capita are assumed to vary between 10 and 15 percent of total service output per capita, or between 5 and 8 percent of the total GNP per capita. The relationship is plotted in Figure 2-31 and expressed by the following equations:

```
HSAPC.K=TABHL(HSAPCT,SOPC.K,0,2000,250)                    21, A
HSAPCT=0/20/50/95/140/175/200/220/220                      21.1, T
    HSAPC   - HEALTH SERVICES ALLOCATIONS PER CAPITA
              (DOLLARS/PERSON-YEAR)
    TABHL   - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    HSAPCT  - HSAPC TABLE
    SOPC    - SERVICE OUTPUT PER CAPITA (DOLLARS/PERSON-
              YEAR)
```

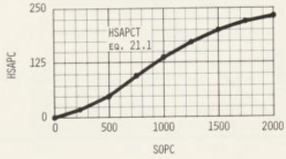

Figure 2-31 Health services allocations per capita table

As health services allocations increase in a given area, is the effect on average life expectancy immediate or delayed? Observations after the introduction of public health campaigns in some nonindustrialized areas indicate that the effect of such campaigns on life expectancy can be very sudden indeed. The classic example is Ceylon, where life expectancy rose from 45.8 years to 59.8 years in the eight-year period from 1946 to 1954 (U.N. 1962, p. 40). Yet it is also true that allocations for health services may not be instantly transformed into functioning doctors, hospitals, or research units and that new health facilities, even when operating efficiently, cannot immediately remove the effects of previous bad health in the population. A population may preserve for a time a "memory" of poor health care in the form of weakened bodies, remaining pockets of unexterminated disease vectors, or suspicious persons who do not make use of new services. In the reverse direction, a collapse of health services allocations would certainly result in some immediate increase in the death rate, but if the previous level of health care had been high, the population would probably possess for a long time enough medical knowledge, vaccinated persons, safe water supplies, and individual habits of sanitation to keep the life expectancy above the level otherwise indicated. We represented this relationship by inserting a first-order delay* between health services allocations per capita HSAPC and the

*For an explanation of first-order and higher-order delays, see Appendix F to this book and Forrester 1961.

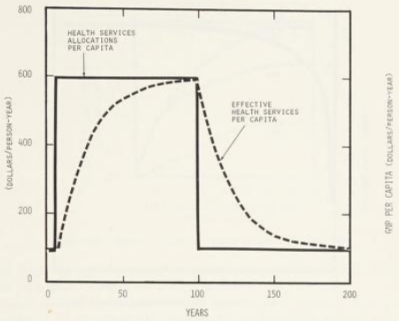

Figure 2-32 Health services impact delay

```
EHSPC.K=SMOOTH(HSAPC.K,HSID)                               22, A
HSID=20                                                    22.1, C
    EHSPC   - EFFECTIVE HEALTH SERVICES PER CAPITA
              (DOLLARS/PERSON-YEAR)
    SMOOTH  - FIRST-ORDER EXPONENTIAL INFORMATION DELAY
    HSAPC   - HEALTH SERVICES ALLOCATIONS PER CAPITA
              (DOLLARS/PERSON-YEAR)
    HSID    - HEALTH SERVICES IMPACT DELAY (YEARS)
```

actual measure of health care, which we call effective health services per capita EHSPC. The time constant of the delayed response, called the health services impact delay HSID, has been set at 20 years. That value was chosen arbitrarily, and it can be easily varied in the model runs.

The delayed response of EHSPC to a sudden increase or a sudden decrease in HSAPC is shown in Figure 2-32. Here EHSPC rises immediately after the increase in HSAPC, but the full effect of the increased allocations is not realized until decades later. Similarly, a sudden decrease in HSAPC causes a quick erosion in EHSPC (and thus life expectancy LE), but it takes more than 50 years for the effective services to fall back to their earlier level.

Now we need to establish the third link in the causal chain—the relationship between effective health services per capita and actual life expectancy. This relationship must clearly be technology-dependent. An investment in health services in 1970 produced a far greater effect on life expectancy than the same investment in 1870 could have produced. In 1900 the average life expectancy, even in the most affluent nations of the world, was probably not more than 56 years (U.N. 1962, pp. 22–23).