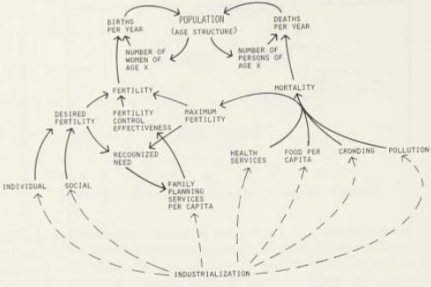

Figure 2-16 External determinants of birth and death rates

the population had perfect control over the reproductive process and produced children only when and always when desired. The maximum fertility is the fertility that would be observed if the population took no measures of any kind to reduce or restrict the fertility of any woman from menarche to menopause; it is the biological upper limit. Fertility control effectiveness indicates the extent to which a population can achieve its desired fertility rather than its maximum fertility, by any means, including late marriage, contraception, and abortion.

Each of these three inputs to fertility is itself responsive to many factors in the social and economic environment. For example, the desired fertility might be considered a function of two further categories of influence: the social norm with regard to fertility, and the average individual response to this social norm. Each category is described in more detail in the section on model equations (2.5). Because maximum fertility is related to the average state of health, it is influenced by all the factors that influence the mortality side of the model. Fertility control effectiveness is assumed to arise from two necessary elements: a socially recognized need for birth-control technology, and an investment in the research, manufacturing, and educational capabilities to develop that technology. Thus fertility control effectiveness, like all technological factors, has a voluntary component. It will not be developed if there is no need for it.

The determinants of mortality might also be segregated into voluntary, involuntary, and control categories. Involuntary or maximum mortality would be the mortality expected if no technologies of control were available beyond those practiced by a primitive hunting-gathering society. Desired mortality would express the social mortality goal. Mortality control techniques, like those of fertility control, may be assumed to arise from two factors: a perceived gap between desired mortality and maximum mortality, and an allocation of resources to mortality control technology.

In World3, desired mortality and the social need for mortality control are not represented explicitly. Instead, we assumed that desired mortality is constant and sufficiently low (perhaps zero) so that the social impetus for developing mortality control techniques is always present. Thus the only dynamic influence on the development of mortality control is the necessary investment in research and health service capital, represented in the model by health services per capita. Two other factors, pollution and crowding, represent the possible effects of the environment on the biological, involuntary aspects of mortality. The fourth input to mortality, food per capita, can be influenced by man's technology for the purpose of reducing mortality, but if it reaches very low values, it can have a major effect on involuntary mortality.

As indicated in Figure 2-16, the process of industrialization affects in some way all the mortality-fertility determinants we have mentioned. Industrialization has been a dominant agent in changing the human environment and the population growth rate in the recent past, as the demographic transitions of the industrialized countries have illustrated. It will continue to be a strong dynamic force in the future, for those transitions are far from complete throughout the world. The growth of industrial capital is generated by the other sectors of the world model, so for the purposes of this sector we assume that it is exogenously determined. When we simulate the behavior of the population sector we drive it with assumptions about the development of industrialization as a function of time.

Many influences on fertility and mortality have been suggested, in addition to the ones shown in Figure 2-16 (see, for example, Adelman and Morris 1966, Davis and Blake 1965, Friedlander and Silver 1967, and Mason et al. 1971). Several factors were omitted from the model because they fell into one of the following categories:

1. Factors that will remain relatively constant over the time span of the simulation (genetic variation, climate).
2. Factors that are strongly covariant with a factor already included (education).
3. Factors that result from primarily discontinuous and partially random processes (wars).
4. Factors that do not appear to have a statistically significant effect on population dynamics on a worldwide scale (religion, sexual mores).

2.4 CAUSAL STRUCTURE

In summary, the global population trends we are trying to capture with a dynamic model are:

1. All populations tend to grow exponentially, although the exponential growth rate is variable.
2. Mortality rates have fallen dramatically in this century.