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Livestock to 2020: The Revolution Continues

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The Livestock Revolution

From the beginning of the 1970s to the mid 1990s, consumption of meat in developing countries increased by 70 million metric tons (MMT), almost triple the increase in developed countries, and consumption of milk by 105 MMT of liquid milk equivalents (LME), more than twice the increase that occurred in developed countries. The market value of that increase in meat and milk consumption totaled approximately $155 billion (1990 US$), more than twice the market value of increased cereals consumption under the better-known "Green Revolution" in wheat, rice and maize. The population growth, urbanization, and income growth that fueled the increase in meat and milk consumption are expected to continue well into the new millennium, creating a veritable Livestock Revolution. As these events unfold, many people's diets will change, some for the better, but others for the worse, especially if food contamination is not controlled. Farm income could rise dramatically, but whether that gain will be shared by poor smallholders and landless agricultural workers who need it most is still undetermined. The environmental and public health impact of rapidly rising livestock

1 This is an updating with new model results supplied by Mark Rosegrant of the projections and analysis in C. Delgado *et al., Livestock to 2020: The Next Food Revolution*, a 40,000 word report in the 2020 Vision discussion paper series of the International Food Policy Research Institute (IFPRI) published in 1999 and drawing on modeling done by Rosegrant in 1998. The former report was produced jointly by IFPRI, the Food and Agricultural Organization of the United Nations (FAO), and the International Livestock Research Institute (ILRI). A short form of the 2020 discussion paper was published under the same authorship as "The Coming Livestock Revolution", in *Choices*, Special Millennium Issue, Fourth Quarter 1999.

production in close proximity to population centers also needs attention (Delgado *et al.*, 1999a, 1999b).

The Livestock Revolution is propelled by demand. People in developing countries are increasing their consumption from the very low levels of the past, and they have a long way to go before coming near developed country averages. In developing countries people consumed an annual average in 1996-98 of 25 kg/capita meat and 51 kg/capita milk, one-third the meat and one-fifth the milk consumed by people in developed countries. Nevertheless, the caloric contribution per capita of meat, milk and eggs in developing countries in the late 1990's was still only a quarter that of the same absolute figure for developed countries and, at 10 percent, accounted for only half the share of calories from animal sources observed in the developed countries, as shown in Table 1.

Per capita consumption is rising fastest in regions where urbanization and rapid income growth result in people adding variety to their diets. Across countries, per capita consumption is significantly determined by average capita income (Cranfield 1998). Aggregate consumption grows fastest where rapid population growth augments income and urban growth (Rae 1998; Delgado and Courbois 1998). Since the early 1980s, total meat and milk consumption grew at 6 and 4 percent per year respectively throughout the developing world.[2.] In East and Southeast Asia--where income grew at 4-8 percent per year between the early 1980's and 1998, population at 2-3 percent per year, and urbanization at 4-6 percent per year--meat consumption grew between 4 and 8 percent per year.

2 Compound annual growth rates estimated between 1982/84 and 1996/98.

The Livestock Revolution has been most evident in East Asia, as illustrated by the per capita figures for China in Table 2. Considerable controversy surrounded the official Chinese feed use and meat production figures in the first half of the 1990's, and conservative adjustments have been incorporated in the analysis here to the extent feasible. However, even a radical downsizing of the estimates of past Chinese growth in consumption only puts off by two or three years the arrival of the situation that will be projected for 2020 below, and does not change significantly the long term conclusions of the modeling. Using the current (downsized) FAO estimates of Chinese consumption changes between 1982/84 and 1996/98, the share of the world's meat consumed in developing countries rose from 37 to 48 percent, and their share of the world's milk rose from 34 to 44 percent (Table 3). Pork and poultry accounted for 76 percent of the large net consumption increase of meat in developing countries from 1982/84 to 1996/98. Conversely, both per capita and aggregate milk and meat consumption stagnated in the developed world, where saturation levels of consumption have been reached and population growth is small. Nine-tenths of the small net increase in meat consumption that occurred in developed countries over the same period was from poultry.

The dominant role of China and Brazil in the meat part of the Livestock Revolution is shown in Table 4. However, the near doubling of aggregate milk consumption as food in India between the early 1980's and the late 1990's suggests that the Livestock Revolution goes beyond just meat and beyond China and Brazil. At 60 MMT of LME in 1996/98, Indian milk consumption amounted to 13 percent of the world's total and 31 percent of milk consumption in all developing countries. The high milk consumption of Latin America in 1996/98, at 112 kg/capita, is half way between the developing world as

a whole (43 kg/capita) and the developed countries (194 kg/capita), because of the very high level (75%) of urbanization in Latin America (Table 2).

The rapid rise in livestock production in developing countries has been confronted in recent years by dwindling grazing resources for ruminant animals and a pattern of effective demand largely centered on rapidly growing mega-cities fueled by non-agricultural development. The latter increases pressures for rapid industrial approaches to satisfying urban meat demand. Together, these trends help explain the large share of non-ruminants in the production increases in both the North and the South. The decline in the feeding of cereals to ruminants in the North and the much larger increase in non-ruminant production in the South helps explain a relative shift to the South in the use of feed cereals. This shift is illustrated in Table 5, which only includes cereals used for feed. Cereals feed use in the developed countries has actually declined since the early 1980's, whereas it increased substantially in developing countries. The share of the latter in world use of cereals for feed went from 21 percent in 1982/84 to 36 percent in 1996/98. This salient fact has inspired many observers to wonder if the rise of production of pork, poultry, eggs, and milk for the urban middle class would jack up the price of cereals to the poor in both rural and urban areas of developing countries. Furthermore, others wondered whether the trends portrayed above could possibly continue far into the future, without resource scarcities or import constraints raising prices to the point that the growth in consumption would peter out.

Whether these trends will continue into the future was explored in 1998 with IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), a global food model first reported in Rosegrant, Agcaolili-Sombilla, and

Perez (1995). Results were put into the context of growing concern about livestock issues in Delgado *et al.* (1999a, 1999b). The present paper reports results from a substantially updated version of IMPACT run in October 2000, which benefited in part from the many comments received on the earlier work.

The IMPACT Model[3]

IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade is useful for analyzing alternative scenarios for global food demand, supply and trade. IMPACT is specified as a set of country or regional sub-models, within each of which supply, demand and prices for agricultural commodities are determined. The present version of IMPACT (October 2000) covers 36 countries and regions (which account for virtually all of world food production and consumption), and 22 commodities, including all cereals, soybeans, roots and tubers, four meats, milk, eggs, oils, oilcakes, meals, sugar, fruits and vegetables.

The model uses a system of supply and demand elasticities, different for each of the 36 markets and incorporated into a series of linear and nonlinear equations, to approximate the underlying production and demand functions. Cross-price elasticities and intermediate demands (such as feed grains for livestock production) ensure the interlink age of markets within each of the 36 country groupings. Sectoral growth multipliers are used to determine the intersect oral effects of changes in income in agricultural and nonagricultural sectors.

3 This section draws heavily on Rosegrant 1999

Demand within each of the 36 country-group markets is a function of prices, income and population growth specific to that market. Growth in crop production in each country-group is determined by crop prices and the rate of productivity growth specific to that group. Future productivity growth is estimated by its component sources, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector agricultural research and development, agricultural extension and education, markets, infrastructure and irrigation.

Prices are endogenous in the system. Domestic prices consist of world prices, expressed in the respective country-group currencies via an exchange rate to the U.S. dollar. The effects of country-group specific price policies are expressed in terms of producer subsidy equivalents (PSE), consumer subsidy equivalents (CSE), and marketing margins. PSE and CSE measure the implicit level of taxation or subsidy borne by producers or consumers relative to world prices and account for the wedge between domestic and world prices. Marketing margins reflect factors such as transport costs. In the model, PSEs, CSEs, and marketing margins are expressed as percentages of the world price.

The 36 country-group sub-models for each commodity are interlinked through trade with a separate, unique "world market" for each commodity, a specification that highlights the inter-dependence of commodity prices across countries and commodities in global agricultural markets. Commodity trade by country-group is the difference between domestic production and demand (excess demand) for that country-group. Countries with positive trade are net exporters, while those with negative values are net

importers. This specification does not permit a separate identification of countries that are both importers and exporters of a particular commodity. Stocks are not explicitly modeled because markets are assumed to be in equilibrium in the medium and longer term.

The world price of a commodity is the equilibrating mechanism such that when an exogenous shock is introduced in the model, the world price will adjust and each adjustment is passed back to the effective producer and consumer prices via price transmission equations. Changes in domestic prices subsequently affect commodity supply and demand, necessitating their iterative readjustments until world supply and demand balance, and world net trade is again equal to zero. For fluid milk, the market-clearing condition applies only domestically.

World agricultural commodity prices are determined annually at levels that clear international markets. The model is written in the General Algebraic Modeling System (GAMS) programming language. The solution of the system of equations is achieved by using the Gauss-Seidel method algorithm. This procedure minimizes the sum of net trade flows at the international level and seeks a world market price for a commodity that satisfies the market-clearing condition that all country-group level excess demands for a given commodity sum to zero, and that this condition holds simultaneously for all commodities.

Improvements to IMPACT since 1998

IMPACT is a constantly evolving tool and has undergone substantial changes since the June 1998 version whose results for livestock were reported in Delgado *et al.*

(1999a). Seven sets of changes in suspected decreasing order of importance to the livestock and feed results are:

- The baseline data are changed from 1992-94 averages to 1996-98 averages. This incorporates the experience of the Asian economic crisis and events in the former Soviet Union.
- GDP projections through 2020 were consequently updated also with better information; the result was slightly less pessimistic for most of Asia than the previous version that had factored in the early impact of the financial crisis starting in 1997, but more pessimistic for the former Soviet Union and Central Asia.
- The population projections to 2020 were reduced by substituting the late 1998 United Nations Medium Variant projections for the same series published by the U.N. in 1996.
- Meat and feed supply and demand elasticities and technological change parameters were significantly upgraded for Argentina and Brazil, to reflect major events of the early to mid-1990's not reflected in the previous model, including the impacts of agricultural liberalization.
- Poultry demand and supply elasticities were increased very slightly in most Asian countries to better track on-going transitions in demand and supply patterns in those countries.
- Six new commodities were added: cane and beet sugar, sweeteners, tropical and temperate fruits, and vegetables.
- The country-group coverage changed slightly, with the splitting off of Central

Asia into a separate grouping, and the incorporation of Madagascar into a larger country-group.

A major change that is currently being worked upon, but which is not available for this paper or the projections in it, is the incorporation of fisheries in IMPACT, expected for late 2001. This poses particularly difficult modeling and data issues that are addressed elsewhere (Delgado *et al.* 2000). Fish are good substitutes for meats in consumption (especially for poultry) and fishmeal is a shared input between high-value carnivorous aquaculture (such as salmon and shrimp) and poultry. Fishmeal is also a good substitute for soy meal. Finally, the infrastructure that has promoted the rapid rise of fish trade in developing countries in recent years (such as cold chains) can also be expected to promote meat trade, especially in tropical countries.

To date, fish is a far more valuable commodity in the aggregate in international trade (U.S.$ 52.5 billion in 1996 according to FAO 1999) than is meat (by a factor of ten), but is a much smaller source of calories in food supply than meat. It is therefore expected that the incorporation of fish will have a much greater effect on meat trade projections than on meat consumption projections, at least on a global basis.

Results from the Updated Model: Consumption and Production

For the 1996/98 to 2020 period, IMPACT projects developing country aggregate consumption growth rates of meat and milk separately to be 2.9 percent per year each, compared to 0.7 and 0.6 percent, respectively, in the developed countries. Aggregate meat consumption in developing countries is projected to grow by 102 MMT between

the late 1990s and 2020, whereas the corresponding figure for developed countries is 16 MMT (Table 6). Similarly, additional milk consumption in the developed countries of 25 MMT of Liquid Milk Equivalents (LME) will be dwarfed by the additional consumption in developing countries of 178 MMT.

In developing countries, 70 percent of the additions to meat consumption are from pork and poultry; in the developed countries, the comparable figure is 81 percent. Poultry consumption in developing countries is projected to grow at 3.7 percent per annum through 2020, followed by beef at 2.9 percent and pork at 2.4 percent. In the developed countries, poultry consumption is projected to grow at 1.3 percent per annum through 2020, with other meats growing at 0.5 percent or less (Table 6). As the growth rates in Table 7 suggest, high growth in consumption is spread throughout the developing world and in no way limited to China, India and Brazil, although the sheer size and vigor of those countries will mean that they will continue to increase their dominance of world markets for livestock products. Experience for individual commodities will vary widely among different parts of the developing world, with China leading the way on meat with a near-doubling of the total quantity consumed; the increments are primarily poultry and pork. India and the other South Asian countries will drive a large increase in total milk consumption.

Production patterns generally follow consumption patterns, as sugg4ested by projected growth rates in production in Table 8 that are similar to growth rates for consumption in Table 6. Because of the relatively high cost of handling perishable final products and taste factors, most meat and milk will be produced where it is consumed, aided by increasing feed imports. By 2020, people living in developing countries are

projected to produce on average 38 percent more meat and 37 percent more milk per capita than in the late 1990s.

Since so much of the expansion in meat production comes from monogastric livestock such as pigs and poultry, effective demand for concentrate feeds in developing countries will continue to increase. IMPACT projects a worldwide expansion of an additional 265 MMT of cereals used as feed per year by 2020, compared to the 1996/98 annual average. This can be compared to an average annual U.S. maize (corn) crop of about 200 MMT in the 1990's. Developing countries accounted for 36 percent of cereals feed use in 1996/98, but are projected to account for 47 percent in 2020. Although the share of cereals feed use occurring in developed countries is projected to fall, the absolute amount will increase to 2020, and developed countries will continue to be the big cereals feed users when there smaller population size is taken into account. On a human per capita basis, cereals feed use in 2020 in developed countries is projected to be 362 kg, compared to 71 kg in developing countries (Table 5).

Results for the Updated Model: Trade and Prices

The actual trade situation for livestock products and feed cereals, and the projected situation for 2020, are shown in Table 9. Several striking conclusions emerge. First, the big trade flows that equilibrate rapidly growing livestock demand with supply in developing countries occur primarily in the feed cereals market. Developing countries as a whole increase their net imports of cereals for all purposes by 98 MMT or to a total of more than 200 MMT of net annual imports from the developed countries. Maize,

sorghum and minor cereals (i.e. excluding rice and wheat) accounted for 42 MMT of net cereal imports into the developing countries (from the developed countries) in 1996/98, and are projected to account for net imports of 97 MMT in 2020. Thus 55 MMT--or substantially more than half—of the projected increase in annual net imports of cereals to developing countries from developed countries between 1996/98 and 2020 are likely to be used for feed.[4] The most impressive increase is projected for China (40 MMT extra net imports of cereals for all purposes), but the rest of Southern and Eastern Asia adds another 27 MMT in net imports.

Changes in meat trade to 2020 tend to be more modest, even if adjusted to value terms. Net imports of beef by developing countries are projected to increase by 1.0 MMT by 2020, while the figures for pork and poultry are 1.4 and 2.5 MMT respectively. Latin America is the only developing region projected to increase its net exports of meat. This is especially striking for beef (an additional 1.3 MMT of net exports), but is also the case for pork and poultry. Developing countries are expected to add another 13.7 MMT (LME) in milk imports by 2020, with net imports growing noticeably in most parts of the developing world. By contrast, India is an exception; despite its size and rapid growth in milk consumption, net imports are only projected to grow by 0.6 MMT (LME) by 2020 because of strong growth in production.

With these large increases in animal food product consumption and cereals use as feed, it is interesting to review inflation-adjusted prices of livestock and feed commodities to 2020. Real prices for these items fell sharply from the early 1970's to the early 1990's, stabilized in the mid 1990's in most cases, and fell again thereafter

4 Some of the imported maize may be used for human food, and some of the minor cereals for brewing, but

(Table 10). Real maize prices did not fall over the 1990's, reflecting perhaps high demand for feed under the Livestock Revolution. By contrast, real beef prices fell by a factor of three from 1970/72 to 1996/98. Interestingly, real beef prices fell by one-third from 1990/92 to 1996/98, but real poultry prices were stable and pork prices actually increased. This phenomenon is re-capped in Table 11 in the line showing the difference between the actual real prices used for the baseline of the June 1998 version of IMPACT (1992/94 averages) and the actual ones used for the updated version (1996/98 averages). The monogastrics and milk had real price increases and the real prices for the ruminant meats fell. This probably reflects a combination of consumer problems for the beef market in Europe associated with fears about BSE and high demand for pork and poultry in Asia over the period.

Looking to the future, the updated version of IMPACT projects the expected change in real prices to 2020 relative to 1996/98 (Table 11, bottom line). The overall picture for 2020 is a noticeable real decline for wheat and rice (13 and 21 percent), a similar decline for milk (12 percent), more modest decreases for meats (4 to 7 percent) and stability or slight increases for feedgrains (0 and 3 percent). The results lend support to the view that the main effect of the Livestock Revolution on agricultural prices is to stem the fall in feedgrain prices, such that maize and soybeans will increase in value over time compared to rice and wheat, whose real prices will fall. The Livestock Revolution will also cushion if not prevent the further fall in real global livestock prices. There is little support from the updated model results for the view that increased livestock consumption in Asia will run up the food grain prices of the poor there or

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quite a bit of the wheat not included in this figure will surely be used for feed.

elsewhere, especially since world maize prices were very significantly higher in the real terms in the 1970's and 1980's than they are now, or are projected to be in 2020.

Sensitivity Analysis

Formal sensitivity analysis of livestock issues has not been completed for the updated model, but both the differences of the present forecast from the previous forecast and detailed sensitivity analysis with the older version of the model reported in Delgado *et al.* (1999a) provide insight into the sensitivity of model results to different components. Beyond the comparison of real price projections for 2020 in Table 11, Appendix tables A2 and A3 present comparisons of projected total and per capita food consumption for different livestock products in different regions from Delgado *et al.* (1999a) and the October 2000 version of IMPACT presented above. Despite the many updates listed above in the model, the projections for 2020 are essentially similar, with two significant exceptions.

The first is that the new runs project a markedly higher rate of growth of poultry in Asia than previously, projecting a further 18 MMT increase in consumption for developing countries as a whole (37 percent above the previous forecast). This stems from the slightly less pessimistic income scenarios in Asia and slightly increased price elasticities.[5] The second significant change between the older and newer set of 2020 consumption projections is that milk consumption in developed countries is expected to be 5 percent higher than forecast previously, and milk consumption in developing

5 The lower baseline price used for poultry in the October 2000 is not a factor, counter to economic intuition. This is because in the normalization of the model, all price changes are in essence percentage price changes from the baseline.

countries is forecast to be 5 percent lower. Within this overall change, India's milk consumption in 2020 is forecast to be 18 percent lower than the very high growth forecast previously (but still a very high increase relative to the late 1990's), and China's is forecast to be one-third higher than previously, but from a low base. The changes stem from a wide series of price adjustments in the model, and are not easily ascribable to any one change in the updating.

Relative to the projections for 2020 real prices in Delgado *et al.* (1999a) (also given in second line from the bottom of Table 11), the updated price projections are essentially similar (within 3 percentage points of difference relative to the baseline) for wheat, lamb, and milk. They are close (within 7 percentage points) for maize, beef, pork, and poultry, and quite different for rice (now forecasting a real price 13 percent lower than in the previous forecast) and for soybeans (now forecasting a real price 11 percent higher than the previous forecast). The new forecast projects feedgrain prices to be higher in 2020 than was forecast previously, and meat and milk prices to fall less than was projected previously. Prices for food grains such as rice and wheat are now forecast to fall a little more than was thought previously. In sum, the projections from the updated model only strengthen conclusions in Delgado *et al.* (1999a) that the livestock revolution is shaping global food markets by arresting the fall in prices of feedgrains and attenuating the fall in real prices of livestock products.

Delgado *et al. (*1999a) tested the sensitivity of projections from the June 1998 version of IMPACT to possible extreme scenarios such as a prolonged and severe economic crisis in Asia, a rapid increase in meat consumption in India, or a global decrease in concentrate feed conversion efficiency stemming from increased use of grain

in animal rations under industrialization. In all cases, the projected growth of aggregate consumption of livestock products in developing countries remained strong. The projected consumption growth in Asia was lower in the severe economic crisis scenario, and world prices fell further in that scenario than they did in the base projection to 2020. The scenario incorporating a dramatic shift in tastes in India toward meat consumption had the opposite effect, raising projected world prices. Other model runs showed that changes in production efficiency and cost matter greatly to the relative competitiveness and production outcomes of individual countries, to the use of cereals as feed, and to world trade patterns, but barely affected projected levels of world livestock consumption. It was assumed in sensitivity analysis that between 1992/94 and 2020 the amount of feed required to produce a unit of meat and milk in developing countries would rise by an additional 60 percent; the result of this change from the baseline in the older model was that world maize prices were only 21 percent higher in 2020 than the original baseline projection. In real terms, that level was still half the prevailing prices in the early 1980s.

Both the projections of the June 1998 version of IMPACT and the updated projections form the October 2000 version are confirmed by events in world markets over the past 30 years. Demand increases for meat and milk have largely been met through expansion of feed production or imports at world prices that have declined in real terms over time. Historically, livestock has been one of the main factors stabilizing world cereal supply. Evidence from years of cereal price shocks in the 1970s and 1980s suggests that reductions in cereal supply were largely absorbed by reductions in feeding to livestock.

The model assumes that the most important forces driving increasing consumption of animal products--population, income growth, and urbanization--will continue during the next twenty years, albeit at reduced rates compared to the past 20 years. The key conclusion from the model is that even with only modestly increasing productivity, large amounts of additional meat, milk, and feed will be supplied without dramatic price increases. The issues then are not whether sufficient animal products and cereals will be available, but what impact increased production and consumption will have on the environment, human health, and the incomes of the poor. Because developing countries will produce 63 percent of world meat and 50 percent of world milk in 2020, the brunt of the benefits and costs of the Livestock Revolution will accrue in those regions.

Conclusions: Opportunities and Perils

The principal conclusion of the present study is to confirm the finding in the previous work that the Livestock Revolution in developing countries will continue at least to 2020 and will increasingly drive world markets for meat, milk and feed grains. Thus whether it is a good thing is not the issue; it is a phenomenon that will occur. In fact the updates actually strengthen this conclusion, as the changes in the world that have been incorporated in the updating have slightly alleviated the basically very conservative assumptions of the original work.

Developing countries as a whole will increase their already large net imports of cereals to a an annual amount in 2020 of about the same magnitude as the annual U.S. corn crop (200 MMT). About half (97MMT) of these net imports will be maize and cereals other than rice and wheat; most of the coarse grains will probably go to feeding, as

may some of the wheat. Net meat imports into developing countries from the developed countries are also projected to expand (by a factor of 10), but from a smaller base at the present time. Developing countries as a whole are projected to increase their net meat impoerts from the North by an annual level of about 5 MMT by 2020; half of this will be poultry imports, with the remainder being 1.4 MMT of pork and 1 MMT of beef. Net milk imports into developing countries are projected to expand by an additional 13.7 MMT (LME) to a annual total by 2020 of 33.7 MMT.

Results also confirm the finding that the Livestock Revolution is not necessarily a threat to the poor through raising cereals prices. The model suggests relative little change in 2020 relative to real price levels in the base years 1996/98. Principally because of net import demand from developing countries, feedgrain prices will remain at about 1996/98 average levels. Meat prices will fall in the range of 4 to 7 percent, whereas the milk price is projected to fall 12 percent. These falls would be substantially higher without the Livestock Revolution. However, an assessment of the impact of the Livestock Revolution on developing countries requires going beyond projections. Because previous trends have been found to hold and perhaps even to be stronger than expected, the rest of the present paper will draw liberally on the previous work in this regard.[6]

On the positive side, increased consumption of animal products can improve the incomes of poor farmers and food processors in developing countries. Considerable evidence from in-depth field studies of rural households in Africa and Asia shows that the rural poor and landless presently get a higher share of their income from livestock than do better-off rural people (von Braun and Pandya-Lorch 1991; Delgado *et al.* 1999a). The

exception tends to be in Latin America, where relative rural wealth correlates more clearly with cattle holdings. In most of the developing world, a goat, a pig, some chickens, or a milking cow can provide a key income supplement for the landless and otherwise asset-poor.

Some analysts contemplating the Livestock Revolution extend the concern with excess animal products consumption in developed countries to the rise in consumption in developing countries. However, for the majority of people in developing countries, whose consumption levels are still very low as evidenced by Table 1, little evidence supports this view. On the contrary, protein and micro-nutrient deficiencies, which tend to disappear with increased consumption of livestock products, remain widespread in developing countries. There is valid concern that those who most need the added meat and milk will not get it simply from increasing production, and this is a highly valid policy concern.

Rapid industrialization of production of monogastrics under the Livestock Revolution will supply urban supermarkets, but may not bolster rural incomes in a widespread manner unless specific actions are undertaken. There are large economies of scale in processing livestock-origin food products and in input supply, but far less in production itself once market distortions favoring powerful producers are removed. Poverty policy can promote vertical integration of small producers with livestock food processors, through contract farming or participatory producer coops. The alternative might be that the poor are driven out by industrial livestock producers and the one growing market they presently supply will be closed to them. Simulations with IMPACT

6 Principally on Delgado *et al.* (1999b).

show that policies affect the costs of livestock production and thus, the location and type of production at home and abroad. Policies towards infrastructure, pollution, access to capital, and rural organization will affect the comparative advantage of smallholders versus large industrial enterprises.

Conversely, the Livestock Revolution may worsen environmental problems (de Haan *et al.* 1997). The expansion of livestock food production in developing countries until recently came primarily from rapidly increasing numbers of animals rather than from higher carcass weights. This increase contributed to large concentrations of animals and people in urban environments in many cities of developing countries with weak regulations governing livestock production (such as in Beijing, Mumbai, Lima, and Dar-es-Salaam). Over-stocking has also occurred In places where land is "free" (such as most of the African Sahel); more intensive use of the land without additional inputs could further degrade its productivity. Property rights systems that do not internalize externalities are responsible for most problems of this kind.

Conversely, animals have tended over time to be produced more intensively in places where financial capital is cheap relative to land (such as the Netherlands), worsening waste and air problems. Nutrient loading has occurred where the social cost has not been fully passed on to the producers and through them to the consumers. Distortions in domestic capital markets, such as subsidized lending to influential organizations, often promote inefficient, large-scale pig, milk, and poultry production in the peri-urban areas of developing countries. These policies distort the pattern of livestock development and ultimately cannot be sustained. Further, poor infrastructure and distortions in the marketing chain, such as extortionate police road stops that prevent

competition from rural areas, poor environmental regulation, and lack of legal accountability for pollution promote urban piggeries and dairies that cannot adequately dispose of waste materials.

Growing concentrations of animals and people in the major cities of developing countries also notably increased the incidence of zoonotic diseases such as infections from Salmonella, E-coli, and Avian Flu--diseases that can only be controlled through enforcement of zoning and health regulations. The Livestock Revolution also raises other major public health concerns. Greater intensification of livestock production has caused a build-up of pesticides and antibiotics in the food chain in many places of both the developed and developing world. Furthermore, as the consumption of livestock products increases in tropical climates, food safety risks from microbial contamination become more prevalent.

Policy needs to focus on removing the overt distortions that produce problems, while promoting institutional change in property rights in commercializing smallholder areas. Governments and development partners wanting to help the poor in commercially viable activities need to follow the Livestock Revolution closely. The rapidly growing demand for livestock products is a rare opportunity for smallholder farmers to benefit from a rapidly growing market. The worst thing that well-motivated agencies can do is to cease public investments that facilitate economic, sustainable, and small-operator forms of market-oriented livestock production. Lack of action will not stop the Livestock Revolution, but it will help ensure that the form it takes is less favorable for growth, poverty alleviation and preservation of the environment.

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Table 1--Annual per capita human food consumption (kg) and percent of calories from selected livestock products, 1973 and 1997

Commodity	Developed Countries		Developing Countries	
	1973	1997	1973	1997
Beef	26	23	4	6
	(3%)	(3%)	(1%)	(1%)
Mutton and goat	3	2	1	2
	(1%)	(0+%)	(0%)	(0+%)
Pork	26	28	4	10
	(4%)	(5%)	(2%)	(4%)
Poultry	11	21	2	7
	(1%)	(3%)	(0%)	(1%)
Eggs	13	14	2	7
	(2%)	(1%)	(0%)	(1%)
Milk and products excluding butter	188	245	29	51
	(9%)	(9%)	(2%)	(3%)
Four meats	67	75	11	25
	(10%)	(10%)	(3%)	(6%)
Four meats, eggs, and milk	268	334	42	83
	(20%)	(20%)	(6%)	(10%)

Source: Calculated from data in FAO 2000.

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.

Table 2—Per Capita meat and milk consumption by region, 1983 and 1997

Region	Meat		Milk	
	1983	1997	1983	1997
	(kilograms)			
China	16	43	3	8
Other East Asia	22	31	15	19
India	4	4	46	62
Other South Asia	6	9	47	63
Southeast Asia	11	18	10	12
Latin America	40	54	93	112
WANA	20	21	86	73
Sub-Saharan Africa	10	10	32	30
Developing world	14	25	35	43
Developed world	74	75	195	194
United States	107	120	237	257
World	30	36	76	77

Source: Values are three-year moving averages centered on the year shown, calculated from data in FAO 2000.

Table 3--Food consumption trends of various livestock products 1983 and 1997

Region	Total Consumption		% of World Total	Per Capita Consumption	
	1983	1997	1997	1983	1997
	(million MT)			(kg)	
Developed world					
Beef	32	30	52.2	27	25
Pork	34	36	43.4	29	28
Poultry	19	28	49.1	16	20
Meat	88	98	46.9	74	76
Milk	233	251	56.4	195	192
Developing world					
Beef	16	27	47.4	5	5
Pork	20	47	56.6	6	9
Poultry	10	29	50.9	3	5
Meat	50	111	53.1	14	21
Milk	122	194	43.6	35	40

Source: Calculated from data in FAO 2000.

Notes: "Consumption" is direct use as food, uncooked weight bone-in. "Meat" includes beef, pork, mutton and goat, and poultry. "Milk" is milk and milk products in liquid milk equivalents. Metric tons and kilograms are three year moving averages centered on the year shown.

Table 4--Food consumption of meat and milk by region, 1983 and 1997

Region	Total Meat Consumption		Total Milk Consumption	
	1983	1997	1983	1997
	(million MT)		(million MT)	
China	16	53	3	10
India	3	4	34	60
Other East Asia	1	2	1	1
Other South Asia	1	3	11	21
Southeast Asia	4	9	4	6
Latin America	15	26	35	54
of which Brazil		11		20
WANA	5	7	21	25
Sub-Saharan Africa	4	6	12	17
Developing world	50	111	122	194
Developed world	88	98	233	251
World	139	208	355	445

Source: Calculated from data in FAO 2000.

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

Table 5--Trends in the use of cereal as feed

Region	Total Cereal Use as Feed 1983	1993	1997	2020
		(million MT)		
China[a]	40-49	78-84	91-111	221
India	2	3	2	4
Other East Asia	3	7	8	12
Other South Asia	1	1	1	1
Southeast Asia	6	12	15	27
Latin America	40	55	58	98
WANA	24	29	36	59
Sub-Saharan Africa	2	3	4	8
Developing world	128	194	235	432
Developed world	465	442	425	493
World	592	636	660	925

Sources: Calculated from data in FAO 2000. Figures are three year moving averages centered on year shown. The 2020 projections are from the October 2000 version of the IMPACT model.

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.

[a]Simpson, Cheng, and Miyazaki (1994) 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.* 1997. FAO (1997a) reports 49 million MT. Extrapolations of the lower figure yield the lower bound estimate. FAO data are used on the upper bound and in the totals.

Table 6--Projected food consumption trends of various livestock products to the year 2020

Region	Projected Annual Growth of Consumption 1997-2020	Total Consumption 1997	Total Consumption 2020	% of World Total 2020	Per Capita Consumption 1997	Per Capita Consumption 2020
	(percent per year)	(million MT)			(kg)	
Developed world						
Beef	0.5	30	34	39.5	23.3	24.8
Pork	0.4	36	39	32.8	27.9	28.8
Poultry	1.3	28	38	36.2	21.7	27.6
Meat	0.7	98	114	34.9	75.3	84.0
Milk	0.6	251	276	42.6	193.6	202.9
Developing world						
Beef	2.9	27	52	60.5	6.0	8.5
Pork	2.4	47	80	67.2	10.4	13.1
Poultry	3.7	29	67	63.8	6.5	11.1
Meat	2.9	111	213	65.1	24.6	34.9
Milk	2.9	194	372	57.4	43.2	61.1

Sources: Total and per capita consumption for 1997 are calculated from FAO 2000 and are three-year moving averages centered on 1997. The 2020 projections are from the October 2000 version of the IMPACT model.

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

Table 7--Projected food consumption trends of meat and milk, 1997-2020

Region	Projected annual growth 1997-2020		Total Consumption in 2020		Per Capita Consumption in 2020	
	Meat	Milk	Meat	Milk	Meat	Milk
	(percent per year)		(million MT)		(kg)	
China	3.0	3.5	104	23	71	16
India	3.5	3.2	9	132	7	104
Other East Asia	3.2	1.7	4	4	54	29
Other South Asia	3.3	3.0	6	42	12	78
Southeast Asia	3.3	2.9	19	12	29	18
Latin America	2.4	1.8	45	82	69	127
of which Brazil	2.3	1.7	19	30	92	142
WANA	2.6	2.2	13	42	26	83
Sub-Saharan Africa	3.2	3.3	11	35	12	37
Developing world	2.9	2.7	213	372	35	61
Developed world	0.7	0.4	114	276	84	203
World	2.0	1.5	327	648	44	87

Sources: Total and per capita meat consumption for 1997 are annual averages of 1996 to 1998 values, calculated from FAO 2000. Projections are from the October 2000 version of IMPACT.

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

Table 8--Projected production growth of various livestock products, to the year 2020

Region	Projected Annual Growth of Production 1997-2020	Total Production		Per Capita Production	
		1997	2020	1997	2020
	(percent per year)	(million MT)		(kg)	
Developed					
Beef	0.56	31	35	23.7	25.6
Pork	0.49	36	41	28.0	29.9
Poultry	1.39	30	41	22.9	30.0
Meat	0.81	100	120	77.1	89.0
Milk	0.53	339	382	261.1	281.0
Developing					
Beef	2.76	27	51	6.0	8.3
Pork	2.29	47	79	10.4	12.9
Poultry	3.54	29	64	6.4	10.5
Meat	2.77	110	206	24.5	33.9
Milk	2.73	208	386	46.3	63.3

Sources: Total and per capita production for 1997 are annual averages calculated from FAO 2000. Projections are from the October 2000 version of IMPACT.

Notes: "Meat" includes beef, pork, mutton and goat, and poultry, carcass weights plus fifth quarter. "Milk" is milk and milk products in liquid milk equivalents.

Table 9-Net exports (imports) of various livestock products by location in 1997 and projected to the year 2020

	Beef		Pork		Poultry		Milk		Cereals	
Region	1997	2020	1997	2020	1997	2020	1997	2020	1997	2020
					(million MT)					
China	-0.042	-0.608	0.159	-1.182	-0.155	-2.231	-1.369	-2.917	-7.760	-47.60
India	0.158	0.072	0	-0.064	0	-0.041	0.048	-0.539	1.701	-6.417
Other East Asia	-0.185	-0.487	0.007	-0.135	-0.038	-0.502	-0.195	-0.553	-13.58	-19.43
Other South Asia	-0.022	-0.128	0	-0.006	-0.001	-0.088	-0.759	-3.584	-4.972	-15.04
Southeast Asia	-0.197	-0.830	-0.008	0.109	0.158	0.280	-4.663	-8.837	-5.704	-8.645
Latin America	0.500	1.823	-0.105	0.049	-0.060	0.588	-5.767	-4.539	-15.35	-3.489
WANA	-0.377	-0.744	-0.006	-0.016	-0.459	-0.905	-4.885	-7.864	-45.23	-73.10
Sub-Saharan Africa	0.011	-0.063	-0.043	-0.092	-0.127	-0.214	-2.279	-4.596	-12.53	-27.34
Developing world	-0.152	-1.156	-0.007	-1.402	-0.701	-3.155	-20.01	-33.70	-104.1	-202.1
Developed world	0.152	1.156	0.007	1.402	0.701	3.155	20.01	33.70	104.1	202.1

Source: Projections are based on production minus consumption in the years shown for the commodity and region shown. Figures for 1997 are annual averages calculated from FAO 2000. Projections are from the October 2000 version of IMPACT.

Notes: Metric tons are carcass weights plus fifth quarter for meat. "Milk" is milk and milk products are in liquid milk equivalents. Net export (import) figures may not sum to zero overall because of rounding.

Table 10--Past trends in real prices of selected crop, feed, and livestock products

Year	Wheat	Rice	Maize	Soybeans	Soymeal	Beef	Pork	Poultry	Lamb	Milk
					(constant 1990 US$/MT)					
1970/72	232	524	215	476	415	5,144	n/a	n/a	3,248	485
1980/82	236	534	169	384	338	3,536	2,344	1,474	3,730	413
1990/92	135	288	104	234	195	2,585	1,781	1,139	2,440	280
1994/96	156	270	116	238	192	1,761	n/a	1,113	2,474	261
1996/98	122	261	111	226	182	1,655	2,110	1,196	2,072	291

Sources: Data is from FAO, Feb/2000, FAO, 2000, IMF 1997, USDA 1997, USDA 2000, USDA/ ERS 1997,and World Bank 1993, 2000 and annual updates. The Manufacturing Unit Value index used for expressing values in constant 1990 US dollars is from World Bank (1997) and annual updates.

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%. Fishmeal is any origin, 64-65%, CIF Hamburg, nfs. 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 U.S. city composite wholesale price, ready-to-cook, delivered. Lamb is New Zealand, frozen whole carcasses, wholesale price, Smithfield market, London. Milk is US whole milk sold to plants and dealers, USDA. "n/a" indicates that comparable prices for those years are not available.

Table 11--Real prices of selected crop, livestock, and fisheries products as projected by the IMPACT model

Year	Wheat	Rice	Maize	Soybeans	Beef	Pork	Poultry	Lamb	Milk
				(constant 1996/98 average US$/MT)					
IMPACT new baseline prices									
1996-98	133	285	94	247	1808	2304	735	2918	318
Impact baseline projections (new)									
2010	129	287	104	248	1775	2320	701	2931	308
2020	115	223	97	248	1696	2147	700	2709	277
				(total percentage change relative to starting period)					
Percentage increase 1992-94 actual to 1996-98 actual									
	-17	-5	-11	-14	-18	+18	+6	-15	+7
Projected percentage increase 1992-94 to 2020 in older version of model									
	-10	-8	-2	-11	-12	-11	-11	-9	-14
Projected percentage increase 1996-98 to 2020 (updated model)									
	-13	-21	+3	0	-6	-6	-4	-7	-12

Notes: The IMPACT base prices in 1996-1998 are comparable to series given in Table 10, except : (a) they are expressed in constant 1996-1998 avg. US$; (b) the base price for maize is the 1997-99 avg. because of the 1996 maize price spike; and (c) a lower price poultry series more representative of developing countries was used in lieu of the U.S. domestic broiler price in the previous table. The latter was used in the previous table to give a longer time series of changes.

Sources: Actual prices are from Table 10, except for items in “notes” above. Projections from the 1992-94 baseline use older version of IMPACT by Rosegrant reported in Delgado *et al*. 1999a. Projections from 1996/98use the Oct. 2000 version of IMPACT.

Table A1--Regional classification of countries

Region	Member Countries
China	Mainland China
Other East Asia	Hong Kong, Macau, Mongolia, North Korea, and South Korea
India	India
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 Caribbean
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 FAO Statistics Database
World	All countries included in FAO Statistics Database

Sources: Regional groupings were chosen based on FAO 1997a, 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.

Table A2—Comparison of projected food consumption trends of various livestock products, to the year 2020 by product using older and current versions of the IMPACT model

Region	Projected Annual Growth of Consumption 1997-2020 *(percent per year)*		Total Consumption		Per Capita Consumption	
	(old)	(new)	2020 (old)	2020 (new)	2020 (old)	2020 (new)
			(million MT)		(kg)	
Developed world						
Beef	0.4	0.5	36	34	26	25
Pork	0.3	0.4	41	39	29	29
Poultry	1.0	1.3	34	38	25	28
Meat	0.6	0.7	115	114	83	84
Milk	0.2	0.4	263	276	189	202
Developing world						
Beef	2.8	2.9	47	52	7	8
Pork	2.8	2.4	81	80	13	13
Poultry	3.1	3.7	49	67	8	11
Meat	2.9	2.9	188	213	30	35
Milk	3.3	2.9	391	372	62	61

Sources: The “old” projections are from the June 1998 run of IMPACT by Rosegrant, as reported in Delgado *et al.* 1999a. The “new” projections for 2020 are from the October 2000 version of IMPACT.

Notes: "Consumption" is direct use as food, uncooked weight bone-in. "Meat" includes beef, pork, mutton and goat, and poultry. "Milk" is milk and milk products in liquid milk equivalents.

Table A3—Comparison of projected food consumption trends of meat and milk, 2020 by region using older and current versions of IMPACT model

	Total Consumption in 2020			
	(old)		(new)	
Region	Meat	Milk	Meat	Milk
	(million MT)		(million MT)	
China	85	17	104	23
India	8	160	9	132
Other East Asia	8	2	4	4
Other South Asia	5	41	6	42
Southeast Asia	16	11	19	12
Latin America	39	77	45	82
WANA	15	51	13	42
Sub-Saharan Africa	12	31	11	35
Developing world	188	391	213	372
Developed world	115	263	114	276
World	303	654	327	648

Sources: The “old” projections are from the June 1998 run of IMPACT by Rosegrant, as reported in Delgado et al. (1999). The “new” projections are from the October 2000 version of IMPACT.

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