# **Natural Resources**

##### **By Sue Ann Batey Blackman and William J. Baumol**

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POST:

The earth’s natural resources are finite, which means that if we use them continuously, we will eventually exhaust them. This basic observation is undeniable. But another way of looking at the issue is far more relevant to assessing people’s well-being. Our exhaustible and unreproducible natural resources, if measured in terms of their prospective contribution to human welfare, can actually increase year after year, perhaps never coming anywhere near exhaustion. How can this be? The answer lies in the fact that the *effective* stocks of natural resources are continually expanded by the same technological developments that have fueled the extraordinary growth in living standards since the [Industrial Revolution](https://www.econlib.org/library/Enc/IndustrialRevolutionandtheStandardofLiving.html).

[Innovation](https://www.econlib.org/library/Enc/Innovation.html)

has increased the [productivity](https://www.econlib.org/library/Enc/Productivity.html) of natural resources (e.g., increasing the gasoline mileage of cars). Innovation also increases the recycling of resources and reduces waste in their extraction and processing. And innovation affects the prospective output of natural resources (e.g., the coal still underneath the ground). If a scientific breakthrough in a given year increases the prospective output of the unused stocks of a resource by an amount greater than the reduction (via resources actually used up) in that year, then, in terms of human economic welfare, the stock of that resource will be larger at the end of the year than at the beginning. Of course, the remaining physical amount of the resource must continually decline, but it need never be exhausted completely, and its effective quantity can rise for the indefinite future. The exhaustion of a particular resource, though not impossible, is also not inevitable.

Ever since the Industrial Revolution, world [demand](https://www.econlib.org/library/Enc/Demand.html) for power and raw materials has grown at a fantastic rate. One respected observer estimates that humankind “has consumed more aluminum, copper, iron and steel, phosphate rock, diamonds, sulfur, coal, oil, natural gas, and even sand and gravel over the past century than over all earlier centuries put together,” and goes on to write that “the pace continues to accelerate, so that today the world annually produces and consumes nearly all mineral commodities at record rates” (Tilton 2001, p. I-1).

Are our natural resources truly being gobbled up by an insatiable industrial world? [Table 1](https://www.econlib.org/library/Enc/NaturalResources.html?to_print=true#lfHendersonCEE2-119_table_037) presents some estimates of known world reserves of five important nonfuel minerals (tin, copper, iron ore, lead, and zinc). Clearly, even though the mining of these minerals between 1950 and 2000 used up much more than the known 1950 reserves, the known supplies of these minerals were greater in 2000 than in 1950. This increase in presumably finite stocks is explained by the way data on natural resources are compiled. Each year, the U.S. Geological Survey (USGS) estimates the amounts of reserves: the quantities of mineral that can be economically extracted or produced at the time of determination (as in [Table 1](https://www.econlib.org/library/Enc/NaturalResources.html?to_print=true#lfHendersonCEE2-119_table_037)). Those quantities can and do rise in response to price rises and anticipated increases in demand. As previously discovered reserves of a resource grow scarce, the price rises, stimulating exploration that frequently adds new reserves faster than the previously proven reserves run out.

Clearly, data on reserves do not show whether a resource is about to run out. There is, however, another indicator of the scarcity of a resource that is more reliable: its price. If the demand for a resource is not falling, and if its price is not distorted by interference such as government intervention or international [cartels](https://www.econlib.org/library/Enc/Cartels.html), then the resource’s price will rise as its remaining quantity declines. So any price rises can be interpreted as a signal that the resource is getting scarcer. If, on the other hand, the price of a resource actually falls, consistently and without regulatory interference, it is very unlikely that its effective stock is growing scarce.

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| Mineral | 1950 Reserves | Production 1950–2000 | 2000 Reserves |
|  | | | |
| Tin | 6 | 11 | 10 |
| Copper | 100 | 339 | 340 |
| Iron Ore | 19,000 | 37,583 | 140,000 |
| Lead | 40 | 150 | 64 |
| Zinc | 70 | 266 | 190 |
|  | | | |
| *Sources:* National Commission on Supplies and Shortages, 1976; and U.S. Geological Survey, [http://www.usgs.gov](http://www.usgs.gov/). | | | |

H. J. Barnett and Chandler Morse (1963) found that the real cost (price) of extraction for a sample of thirteen minerals had declined for all but two (lead and zinc) between 1870 and 1956. William Baumol et al. (1989) calculated the price of fifteen resources for the period 1900–1986 and found that until the “[energy](https://www.econlib.org/library/Enc/Energy.html) crises” of the 1970s, there was a negligible upward trend in the real ([inflation](https://www.econlib.org/library/Enc/Inflation.html)-adjusted) prices of coal and natural gas and virtually no increase in the price of crude oil. Petroleum prices catapulted in the 1970s and 1980s under the influence of the Organization of Petroleum Exporting Countries ([opec](https://www.econlib.org/library/Enc/OPEC.html)). After that, as [Figure 1](https://www.econlib.org/library/Enc/NaturalResources.html?to_print=true#lfHendersonCEE2-119_figure_035) shows, real oil prices returned to their historical levels, until 2003, when oil prices increased significantly again. While the longer-term prospects for these prices are uncertain, new energy-producing techniques such as nuclear fusion, along with the increasing use of renewable energy sources such as wind power, solar power, and hydrogen fuel cells, may be able at least to offset the upward pressure on energy prices.

The price history of nonfuel minerals is even more striking, with the prices of almost all exhibiting a generally declining (though fluctuating) trend after correction for inflation. Zinc, for example, which cost $2,021 (in 2000 dollars) per ton in 1900, had dropped to $1,226 in 2000 (with many peaks and valleys in between). The price of lead fell overall over the century, with its 2000 price at $961 per ton compared with $2,083 in 1900. The real price of iron ore, which increased for most of the twentieth century, has now returned to its pre–World War II levels. Real copper prices have fluctuated wildly, with no upward trend. And for some minerals, such as aluminum, inflation-adjusted prices today are far lower than they were one hundred years ago (U.S. Geological Survey). The USGS mine production composite price index, which provides an overall snapshot of mineral prices, declined throughout the twentieth century, dropping from 185 in 1905 to 100 in 2000 (USGS, *Economic Drivers of Mineral Supply,* 2002, p. 63). This is hardly evidence of imminent exhaustion.

The effective stocks of a natural resource can be increased in at least three ways:

1. A technological innovation that reduces the amount of iron ore lost during mining or smelting increases the effective stock of that resource. Likewise, a new technique may make it economical to force more oil out of previously abandoned wells. This decrease in waste translates directly into a rise in the effective supplies of oil. For example, say that in 1960, with known drilling techniques, only 40 percent of the oil at a site in Borger, Texas, could have been extracted at a cost ever likely to be acceptable, but by 2000 improved technology had raised this figure to 80 percent. Assume, for simplicity, that the amount of oil in Borger was 10 million barrels. Let us say that between 1960 and 2000, 5 percent of the originally available oil—500,000 barrels—has been used up. Then, by 2000, the effective supply of oil in that part of the Texas Panhandle will have risen from its initial level of 4 million barrels (40 percent of 10 million) to 7.6 million barrels (80 percent of 9.5 million), which yields a net rise of effective supply equal to 90 percent. In these cases, what occurs is not a rise in the physical quantity of oil, but an increase in the productivity of the remaining supply.

**Figure 1** Real (Inflation-Adjusted) Petroleum Prices, 1949-2006

ZOOM

*Sources:* Oil prices: U.S. Department of Energy, Energy Information Administration, Annual Energy Review 2003 and Petroleum Marketing Monthly, Nov.2004 ([http://www.doe.gov](http://www.doe.gov/)); Implicit price deflator, Bureau of Economic Analysis ([http//www.bea.gov](https://www.econlib.org/library/Enc/http//www.bea.gov)).

*Note:* Prices are crude oil domestic first-purchase prices in constant 2000 dollars, calculated using GDP implicit price deflators.

2. The (partial) substitutability within the economy of virtually all resources for others is at the heart of the second method for increasing the effective stocks of natural resources. The energy crises of the 1970s provided dramatic illustrations of the substitutability of resources. Homeowners increased their expenditures on insulation to save on fuel costs, thus substituting fiberglass for heating oil. Newspapers even reported that the cattle drives of earlier eras were being revived, with cowhand labor substituting for gasoline. Technological innovation can reduce the cost of extracting or processing a resource. A new oil rig, for example, may require fewer labor hours to operate and use less electricity and less steel in its manufacture. Those [saving](https://www.econlib.org/library/Enc/Saving.html)s of other resources can translate into savings of oil, because those other resources are thus freed up to be used elsewhere in the economy, and some of the alternative uses will entail substitution for oil. Second, technology can reduce the amount of the resource needed in a given use. Innovation in the auto industry, for example, has roughly doubled miles per gallon in all petroleum used for transportation. Scientists measure this progress as a decrease in “energy intensity,” or the amount of raw energy resource required per unit of economic output. The Worldwatch Institute reported that in the United States, one unit of gross domestic product (GDP) in 2000 required less than one-fifth as much energy as it did two hundred hundred years ago (Worldwatch Institute 2001, p. 91).

3. The third way we can increase our effective stocks of a natural resource is, of course, by technological changes that facilitate [recycling](https://www.econlib.org/library/Enc/Recycling.html). Say, for example, that a new recycling technique allows copper to be reused before it is scrapped and that no such reuse was economical before. Then this technique has doubled the effective reserves of copper (aside from any resources used up in the recycling process). It is important to note, however, that recycling adopted without regard for economic considerations can actually waste resources rather than save them. For example, some researchers have found that combustion of municipal garbage to generate electricity sometimes actually uses up more energy than it produces.

These three means can all increase the effective supplies of exhaustible resources and can augment the prospective economic contribution of the current inventory of resources, perhaps more than enough to offset the consumption of resources during the same period.

Some people believe that the burst of productivity and the improvement in living standards that have occurred since the industrial revolution can be attributed to our willingness to deplete our natural heritage at the expense of future generations. But as we have seen here, rising productivity (the source of the great leap in [economic growth](https://www.econlib.org/library/Enc/EconomicGrowth.html)) may actually augment humanity’s stock of natural resource capital instead of depleting it, and may be able to do so, for all practical purposes, “forever.” The evidence of trends in the prices of natural resources suggests that technological innovation has indeed provided continuing increases in the effective stocks of finite resources. But is there a limit to this process? Can we expect the wonders of technology to continue to wring ever more from the earth’s resources? No one knows. One observer summed up the situation as follows:

So far, the pessimists have been wrong in their predictions. But one thing is also clear: to conclude that there is no reason whatsoever to worry is tantamount to committing the same mistake the pessimists are often guilty of—that is the mistake of extrapolating past trends. The future is something inherently uncertain…. That the alarmists have regularly and mistakenly cried “wolf!” does not *a priori* imply that the woods are safe. (Neumayer 2000, p. 309)

More recently, accumulating evidence has led to some shift in the main focus of concern. Observers do not place primary emphasis on the prospect of total resource exhaustion. Rather, their attention has shifted to the consequences of the extraction processes—their degradation of pristine wilderness areas in places such as Alaska and the Amazon—and the effects of resource consumption on the environment overall, with the burning of fossil fuels and their connection to [global warming](https://www.econlib.org/library/Enc/GlobalWarmingABalanceSheet.html) the most critical issues. These are matters that cannot be ignored. Rational responses, however, require evaluation of the prospective costs to society of both counteraction and inaction.

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## **Further Reading**

Barnett, H. J., and Chandler Morse. *Scarcity and Growth: The Economics of Natural Resource Availability.* Baltimore: Johns Hopkins University Press for Resources for the Future, 1963.

Baumol, William J., Sue Anne Batey Blackman, and Edward N. Wolff. *Productivity and American Leadership: The Long View.* Cambridge: MIT Press, 1989. Earlier estimates in this entry are taken from Baumol, William J., and Wallace E. Oates, with Sue Anne Batey Blackman. *Economics, Environmental Policy and the Quality of Life.* Englewood Cliffs, N.J.: Prentice Hall, 1979.

Kelly, Thomas, Grecia Matos, et al. “Historical Statistics for Mineral and Material Commodities in the United States.” USGS Data Series 140, 2006. Online at: <http://minerals.usgs.gov/ds/2005/140/>.

Krautkraemer, Jeffrey A. “Nonrenewable Resource Scarcity.” *Journal of Economic Literature* 36 (December 1998): 2065–2107.

National Commission on Supplies and Shortages. *Government and the Nation*’*s Resources.* Washington, D.C.: U.S. Government Printing Office, 1976. P. 16.

Neumayer, E. “Scarce or Abundant? The Economics of Natural Resource Availability.” *Journal of Economic Surveys* 14, no. 3 (2000): 307–335.

Resources for the Future. Online at: [http://www.rff.org](http://www.rff.org/).

Simon, Julian L., and Herman Kahn. *The Resourceful Earth.* Oxford: Basil Blackwell, 1984.

Tilton, John E. “Depletion and the Long-Run Availability of Mineral Commodities.” In *Mining, Minerals and Sustainable Development.* Vol. 14, March 2001, International Institute for Environment and Development. Available online at: [http://www.iied.org](http://www.iied.org/).

Tilton, John E. *On Borrowed Time? Assessing the Threat of Mineral Depletion.* Washington, D.C.: Resources for the Future Press, 2003.

U.S. Geological Survey. *Economic Drivers of Mineral Supply.* Washington, D.C.: U.S. Geological Survey, 2002. Available online at: <http://pubs.usgs.gov/of/2002of02-335/of02-335.pdf>.

U.S. Geological Survey. *Mineral Commodity Summaries.* Published annually. Washington, D.C.: U.S. Geological Survey. Available online at: [http://minerals.usgs.gov](http://minerals.usgs.gov/).

Worldwatch Institute. *State of the World 2001* [and following years]. Online at: [http://www.worldwatch.org](http://www.worldwatch.org/).