on the equality of distribution of the food supply. If food were always evenly distributed among the populations of the world, the life expectancy would drop to zero almost immediately as food per capita falls below subsistence, since no one would have enough food to stay alive. In that case the slope of the curve would reflect only individual physiological differences in food requirements; it would look roughly like the dashed line in Figure 2-27. Food is of course far from evenly distributed in the real world. Therefore, we made the assumption that at any level of food production above zero some fraction of the population will acquire sufficient food for survival. In the absence of any information about how unequal food distribution might actually become under circumstances of scarcity, we made the relationship linear from FPC/SFPC = 0 to FPC/SPFC = 1. This linearity implies that the fraction of the population that does obtain food will consume only enough food per capita to survive and no more. If the few people with food actually consume a luxury diet, and if the extremely unequal food distribution persists as food supplies rise, a curve such as the dotted line in Figure 2-27 would express the relationship.

As the available food per capita rises above 230 kilograms per person-year, how much can life expectancy be expected to rise, given that all other factors remain the same? The answer to this question is complicated by the fact that no distinction is usually made between deaths from nonnutritional causes and deaths that are technically caused by infectious disease but that would not have occurred if the victim had not been weakened by malnutrition. Wyon and Gordon (1971, p. 194) have attempted to make this distinction in their studies of villages in northern India. They indicate that among 0–2-year-olds as many as 100 deaths per 1,000 live births could have been prevented by proper nutrition alone. Therefore, raising food per capita in these villages could have increased the average life expectancy by as much as twelve years.*

We assumed in the world model that increasing food above the subsistence level, with no other inputs, can raise the life expectancy of a preindustrial population by 40 percent—from 28 years to 39 years. This estimate agrees with the maximum life expectancy of 35–40 years observed in anthropological studies of primitive societies in favorable environments (Howell-Lee 1971). Most of this improvement in life expectancy would probably come from decreased infant and child mortality (Gordon, Wyon, and Ascoli 1967). The complete relationship we assumed between food per capita and life expectancy is shown in Figure 2-28 and is represented by the following equations:

```
LMF.K=TABHL(LMFT,FPC.K/SFPC,0,5,1)                    20, A
LMFT=0/1/1.2/1.3/1.35/1.4                             20.1, T
    LMF    - LIFETIME MULTIPLIER FROM FOOD
                (DIMENSIONLESS)
    TABHL  - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    LMFT   - LMF TABLE
    FPC    - FOOD PER CAPITA (VEGETABLE-EQUIVALENT
                KILOGRAMS/PERSON-YEAR)
    SFPC   - SUBSISTENCE FOOD PER CAPITA (VEGETABLE-
                EQUIVALENT KILOGRAMS/PERSON-YEAR)
```

*Calculated from the formula (Keyfitz 1971*b*, p. 658)

$$\Delta e_0^0 = -5\frac{l_x}{l_0}(e_x^0 - 2.5)\Delta_5 M_x,$$

where l_x/l_0 is the probability of surviving to age x (= 1.0 here), e_x^0 is the life expectancy at age x (28.0 here), and $\Delta_5 M_x$ is the change in the death rate over the 5-year period including x (−0.1 here).

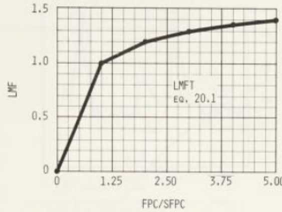

Figure 2-28 Lifetime multiplier from food table

Figure 2-28 reflects our estimate of the present apparent distribution of food among the world's people and among age groups within populations. Life expectancies might well be raised by 40 percent with much less food than is indicated by this figure if populations could be better educated about nutrition, if food were more equitably distributed, and if prevailing food habits could be changed. As Gordon mentions in his description of a Guatemalan village:

> In a region where everything grows . . . the choice of basic foods was culturally restricted to corn and beans morning, noon, and night. Fruits and garden vegetables were cash crops. An animal census of the villages showed few sources of animal protein and especially of milk for toddlers and young children. Cows existed but were scarce. As features of the social environment, tradition, custom, and taboos strongly influenced the choice of foods in a land of potential plenty. [Gordon 1969]

Social customs can conceivably be changed as a matter of deliberate policy. We would represent such a policy in World3 by altering the lifetime multiplier from food relationship to allow a steeper rise in life expectancy as food per capita increases. A model run under this policy is shown in section 2.6.

Is the causal relationship represented by the lifetime multiplier from food LMF instantaneous or delayed? It is true that human adults can exist for long periods on greatly reduced nourishment—as documented by numerous examples from famines and concentration camps (Keys et al. 1950). When human populations are viewed as a whole, however, the aggregate death rate rises very quickly under conditions of food shortage. Figure 2-29 shows the historical match between famines and death rates in medieval France. Although previously well-fed adults can survive food shortages, often for years, the weaker members of the human population, especially the very young, the old, and those already ill or malnourished, succumb very quickly, causing the average life expectancy to fall with little delay. In populations deprived of adequate food during World War II, peaks in clinical symptoms and death rates