The industrial output per capita IOPC is obtained by dividing the current industrial output IO by the current population POP. This variable, measured in dollars per person-year, is an indication of the average amount of material goods available to each member of the population for consumption or investment. It has an impact on all other sectors of World3. The distribution of industrial output across the population is not reflected in the simple calculation of IOPC. As described in Chapter 2 in conjunction with the lifetime multiplier from food LMF, different global distributions of IO can be represented implicitly through changes in the numerous model relationships that depend on IOPC.

Industrial Output IO

```
IO.K=(IC.K)(1-FCAOR.K)(CUF.K)/ICOR.K                    50, A
    IO      - INDUSTRIAL OUTPUT (DOLLARS/YEAR)
    IC      - INDUSTRIAL CAPITAL (DOLLARS)
    FCAOR   - FRACTION OF CAPITAL ALLOCATED TO OBTAINING
                RESOURCES (DIMENSIONLESS)
    CUF     - CAPITAL UTILIZATION FRACTION
                (DIMENSIONLESS)
    ICOR    - INDUSTRIAL CAPITAL-OUTPUT RATIO (YEARS)

ICOR.K=CLIP(ICOR2,ICOR1,TIME.K,PYEAR)                   51, A
ICOR1=3                                                 51.1, C
ICOR2=3                                                 51.2, C
    ICOR    - INDUSTRIAL CAPITAL-OUTPUT RATIO (YEARS)
    CLIP    - A FUNCTION SWITCHED DURING THE RUN
    ICOR2   - ICOR, VALUE AFTER TIME=PYEAR (YEARS)
    ICOR1   - ICOR, VALUE BEFORE TIME=PYEAR (YEARS)
    TIME    - CURRENT TIME IN THE SIMULATION RUN
    PYEAR   - YEAR NEW POLICY IS IMPLEMENTED (YEAR)
```

The fraction of capital allocated to obtaining resources FCAOR (described in Chapter 5) is subtracted from the total industrial capital IC to leave in the calculation of output only the capital that is directly involved in the production of finished industrial goods. Industrial output is then calculated by dividing the remaining industrial capital, (IC)(1−FCAOR), by the industrial capital-output ratio ICOR. For reasons described later, we made the industrial capital-output ratio ICOR a constant with a normal value of 3.0. The industrial output thus calculated is that available through full utilization of the capital. If there were a sudden and serious shortage of labor, not all the capital could be utilized. The industrial output would then be less than that possible with full use of the industrial capital plant. The capital utilization fraction CUF varies between zero and 1.0 and is a crude measure of the impact of a labor shortage on industrial production. It is described in section 3.6. Under most circumstances it will have a value equal to 1.0 and thus no influence on IO.

Two assumptions about the industrial capital-output ratio ICOR are important: its specification as a constant rather than a variable, and the choice of its specific value, 3.0 years. Economic theory defines "capital deepening" as the process of accumulating capital goods faster than labor (Samuelson 1970, p. 719). An increase in the amount of capital per capita is rough evidence of capital deepening. When it occurs, as it has throughout the world over the last seventy years, one would normally expect the marginal productivity of capital to decrease (that is, the capital-output ratio to increase) so that each additional unit of capital would contribute proportionately less output. If capital did act in accordance with the law of diminishing returns, the relationship between industrial capital IC and industrial output IO would be that shown in Figure 3-14, curve A. As the marginal return to additional capital decreases, each unit added to the capital stock produces less additional output. Total output, as represented by curve A, thus moves toward some horizontal asymptote. When additions to the capital stock produce no increase in output, the marginal capital-output ratio is effectively infinite.

Curve B of Figure 3-14 represents the case in which the capital-output ratio remains constant, so that total output is directly proportional to total capital. In a period of capital deepening, the capital-output ratio can stay constant only if technical advances, improvements in the productive efficiency of new capital, are great enough to offset decreasing returns to scale. If constant returns to scale are observed, technical progress is filling the gap between curve B and curve A.

Economists disagree over whether technological advance in the means of production has in fact offset the tendency toward diminishing returns. Kuznets suggests that the reproducible (that is, physical machinery) capital-output ratio has risen (Kuznets 1966, p. 76) for Great Britain, Japan, and the United States. His data (Figure 3-15) suggest that between 1850 and 1950 the industrial capital-output ratio in the United States rose 11 percent, while the capital-output ratio for all forms of capital fell 23 percent.

Samuelson (1970), on the other hand, suggests an approximately constant capital-output ratio for the United States (Figure 3-16) by arguing that technology offset decreasing returns over the 1900–1968 period.

We chose to accept Samuelson's more optimistic analysis of the United States as representative of the global capital stock. The industrial capital-output ratio ICOR is assumed to be constant at a value of 3 years. Through the inclusion of a CLIP function, however, it is possible to alter the value of the capital-output ratio from ICOR1 to ICOR2 at any set time (PYEAR) during the course of a model run. In most analyses of World3, both values of ICOR were set equal to 3.0.

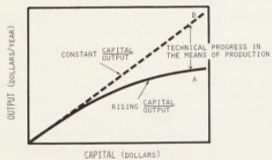

Figure 3-14 The relation between capital and output for rising and for constant capital-output ratios