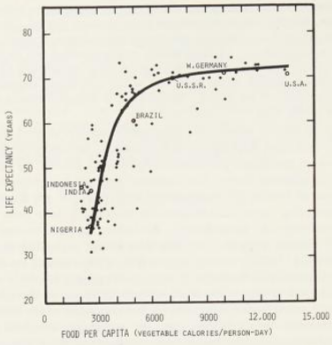

Figure 2-23 Food per capita versus life expectancy
Sources: U.N. 1972*a*, Keyfitz and Flieger 1971.

scarce, a small increase in either one results in a large increase in life expectancy. When food is plentiful and health care is readily available, however, a further increase of either has only a small effect on lifetime. Second, the variables plotted on each axis are mutually dependent. The denominator on both horizontal axes is population, and population depends on past values of life expectancy, among other things. This circular interdependence may strongly influence the empirical measurements that can be made. There are no points in Figure 2-23 below 2,000 calories per person per day, because a population with so little food would decrease rapidly, causing the available food per person to rise again above subsistence level.

Another problem in a statistical analysis of the data shown in Figures 2-23 and 2-24 is that food and doctors per person are correlated not only with life expectancy but also with each other. The empirical relationship between the two variables is shown in Figure 2-25. Food per capita and doctors per capita are roughly colinear, but with a good deal of variation in the relationship. The variation is especially noticeable at high values of both variables, where the marginal return of each (in terms of increased life expectancy) is nearly zero, so that the choice of more food or more health care is governed by secondary cultural differences rather than by the goal of minimizing mortality.

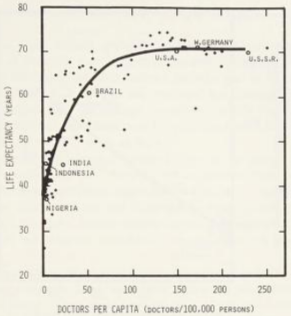

Figure 2-24 Doctors per capita versus life expectancy
Sources: U.N. 1972*a*, Keyfitz and Flieger 1971.

Given these multiple, complex interrelationships among the determinants of human health and the fact that the data base is and probably will continue to be unreliable, we did not attempt to investigate the determinants of life expectancy by statistical inference techniques. Instead, we tried to quantify approximately the causal relationships from what we know of the physical, biological, and economic facts underlying them. A detailed description of that process follows:

```
LE.K=LEN*LMF.K*LMHS.K*LMP.K*LMC.K                          19, A
LEN=28                                                     19.1, C
    LE     - LIFE EXPECTANCY (YEARS)
    LEN    - LIFE EXPECTANCY NORMAL (YEARS)
    LMF    - LIFETIME MULTIPLIER FROM FOOD
               (DIMENSIONLESS)
    LMHS   - LIFETIME MULTIPLIER FROM HEALTH SERVICES
               (DIMENSIONLESS)
    LMP    - LIFETIME MULTIPLIER FROM PERSISTENT
               POLLUTION (DIMENSIONLESS)
    LMC    - LIFETIME MULTIPLIER FROM CROWDING
               (DIMENSIONLESS)
```

Four factors—food, health services, crowding, and pollution—are incorporated in the equation for life expectancy as modifiers, or multipliers, of a "normal" life expectancy LEN. The normal life expectancy LEN can be set at any arbitrary value as long as the four multipliers are all defined properly with respect to that value. We set the normal life expectancy at 28 years, the approximate value for a primitive