tions, can we begin to have confidence that the model is a useful representation of reality.

In this section we present numerous computer simulations of the population system alone. Chapter 7 presents simulations of the population sector incorporated into the rest of the world model. Since the sector is not a complete model in itself, but requires inputs reflecting the natural and economic environment, the model runs shown in this section are all driven by assumptions about the system external to the population sector. The values of total industrial output, service output, food output, and pollution must be specified as exogenous functions of time to simulate the population sector.

Comparison of Different Levels of Aggregation

Historical Behavior A minimum requirement for a useful simulation model is that it duplicate the historical behavior of the real system within the desired degree of accuracy. In Run 2-1 (Figure 2-84) we simulated the population sector under driving assumptions that roughly duplicate world economic behavior from 1900 to to 1975.* Total industrial, service, and food outputs were set at their 1900 values and driven by smooth exponential functions, calculated to intersect their known 1970 values. The initial conditions and assumed rates of growth are:

	Initial Value†	Annual Growth Rate†
Industrial output	7.10^{10} dollars	3.7 percent
Service output	15.10^{10} dollars	3.0 percent
Food output	40.10^{10} vegetable-equivalent kilograms	2.0 percent

The value for population size generated by the model is used to calculate values for industrial, service, and food output per capita. Pollution is held constant at a low level so that it does not become important in these runs. The complete equations for generating the runs shown in this section are listed in Appendices A, B, and C to this chapter.

Run 2-1 (Figure 2-84) shows a comparison of the behavior of the three age-disaggregated models under identical historical driving conditions. The general behavior patterns of the three models are very similar, the only differences being small, quantitative ones that are well within the margin of error expected from this model. In each case the population grows exponentially, reaching a value of approximately 4 billion after 75 years (1975). All per capita economic variables also grow, the increase in industrial output per capita IOPC being considerably greater than the increase in food per capita FPC. The fifteen-level model generates a slightly faster population growth rate, and thus a slightly slower rate of per capita economic growth than do the one- and four-level models.

*Appendix E to this volume describes how to read DYNAMO output graphs.
†See the capital and agriculture sectors, Chapters 3 and 4, for discussions of these values.

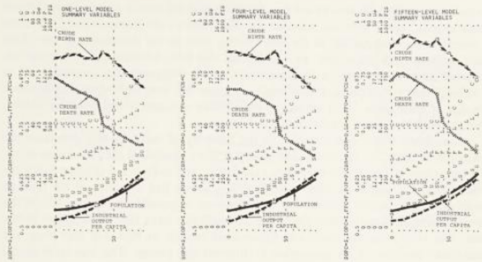

Figure 2-84 Run 2-1: historical behavior, 1900–1975

In all three models the calculated crude birth rates in the initial time interval (year 0) are between 40 and 45 per thousand. The birth rates all decrease gradually to a value of about 33 per thousand in the year 70. The calculated birth rate in the fifteen-level model is always somewhat higher than that in the simpler models, because the pattern of age-specific birth rates generates more births to younger women than to older women. In all models the crude death rates decline gradually until year 40, at which point the CLIP in the lifetime multiplier from health services brings about a step increase in life expectancy. After a precipitous drop at year 40 the crude death rates continue to decrease fairly rapidly. They begin at year 0 at about 36 per thousand and reach values of 15–20 per thousand in year 70. In all three models life expectancy in year 70 is about 50 years, the fraction of population urban is 35 percent, and fertility control effectiveness is about 0.9 and rising rapidly. Industrial output per capita is approximately 250 dollars, service output is 325 dollars per capita, and food output is 450–500 vegetable-equivalent kilograms per person, or about twice the subsistence level.

The behavior of each variable plotted in Run 2-1 generally agrees with our knowledge of the real world from 1900 to 1970: population has increased exponentially, the birth rate has fallen, the death rate has fallen faster, industrialization and urbanization have increased, and birth control has become more widespread and more effective. The model produces a fair quantitative fit, given the uncertainties in the real-world data and the simplifying assumptions in the equations. The most serious quantitative error is in the death rate, which is too high in the model year 70, thus making the calculated net population growth rate too low. This discrepancy could be eliminated by altering any one of the lifetime multiplier tables or the timing or extent of the CLIP function in the lifetime multiplier from health services. If the death rate were lowered in the model, however, the calculated total population in the year 70