When the ratio of actual to indicated output per capita is less than 1.0, for example, when fewer services are available than desired by the population at their current level of industrialization, the fraction of industrial output per capita allocated to services is increased. As a result, investment in services rises, increasing the level of the service capital stock and the amount of services produced. If the ratio of actual to indicated services is equal to or is greater than 1.0, the current fraction of industrial output allocated to services is maintained or is reduced, respectively.

Loop 1 of Figure 3-10 is composed of seven causal relationships that influence the amount of investment available to the service sector. As the industrial capital grows, industrial output increases. Increased output raises the industrial output per capita, which in turn raises the level of services indicated per capita and thus increases the fraction of industrial output allocated to services. As the fraction of industrial output invested in services increases, the fraction of output left for reinvestment in the industrial sector decreases, tending to counteract the initial rise in the industrial capital stock. An analogous set of relationships shown in loop 2 governs the fraction of industrial output allocated to agriculture.

Loop 3 is composed of five principal elements that moderate the change in the fraction of industrial output allocated to services. As that fraction increases, the investment in service capital increases, leading to growth in the service capital stock and thus to increased service output. For constant population the increase in service output leads to increased service output per capita. If the actual service output per capita increases, the fraction of industrial output allocated to services tends to decrease.

The elements in loop 4 are analogous to those in loop 3; they serve to moderate changes in the fraction of industrial output allocated to agriculture. There is one difference between the functions of loops 3 and 4. The industrial output allocated to services is employed only to increase the service capital stock. Industrial output allocated to the agriculture sector may be used either in the development of additional arable land or in raising the capital employed on the current land stock. However, either use serves to increase food output and, ultimately, to decrease the fraction of industrial output allocated to agriculture.

The capital sector contains only the endogenous determinants of service and industrial output. All the elements included in the sector are illustrated in Figure 3-12. The factors governing the use of industrial output to increase the stock of arable land and to increase land yields are discussed in the agriculture sector of the model, Chapter 4.

The more detailed representation of the causal relationships in the capital sector of the model, shown in Figure 3-12, supplements the relationships drawn in Figure 3-10 with two minor negative depreciation loops; the service and industrial capital-output ratios; and the variables outside the sector that influence or are influenced by the relationships within the sector. The depreciation loops have the implicit goal of decreasing the level of capital to zero. As the capital stock increases, the amount of capital depreciating each year also increases, counteracting the initial rise in capital. Of course, so long as investment is greater than depreciation the capital stock will

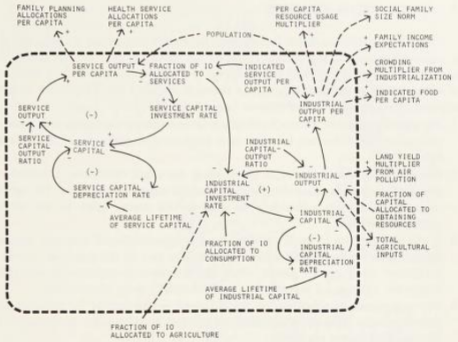

Figure 3-12 Causal-loop diagram of the capital sector

increase. The capital-output ratios simply indicate the quantities of capital required to produce one dollar of industrial and service output per year. Because the size of the labor force does not affect the level of industrial output during the growth phase of the World3 simulations, it is not represented in the causal-loop diagram.

It is in the formulation of capital investment that we departed furthest from our goal of representing the causal mechanisms underlying material and demographic growth. A causal representation of investment based explicitly on the diminishing returns to increased output in each sector and on political pressures would be useful for many purposes. Such a representation would probably also introduce additional short-term negative loops in the capital sector. We would not expect these short-term loops to change general long-term behavior modes, since the latter are governed by processes with very long time constants. However, the short-term causal loops would stabilize the model's behavior for a wider variety of coefficient values. Adding these influences on investment is an important goal for future extensions of the model.

Having described in general terms the investment allocation mechanisms employed in the model, we turn now to a description of the precise DYNAMO equations used to incorporate the causal relationships in the capital sector of World3.