths that must be fed, but also the type of diet they will be able to afford. Rising incomes and dietary change are likely to pose a considerably greater challenge to agriculture in the future than does population growth.

Incorporating the Impact of Income Growth

To project the demands on agriculture any future population may pose requires a number of simplifying assumptions. Ideally demand should be expressed in terms of the multitude of individual commodities which make up the global agricultural economy. For the short term and for countries with reliable statistics, this is possible to estimate, but not easily. Globally and for the long run, it presents impossible challenges.

A first simplification, therefore, is to think in aggregate rather than individual commodity terms and to express this aggregate demand as calories per person per day. Past experience is not an unreliable indicator of what this will be at various income levels.

The second simplification is to incorporate the impact of the income/dietary change relationship by distinguishing between calories consumed directly (final calories) and those needed to feed the animals which convert them into the meat, dairy products, and eggs ultimately consumed. This latter figure may be thought of as indirect, or primary, calories, and obviously varies with the final product and the conditions under which it is produced, but it depends above all on the percentage of final calories in the diet derived from animal products, a figure easy to conceptualize and calculate from food balance sheets.

It should not be thought, however, that the total of direct and indirect calories so calculated will yield a precise estimate of the future demand for food. Much is ignored, notably the pulses, fats and oils, sugar, fruits and vegetables, and no account is taken of the contribution of tree crops, pasture and fisheries. But this total of direct and indirect calories, especially when expressed in terms of millions of tons of grain equivalents, gives us a measure by which to express *relative magnitudes* and in this way note the likely impact of future trends in population and income.

Even if future populations are taken as givens and precision in the forecast is not expected, three problems warrant exploration before attempting to project grain equivalent demand. One concern is the income figures to use. So that some comparability between countries may be achieved, it is necessary to convert incomes into a common currency, and alternative approaches to such conversions exist. A second set of problems deals with the relationships between income and diet. These are not uniform around the world. Body size, climate, and activity patterns can have an impact on the apparent consumption of direct calories, as can dietary taboos (such as vegetarianism) on the proportion of calories derived from animal products. Finally, there is the matter of the energy conversion ratio to use in estimating the primary energy needed to feed livestock. Such ratios differ from one product to another, within countries depending on management practices, and from one part of the world to another.

Converting Income to a Common Currency

The conventional practice for converting the world's many currencies into a common one, usually U.S. dollars, is to use the prevailing market exchange rates. Such conversions, however, need not necessarily reflect differences in actual purchasing power. Recent work has shown that most developing countries have incomes which can actually purchase quantities of goods and services several times greater than that which exchange rate conversions suggest is the case.

The reason market exchange rates are imperfect converters of income into a common currency is that while such rates tend to equalize prices of internationally traded goods, big differences can and do remain in the prices of nontraded goods and services. Developing countries tend to have cheaper services—domestic help is the classic example—than developed ones and countries in the former Soviet bloc kept food, housing, and energy artificially cheap. Converting these countries' GDP using market exchange rates therefore has the effect of systematically understating their real output and income.

The International Comparison Program (ICP) sponsored by the United Nations attempts to correct for these biases by collecting and comparing prices for over 1,500 commodities, services, and labor inputs representing the universe of items priced in a country. The price comparisons that emerge are then aggregated into an overall purchasing-power-parity (PPP) figure used to relate income to a common currency unit (Summers and Heston 1991). ICP estimates of per capita GDP converted into US dollars using PPP conversions have been available in several forms since 1989, the most complete being the Penn World Table (PWT), an annex to Summers and Heston (1991). The versions of that table used here, PWT (Mark 5.5) and PWT (Mark 5.6) were released in 1993 and 1995, respectively, cover the years 1950 through 1992 for most countries, and have 1985 as the base year (PWT 5.5 1993; PWT 5.6 1995).

The picture the PPP conversions paint of the global economy is strikingly different from that conveyed if market exchange rates are used. The developing countries' share of world output circa 1990 as calculated by the International Monetary Fund jumps from 18 to 34 percent, while that of the industrialized countries drops from 73 percent to 54 (IMF 1993). The countries of the former Soviet block account for the remainder. China becomes the world's second or third biggest economy and India moves up to fifth place. Some country comparisons as of 1985 are shown in Table 2. In all instances the PPP conversion points to per capita incomes considerably above those suggested by exchange rate conversions, typically by a factor of three or four among the poorest countries. (As countries become wealthier—and more involved in the global economy—the differences between the two conversions lessen.) Such figures may seem overly large to those accustomed to thinking of the typical third-worlder as being dirt-poor, but this in no way diminishes their validity.

The Linkage Between Income and Diet Composition

Although in physical appearance they may differ markedly, the diets of poor people the world over have a number of things in common. One is that a high proportion of the dietary energy and a fair share of the protein will come from foods composed principally of starch. These "starchy staples" are the cereals and the starchy fruits, roots, and tubers. Depending on the staple, this dietary cornerstone will either be served steamed or boiled (as with rice and potatoes), a leavened (wheat) or unleavened (maize) bread, or as a doughy past or stiff porridge (cassava, yams, and plantains). It will normally be accompanied by side dishes or sauces, which, in addition to adding flavor to an otherwise bland meal, will contribute considerable protein and the bulk of the fat, vitamin, and mineral content. A second characteristic of poor people's diets is that the protein in these sauces and side dishes will tend to be more vegetable than animal in origin. Thus the nutritional rationale underlying the traditional Mexican diet of *tortillas* and *frijoles*.

The starchy staples dominate the diets of the poor everywhere for a very simple reason: their cheapness, whether expressed in terms of market price or production cost. Far less land and far less labor are typically needed to produce a thousand calories of energy value in the form of the starchy staples than in the form of any other foodstuff. Meat and vegetables by comparison are inefficient converters: vegetables because their calorie content is low, meat because an animal must be fed between two and ten pounds of grain for it to produce a pound of edible product.

As wealth increases the contribution of the starchy foods falls and a still largely vegetarian diet becomes more diversified; this is Bennett's Law, observed in the 1930s by M. K. Bennett (1941; 1954:165-168), the pioneering student of world food economics. Then products of animal origin—meat, eggs, and

Table 2. Per Capita Income ($US 1985) Computed by Market Exchange Rates and Purchasing Power Parity, Selected Countries, 1985

	Per Capita Income ($US 1985)	
	GNP Market Exchange	Purchasing Power Parity
India	270	1,116
China	310	1,811
Ghana	380	759
Egypt	610	1,859
Thailand	800	2,422
Brazil	1,640	3,951
Venezuela	3,080	6,037
Singapore	7,420	8,153
Canada	13,680	15,695

Purchasing-power-parity GDP per capita figures are expressed n 1985 U.S. dollars and are from:
Penn World Table (Mark 5.5). 1993. Annex to Summers, Robert and A. Heston. 1991. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics*. May.

Exchange rate figures are from: World Bank 1987. *World Development Report, 1987*. New York: Oxford University Press.

dairy products—begin to play an increasingly important role in the diet, supplementing or replacing the vegetable protein, and the consumption of sugars, fats and oils, and fruits and vegetables rises. This dietary evolution seems to be universal, although the exact modifications which take place will vary in accordance with local circumstances such as market availability and price and cultural considerations such as religious taboos.

Figure 3 illustrates how this course of dietary change is related to income and where the various countries of the world stood in the progression as of 1984-86, as reported in the food balance sheets published by the Food and Agriculture Organization (FAO 1991). Average per capita incomes are expressed in terms of 1985 U.S. dollars and were calculated using purchasing-power-parity rather than exchange-rate conversions. Incomes of the order of $US 8,000, or about half that then prevailing in the United States, were sufficient to complete the dietary transition.

In the poorest countries, where incomes average $US 1,000 or less, the percentage contribution of the starchy staples to total energy availabilities—the starchy staple ratio—can approach or even exceed 80 percent. It then drops rapidly as countries attain middle-income status. With incomes in the $US 3,000-4,000 range, ratios of 50-60 percent are the rule. Thereafter, location and diet influence the extent to which the starchy staple ratio will fall. In Mexico where average PPP income in the mid-1980s was of the order of $US 5,300 the ratio was 49 percent; in 1997 it had fallen only two points, to 47 percent—a rather depressing commentary on the state of the Mexican economy in recent years (FAO 1999).

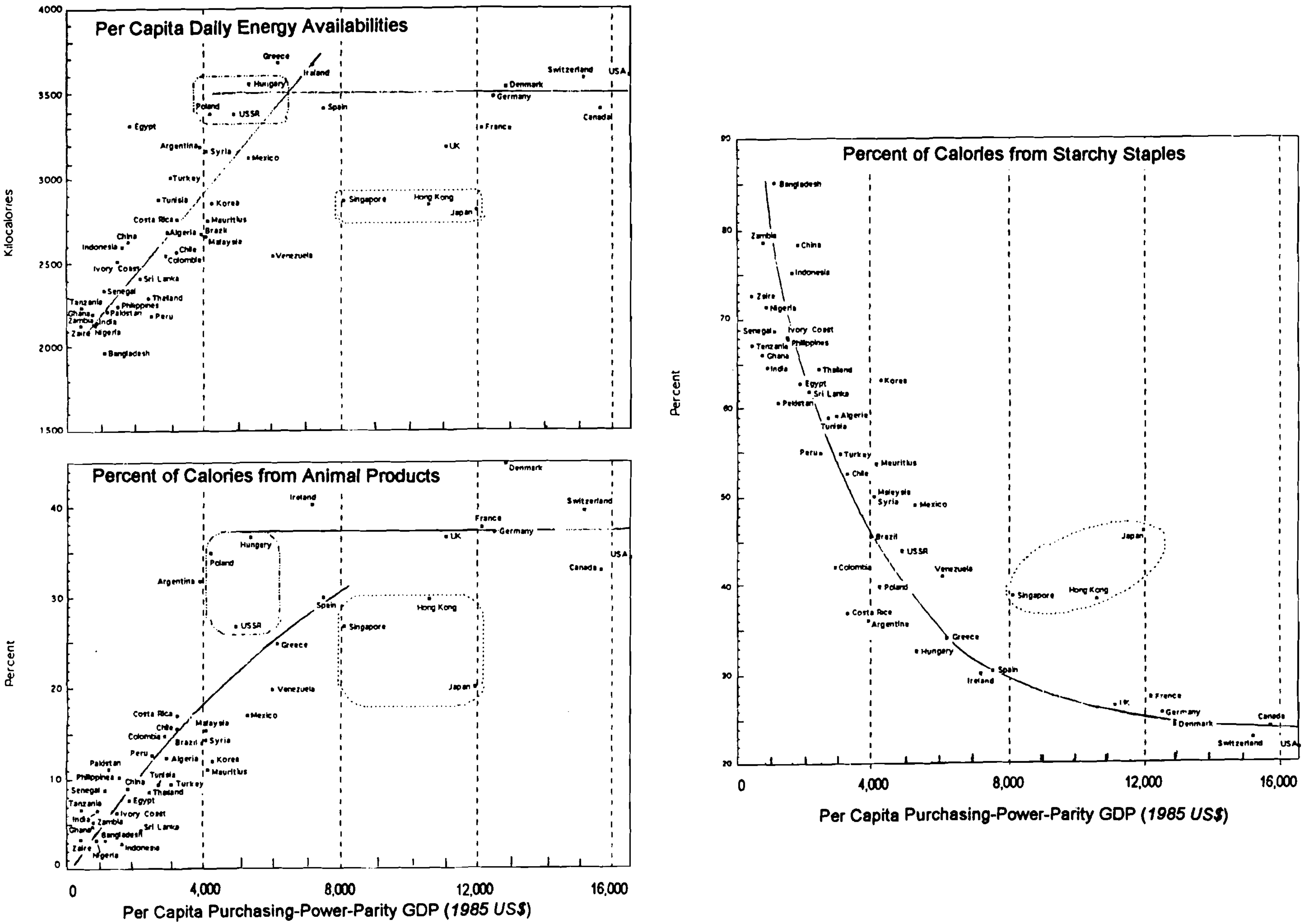
With products of animal origin the direction of change induced by income growth is, of course, in the opposite direction. At very low income levels even fewer than five percent of the calories in the diet will derive from such products, whereas in the wealthy countries of Europe and North America the range is from 30 to 40 percent.

Accompanying these changes in diet composition is an increase in total energy availabilities. In the poorest countries, the balance sheet calculation suggests this can be as low as 2,000 kcal. per person per day, although this may well understate reality. As incomes increase it rises rapidly to 3,500 kcal., where it levels out in all parts of the world except the Far East.

It is evident that while the broad course of dietary evolution holds for all countries, few of them follow exactly the progression of change suggested by the trend lines shown in Figure 3. The deviations are attributable to a number of factors (Sanderson 1995):

- A country's agricultural resource endowment. (1)
- The extent to which the market is distorted by governmental manipulation of prices and trade. (2)
- The degree to which the health hazards associated with the consumption of particular foods, especially animal products, are known to a population. (3)
- The pervasiveness of dietary taboos. (4)
- A lag in dietary change associated with very rapid income growth. (5)
- The pervasive role of rice in some Asian diets. (6)
- Differences in the body size, age distribution, and activity patterns of a population. (7)

Figure 3. Indicators of Dietary Change Related to Purchasing-Power-Parity GDP Per Capita, Selected Countries, About 1985



Data are from Appendix Table 1.

Thus, the "excess" consumption of animal products in Poland, Hungary, and the former USSR can be attributed to (2), meat products having been heavily subsidized in the former Soviet block of countries, whereas in Argentina, Ireland, and Denmark, lands abundantly endowed with pasture, it doubtless is a reflection of (1). Lower than expected utilization of animal products in Korea may in part be explained by (5), in part by (6). Indeed, these factors, plus (7), would appear to go far toward explaining why the countries of East and Southeast Asia demonstrate the greatest deviations from the expected dietary changes associated with rising incomes.

For the projection of demand over the long term, the problem is less whether these factors impact on the course of the dietary transition, but whether their deviant effects are temporary or lasting. Figure 4 is instructive in this connection. In it are plotted individual country trends for the years 1964-66, 1969-71, 1974-76, 1979-81, and 1984-86. The income figures are for the mid-year of these averages and again are PPP conversions expressed in constant 1985 U.S. dollars. The hand-fitted trend lines from Figure 3 are reproduced in the individual panels.

Developed Countries. All the developed countries plotted in the panels on the extreme left have passed through the dietary transition and, with the notable exception of Japan, display similar dietary features. In all the starchy staple ratio has dropped to the neighborhood of 20-22 percent and the apparent consumption of final calories has leveled out at about 3,500 kcal. There is, however, conflicting evidence as to where the ultimate contribution of animal products stabilizes. Denmark—where dairy and fishery products loom particularly large—is clearly an anomaly at 45 percent. But it is by no means certain whether considerations of health and the substitution of vegetable for animal fats in the diet will bring it to the 33-34 percent range found in North America or whether it will remain at the 37-39 percent level prevailing in the principal European countries. The trend in the United Kingdom suggests the former eventuality, whereas the French and German evidence points to the latter.

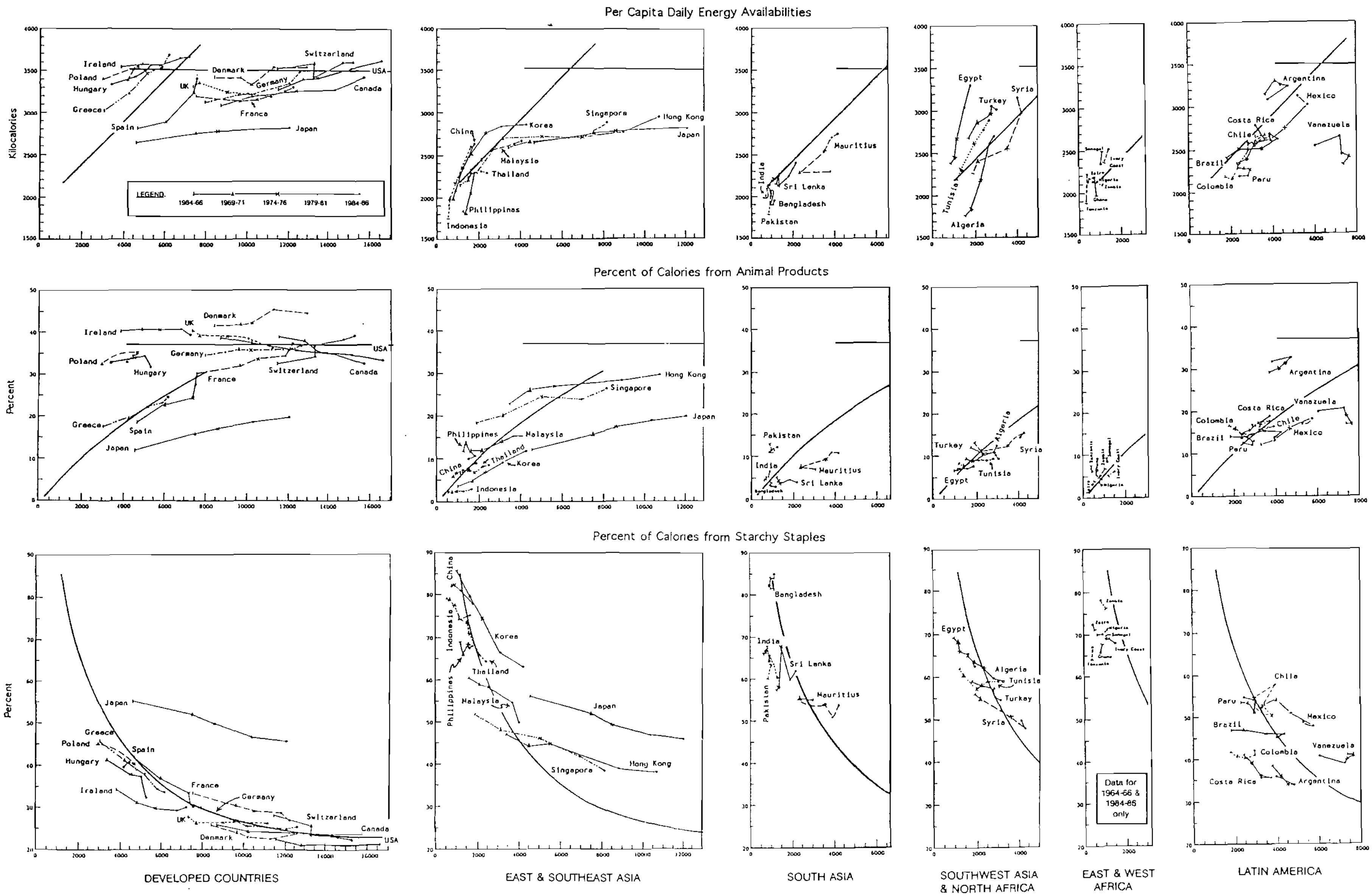
In Japan the percentage of calories from animal products is at any given income appreciably below what the Western model would predict and the starchy staple ratio higher. Per capita disappearance of final calories in Japan also stabilizes well below the expected level. Of the various explanations that have been offered for the former two deviations, I suspect the most important is (2), the price of food being inordinately high in Japan. That the domestic price of rice ranges between six and eight times that prevailing on the world market is well known, and to purchase animal protein in a Tokyo restaurant is to risk financial as well as digestive distress. Both reflect policies designed to protect the Japanese farmer from overseas competition.

East and Southeast Asia. The deviations from the Western model found in Japan are also displayed in the other East and Southeast Asian countries plotted in the next set of panels. Whereas daily apparent consumption of final calories levels out at ±3,500 Kcal. in the West, the figure is more like 2,800-3,000 Kcal. in the Far East. Smaller body size and reduced wastage, particularly of animal fats lost in cooking, doubtless account for these particular differences, but other factors are probably also at work. One is (6), the pervasive role played by rice in the region's dietary. In both Singapore and Hong Kong, from the point of view of dietary evolution the most advanced countries in the Far East, the decline in the starchy staple ratio appears to falter in the range of 35-38 percent, while the contribution of animal products seems to go no higher than the neighborhood of 30 percent. So long as rice remains the cornerstone of most home-prepared meals in the Far East, such figures may well represent the final stage of the dietary transition. Otherwise, the data for East and Southeast Asia offer telling confirmation of the impact rapid economic growth can have on dietary change.

South Asia. Incomes are still too low in the South Asian countries plotted for us to know whether the East and Southeast Asia pattern will be replicated there. Because of smaller body size apparent consumption of energy may level out at the same 2,800-3,000 Kcal. level. As to the impact of dietary

Figure 4. Indicators of Dietary Change Related to Per Capita GDP, Selected Countries by Region, About 1965, 1970, 1975, 1980, and 1985

(Purchasing-Power-Parity GDP in 1985 US$)



Data from Appendix Table 1.

taboos, especially vegetarianism, one can only speculate. At present its effects are clearly significant; at similar income levels the percentage contribution of livestock products to the Indian diet stands at about half the figure for Pakistan. But it can be argued that the prevalence of vegetarianism in India is less a matter of religious dictate than of making a virtue of necessity, and that with wealth it will be practiced by a declining element of the population.

Southwest Asia and North Africa/Latin America. In Latin America and the predominantly Muslim countries of Southwest Asia and North Africa the Western model would appear to be holding. The substitution of livestock products for starchy staples seems to be on course and in the wealthier countries average per capita daily energy disappearance approaching 3,500 Kcal. The operation of (2) governmental policy, is particularly evident in these regions. In Egypt, for instance, the consumer price of staple foods is heavily subsidized, while animal products command whatever the market will bear. The result is an abnormally high starchy staple ratio and apparent consumption of energy rather greater than in other countries with similar incomes. These policies had their origin in rationing programs introduced during the Second World War. Though expensive and much criticized by international lenders, they have become such a part of Egyptian life that it is unlikely they can be modified in the foreseeable future.

Sub-Saharan Africa. Only data for 1964-66 and 1989-91 are plotted in the panels for Sub-Saharan Africa. It is not just that the figures are of questionable accuracy; incomes have grown so little and changes in diet have been so modest that to show the intervening years would serve only to obfuscate. About all that can be said is that the dietary transition has hardly begun in this unfortunate part of the world. But when it does there is every reason to believe it will track the Western experience; Africans and Westerners are of a similar body size and their taste for livestock products is similarly unhampered by various proscriptions.

Feed Utilization Efficiencies

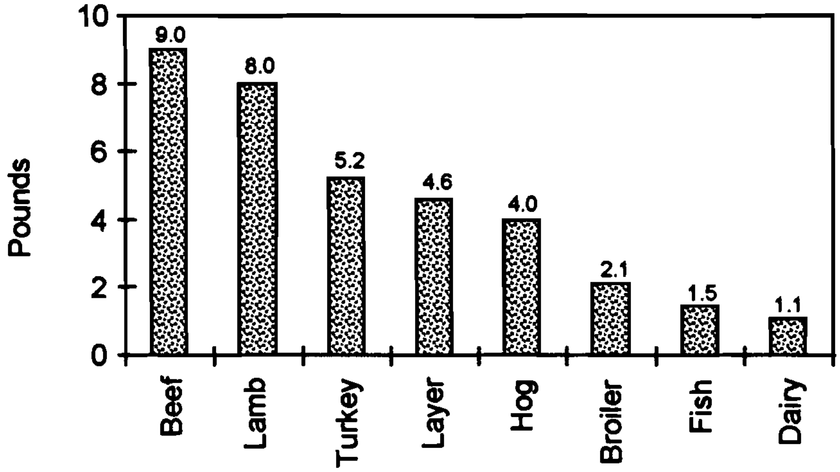
Finally, there is the question of the relationship to be employed in linking the final calories consumed in the form of livestock products to the indirect, or primary, calories needed to feed the animals. After fiddling with this problem on and off for a couple of years, I confess to defeat and employ in the calculations which follow the rather arbitrary ratio of 6:1.

The ability of livestock to convert feedstuffs into edible product is usually expressed as a ratio between the feed required and output of product, expressed in units either of weight or nutritive component. These ratios vary greatly among animal types, as Figure 5 illustrates. Whereas it takes only one pound of feed to produce a pound of milk on dairy farms in the United States, nine pounds are required for a pound of on-foot beef produced in a feedlot. Broilers, on the other hand, require 2.1 pounds of feed per pound of weight gain.

Such ratios are legitimate indices of the efficiency with which animals of a specific age, quality, and conditioning will produce food during a period of feeding, but are not good indices of overall efficiency. They ignore the inputs needed to rear and maintain young stock, breeding animals, cows not in milk, and losses from infertility and mortality, all of which can be substantial (Reid 1975). The ratios are also quite specific as to the feedstuffs and management practices they assume. They do not pretend to be averages, national or otherwise, and we do not have the evidence on herd composition and feeding practices needed to compute such averages. In the circumstances, much guesswork is called for.

FAO (1996:32) has suggested the ratios shown in Table 3 for global application and a commonly employed rule of thumb is that a mixed animal population will convert plant material into edible product with an efficiency of 20 percent; that is, at a ratio of 5:1 (Chrispeels and Sadava 1977:76). Sanderson

Figure 5. Pounds of Feed Required to Produce One Pound of On-Foot Product in the United States, c. 1990



Adapted from Ensminger, M. E., *et al.* 1990. *Feeds and Nutrition Digest.* Clovis, CA: Ensminger Publishing Co.:4.

Table 3. Feeding Efficiency Ratios Suggested by FAO for Global Application

Plant-Derived Calories . . .	needed to produce . . .	1 Calorie of
11		beef
11		mutton
8		milk
4		pork
4		poultry
4		egg

Data from FAO. 1996. "Requirements and Population Growth." World Food Summit Technical Paper 10. Provision Version. June.

(1988:197) has refined this by suggesting that, because of differences in herd makeup and management practices, 7:1 is a more appropriate figure for countries in the Western Hemisphere, 5:1 for South and East Asia, and 6:1 for the rest of the world. Beyond that one treads with caution. Food balance sheets are of little help in calculating ratios for individual countries: the computation ignores the contribution of pasture and aquatic matter, and merely indicates that the availability of feedstuffs derived from the starchy staples and oilseeds rises as livestock consumption increases, but does so in no consistent manner from country to country.

About all that can be said in defense of the 6:1 efficiency ratio used here is that it is within the range of the conventional wisdom and that if it errs it probably does so on the side of conservatism. For projecting future demand it is preferable to exaggerate the future challenges confronting global agriculture than to minimize them.

Projecting Demand in 2025 and 2050

I now take leave of the world of reality and offer for your consideration my projections of demand to the years 2025 and 2050. These years were chosen not just because 2050 is the farthest year demographers can go without excessive flights of fancy; it also approximates the time when population stability is anticipated in most of the world save Africa. 2025 is chosen because the greatest population and income spurs are anticipated between now and then. If the world can get through the next 25 years, the rest should be comparatively easy.

In making these projections I confess that I will be violating several of the precepts I have endeavored to teach Cornell students for the past 36 years. One is to never project beyond a reasonable number of years: say five or ten. The other is never to project a single figure into the future, but rather a reasonable and justifiable range, including a high and low estimate of what conceivably might happen. I ignore these precepts in the hope that despite the limitations of the projections they may reveal something instructive.

My assumptions regarding income and its impact on dietary change, region by region, are detailed in Appendix Table 2 and summarized in Table 4. Incorporated into these tables are the UN's 1998 medium population projections. 1985 is taken as the base year because that was the latest year for which food balance sheets had been published by FAO in 1995 when I prepared the dietary change charts in Figures 3 and 4 and was the base year for the Penn World Table.[1]

The assumptions on which the data for 1985 shown in the left column of Table 4 are based are shown in Table 5. The per capita daily energy availabilities and the percentage of calories from animal products are from the FAO food balance sheets; the per capita income figures are from the Penn World Table.

The computation for the developed countries can serve as an example. Apparent per capita daily energy consumption was reported to be 3,366 kilocalories, of which 30 percent were derived from animal products. Assuming a conversion ratio for livestock products of 6:1, the 1,010 kilocalories of animal

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[1] When, some 18 months ago, Dr. Higuera asked me to prepare this paper, I had hoped to use a newer version of the Penn World Table in my analyses. Release of PWT (Mark 5.7), which carries the data beyond 1992 and uses 1990 as its base year was then described as "imminent." But at the time of writing, a year later (July 1999), "unforeseen technical difficulties" had still precluded its release. Soon, however, it should be released and will enable others to update my work, especially since FAO now makes its most recent food balance sheets available on the web via FAOSTAT (http://apps.fao.org) with considerable dispatch; balance sheets for 1997 were released in June 1999.

Table 4. Summary of the Assumptions and Calculations Used in the Demand Projections

	1985			2000			2025			2050		
	GDP/Capita (PPP $US 1985)	P.C. Direct Energy	% Animal Products	GDP/Capita (PPP $US 1985)	P.C. Direct Energy	% Animal Products	GDP/Capita (PPP $US 1985)	P.C. Direct Energy	% Animal Products	GDP/Capita (PPP $US 1985)	P.C. Direct Energy	% Animal Products
World - Total	–	–	–	–	–	–	–	–	–	–	–	–
Developed - Total	10,000	3,366	30	10,000+	3,500	34	10,000+	3,500	34	10,000+	3,500	34
Developing - Total	–	–	–	–	–	–	–	–	–	–	–	–
E & SE Asia	2,000	2,500	10	3,600	2,700	15	9,602	3,000	30	10,000+	3,000	30
S. Asia	900	2,143	6	1,211	2,300	8	1,987	2,500	10	3,684	2,800	15
SW Asia & N. Africa	3,000	3,000	10	4,674	3,200	20	9,786	3,500	34	10,000+	3,500	34
Sub-Saharan Africa	750	2,200	5	870	2,300	7	1,127	2,600	10	1,848	2,900	15
Latin America	4,500	3,000	15	7,010	3,500	25	10,000+	3,500	34	10,000+	3,500	34

	Total Daily P.C. Energy Utilization	MMT Grain Equiva-lent	Total Daily P.C. Energy Utilization	MMT Grain Equiva-lent	Total Daily P.C. Energy Utilization	MMT Grain Equiva-lent	Total Daily P.C. Energy Utilization	MMT Grain Equiva-lent
World - Total	–	2,606	–	3,803	–	6,258	–	7,316
Developed - Total	9,425	1,159	10,640	1,318	10,640	1,514	10,640	1,383
Developing - Total	–	1,447	–	2,485	–	4,744	–	5,933
E & SE Asia	4,000	638	5,130	1,005	8,400	2,019	8,400	2,078
S Asia	2,914	322	3,404	531	4,000	850	5,320	1,203
SW Asia & N Africa	4,800	120	7,040	249	10,640	606	10,640	879
Sub-Saharan Africa	2,860	130	3,266	230	4,160	508	5,510	875
Latin America	5,700	237	8,750	470	10,640	761	10,640	898

Data are from Appendix Table 2.

Table 5. Estimates for 1985 of Per Capita Income, Apparent Direct Daily Energy Consumption, and Percentage of Calories Derived from Animal Products, by Region.

	Per Capita		
	GNP *(1985 $US)*	Apparent Daily Direct Energy Consumption *(Kcal)*	Percentage Calories from Animal Products
Developed - Total	10,000[a]	3,366	30
Developing - Total	--	--	--
East & Southeast Asia[b]	2,000	2,500	10
South Asia[c]	900	2,143	6
SW Asia & N. Africa[d]	3,000	3,000	10
Sub-Saharan Africa[e]	750	2,200	5
Latin America[f]	4,500	3,000	15

Sources: Either taken directly or guessed at from:

FAO. 1991. *Food Balance Sheets, 1984-86 Average.* Rome.

Penn World Table (Mark 5.5). 1993. Annex to Summers, Robert and A. Heston. 1991. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics.* May.

[a] The figures for energy availabilities and percent calories from animal products are from the food balance sheet collection. The income estimate is a rounded-up simple average of the figures for the United States ($16,559), USSR ($4,894), France ($12,186), and Poland ($4,204).

[b] The figures for China are $1,811, 2,622 Kcal., and 8.8 percent.

[c] The figures for India are $899, 2,143 Kcal., and 6.4 percent.

[d] The figures for Egypt are $1,859, 3,310 Kcal., and 7.5 percent.

[e] The figures for Ghana are $759, 2,196 Kcal., and 4.6 percent.

[f] The figures for Mexico are $5,289, 3,118 Kcal., and 16.9 percent.

products required primary food energy in the form of feed of 6,059 kilocalories. Total per capita daily energy utilization was therefore 9,425 kilocalories. Expressed in terms of yearly energy utilization per capita, this is equal to 983 kilograms of grain equivalents, there being roughly 3,500 kilocalories in a kilogram of grain. Multiplied by a population of 1,179 million, the resultant total energy utilization in the developed countries was 1,159 million metric tons of grain equivalent.

If we apply the daily energy availabilities and animal product percentages in Table 5 to the other regions of the world, the picture which emerges for 1985 is as summarized in Table 6. Apparent energy utilization totaled 2,606 million metric tons of grain equivalents, 44 percent of it in the developed countries, 56 percent in the less-developed ones.

Table 6. Estimated Per Capita and Total Energy Utilization, 1985, By Region

	Population (*millions*)	Total Daily Per Capita Energy Utilization (*Kcal*)	Total Annual Energy Utilization (*MMT grain equivalent*)
World - Total	4,844	--	2,606
Developed - Total	1,179	9,425	1,159
Developing - Total	3,666	--	1,447
E & SE Asia	1,529	4,000	638
S Asia	1,058	2,914	322
SW Asia & N Africa	239	4,800	120
Sub-Saharan Africa	435	2,860	130
Latin America	399	5,700	237

Source: Appendix Table 2.

Such a figure is within the realm of the reasonable. Actual grain production in 1984-86 averaged 1,839 million metric tons, and actual starchy staple production (in grain equivalents), 1,987 million metric tons. One would expect calculated utilization expressed in terms of grain equivalents to exceed these totals by a considerable margin, but by how great a margin is impossible to say. The calculation assumes all livestock are fed, whereas in reality the contribution of grazing and scavenging can be appreciable. Further it implies that all nonanimal product calories are supplied directly by the cereals, whereas the global starchy ratio was actually about 57 percent, and that all cultivated land is planted to these crops, whereas only about two-thirds actually is. Therefore it is important to repeat that these grain equivalent tonnages, and those which will be projected subsequently, should not be seen as actual quantities, but as indicators of *relative magnitude* and changes therein. In that sense they are legitimate and the best single indicator of global demand for food.

From this point onwards, the demand projection exercise is pretty much mechanical. All one needs do is consult his crystal ball, decide what income levels will obtain in the future, and refer to Charts 3 and 4 to estimate the likely dietary impact.

My best guesses as of Spring 1999 were as follows. If some of the assumptions seem optimistic, I should explain that they included an input from my students, many of whom were from developing countries and understandably reluctant to view the future too darkly.

Developed Countries. I assumed per capita GDP will continue to grow at 2 percent per annum throughout the period, more or less the US postwar experience. Since the dietary transition has ended when incomes reach a level of ±$10,000 (expressed in terms of $US1985 PPP) I do not project incomes beyond this level. In the developed countries of the West final calories at this income level out at about 3,500 Kcal. I assume that the percentage of calories from animal products will, for reasons of health, level out at 34 percent, the North American experience.

East and Southeast Asia. This is "tiger" country and, despite the setbacks of the past few years, I assume a growth rate of 4 percent per annum, which yields an income figure of almost $10,000 in 2025 and well in excess of it in 2050. The question is at what level calories will level out and what will be the percentage derived from livestock products. We have two models: Japan or Hong Kong/Singapore. In both, final calories seem to rise no higher than 3,000 Kcal., 500 Kcal. below the Western model. I take this to be a reflection of smaller body size. In Japan the percentage of final calories from livestock products is now ±20 percent, whereas in Hong Kong/Singapore it seems to level out at 30 percent. I take the latter figure as being applicable to Asia in the long term; Japan is home to a set of food policies which will probably not prove durable.

South Asia. This part of the world seems to be getting its economic house in order and I project the so-called "Hindu" rate of growth of 2 percent per annum to 2025, rising to 2.5 percent thereafter. This yields incomes of ±$2,000 in 2025 and $3,700 in 2050. I also project the East Asian direct energy maximum of 3,000 Kcal. will apply to South Asia; body size is similar. This yields 2,500 Kcal. in 2025; 2,800 Kcal. in 2050. Vegetarianism is common in South Asia. Whether it will endure into more prosperous times or simply makes a virtue of necessity among the poor for now is a much debated topic. Knowing little of Eastern metaphysics, I looked out the window and postulated 10 percent from animal products in 2025; 15 percent in 2050, rather below what would obtain were it not for vegetarianism.

SW Asia and North Africa. Income growth in the Islamic belt of countries has varied a great deal in the past, in part because of the changing fortunes of the petroleum industry. I assume—arbitrarily, but optimistically—3 percent growth throughout the period. This yields incomes of almost $10,000 in 2025 and much above it in 2050. The Islamic countries seem to be following the Western path of dietary evolution and this is what I project.

East and West Africa. Sub-Saharan Africa is the economic and political sick man of the world. Growth has been negligible or even negative since these states achieved independence. I project a 1-percent growth rate through 2025, 2 percent thereafter. This yields incomes of $1,127 (2025) and $1,850 (2050). Apparent direct calories are 2,600 Kcal. and 2,900 Kcal. The percentage of calories from livestock follows the Western pattern: 10 percent (2025) and 15 percent (2050).

Latin America. The 1980s were a bad time for Latin America. But with the debt crisis largely a thing of the past and Brazil and Mexico striving toward economic stability, I assume a 3 percent growth rate through 2025, 2 percent thereafter. This yields incomes in excess of $10,000 by 2025. Latin America seems to be following the Western course of dietary change, so:

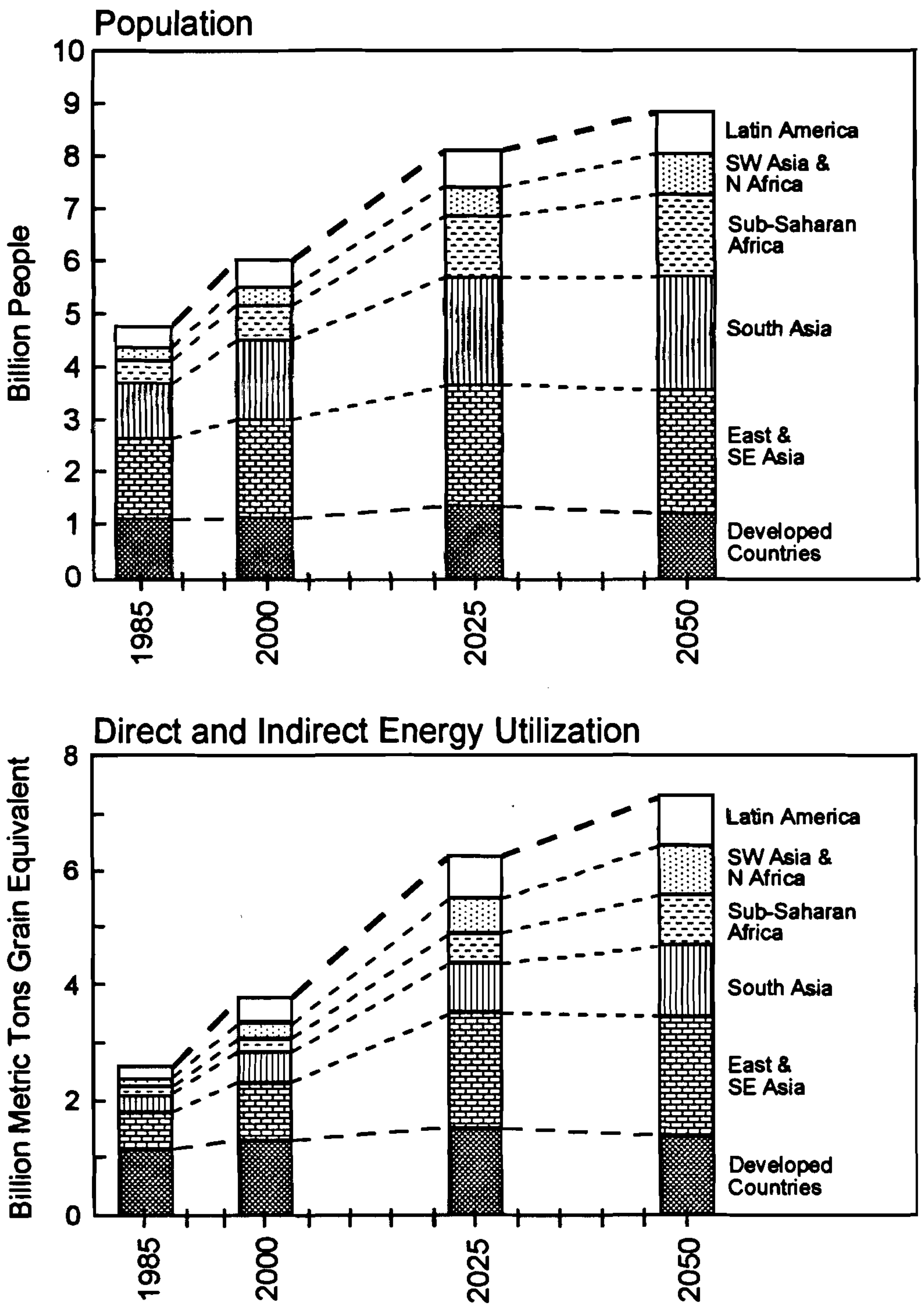
Apparent direct calories:	3,500 Kcal. in both years
Percentage from livestock:	34 percent in both years.

Conclusions

The conclusions I draw from these assumptions are summarized in the three right-hand columns of Table 4 and illustrated graphically in Figure 6. The top graph in this figure shows the impact of projected population growth; the bottom one the combined impact of population and income change. Several things are immediately apparent:

- First, that the next 50 years will witness hardly any changes in the developed countries of today
- Second, that while the population of today's developing countries will increase by half again during the next 50 years, their demand for food will grow by a factor of almost two and a half.
- In East and Southeast Asia and in South Asia this increase in agricultural demand will occur mainly during the next 25 years; while in the Islamic countries and Sub-Saharan Africa the greatest upsurge will take place after 2025.

Figure 6. World Population and Computed Direct and Indirect Energy Utilization, 1985, 2000, 2025, and 2050, By Region



Data are from Appendix Table 2.

These differences in timing and magnitude are more clearly shown in Table 7, which is designed to emphasize *relative magnitudes*, since this is what the methodology is designed to reveal.

- Latin America. Although population growth is beginning to taper off in Latin America, incomes are at the stage where dietary change is most rapid. The challenges to agriculture this poses will be greatest during the next quarter century.
- East and Southeast Asia. Rather the same situation obtains in the economically dynamic countries of East and Southeast Asia, although population growth there is slowing more dramatically. The next 25 years will witness the most significant increases in demand.
- South Asia. In India and its neighbors the turn down in population growth is less in evidence, as are sharp increases in income. Demand will continue to grow through at least 2050.
- The greatest challenges to agriculture will clearly take place in Sub-Saharan Africa and in the Islamic countries of North Africa and the Middle East. In both regions the projections suggest growth in demand of the order of 3.5- to 4-fold, and because incomes in Sub-Saharan Africa will still be so low at mid-century that the latter half of the century will continue to see a rapid growth in demand.

The Challenge Ahead

The obvious question is: Does global agriculture have the capability of meeting this upsurge in demand? My response to students who asked my opinion was that I was optimistic—with a few important caveats. I based this conclusion in part on agriculture's record since the end of the Second World War. FAO's indices of total and per capita food production (Figure 7) indicate that production in the developing countries has increased rather more rapidly than in the developed ones and that in all regions of the world save Sub-Saharan Africa output per capita has grown despite the huge upsurge in population.

I also called their attention to Figure 8, in which are plotted the production, acreage, and yields of cereals just after the war, prior to the Green Revolution, and in 1990. There are obvious problems with this figure, particularly in that it asks us to compare, say, wheat produced extensively in the United States and Russia, with intensively produced, irrigated wheat grown in Mexico, and all cereals with rice grown under garden conditions in the Far East. Still the figure does convey an impression of what has been accomplished in various parts of the world and what might be achieved under more optimal conditions.

The impact of the Green Revolution on yields in the developing countries is strikingly evident, as is the fact that yields in many parts of the world still have a long way to go before reaching the average attained in more advanced countries. And who can say what wonders biotechnology may bring, other than that they will be substantial.

Also worth noting are the factors by which cereal output increased between 1950 and 1990: 3.2 times in the developing countries as a whole, 5-fold in China, 3.7 times in India, and 3.4 times in Latin America.

My guess is that the world will somehow manage to soldier on. Exports from the developed countries will doubtless grow and American farmers in particular will increasingly supply feedstuffs to the Asian and Latin American markets.

If problems emerge, they will likely be centered on Africa, the Middle East, and India. Problems in Africa will be self-inflicted. I have been visiting that region for over 30 years and never cease to be impressed by the potential of its untapped resources. The Middle East is another matter. Its agricultural potential is quite limited and I take comfort in the fact that its energy surpluses are obvious items to be

Table 7. World Population and Computed Direct and Indirect Energy Utilization, 1985, 2000, 2025, and 2050, By Region

POPULATION (*Billion People*)

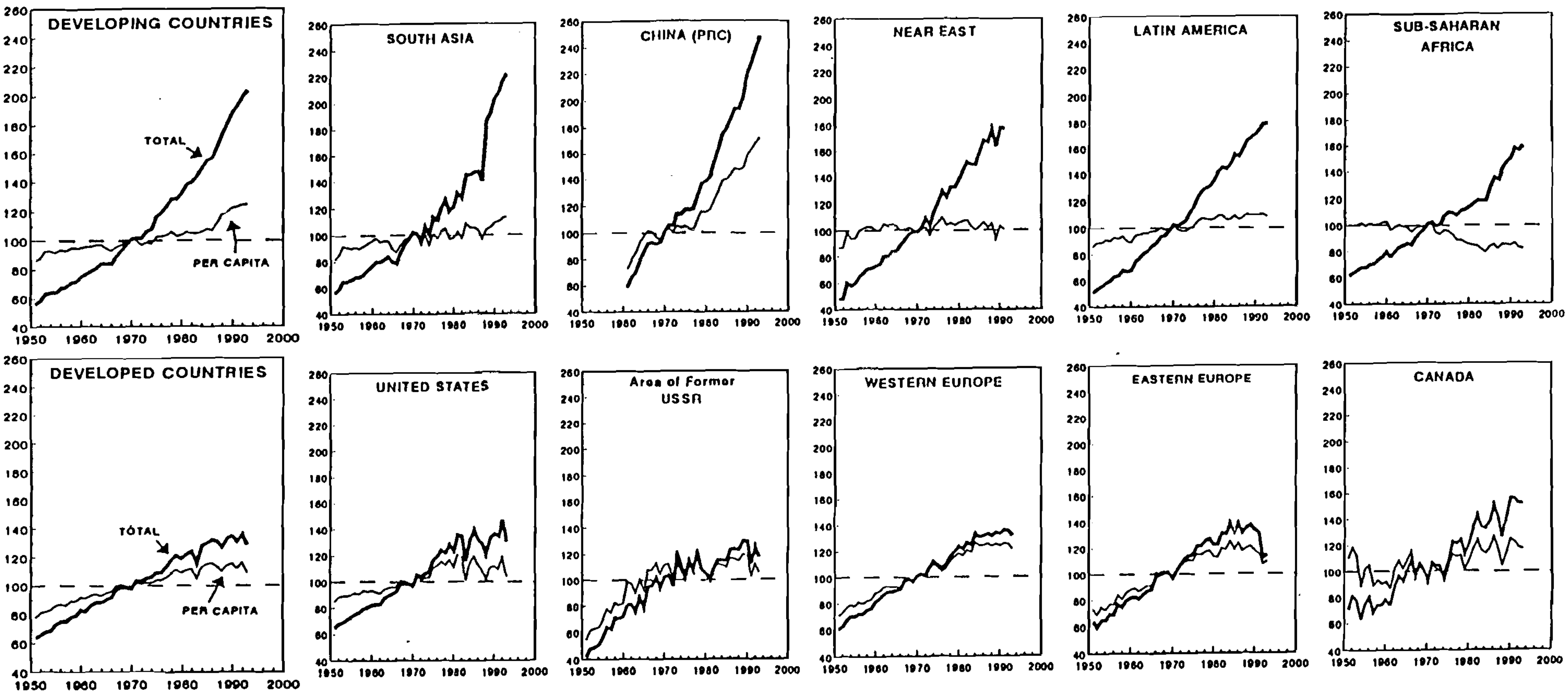
	1985	Increase	2000	Increase	2025	Increase	2050
World - Total	4.84	**1.25X**	6.09	**1.3X**	8.12	**1.5X**	8.91
Developed	1.18	**0**	1.19	**0**	1.36	**0**	1.25
Developing	3.67	**1.36X**	4.90	**1.4X**	6.76	**1.6X**	7.66
Latin America	.40	**1.25X**	.51	**1.4X**	.69	**1.6X**	.81
E & SE Asia	1.53	**1.27X**	1.88	**1.2X**	2.31	**1.3X**	2.37
South Asia	1.06	**1.36X**	1.50	**1.4X**	2.04	**1.4X**	2.17
SW Asia & N Africa	.24	**1.5X**	.34	**1.6X**	.55	**2.3X**	.79
Sub-Saharan Africa	.44	**2.0X**	.67	**1.7X**	1.17	**2.3X**	1.52

DIRECT AND INDIRECT ENERGY UTILIZATION (*Billion Metric Tons Grain Equivalent*)

	1985	Increase	2000	Increase	2025	Increase	2050
World - Total	2,606	**1.5X**	3,803	**1.6X**	6,258	**1.9X**	7,316
Developed	1,159	**0**	1,318	**0**	1,514	**0**	1,383
Developing	1,447	**1.7X**	2,485	**1.9X**	4,744	**2.4X**	5,933
Latin America	237	**2.0X**	470	**1.6X**	761	**1.9X**	898
E & SE Asia	638	**1.6X**	1,005	**2.0X**	2,019	**2.1X**	2,078
South Asia	322	**1.6X**	531	**1.6X**	850	**2.3X**	1,203
SW Asia & N Africa	120	**2.0X**	247	**2.4X**	606	**3.6X**	879
Sub-Saharan Africa	130	**1.8X**	230	**2.2X**	508	**3.8X**	875

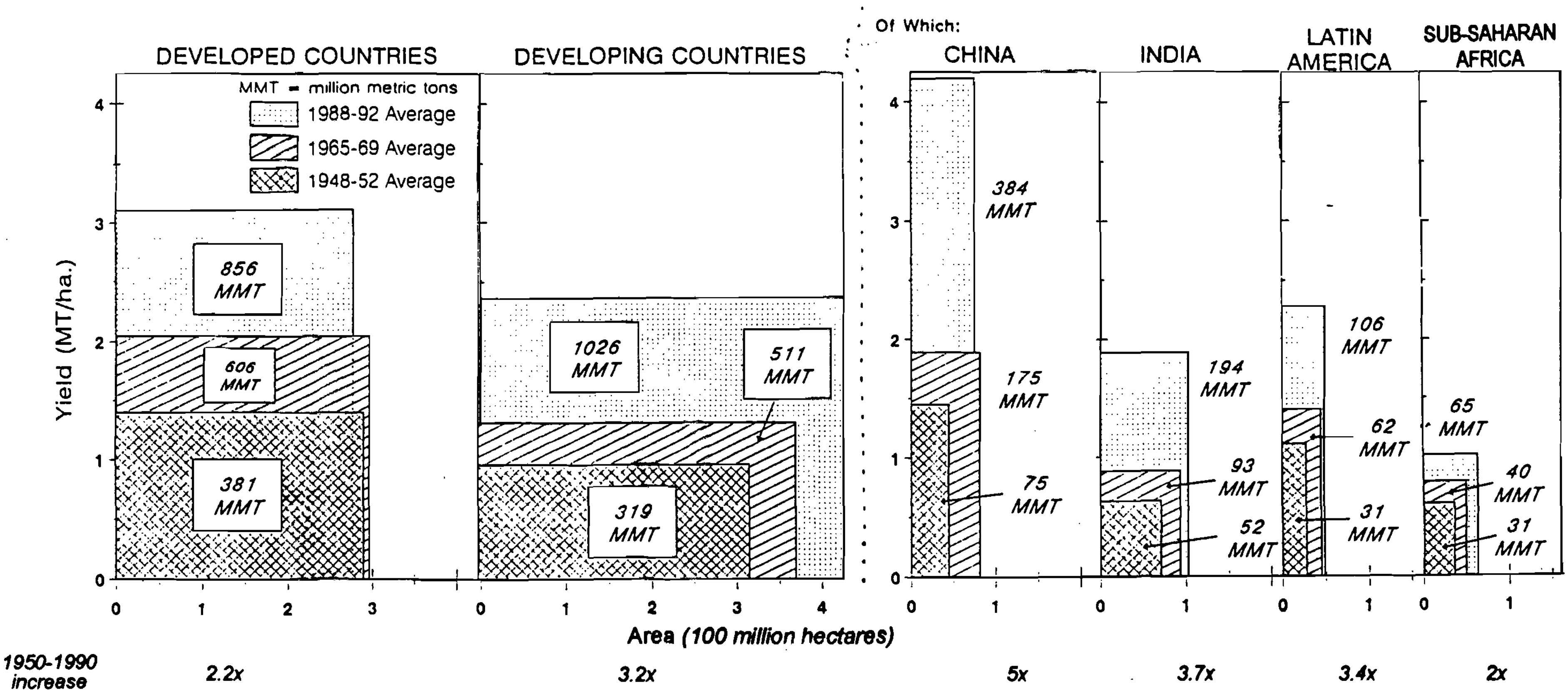
Data are from Appendix Table 2.

Figure 7. Indices of Total and Per Capita Food Production, 1951-1993 (*1969-71 = 100*)



Data from FAO. 1994. Index Numbers: Production. *AGROSTAT-PC 3.0* [Computer data set]. Available on diskettes from FAO, Rome, Italy.

FIGURE 8. WORLD PRODUCTION, AREA, AND YIELD OF CEREALS, AVERAGE 1948-52, 1965-69, AND 1988-92*



* Data from FAO, *Production Yearbook* (various issues).

exchanged for its deficiencies in food production. With such a mutually advantageous basis for trade, the conflict between Islam and Christendom envisioned by many need not take place.

As to Mexico, it matters little that it may never be able to achieve self-sufficiency in food. When I wrote 30 years ago that its salvation lay in closer economic integration with the United States, my Latino students laughed. NAFTA is an arrangement whose wisdom amazes us all.

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Appendix Table 1. Dietary Indicators and Purchasing-Power-Parity GDP Per Capita, Selected Countries, About 1965, 1979, 1975, 1980, and 1985

Country	1964-66			1965 PPP GDP/ capita	1969-71			1970 PPP GDP/ capita	1974-76			1975 PPP GDP/ caoita	1979-81			1980 PPP GDP/ capita	1984-86			1985 PPP GDP/ capita
	Kcal	SS (%)	Animal (%)		Kcal	SS (%)	Animal (%)		Kcal	SS (%)	Animal (%)		Kcal	SS (%)	Animal (%)		Kcal	SS (%)	Animal (%)	
Algeria	1745	65.1	9.2	1,551	1829	63.7	8.7	1,837	2160	62.0	10.2	2,311	2596	59.5	10.6	2,778	2680	59.0	12.2	2,951
Argentina	3143	38.4	29.2	3,720	3317	36.0	29.8	4,165	3259	34.1	31.3	4,475	3243	33.9	32.6	4,745	3186	36.0	31.7	3,887
Bangladesh	2009	81.7	3.8	974	2065	82.3	3.4	919	1918	84.2	3.2	973	1906	84.2	3.1	1,098	1963	85.0	3.1	1,116
Brazil	2405	47.9	14.1	1,843	2504	47.0	13.8	2,401	2507	46.2	15.3	3,470	2623	46.2	15.0	4,254	2667	45.3	13.9	3,951
Canada	3077	25.7	39.1	8,709	3180	24.3	37.8	10,175	3251	24.0	36.0	12,348	3266	23.7	35.2	14,231	3400	23.8	32.8	15,695
Chile	2635	53.0	16.4	3,256	2659	50.4	17.8	3,687	2576	54.5	16.5	2,906	2658	50.8	16.6	3,900	2565	52.5	15.4	3,238
China	1914	79.9	6.0	--	1989	82.2	5.9	825	2070	82.6	6.3	952	2328	81.0	7.2	1,241	2622	78.2	8.8	1,811
Colombia	2176	41.6	16.4	1,782	2167	40.7	15.9	2,097	2340	40.3	14.7	2,435	2491	40.9	14.5	2,892	2539	41.8	14.6	2,893
Costa Rica	2328	41.0	14.5	2,368	2410	39.3	15.3	2,796	2563	36.3	16.9	3,185	2610	35.6	18.4	3,694	2757	36.8	16.9	3,258
Denmark	3415	26.0	41.8	8,433	3410	24.2	42.0	9,675	3327	23.0	42.4	10,185	3530	22.5	45.7	11,234	3528	24.1	44.7	12,884
Egypt	2376	69.4	6.4	975	2447	68.2	6.8	1,105	2673	65.9	6.9	1,222	3031	65.5	7.0	1,572	3310	62.6	7.5	1,859
France	3180	33.5	30.3	7,540	3137	30.4	32.0	9,621	3148	29.2	33.8	10,467	3244	28.8	34.6	11,798	3285	27.2	37.6	12,186
Germany, Fed. Rep.	3096	30.0	34.6	7,999	3207	26.8	36.0	9,557	3205	25.6	35.8	10,127	3337	25.0	36.1	12,013	3473	25.4	37.1	12,543
Ghana	1969	67.8	4.5	857	2200	65.2	5.9	1,012	2164	62.0	5.9	876	1953	69.0	5.2	921	2196	65.9	4.6	759
Greece	3021	45.8	17.7	3,066	3221	41.3	19.7	4,234	3467	38.1	22.3	5,198	3540	34.4	23.5	5,895	3678	33.9	24.7	6,184
Hong Kong	2557	46.8	22.7	3,457	2648	44.2	26.2	4,456	2666	44.6	26.7	5,567	2758	39.2	28.2	8,801	2831	38.2	29.6	10,653
Hungary	3189	47.4	29.7	--	3331	41.5	33.1	3,382	3419	38.0	34.1	4,538	3478	37.6	34.6	5,051	3550	32.5	36.1	5,309
India	1988	66.1	4.8	644	2016	66.4	4.7	704	1989	66.7	5.1	716	2091	67.7	5.1	763	2143	64.4	6.4	899
Indonesia	1778	79.1	2.1	593	1982	78.8	2.2	700	2155	77.7	2.3	935	2375	74.4	2.4	1,252	2589	75.0	2.7	1,626
Ireland	3530	34.4	40.6	3,862	3567	31.4	40.8	4,884	3561	29.7	41.0	5,756	3641	29.4	41.0	6,785	3663	30.2	39.8	7,215
Ivory Coast	2356	69.1	5.0	1,199	2392	66.5	6.2	1,320	2322	65.6	6.3	1,593	2543	66.3	7.2	1,563	2506	67.9	6.1	1,499
Japan	2636	56.2	12.1	4,600	2741	52.1	15.8	7,500	2768	49.3	17.3	8,572	2791	46.9	18.9	10,292	2805	45.8	20.0	12,004
Korea, S.	2240	85.7	3.7	1,058	2528	79.4	4.8	1,688	2757	74.4	6.7	2,338	2829	66.6	9.2	3,123	2848	63.0	11.8	4,267
Malaysia	2320	60.4	11.8	1,645	2445	59.1	11.8	2,117	2552	58.2	13.9	2,616	2623	54.6	15.3	3,772	2655	49.9	15.2	4,073
Mauritius	2320	55.0	7.2	3,082	2293	55.4	7.5	2,348	2549	54.3	9.4	3,585	2721	50.9	11.4	3,892	2747	53.6	10.8	4,136
Mexico	2580	52.9	12.3	3,320	2622	54.3	13.0	3,950	2748	51.3	15.8	4,639	3014	48.2	17.9	5,707	3118	48.9	16.9	5,289
Nigeria	2179	70.3	3.3	628	2133	69.3	3.5	769	2084	68.5	3.6	1,034	2255	68.3	4.5	1,196	2127	71.3	3.1	860
Pakistan	1795	60.0	13.2	862	2031	63.5	11.5	997	2141	65.6	11.0	893	2231	63.6	10.7	1,076	2214	60.5	10.9	1,221
Peru	2295	53.4	14.4	2,382	2289	53.4	13.8	2,648	2271	51.3	12.7	2,959	2196	54.2	12.2	2,889	2181	54.8	12.5	2,481
Philippines	1832	69.2	11.4	1,232	1819	66.2	13.4	1,368	2048	68.4	11.5	1,623	2299	68.2	10.7	1,869	2239	67.7	10.1	1,521
Poland	3285	49.8	29.8	--	3390	45.1	32.6	2,999	3539	40.4	35.1	4,680	3516	40.7	34.8	4,465	3377	39.8	34.4	4,204
Senegal	2491	68.8	9.2	1,104	2380	67.9	9.2	1,104	2267	67.6	7.8	1,082	2401	65.6	7.5	1,087	2338	68.5	8.7	1,109
Singapore	2301	51.9	18.4	1,931	2693	48.0	20.0	3,155	2714	45.9	24.5	5,006	2707	41.7	23.9	6,958	2861	38.6	26.6	8,153
Spain	2805	42.0	18.9	4,692	2875	37.0	22.8	6,017	3221	33.6	24.6	7,389	3325	30.8	27.9	7,495	3403	30.3	29.9	7,547
Sri Lanka	2165	57.5	5.1	1,223	2256	58.3	4.3	1,315	2152	67.8	3.8	1,350	2256	59.8	4.6	1,851	2404	61.8	4.3	2,152
Switzerland	3518	28.4	32.7	11,425	3,577	25.8	34.3	13,274	3420	23.8	37.3	13,228	3582	23.1	38.8	14,653	3580	22.6	39.5	15,209
Syria	2245	56.0	13.1	1,936	2393	54.9	11.3	2,201	2539	50.5	12.0	3,538	2968	47.8	15.2	4,286	3157	49.8	14.1	4,075
Tanzania	1837	63.7	7.6	372	1813	62.2	8.7	429	2089	67.4	7.2	516	2254	66.3	6.2	482	2236	66.9	6.5	452
Thailand	2140	74.4	6.9	1,121	224	73.6	7.5	1,508	2285	70.9	6.9	1,662	2305	66.1	8.0	2,146	2286	64.3	8.4	2,422
Tunisia	2178	62.0	8.0	1,219	2291	60.4	7.6	1,398	2594	57.1	9.0	2,002	2759	58.8	8.8	2,473	2874	58.9	9.2	2,704
Turkey	2673	59.0	11.8	1,793	2851	57.7	10.9	2,179	2954	57.2	10.8	2,832	3042	55.1	10.4	2,853	3006	54.6	9.3	3,059
USSR	3204	53.5	21.7	--	3323	49.0	24.6	2,873	3364	46.0	26.2	3,609	3370	44.6	25.8	4,270	3375	43.6	26.7	4,894
UK	3307	27.8	40.6	7,378	3352	26.4	39.5	7,695	3236	26.5	39.4	9,014	3215	26.6	38.9	10,028	3178	26.3	36.6	11,137
USA	3252	22.4	39.3	11,492	3390	21.0	38.2	12,725	3398	21.3	35.6	13,479	3510	21.1	34.9	15,097	3595	21.5	34.1	16,559
Venezuela	2325	41.0	16.8	7,349	2413	41.3	16.8	7,624	2446	40.1	18.8	7,341	2652	39.0	20.6	7,233	2536	40.8	19.8	6,037
Zaire	2175	71.0	3.9	514	2256	68.9	3.8	644	2289	69.1	3.4	603	2108	70.4	2.9	450	2124	72.5	3.2	422
Zambia	2094	76.1	6.7	1,088	2192	70.0	7.4	1,091	2322	71.5	7.1	1,217	2205	76.0	5.7	930	2130	78.4	5.1	774

Dietary indicators are: Kcal--per capita daily energy availabilities; SS (%)--percent of calories from starchy staples; Animal (%)--percent of calories from animal products, and are calculated from FAO. 1991. *Food Balance Sheets, 1984-86 Average*. Rome.

Purchasing-power-parity GDP per capita figures are expressed in 1985 U.S. dollars and are from Penn World Table (Mark 5.5). 1993. Annex to Summers, Robert and A. Heston. 1991. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics*. May.

Appendix Table 2. Demand Projection Work Sheet

	1985			2000			2025			2050		
WORLD - Total												
Population (m)			4,844 m			6,091 m			8,121 m			8,909 m
Annual energy utilization (MMT grain equivalent)			2,606 mmt			3,803 mmt			6,258 mmt			7,316 mmt
DEVELOPED - Total												
Population (m)			1,179 m			1,187 m			1,364 m			1,246 m
GDP per capita (PPP $US 1985)	10,000			10,000+			10,000+			10,000+		
Apparent daily direct energy consumption per capita		3,366			3,500			3,500			3,500	
Percent calories from animal products	30			34			34			34		
Primary energy for livestock (at 6:1)		6,059			7,140			7,140			7,140	
Total daily per capita energy utilization		9,425			10,640			10,640			10,640	
Annual per capita energy utilization (kg. grain equivalent)		983 kg			1,110 kg			1,110 kg			1,110 kg	
Total annual energy utilization (MMT grain equivalent)			1,159 mmt			1,318 mmt			1,514 mmt			1,583mmt
DEVELOPING - Total												
Population (m)			3,666 m			4,904 m			6,762 m			7,663 m
Annual energy utilization (MMT grain equivalent)			1,447 mmt			2,485 mmt			4,744 mmt			5,933 mmt
EAST & SOUTHEAST ASIA												
Population (m)			1,529 m			1,879 m			2,305 m			2,372 m
GDP per capita (PPP $US 1985)	2,000			3,600			9,602			10,000+		
Apparent daily direct energy consumption per capita		2,500			2,700			3,000			3,000	
Percent calories from animal products	10			15			30			30		
Primary energy for livestock (at 6:1)		1,500			2,430			5,400			5,400	
Total daily per capita energy utilization		4,000			5,130			8,400			8,400	
Annual per capita energy utilization (kg. grain equivalent)		417 kg			535 kg			876 kg			876 kg	
Total annual energy utilization (MMT grain equivalent)			638 mmt			1,005mmt			2,019 mmt			2,078 mmt
SOUTH ASIA												
Population (m)			1,058 m			1,496 m			2,038 m			2,168 m
GDP per capita (PPP $US 1985)	900			1,211			1,987			3,684		
Apparent daily direct energy consumption per capita		2,143			2,300			2,500			2,800	
Percent calories from animal products	6			8			10			15		
Primary energy for livestock (at 6:1)		771			1,104			1,500			2,520	
Total daily per capita energy utilization		2,914			3,404			4,000			5,320	
Annual per capita energy utilization (kg. grain equivalent)		304 kg			355 kg			417 kg			555 kg	
Total annual energy utilization (MMT grain equivalent)			322 mmt			531 mmt			850 mmt			1,203 mmt

	1985			2000			2025			2050		
SW ASIA & NORTH AFRICA												
Population (m)			239 m			339 m			546 m			792 m
GDP per capita (PPP $US 1985)	3,000			4,674			9,786			10,000+		
Apparent daily direct energy consumption per capita		3,000			3,200			3,500			3,500	
Percent calories from animal products	10			20			34			34		
Primary energy for livestock (at 6:1)		1,800			3,840			7,140			7,140	
Total daily per capita energy utilization		4,800			7,040			10,640			10,642	
Annual per capita energy utilization (kg. grain equivalent)		501 kg			734 kg			1,110 kg			1,110 kg	
Total annual energy utilization (MMT grain equivalent)			120 mmt			249 mmt			606 mmt			879 mmt
SUB-SAHARAN AFRICA												
Population (m)			435 m			675 m			1,170 m			1,521 m
GDP per capita (PPP $US 1985)	750			870			1,127			1,848		
Apparent daily direct energy consumption per capita		2,200			2,300			2,600			2,900	
Percent calories from animal products	5			7			10			15		
Primary energy for livestock (at 6:1)		660			966			1,560			2,610	
Total daily per capita energy utilization		2,860			3,266			4,160			5,510	
Annual per capita energy utilization (kg. grain equivalent)		298 kg			340 kg			434 kg			575 kg	
Total annual energy utilization (MMT grain equivalent)			130 mmt			230 mmt			508 mmt			875 mmt
LATIN AMERICA												
Population (m)			399 m			515 m			686 m			809 m
GDP per capita (PPP $US 1985)	4,500			7,010			10,000+			10,000+		
Apparent daily direct energy consumption per capita		3,000			3,500			3,500			3,500	
Percent calories from animal products	15			25			34			34		
Primary energy for livestock (at 6:1)		2,700			5,250			7,140			7,140	
Total daily per capita energy utilization		5,700			8,750			10,640			10,640	
Annual per capita energy utilization (kg. grain equivalent)		594 kg			912 kg			1,110 kg			1,110 kg	
Total annual energy utilization (MMT grain equivalent)			237 mmt			470 mmt			761 mmt			898 mmt

Population data and projections from United Nations. 1997. *World Population Prospects: The 1996 Revision*. New York: Department of Economic and Social Affairs. Population Division. Updated by U.N. 1999. "Revision of World Population Estimates and Projections." *www.popin.org/pop1998/3.htm*

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