equipment and buildings were included. The availability of nonrenewable resources affects the world economy in two extremes: when they are in plentiful supply, they contribute with little cost to the process of creating industrial output; however, if there is a shortage of these materials, industrial production can be curtailed.

Although all mineral and fossil fuel resources share similar dynamic characteristics, they do not share a common initial value. One discrepancy among materials occurs in the variety of measuring schemes used: mercury is expressed in terms of 76-pound flasks, silver in terms of troy ounces, coal in terms of tons. To eliminate this source of confusion, resources are expressed as a multiple of the usage in some base year, as suggested by Forrester (1971). If 1970 is the base year, then by this measure the level of mercury resources in 1970, for example, would be the number of years the 1970 supply of mercury could sustain the 1970 level of mercury usage.

When this method is used to compute the remaining total stock of a resource at a given time, we have termed the resulting number the *static resource index*. In the world model, because both undiscovered resources and proven reserves are aggregated into one level, current estimates of the static index for world nonrenewable resources must reflect this aggregated level. This index thus represents the number of years the world's total stock of unused resources could support the 1970 level of industrialization, given the total 1970 population. Column 5 of Figure 5-1 gives the current resource indices for nineteen of the most important nonrenewable resources.

The static resource indices represent U.S. Geological Survey estimates of total world resources. Because of the high level of uncertainty involved in these estimates, both high and low estimates are given for each resource. The low index is calculated from *identified* resources (column 2), defined as specific, identified mineral deposits that may or may not have been evaluated for extent and grade and whose contained minerals may or may not be profitably recoverable with existing technology and economic conditions. The high index is calculated from the sum of *identified*, *hypothetical*, and *speculative* resources (column 2 plus column 3). Hypothetical resources are defined as undiscovered mineral deposits, whether of recoverable or subeconomic grade, that are geologically predictable as existing in known districts. Speculative resources are defined as undiscovered mineral deposits, whether of recoverable or subeconomic grade, that may exist in unknown districts or in unconventional form (USGS 1973).

These estimates represent the ultimate *geologic availability* of each resource, irrespective of economic or technological conditions. As stated by Brobst and Pratt of the U.S. Geological Survey, "geologic availability . . . is the ultimate determinant of mineral potential" (USGS 1973, p. 6). It is this concept of ultimate geologic availability that is encompassed by the level of nonrenewable resources NR in the world model. Economic and technological factors are included in the determination of the fraction of capital that must be allocated to obtaining these resources FCAOR, which is explained later in this section.

An evaluation of column 5 of Figure 5-1 indicates that a realistic range for the aggregate static resource index is probably between 100 and 500 years. The current model uses 250 years as an order-of-magnitude estimate of the 1970 static index of global nonrenewable resources. Other estimates for the parameter will be tested in section 5.6 of this chapter.

The 250-year estimate of the static resource index assumes a substantial degree of substitutability between the available stocks of currently utilized nonrenewable resources: as materials with reserve life indices lower than 250 years are depleted, those with higher indices can be used in their place at slightly higher costs. If little substitutability were assumed, the aggregate resource index would reflect the resource index of the scarcest resources, for as those resources are depleted, the world economy would be severely restricted.

The world model estimate of 250 years reflects the order of magnitude of the resource indices of only the nonrenewable resources listed in Figure 5-1. Thus the 250-year estimate assumes that no new materials more abundant than those listed in Figure 5-1 will become substantial inputs to the industrial production process without an enormous increase in real costs. Other assumptions might be tested by varying both the initial value of nonrenewable resources NRI and the cost associated with those resources, represented by the fraction of capital allocated to obtaining resources FCAOR.

The calculation of nonrenewable resources initial NRI proceeds as follows: for a 250-year static resource index in 1970, the value of nonrenewable resources NR in 1970 must equal the amount of resources consumed each year by one person in 1970 (defined as one resource unit), multiplied by the population POP in 1970, and multiplied by 250 years. The nonrenewable resource utilization factor NRUF is a policy test variable that enables the analyst to change the rate of usage of resources. When NRUF equals one, the usage rate of resources in 1970 equals one resource unit per year:

$$\begin{aligned} \text{NR(1970)} &= \text{NRUF} \times \text{POP} \times 250 \\ &= 1 \times 3.6 \times 10^{9} \times 250 \\ &= 9 \times 10^{11}\,\text{resource units} \end{aligned} \tag{5.3}$$

To obtain the initial value of nonrenewable resources NRI, the amount of resources consumed from 1900 to 1970 must be added to the 1970 level of resources. The growth in population and resource usage indicates that this quantity is on the order of 1×10^{11} resource units. Simulations of the model indicate that a value of NRI equal to 1×10^{12} yields a static resource index of 250 years in 1970. It is interesting to note that the level of resources available in 1900 is equivalent to a static resource index of approximately 3,500 years. The sensitivity of the model to changes in the initial value of nonrenewable resources NRI is tested in the final section of this chapter.

Nonrenewable Resource Usage Rate NRUR

```
NRUR.KL=(POP.K)(PCRUM.K)(NRUF.K)                          130, R
    NRUR    - NONRENEWABLE RESOURCE USAGE RATE (RESOURCE
                 UNITS/YEAR)
    POP     - POPULATION (PERSONS)
    PCRUM   - PER CAPITA RESOURCE USAGE MULTIPLIER
                 (RESOURCE UNITS/PERSON-YEAR)
```