The nutritional level of a population can be expressed in several different units, none of which is entirely satisfactory, since human diets and metabolic needs are complex and vary greatly. In the agriculture sector of World3, world food output is generated in units of total kilograms of vegetable crops per year. Thus food per capita in the population sector is most easily calculated in kilograms of vegetable crops per person-year. The meat and animal products generated by the food production system are counted in terms of their vegetable equivalent—the number of kilograms of vegetable crops (grains, grasses) necessary to produce a kilogram of animal matter. On the average, about 7 kilograms of vegetable fodder are required to produce 1 kilogram of food of animal origin (Cépède, Houtart, and Grond 1964, p. 253). Thus in the world model:

$$\frac{\text{kilograms vegetable-equivalent food}}{\text{person-year}} = \frac{\text{kilograms vegetable food}}{\text{person-year}} + \frac{7 \times \text{kilograms animal food}}{\text{person-year}}$$

The measurement of food per capita in terms of vegetable equivalents accounts at least in part for both the quantity and the quality of the diet. Food of animal origin, which is higher in protein and usually more expensive, is counted seven times more heavily than food of vegetable origin. The index of vegetable-equivalent food intake is probably the best single measure of dietary sufficiency available at present.

> A population's health standards (over-all mortality, diseases and deaths from special causes, expectation of life at birth) are, indeed, much more closely tied in with the nutritional level when the latter is figured in vegetable calories than when it is figured in "final" calories. . . . P. V. Sukhatme, who heads the statistical branch of FAO, made a study of the different units of measurement proposed for calculating levels of nutrition, and concluded that the vegetable (primary or original) calorie gives the best simple scale, in terms both of food production and of human needs. [Cépède, Houtart, and Grond 1964, pp. 257–258]

The conversion between food expressed in kilograms per year and food expressed in kilocalories* per day can be calculated from the average energy content of vegetable matter—about 4.5 kilocalories per dry gram (Kormondy 1969, pp. 18–20), or 3.5 kilocalories per (wet) gram of harvested crops (see Chapter 4). To make the interface with the agriculture sector as simple as possible, we shall use the wet crop value:

1 kilogram vegetable food = 3,500 kilocalories.

The average minimum amount of food necessary for human subsistence (called subsistence food per capita SFPC in the model) is approximately 2,200 vegetable-equivalent kilocalories per day (FAO 1970, vol. 2, p. 491), which is equivalent to:

$$\frac{2200 \text{ kilocalories}}{\text{person-day}} \times \frac{1 \text{ kilogram}}{3500 \text{ kilocalories}} \times \frac{365 \text{ days}}{\text{year}} = \frac{230 \text{ kilograms}}{\text{person-year}}$$

1 kilogram per person-year = 10.4 kilocalories per person-day.

*One kilocalorie is often referred to as a Calorie in discussions of nutrition, and occasionally the capital C is omitted. Usually, a calorie or Calorie in the literature on nutrition is equivalent to 1,000 calories or a kilocalorie in terms of the physical measure of energy.

All the numbers used in discussing vegetable equivalents are rough averages and somewhat arbitrary. Given different conditions, kinds of animals, and animal products, the conversion factor from vegetable feed to animal product can vary from 9.2 (Cépède, Houtart, and Grond 1964, p. 259) to 2 (PSAC 1967, p. 250)—the lower figure applies only when the feed and the animal stock are very highly selected. The energy content of vegetable matter normally ranges from 4.1 to 5.2 kilocalories per dry gram (Kormondy 1969, p. 20). The energy needs of persons vary with their age, activity, climate, and basal metabolism. For each of these numbers we tried to choose an intermediate value that is commonly used by authorities in the field. Given the imprecise purpose of our model, such approximations are justified, especially since many of the differences between animals, crops, and people average out on a global scale.

The empirical relationship between food per capita FPC and life expectancy LE has already been shown in Figure 2-23. We cannot conclude of course, as Figure 2-23 implies, that a simple increase in food per capita is in itself sufficient to raise human life expectancy from 40 years to 70 years. The data have not been corrected for the impact of other variables on life expectancy, in particular for the fact that medical and public health services are also increasing in Figure 2-23 as food per capita increases. Since a statistical unraveling of these interconnected factors seems to be unattainable, we constructed the lifetime multiplier from food LMF relationship according to the following chain of reasoning.

The normal life expectancy, 28 years, was defined as that which prevails when the food supply is at subsistence level. Thus we have one point (indicated by X in Figure 2-27) in the desired relationship—the lifetime multiplier from food LMF must be 1.0 when the food per capita FPC equals the subsistence level of 230 vegetable-equivalent kilograms per person-year.

If food per capita falls below the subsistence level (FPC/SFPC $<$ 1.0), the life expectancy would certainly decrease very quickly, since on the average there is not enough food per person to sustain life. The actual sharpness of the decline depends

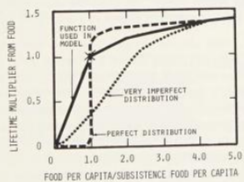

Figure 2-27 The effects of food distribution on the lifetime multiplier from food