

CHAPTER Db

Natural Resource Industries

Editor: Gavin Wright

MINING, ENERGY, FISHERIES, AND FORESTRY

Gavin Wright

From the beginnings of European settlement, a substantial portion of American economic activity has been closely tied to natural resources. Products of the forest – naval stores, gums, resins, turpentine, and timber – were vital to the British mercantile economy. New Englanders engaged in ocean-going cod and mackerel fishing during the colonial era extensively enough for Adam Smith to write in 1776: “The New England fishery in particular was before the late disturbances one of the most important perhaps in the world.” (volume 2, p. 90). The minerals economy rose to prominence in the nineteenth century, forming the backbone of America’s world leadership in manufacturing.

Resource-based industries became less economically central in the twentieth century, as measured by shares of employment or gross domestic product. But the problem of energy was critical, and energy issues in turn were linked to long historical trends in the production and trade of essential minerals, in technology, and in the pressure of environmental concerns. The tables in this chapter provide basic historical information about these trends and their implications.

Minerals and the American Economy

Mining and mineral products were an important part of America’s rise to world economic preeminence by the end of the nineteenth century, both directly as a source of production value and indirectly as a stimulus to manufacturing, to technology, and to regional development. At its peak in 1919, employment in mineral operations exceeded one million persons (series Db5–6). This amounted, however, to less than 3 percent of the total number of production workers in the economy at that time, about the same as the share of mining in national income. Although the minerals sector was not nearly as large as agriculture or manufacturing, its economic contribution was in many ways central. Contrary to the intuition that the importance of natural resources should decline over time, the share of mining in the labor force rose until 1909, and its contribution to the national product increased until the 1920s. The

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relative price of material inputs declined, and American manufacturing exports became more resource intensive between 1880 and 1920, the very period in which the country rose to a position of world economic leadership. Econometric studies have found a significant materials-using bias in technological change in manufacturing during this era, including many of the most prominent and successful U.S. industries (Cain and Paterson 1986). It is arguable, indeed, that resource-intensity and materials-using biases are persistent characteristics of the American economy down to the present day.

The quantitative record of rising U.S. mineral production is displayed in the various series on the physical volume of output, grouped into fuel minerals (Table Db25–33), metals (Tables Db73–103), and nonmetal minerals (Table Db112–121). The modern sources for these data begin in 1880, shortly after the establishment of the U.S. Geological Survey, which issued an annual report entitled *Mineral Resources of the United States*. (Beginning in 1924, the Bureau of Mines assumed responsibility for the report, and the title changed to *Minerals Yearbook* in 1932.) Longer-term series such as coal, lead, iron ore, gold, silver, and copper have been estimated not only from the decennial census but also from state and industry sources, which generally reflect the smelter or refining (or minting) phase rather than direct measurement of production at the mines. As such, they probably underestimate total production for the early years.

Despite the deficiencies of the data, the growing interest in mineral statistics seems to have reflected the rising importance of minerals in the economy. Virtually without exception, the longer-term series such as coal, lead, and iron ore (proxied by shipments of pig iron) show rapid increases from near-zero levels early in the nineteenth century. Other series, such as gold, silver, and copper, begin only in the 1830s or 1840s because mining of these items was negligible or nonexistent before that time. Thus, the country was not always minerals-rich. Writing in 1790, Benjamin Franklin declared: “Gold and silver are not the produce of North America, which has no mines” (quoted in Rickard 1932, p. 2). (In the eighteenth century, the term “mine” meant an outcropping or deposit of a mineral, not an operation for actually extracting the mineral from the ground.) A century later, however, the United States had achieved world leadership or near-leadership in the production of coal, petroleum, copper, iron ore, antimony, magnesite, mercury, nickel, gold, silver, and zinc. On one or another of these minerals, production in another country may have rivaled that of the United

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States. But no other country in the world possessed the depth and range of mineral supplies found in the United States during the first decades in the twentieth century.¹ Mineral abundance was particularly important for the rise of American manufacturing in an era during which technologies were resource dependent and transportation costs were high by modern standards (see Wright 1990).

It has long been conventional in economics to view mineral deposits as an exogenous “resource endowment” to the economy; indeed, they are the classic illustration of *nonrenewable* resources, available only in fixed supply and destined for inevitable rising scarcity and exhaustion. The U.S. historical record is precisely the opposite of this scenario. For almost all major minerals, new deposits were continually discovered, and production continued to rise, well into the twentieth century – for the country as a whole, if not for every mining area considered separately. To some extent, this growth was a function of the size of the country and its relatively unexplored condition prior to the westward migration of the nineteenth century. But mineral discoveries were not mere byproducts of territorial expansion. Some of the most dramatic production growth occurred not in the Far West but in the older parts of the country: copper in Michigan, coal in Pennsylvania and Illinois, and oil in Pennsylvania and later Indiana, for examples. Many other countries in the world were large and (as we now know) well endowed with minerals. But no other country exploited its geological potential to the same extent. Using modern geological estimates, Paul David and Gavin Wright show that the U.S. share of world mineral production in 1913 was far in excess of its share of world reserves (David and Wright 1997, p. 205). Mineral development was thus an integral part of the broader process of national development.

David and Wright identify three major elements in the rise of the American minerals economy: (1) an accommodating legal environment; (2) investment in the infrastructure of public knowledge; and (3) education in mining and metallurgy (David and Wright 1997).

U.S. mineral law was novel in that the government claimed no ultimate legal title to the nation’s minerals, not even on the public domain. All other major mining systems retained the influence of the ancient tradition whereby minerals were the personal property of the lord or ruler, who granted user rights as concessions if he so chose. This liberality was not entirely intentional. The Land Ordinance of 1785 did claim for the federal government “one third part of all gold, silver, lead and copper mines” on the public domain, and between 1807 and 1846 a federal leasing system for lead mines was in operation (see Wright 1966). The system collapsed in the 1830s and 1840s because of noncompliance and fraud, and leasing was discontinued in 1846. Thus, the great California gold rush that began in 1848 took place in a legal vacuum, only partially filled by the rules of local mining districts and the intervention of state courts. The federal Mining Laws of 1866, 1870, and 1872 ultimately codified what by then was an established tradition of minimal federal engagement: open access for exploration; exclusive rights to mine a specific site upon proof of discovery; and the requirement that the claim be worked at some frequency or be subject to forfeit. Although the fuel minerals coal and oil have received

separate treatment in the twentieth century, for most minerals, the Mining Law of 1872 remains the basic mineral law of the country (Mayer and Riley 1985).

This discussion may convey the impression that the rise of U.S. mineral production was primarily an exercise in rapid exhaustion of a nonrenewable resource in a common-property setting. Although elements of such a scenario were sometimes on display during periodic mineral “rushes,” resource extraction in America was also associated with ongoing processes of learning, investment, technological progress, and cost reduction, generating a many-fold expansion rather than depletion of the nation’s resource base. The point is illustrated by the work of the U.S. Geological Survey (USGS). Established in 1879, the USGS was the most ambitious and productive governmental science project of the nineteenth century. The agency was successor to many state-sponsored surveys and to a number of more narrowly focused federal efforts. It proved to be highly responsive to the concerns of Western mining interests, and the practical value of its detailed mineral maps gave the USGS, in turn, a powerful constituency in support of its scientific research. The early twentieth-century successes of the USGS in petroleum were instrumental in transforming the attitudes of the oil industry from hunches and folklore toward trained geologists and applied geological science (Williamson, Andreano, et al. 1963).

The third force was education. By the late nineteenth century, the United States emerged as the world’s leading educator in mining engineering and metallurgy. The early leader was the Columbia School of Mines, opened in 1864; some twenty schools granted degrees in mining by 1890. After a surge in enrollment during the decades bracketing the turn of the century, the University of California at Berkeley became the largest mining college in the world. A manpower survey for military purposes in 1917 identified 7,500 mining engineers in the country, with a remarkably broad range of professional experience, domestic and foreign. The most famous American mining engineer, Herbert Hoover, maintained that the increasing assignment of trained engineers to positions of combined financial and managerial, as well as technical responsibility, was largely an American development (Hoover 1909).

Trends in Mineral Scarcity and Self-Sufficiency

The preceding discussion implies that informative as the long-term mineral production series may be, they can only be given an economic-historical interpretation in conjunction with supplementary information on technology, costs, reserves, international trade, and other aspects of the subject. Some data of this sort are presented in these tables, but specialists will want to consult a wider range of statistical and technical sources. As in most economic problems, the first step in interpreting evidence on quantities is to examine the trends in mineral prices, relative to the general price level. This information may be extracted from the tables by dividing the *value* of production (Tables Db34–39, Db104–111, and Db122–131) by the corresponding series on quantity. Unfortunately, USGS reports on the value of output beginning in 1880. Some longer-term price data are presented for coal and petroleum in Tables Db56–72; many other historical mineral price series are collected in Schmitz (1979); for more recent years price and cost data are readily available in the *Minerals Yearbooks* and other sources.

¹ Comparative international statistics are conveniently collected in Schmitz (1979).

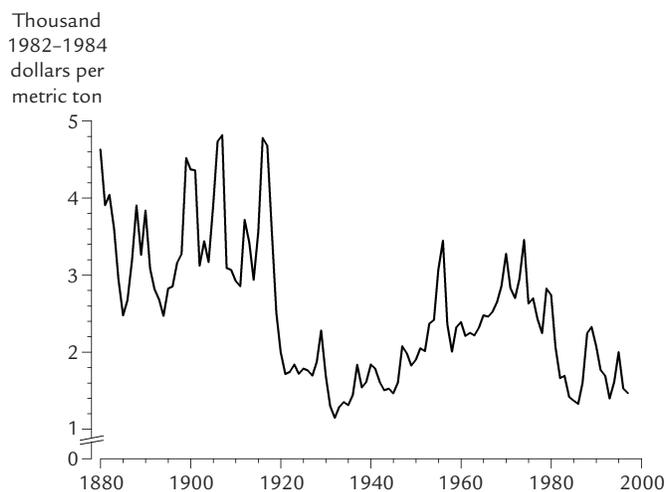


FIGURE Db-A Real price of copper: 1880–1997

Sources

Series Db106, divided by series Db75, and then deflated by series Cc1.

The procedure for constructing real prices from the value of output is illustrated in Figure Db-A for the case of copper. Series Db105 has been divided by series Db75, and the resulting nominal price series (dollars per metric ton) was then deflated by the David-Solar all-commodity consumer price index, series Cc1. The graph indicates that although the course of real copper prices has by no means been smooth, the long-term trend has been downward.

Similar long-term declines in relative prices have been observed for virtually all nonrenewable minerals, as shown in a 1963 study by Howard Barnett and Chandler Morse. The downward trend appeared to be at an end during the 1970s, when restrictions on oil production generated fears of impending material scarcities, but it was subsequently renewed in the 1980s and 1990s. This record is contrary to the predictions of economic theory, which hold that prices of nonrenewable resources must inevitably begin to rise.²

What forces have staved off mineral exhaustion across two centuries? Until World War II, the dominant factor was technological progress in the minerals industries. This category includes not just the discovery of new deposits but also advances in the techniques of search, in the methods for extracting ores from the ground, and in the processes used to separate the metal from the ore (smelting and refining). In the example of copper, U.S. firms pioneered the use of electrolytic refining and the oil flotation process for concentrating the ore. These metallurgical methods were complementary to the application of the Jackling method of large-scale, nonselective copper mining in the first decade of the twentieth century, using highly mechanized techniques to remove all material from the mineralized area. Together, this technological revolution allowed U.S. firms to drive the margin for commercially profitable copper ore below 2 percent, at a time when yields in copper-rich Chile averaged between 10 and 13 percent. Knowing only the yields, we might interpret this comparison as a sign of worsening scarcity. But the fact that the real price of copper was declining during this period confirms that the fall in yields was an indication of

technological progress; it was, in effect, an expansion of the national resource base.

Since World War II, the continuing fall in U.S. minerals prices no longer derived primarily from an expansion in domestic production but reflected an increased reliance on imports from abroad. The shift of the United States to a position of net minerals importer may be traced in the tables for fuel minerals (Tables Db56–72), for selected metals (Table Db132–149), and for selected nonfuel and nonmetal minerals (Table Db150–154). Bauxite became a net import even before the war. Lead, zinc, and copper followed in the late 1940s. Imports of crude oil and iron ore became significant in the 1950s. By the 1980s, the country was a net importer of most minerals, the only major exceptions being bituminous coal and phosphate rock.

During the first postwar decade, many national leaders viewed these trends with alarm. Their concerns led to the appointment of the President's Material Policy Commission (the Paley Commission), whose 1952 report was entitled *Resources for Freedom*. The commission called for liberalization of international trade in raw materials as well as intensification of domestic resource development. As events took their course, the ready availability of imports largely allayed fears of impending scarcity. The obvious exception is petroleum, for which the Organization of Petroleum Exporting Countries (OPEC) embargo and the resulting economic turbulence of the 1970s vividly displayed the potential drawbacks to reliance on imports. Taking a long view, however, the rise of a global market in minerals – petroleum included – has been an important contributor to world economic growth during the modern era. Although depletion of domestic supplies has been a factor in some cases, the more important force has been the fall in transportation costs and the development of new ore deposits around the world. Thus, the United States is now a net importer even of minerals for which domestic production continues at or near historic peaks, such as zinc, molybdenum, and copper.

In addition to increased supplies, impending mineral scarcities have also been forestalled by adjustments on the demand side, including substitutions of relatively abundant resources for those that are relatively scarce and conservation in the uses of certain metals. Issues concerning energy are discussed in the next section of the essay. An interesting illustration of conservation may be found in the present section in the trend toward secondary production of a number of metals, using both new and old scrap. The growing importance of recycling may be seen for aluminum, magnesium, lead, zinc, nickel, and copper (see Tables Db73–103). Generally, scrap is categorized as old or new, where “new” indicates pre-consumer sources and “old” suggests postconsumer sources. When metal is converted into shapes, new scrap is generated in the form of turnings, stampings, cuttings, and off-specification parts. After a product completes its useful life, it becomes old scrap. An example is used aluminum beverage cans, which now account for approximately one half of the old aluminum scrap consumed in the United States. More than three fourths of the refined lead produced in the United States in 1997 was recovered from recycled scrap, of which a major source was spent lead-acid storage batteries. Not only does recycling of metals contribute to the sustainability of their use, but the practice also has environmental benefits in the form of reduced volumes of waste and reduced emissions. Detailed industry reports on the status of recycling are issued each year by the U.S. Geological Survey in the *Minerals Yearbook*.

² The classic article is Hotelling (1931). An excellent review of concepts and evidence is Krautkraemer (1998).

Energy in American Economic History

Whereas the tables discussed in the previous section reported mineral production either in physical units or aggregated in terms of dollar values, Tables Db155–181 report many of the same commodities reduced to the common denominator of energy, the British thermal unit (BTU) – the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit, at or near its point of maximum density. Why do we need this alternative mode of social accounting? Textbooks commonly explain that “energy is essential to life” and imply by extension that high levels of energy consumption are essential to economic life at modern standards of living. But a distinct and voluminous body of historical statistics would hardly be justified by the mere need for the economy to conform to the laws of physics. The more compelling explanation for the study of energy is historical. At recurring points through American history, fears of impending energy scarcities have become widespread, generally because of disruptions to or doubts about future supplies of a major energy source. In light of these episodes, it is informative to analyze the sources of energy more comprehensively and to consider the ways in which these sources have changed through history in response to changes in incentives and in technology.

There are, however, a number of drawbacks to this form of aggregation. First, historical accounts of the production and consumption of “energy” are by no means comprehensive from a scientific standpoint: animal power, wind power for sailing vessels, and even “direct” industrial water power are typically not included. Second, conversion into BTUs does not reflect the different thermal efficiencies of the various fuels. This problem is most serious with respect to wood, long the nation’s dominant fuel source, but one that involved an especially low thermal efficiency. Thus the series on fuelwood consumption, superseded by the series on biomass production and consumption, probably overstates energy *consumed* – as opposed to the energy *produced* – from this source (see series Db171, Db174, and Db179). Third, the conversion of hydroelectric power represents a special problem. Because the energy exerted by the flowing water is not measured directly, the energy provided by hydroelectric power is typically constructed by estimating the “fuel equivalent” of the kilowatt hours generated (see, for example, series Db163). But this procedure means that the series on hydroelectric power is influenced by the changing efficiency of converting fuel into electricity elsewhere in the economy. The time profile of hydroelectric power looks quite different in tables in which the electricity generated is measured directly in kilowatt hours, as in series Db224.

The general point is that tables like these involve a considerable amount of construction, some of which is arbitrary. Students of energy history will want to use them in conjunction with the full range of information on the volume and value of production in the minerals section. More technical researchers will want to turn to the underlying sources (such as the *Minerals Yearbook* and the *Annual Energy Review*) to analyze the definition and historical evolution of the conversion factors themselves.

Despite these shortcomings, Tables Db155–171 do provide a quantitative rendition of the two major historical revolutions in American energy: the transition from wood to coal in the nineteenth century and the shift from coal to petroleum in the twentieth century. The first of these was fundamental to the Industrial Revolution of eighteenth-century England, releasing the economy from

the constraints of the “organic economy” (Wrigley 1988). So long as energy had to be obtained from vegetable sources such as timber, its supply was either limited to an annual harvest or subject to rising costs because it had to come from greater and greater distances. The replacement of wood by coal, however, opened up for human use a vast inventory of already-stored energy. Because major coal deposits are geographically concentrated, moreover, specialized transportation systems could carry these materials to appropriately located establishments for use. Cheap, concentrated energy thus served to relax geographic limits on the scale of production and to increase the return on fixed investments in all sectors.

Ironically, in the United States this transition was delayed by an abundance of forestland, which readily generated timber as a byproduct in the ongoing process of clearing forests for farmland. As late as 1870, wood fuel constituted as much as 75 percent of U.S. energy consumption (Table Db164–171). Cheap timber helped give the United States world leadership in shipbuilding during the era of wooden ships, and Americans developed woodworking expertise and a wood-based lifestyle unique in the world at that time. But reliance on wood fuels consigned industries to what were then outmoded technologies, such as charcoal-using iron foundries. According to Alfred Chandler, it was not until the opening of the anthracite fields of eastern Pennsylvania that large-scale, steam-powered factories were feasible in America (Chandler 1972). Only with the rise of bituminous coal in the 1850s did American blast furnaces begin to adopt coke-using technologies. Making up for lost time, U.S. coal production surpassed that of Britain and Germany by the end of the nineteenth century. This development coincided with the rise of the United States to the position of the world’s largest industrial nation, a transition forecast in W. S. Jevons’s classic, *The Coal Question* (1866).

Figure Db-B shows that through 1890 the rise of coal was largely a substitute for wood energy; thereafter, the country’s energy consumption rose to a new plateau of nearly 200 million BTU per

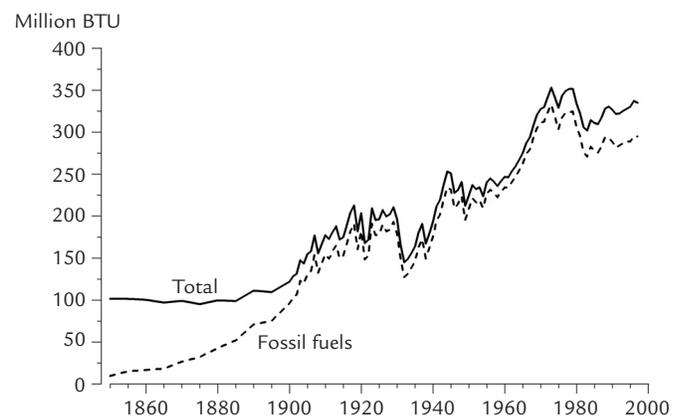


FIGURE Db-B Energy consumption per capita: 1850–1998

Sources

Fossil fuels: series Db164. Total: sum of series Db164 and Db168–171. Population: series Aa7.

Documentation

The gap between fossil fuels and the total in the nineteenth century is explained by the use of wood for fuel. Wood’s share of non-fossil-fuel energy consumption declined steadily during the twentieth century, from nearly 100 percent in 1890 to 50 percent by 1941, 25 percent by 1961, and less than 10 percent beginning 1971.

capita by 1920, easily the highest in the world at that time. This was the era during which coal was dominant – as fuel for household heating (primarily anthracite) and transportation (primarily railroads) and as an industrial energy source (dominated by the giant steel industry). Forecasters projected an enormous expansion in the demand for coal by the mid-twentieth century, but relative to gross domestic product, coal's share peaked during the 1910–1920 decade. The transition to petroleum energy was already underway.

The Era of Petroleum

World petroleum production was dominated by the United States for nearly a century, from the time of Edwin Drake's first oil strike near Titusville, Pennsylvania, in 1859 until the 1950s. Through most of the nineteenth century, petroleum's chief use was as an illuminant, a role claimed by electricity after 1900. In the twentieth century, oil became the nation's primary source of energy: as fuel oil for industry, heating oil for homes, and gasoline and diesel fuel for transportation. One of the advantages of oil over coal was its cost, but the primary advantage was transportability, both in relocating from the point of origin to the point of use and in moving the vehicles themselves. Industrialization in California, which had been held back by an absence of coal, flourished under the new oil regime. And California became a symbol of the oil-using, high-mobility American lifestyle of the twentieth century. Primarily through automobiles and electrification of the household, per capita energy consumption nearly doubled again between the 1920s and the 1970s, peaking at more than 350 million BTU per person.

The American love affair with oil was first prompted by a series of major new fields developed between 1900 and 1930, allaying (at least temporarily) the recurring fear that domestic supplies would run out. New discoveries led to an ever-widening range of uses (see Table Db45–55). Nonetheless, by the 1950s, the long-delayed exploitation of the vast oil fields in the Middle East was finally underway, and the United States became a major net importer of petroleum energy (Tables Db182–197). Although oil allowed great flexibility to firms and households, the nation as a whole became quite committed to it through massive investments in an infrastructure of pipelines and roads and through its commercial and household capital stock. The availability of cheap imports sustained the growth of consumption. But this commitment proved to be a heavy burden during the oil shocks of 1973 and 1979, brought on by the steep rise in prices resulting from cutbacks in production coordinated by OPEC. The effects of this traumatic decade may be traced in virtually all of the minerals and energy tables presented here.

It is interesting to reflect on the historical roots of the oil crisis of the 1970s for the nation and for the world in light of changing perceptions about oil supplies and energy requirements. Table Db198–205 displays estimates of crude oil reserves for the major regions of the world, between 1948 and 2000. (A longer-term U.S. series may be found in series Db59.) Such data must be taken with considerable skepticism. Because new reserves are added to the totals every year, geologists understand that these figures do not represent the ultimate oil energy potential of the earth; they are more like a working inventory, subject to discretionary financial and technical decisions over time. International reserve estimates are particularly subject to guesswork and variability. Nonetheless, when viewed over an extended period, reserve

estimates convey some important lessons. Although U.S. oil formerly dominated both world and national production, U.S. reserves at the turn of the twenty-first century are an extremely minor part of the world picture. U.S. reserve levels peaked in 1971 (when the Alaskan Prudhoe Bay discovery was recorded) and have gently declined ever since. One may note, however, that estimates of aggregate world reserves have continued to increase rather than decrease. This perhaps surprising phenomenon reflects the ongoing processes of exploration and development, which draw upon increasingly sophisticated branches of geological and geophysical science. Indeed, if one were to accumulate the entire volume of oil ever extracted from U.S. wells and put it back in the ground, the totals would still constitute a relatively small part of the modern world oil reserve picture. Thus, data on oil production and reserves should not be evaluated hastily. Far more detailed studies may be pursued using the voluminous information issued each year in the *Annual Energy Review*, the *Petroleum Supply Annual*, the *Crude Oil, Natural Gas and Gas Liquids Report*, and other publications of the Energy Information Administration.

With hindsight, in other words, the crisis of the 1970s reflected short-term vulnerability rather than an impending long-term energy scarcity. With some lags in adjustment, the tables show that patterns of energy production and consumption have demonstrated a remarkable range of flexibility and responsiveness to incentives. In addition to the discoveries and developments of oil reserves around the world, American homes and industries have moved away from exclusive dependence on oil, currently favoring natural gas or electricity (mainly generated by coal). The overall efficiency of energy use has dramatically improved, with per capita consumption leveling off or declining from the peaks of the 1970s. Table Db206–217 shows that even the gas-guzzling American automobile has increased its fuel efficiency since 1960, albeit prompted by federal legislation as well as heightened consumer sensitivity to gas mileage.

Responsiveness to incentives is a double-edged sword, however. The tables also show that many of the energy initiatives of the 1970s have stagnated as oil prices have declined. The record of renewable energy sources can only be considered disappointing to their advocates (Tables Db172–181 and Db242–260). Improvements in average gasoline mileage have largely come to an end, with the growing popularity of minivans and sport-utility vehicles (series Db211). The U.S. transport sector continues to consume far more oil than do its counterparts in other advanced industrial nations, American drivers responding not just to low world oil prices but to uniquely low gasoline taxes in the country. Nonetheless, the record indicates that a considerable array of alternative energy sources and margins for energy improvement does exist and could be called upon should another crisis occur.

Electrification and Energy Efficiency

Across the twentieth century, a steadily rising share of America's energy consumption has been provided through the medium of electricity. Electricity is not a primary energy source because it is itself produced from fuels through costly conversion processes. Table Db218–227 traces the sources net generation by electrical utilities since 1920. One may see that although generation from all sources has increased (including nuclear and hydroelectric energy), the dominant fuel source for electricity throughout the century has

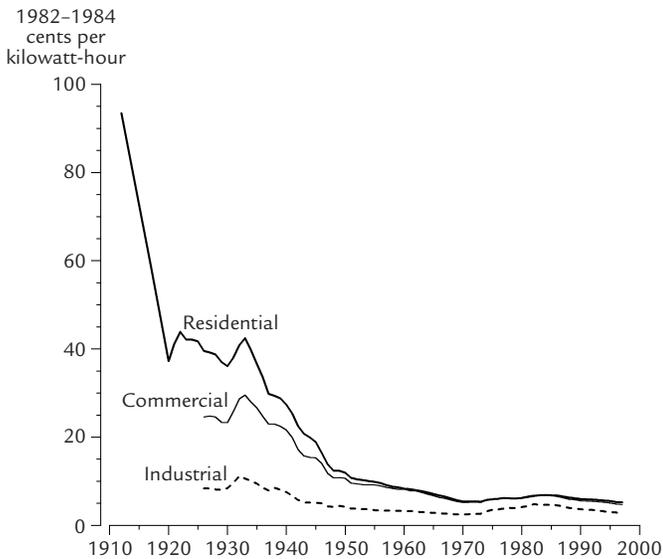


FIGURE Db-C Real electricity prices, by type of use: 1912–1997

Sources

Series Db235–237, deflated by series Cc1.

been coal. This persistence is a clear demonstration of the broader proposition that what is most important for the energy economy is the form, flexibility, and convenience through which energy is supplied, as contrasted with the cost or price of a unit of energy per se. Electrification is an indirect form of energy supply and, therefore, contributes to increased costs. Yet electrification has also been a major contributor to the long trend toward greater efficiency in energy utilization for the economy as a whole.³

Table Db228–233 presents data on sales and use of electricity since 1902, showing a steady expansion in residential, commercial, and industrial markets. The surge of electrification that began in the 1920s was triggered by the rapid decline in electricity prices during the 1910–1920 decade and sustained by the real price fall that continued into the 1960s. These trends may be seen in Figure Db-C, which uses price data from Table Db234–241, deflated by the David-Solar index of consumer prices. The price fall was driven by the scale economies made possible by central power stations in which giant generators were driven by high-speed steam turbines and by integration and extension of power transmission networks over an expanded territory. In comparison with these dramatic developments of the first half of the century, the price increases after the 1970s were moderate and soon reversed.

Series Db238 shows that the diffusion of electric service to American households was essentially complete by the early 1950s. The process was somewhat delayed in rural areas but was encouraged by the loans and assistance provided by the Rural Electrification Administration established in 1936; electrification in farm households had nearly closed the gap by 1950 (series Db239). After service was established, electricity use per household steadily increased, its growth slowing only moderately in response to the price increases of the 1970s and 1980s (series Db241).

How then has electricity contributed to improved energy efficiency? The greatest impact has been on the manufacturing sector, where electrification actually predated that of households, in part because high-volume industrial rates came down much earlier (series Db237). During the 1920s, purchased electricity replaced steam power as the primary power source in manufacturing. The transition had begun earlier, but only with the favorable investment conditions of that decade were manufacturing firms in position to implement the thorough restructuring of plant design and machine layout that would allow them to take advantage of electricity's potential to increase the productivity of both capital and labor. This episode has been identified by Paul David as a classic example of an innovation whose major impact is delayed by the need for accommodating changes in the structure of markets and of the workplace. For electrification, the crucial step was the shift from "group drive" (in which electric power simply replaced steam in a plant that retained the huge shafts and belts of the earlier era) to "unit drive" (in which each machine was equipped with its own electric motor).⁴ By improving the reliability and flexibility of power, electrification thus made possible a fuller utilization of the nation's manufacturing capital stock, as well as its labor force. According to Murray F. Foss, this trend continued into the 1970s and played a significant role in generating the high rates of total-factor-productivity growth enjoyed during that era (Foss 1997).

For present purposes, the important point is that electrification was an essential background prerequisite for an entire set of technological and efficiency improvements in the economy; however, this progress had little to do with reducing the unit price of energy to its users. Thermal efficiency has indeed continued to improve, but the more important impact came through the "efficiency of energy utilization," adaptations made possible by electricity's ease of transport, convenience, and flexibility. The result has been an overall reduction in the energy intensity of the economy, or an increase in the productivity of energy.

Forest Areas of the United States

Americans have long been concerned about the disappearance of their forests. Unfortunately, careful surveys of woodland areas date only from the emergence of this concern at or shortly after the turn of the twentieth century. Earlier, of an estimated original forestland of some 900 million acres, only 470 million acres remained in 1920, and the majority of these had been disrupted to such an extent that they were no longer self-restoring. The most rapid destruction occurred between 1800 and 1920, the very period when Americans were so ingeniously adding to the country's mineral resource base. The last phase of this process may be traced in series Cf107 and Cf115, where the sum of these two forest land categories declines from 558 million acres in 1880 to 328 million in 1920. Although forests have always been renewable in principle, during most of this era they were viewed by settlers and lumber companies as a one-time gift of nature, and the abundance of American forest products supported expertise in woodworking technology and a wood-based lifestyle unique in the world at that time.⁵

The tide began to turn early in the twentieth century. Table Cf135–144 shows a remarkable increase in both public

³ This apparent paradox is persuasively elaborated in Schurr, Burwell, et al. (1990).

⁴ For fuller accounts, see David (1991) and Devine (1983).

⁵ A good historical account may be found in Williams (1989).

and privately owned forest land, the largest jumps occurring between 1940 and 1970. Although precise comparisons are difficult, it seems accurate to say that at the end of the twentieth century, U.S. forest acreage was higher than it was a century before. Table Db379–386 shows that two thirds of the forest acreage is commercial timberland, a share that has been stable since the 1960s. Of this, nearly three fourths is privately owned.

Nonetheless, changes in public policy have played an important role in reversing the trend. In 1891, the first legislation was passed permitting the president to set aside public forest reservations (see Table Db387–389). Subsequent laws led to the creation of the Forest Service in 1905, with Gifford Pinchot as its first director. Under Pinchot's aggressive leadership, national forest acreage rose to 172 million acres by 1909, very close to its modern levels. The gross area within the national forest system boundaries, however, continued to expand until the late 1930s (Table Db390–397).

The national forest system was never intended, and has not functioned, to protect wooded lands from commercial uses. Although the conservation movement provided political pressure, the Act of 1891 intended no more than a temporary withdrawal of land from sale to the public, to protect area water supplies. Throughout his tenure, Pinchot argued that the national forests could be run at a profit, serving as a kind of model of enlightened, farsighted business practices. Thus, from the beginning in 1905, a considerable volume of timber has been cut and sold commercially from the national forest system (series Db390–392 and Db399). Grazing use receipts have also been important; in fact, until the 1920s, they were larger than timber sales (series Db400). Taking advantage of the regenerative capacities of previously logged-over and abandoned land, managing the annual timber harvest became a major activity of the Forest Service by the 1950s, with commercial sales peaking in the late 1980s. The goal of a profit for the system as a whole, however, has been elusive. Reliable long-term cost data are not readily available, but the evidence suggests that these operations have generally made losses, serving as an implicit subsidy to the lumber industry.⁶

Under budgetary and political pressure, the Forest Service has gradually grown into a wider set of noncommercial mandates, including improved tree breeding, habitat restoration, wilderness preservation and recreation, and forest conservation. The Multiple Use–Sustained Yield Act of 1960 was something of a landmark in this evolution, identifying timber as only one among many Forest Service goals. The Wilderness Act of 1964 went much further, mandating a system of wilderness lands reserved from all forms of development. These broadened responsibilities were to be shared with the National Park Service and the Fish and Wildlife Service. In the 1990s, as a result, clear-cut harvests on the national forests were substantially reduced, and the number of visitor-days to national forest system lands steadily increased (series Db402). The Forest Service now claims to be the single largest supplier of public outdoor recreation in the nation. A sense of its emerging institutional identity may be gained from the *Report of the Forest Service*, published annually.

Eventually, attitudes and practices in the private forest sector also gravitated toward longer-term sustainability. The diffusion of sustainable private-sector practices depended on improvement in the general knowledge base and level of training in forest management, as well as on attainment of sufficiently long organizational

time horizons to make these investments worthwhile. A major factor in this transition was the conquest of forest fires, which were frequent and devastating in the nineteenth century, adding to the motivation for realizing revenue quickly. When the early forest surveys of the 1920s reported surprisingly rapid regeneration, they also found that in roughly half the area surveyed, timber drain exceeded timber growth. The prime culprit was fire, the direct or indirect cause of three fourths of pine timber mortality. The problem had a strong regional component: the South accounted for some 85 percent of all forest fires in the country during the 1920s and 1930s, though the region contained less than one third of the nation's forest area. Roughly 40 percent of these fires were of suspected incendiary origin, reflecting the time-honored tradition of annual woods-burning, practiced in order to improve livestock grazing and eliminate pests. Between the 1920s and the 1950s, an ambitious federal–state–voluntary cooperative program undertook to transform the regional culture through education and prosecution and to expand the forest area under federal protection.

The success of the program may be seen in series Db404, which shows that the total burned-over forest area peaked in 1930 at more than 50 million acres and declined to less than one tenth of this level by the 1950s. The decline in the number of fires was somewhat less, reflecting success at fire containment as well as prevention (series Db403). As a result, the Federal Reserve Board amended its regulations in 1953 to allow financial institutions to make loans on timberland. This step was a significant milestone in the restoration and expansion of the South's forest industries.⁷

In recent years, enlightened forestry opinion has developed an appreciation of some of the benefits of controlled forest fires, for certain ecosystems and for the moderation of uncontrolled fires. A policy of complete fire exclusion can create a multistoried forest structure with a continuous vertical fuel arrangement, allowing what would be a surface fire to spread into the trees and become a crown fire. An unusually severe fire can seriously diminish the long-term sustainability of the land. Further, fire exclusion sometimes favors nonnative species in fire-dependent areas. For these reasons, many authorities actively favor the reintroduction of forest fire on a controlled basis.⁸ From a century-long standpoint, these modern discussions are possible only because of the prior demise of the uncontrolled fire regime.

Forest Products Industries

Production and consumption of forest products are unusual in American history in that they have gone through a long cycle of decline and rebirth. The longest statistical series is for lumber production, which shows a peak at 46 billion board feet in 1906–1907 (series Db423). If we convert this into a series on consumption per capita, by adding imports (series Db426), subtracting exports (series Db429), and dividing by the national population, we can see that the country underwent a spectacular nineteenth-century expansion of its use of wood, followed by an equally precipitous decline in the first half of the twentieth century (see Figure Db-D).

⁷ Greater detail on the regional incidence and causes of forest fires may be found in the sources for Table Db403–408.

⁸ See the multiagency Federal Wildland Fire Policy memorandum of 1995, available at the Forest Service Internet site.

⁶ For an informed discussion, see Wolf (1997).



FIGURE Db-D Lumber consumption per capita: 1799–1997

Sources

Lumber consumption: series Db423, plus series Db426, minus series Db429. Population: series Aa7.

Remarkably, the decline ended during World War II, and per capita lumber consumption has been largely stable since then. Since the 1970s, imports of lumber have increased, overwhelmingly from Canada. But for most timber products, the growth of consumption has closely tracked the growth of domestic production, the most impressive growth sector being pulp products (Table Db409–422).

Largely occurring in the South, this expansion is a reflection of a revolution in technology and practice that has converted that region's forest economy into an advanced form of tree farming. Important enabling factors included the invention of the kraft or sulfate pulping process in Germany and successes at the U.S. Forest Products Laboratories in showing that suitable paper could be made from young, resinous pine trees, using the kraft process. Having then conquered the forest fire problem, firms relocating in the South could draw upon tree breeding and improvement programs first developed in Sweden and other European countries. Federal–state–industry collaboration subsequently led to the creation of a network of state nurseries in the South, and in recent years, university–industry programs like the North Carolina State Cooperative have led to remarkable advances in genetically based artificial regeneration. Some indication of this regional progress is visible in the data on lumber from principal tree species, which show that production from southern pine has nearly tripled from its low in the early 1960s, while nearly all other softwoods show decline (Table Db432–445). Pulpwood has also expanded, the South now accounting for about three fourths of the U.S. total and over half of paper and board production (Table Db446–453).⁹

The behavior of resource prices over the past two centuries has confounded the predictions of economic theory, which holds that nonrenewables should become more costly over time as they become more scarce, while the price of renewables should stabilize at the cost of production. As we have seen in the section on minerals, the price trend for most nonrenewables has been downward. Prices of lumber and forest products, on the other hand, despite the fact that they are renewable, show a long-term upward trend over the past two centuries. Peter Berck and William R. Bentley

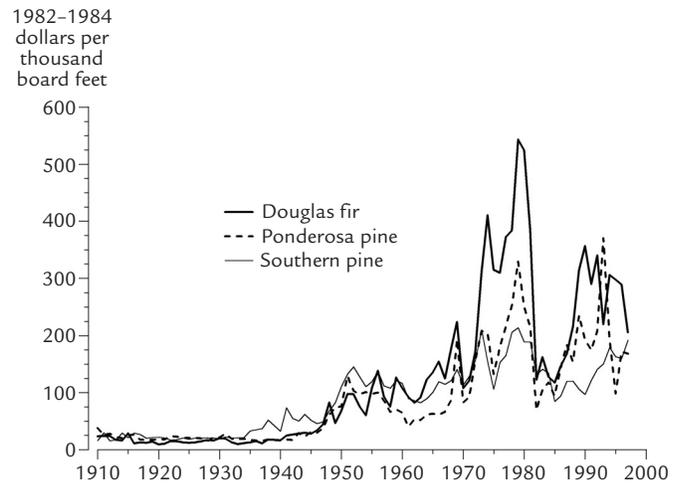


FIGURE Db-E Real stumpage prices: 1910–1997

Sources

Series Db454–455 and Db457, deflated by series Cc1.

(1997) show that Hotelling's theory of rising *nonrenewable* prices provides a good fit for the historical record for redwoods, a variety of which the old-growth supply is essentially fixed for practical purposes.¹⁰

What could possibly be the last phase of this era of rising scarcity may be seen in the first part of Figure Db-E, which graphs stumpage prices since 1910 for three major tree species, deflated by the David-Solar consumer price index. The continued increase during the first half of the century is evident. However, even though price levels since the 1950s have been highly volatile, the figure suggests that the long-term rising trend may have come to end. This is particularly so for the southern pine, which was the high-price variety before the 1960s but has now become relatively less expensive because its production has been placed on a sustainable and renewable basis.

This historical overview puts into somewhat different perspective the debate over preservation of the old-growth forests in the Pacific Northwest. These areas are often portrayed as the last vestiges of a once-vast American woodland, a characterization that is far from accurate. Because the cycle of regeneration is much longer in this region than in the South, logging still retains much of the character of the old once-over pattern and is less amenable to change through incentives. The issues largely turn, however, not on the need to conserve timber resources for future generations, nor on the vital importance of timber to the national economy, but on the social value of preserving the unique ecosystems that the old-growth forests represent, particularly as habitats for diverse plant and animal life. The annual harvest of Douglas fir declined precipitously between the 1980s and the 1990s because of the demands of the Endangered Species Act (series Db434).¹¹ These ecological values are subject to great uncertainty and wide differences of opinion. But compromise is difficult because of the probable irreversibility of many of the ecological consequences, unlike the highly regenerative quality that other American forests have displayed.

¹⁰ Price data for the nineteenth century may be found in U.S. Forest Service (1948).

¹¹ This history is recounted by Yaffee (1994).

⁹ For a compelling account, see Boyd (2001).

Fisheries

The term “fishery” has at least two distinct meanings: (1) the business of catching, packing, or selling fish or other products of lakes, rivers, or the sea; and (2) a place where fish and the like are caught – a fishing ground. It may also refer to a legal right to catch fish in certain waters or at certain times, or a place where fish are bred. All these meanings come into play in American history, but the first two have been paramount in the statistics collected since the founding of the U.S. Fish Commission in 1871. Following in this tradition, the main focus of these tables is the record of the quantity and value of fish and related products generated by the U.S. domestic industry, with some attention to the question of sustainability, in light of the fact that fish are a renewable natural resource subject to depletion. Because most fish populations swim in international waters, however, it is inherently difficult to draw inferences about resource stocks from trends in the annual catch by fishermen of a single nation.

The American fishing industry long predates the statistical tables presented here. Aided by a federal bounty enacted in the 1790s, East Coast fishing experienced a considerable expansion in the first half of the nineteenth century.¹²

This period of growth was followed by contraction after the Civil War. The latter stages of this decline may be seen in the series on total domestic yield of fishery products (series Db273), and especially in the fall in the landed catch of Atlantic cod between 1887 and 1905, and in the landed catch of Atlantic mackerel between 1880 and 1910 (Table Db283–300). It is not clear that this development reflected a deterioration of fishery resources. Other important historical factors would include the abolition of the federal fishing bounty in 1866; the rise of Canadian competition in the Grand Banks of Newfoundland and other international waters; the increase in U.S. tariffs, which raised the cost of imported curing salt; changes in consumer preferences; and the rise of new regional fishing industries in the South, the Great Lakes, and the Pacific.¹³ Note that the U.S. whaling industry went through a similar rise-and-fall cycle, which does not seem to be attributable to pressures on stocks of the major hunted whale species (Table Db371–376).¹⁴

After 1900, the aggregate figures show alternating periods of growth and stagnation in the domestic yield of fishery products, with a pronounced upward trend across the century as a whole (Tables Db273–282 and Db311–314). The growth of the fish catch allocated toward industrial purposes (primarily animal feed) began to decline after the early 1980s, but the fish yield for human consumption resumed its positive long-term trend at roughly the same time. Both fish product imports and exports have grown, reflecting the general expansion of world trade rather than generalized pressures on domestic supplies (Table Db273–282). Constructed series on unit values (obtained by dividing value figures by the corresponding quantity figures) show no indication of an increase in the average price of fish, relative to the general price level. Perhaps as a result, per capita consumption levels have drifted upward across the century (Table Db342–352).

When we turn to the record for particular fish species, the picture is more mixed (Table Db283–300). Although the total landed catch of fish increased between the 1960s and the 1990s, many individual species show evidence of recurrent overfishing. The yield of Atlantic mackerel all but disappeared from the 1950s to the 1980s, before recovering moderately in the 1990s. The yield of Pacific mackerel peaked at 176 million pounds in 1947, falling to 18 million pounds in 1973; after a resurgence in the 1980s, the catch fell once again to a low of 23 million pounds in 1995. The collapse of tuna and haddock has been even more precipitous. The virtual disappearance of the Pacific sardine fishery in the 1950s is recounted in detail by Arthur F. McEvoy (McEvoy 1986). According to McEvoy, that episode represented an extreme example of failure by federal and state authorities to “manage” fish stocks successfully, a failure attributable to the use of inadequate single-stock biological models to estimate maximum sustainable yield (MSY) and an inability to forecast changes in climatic conditions bearing on fish stock dynamics. In most cases where the fish catch declines, however, it is difficult to assign precise responsibility to overfishing, as opposed to other factors, such as pressures on habitats arising either from human actions or from natural causes.

The record for shellfish is broadly similar (Table Db301–310). Most of the species for which long-term data are available – clams, lobster, Atlantic and Pacific squid – show rising trends in landed catch over more than a century. Shrimp is a partial exception, showing rising yields until the 1970s, followed by decline in the 1990s to levels that were typical during the 1950s. The series on oysters begins only in 1929, but it clearly deviates from the others. From yields greater than 90 million pounds in the 1930s, the landed catch of oysters has declined to less than 40 million pounds per year in the 1990s. Consistent with this downward trend, the relative price of oysters has been rising in recent years. Nonetheless, the total landed catch of shellfish grew markedly between 1960 and 1991, though it subsequently declined.

In recent years, the National Marine Fisheries Service (NMFS) has expanded and improved its statistical reporting services. One new initiative is reflected in Table Db334–341, the effort to monitor recreational fishing in coastal waters. The figures suggest that the number of recreational fishing trips per year was relatively stable from the 1970s to the 1990s, but the number and weight of fish caught actually declined during this period.

Another new development is the emergence of commercial aquaculture, which has been monitored by the Department of Agriculture since 1983 (Tables Db353–370). The total value of U.S. aquaculture production tripled between 1983 and 1997, possibly an important factor in restraining increases in market prices generally. The most rapid increase has been catfish, which in 1997 accounted for two thirds of aquaculture production by weight, though only 40 percent by value. Salmon aquaculture also shows a large increase between 1983 and 1995, though the share of aquaculture in total domestic salmon supply is still relatively small (compare series Db294 and Db357). Shellfish aquaculture has grown very slowly, and its share in total shellfish supply also remains relatively small (compare series Db359–361 and Table Db301–310).

Perhaps the most important new responsibility of the NMFS is to report each year on the status of fisheries by geographic area and to identify those fisheries that are overfished or are approaching a condition of being overfished. This charge was established by the Sustainable Fisheries Act of 1996, which reauthorized and amended the Magnuson–Stevens Fishery Conservation

¹² Accounts of this growth may be found in Innis (1954) and O’Leary (1996). The latter work presents numerous statistical tables with state data and references to available national series.

¹³ The best recent discussion of these trends is in O’Leary (1996).

¹⁴ See the discussion in Davis, Gallman, and Gleiter (1997).

and Management Act of 1976. This Act reflected the prevalent view among informed observers that the high catch levels of the 1990s are not sustainable but instead represent an intensified exploitation of fishery resources. Such conclusions have been documented by various international studies, such as the Food and Agricultural Organization's *Chronicles of Marine Fisheries Landings (1950–1994)*, which showed that a growing number of world marine fisheries were in either a “mature” or “senescent” stage of declining yield (Food and Agricultural Organization 1996). In its “Reports on the Status of Fisheries of the United States,” the NMFS estimates of “overfished” species increased from 86 in 1997 to 98 in 1999. The number of species classified “not overfished” decreased from 183 in 1997 to 127 in 1999. However, the status of the largest number of fish species (674 in 1999) was unknown.¹⁵

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¹⁵ The 1999 report and other relevant material may be found at the NMFS Internet site.