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Technological Change and the Profit Motive

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Introduction

The United States emerged with a superior technology early in the nineteenth century. British customs officials confiscated shiploads of American clocks and other products as a violation of British antidumping laws. They discovered, however, that the low prices on American clocks reflected lower costs of production because of the machine production of interchangeable parts, compared to the British clock industry, which relied on higher cost handmade parts. The British began sending delegations to inspect the technology of mass-produced interchangeable parts in the clock and firearms industries. At the Crystal Palace Exhibition in London in 1851, this new technology was referred to as the American system of manufacturing.[1]

By the second half of the nineteenth century, Americans had achieved a technological superiority in most industries, while the British technology seemed to stagnate. Corresponding to these trends in technological change, the American economy experienced rapid economic growth while the British economy entered a period of secular stagnation or climacteric.[2] In the second half of the twentieth century and especially in the last decade, the United States, seems to be repeating the British experience; there is evidence of retardation in the rate of technological change, coinciding with slower rates of productivity advance and economic growth.[3] An explanation for the pace and pattern of technological change is important in understanding the growth and welfare of countries at different points in time; yet the traditional analysis of technological change does not provide such an explanation. In this paper we will review the traditional analyses of technological change and contrast them with an Austrian approach to technological change focusing on entrepreneurial decision-making. We will then explore technological change in the American economy, contrasting the nineteenth and twentieth century experience. Specific reference will be made to technological change in the development of our energy resources that illustrates the limits of the traditional analyses and points out the need for new directions, suggested by Austrian theory, in research on technological change. The analysis also illustrates (1) how myths and misconceptions about technological change continue to dominate our public policies, and (2) why new directions are needed in public policies affecting technological change.

The Traditional Analysis of Technological Change

A number of writers have offered different explanations for the pace and pattern of technological change, and indeed, this controversy continues down to the present day. On the one hand are economists, such as Jacob Schmookler, who maintain that technological change can be explained by economic forces.[4] He argues that inventive activity and the diffusion of inventions are determined primarily by changes in consumer demand over time. As consumer demand changes, the prospective profit to inventive activity increases, thus rechanneling the efforts of inventors into those lines of activity. In Schmookler's analysis, developments in science and technology are relevant in determining the specific characteristics of inventions, e.g., mechanical, electrical, chemical, biological; but inventive activity is channeled into a specific class of final commodities demanded by the consumers. Science and technology do not function as major independent forces in shaping the timing and direction of the inventive process. Rather, the line of causation runs from economic forces to inventive activity, which then influences not only technology but science as well.

Schmookler's emphasis on demand in explaining inventive activity has been challenged by other writers who focus on the supply side and who see an independent role for scientific and technological advance. Nathan Rosenberg, for example, points to fields such as medicine, where there was an obvious demand for improvements but where progress was delayed until developments took place in the science of bacteriology in the second half of the nineteenth century.[5] For Rosenberg the body of scientific knowledge grows at uneven rates in different fields, setting constraints on and shaping the direction of progress. He does not view scientific advance as induced in some deterministic sense by economic forces, nor does he see the scientific enterprise as completely autonomous, propelled by its own internal logic. Rather, the disparate growth of scientific knowledge reduces the cost of science-based inventive activity in different industries at different points in time. Similarly, Rosenberg argues that inherent complexity at the technological level influences the allocation of resources to inventive activity and the payoffs to successful invention. For example, the timing of the introduction of coal as a substitute for wood fuel was influenced by technical problems that varied in complexity in different industries. It was relatively easy to introduce coal in the production of salt, lime, and bricks in the seventeenth century. But it was more difficult to substitute coal for wood in the brewing, glass, and iron industries, and successful technological breakthroughs in these industries lagged by as much as a century. Rosenberg concludes that the timing and direction of inventive activity is influenced by the supply side, i.e., developments in science and technology, as well as by the demand for final goods and services.

We can reject the deterministic view that scientific progress and technological change are induced by economic forces, and we can reject the view that science and technology are completely autonomous and follow some internal logic. But the question remains: How can we explain the pace and pattern of technological change at different points in time? As Rosenberg points out, how do we explain the fact that England experienced rapid technological advance in the late eighteenth century at a time when English science was in a state of decline, or the fact that France, with the most advanced scientific community at that time, lagged behind the British in virtually every phase of technological change? How do we explain the relative stagnation of British technology in the late nineteenth century? There was an obvious demand for technological change in a number of industries, but the British failed to respond to that demand. The demand for electricity in the highly urbanized British society was as great as it was anywhere else in the world, but British electrical engineers failed to respond to that demand. The British electrical industry was developed primarily by foreign electrical engineering firms.

It is clear that to understand the pace and pattern of technological change, we must understand the institutional framework within which technological change occurs. Translating scientific and technological knowledge into new products and production methods is not something that is induced automatically by economic forces. In the final analysis, it is the individual entrepreneur who assumes the responsibility for initiating technological change.

The role of the individual entrepreneur is for the most part ignored in the literature on technological change. The study of individual entrepreneurs is relegated to business history, which has never had a respected niche among academic disciplines. Only recently have scholars begun the sort of systematic analysis of individual entrepreneurial activity that can provide the empirical information necessary to understand the role of the entrepreneur in the process of technological change.[6]

There is one aspect of entrepreneurial behavior that has been explored extensively. Particular groups in a given society supply a disproportionate share of entrepreneurs relative to their share of the total population. One line of inquiry is to explore the social and psychological factors that influence a particular group to emerge in this unique entrepreneurial role. The early work of Weber and Tawney associated this entrepreneurial behavior with religious nonconformity during the Protestant Reformation.[7] There is an extensive literature on the Protestant Ethic and the rise of capitalism, much of it challenging the Weber-Tawney thesis. More recently, scholars such as Hagen and McClelland have borrowed tools of analysis from social psychology to explore the role of unique entrepreneurial groups, but that work has also stirred controversy.[8]

Perhaps the most important contribution to the analysis of entrepreneurial behavior is the work of Joseph Schumpeter.[9] Schumpeter placed the entrepreneur as the prime mover in waves of inventive and innovative activity. The entrepreneur launched major technological changes such as the introduction of railroads, which in turn induced secondary innovations in related industries. These waves of innovation were linked to long waves of economic activity. Schumpeter recognized the importance of the institutional framework for entrepreneurial behavior. He argued that rapid technological change in America in the nineteenth century was due to the existence of a laissez-faire economy in which the entrepreneur was given a wide range of freedom to exploit economic opportunities. Schumpeter questioned whether such entrepreneurial behavior would emerge in an economy with extensive government intervention in the market, characterized by bureaucratized decision-making. He expressed reservations regarding the potential for entrepreneurial behavior and continued rapid technological change in the American economy in the twentieth century because of the expanded role for government.

While the entrepreneur is the prime mover in Schumpeter's analysis, his role is largely exogenous to the economic system. The entrepreneur is assumed to exploit the economic opportunity presented by a new product or production method. Technological change is exogenous to the system in the sense that (1) the entrepreneur creates a disequilibrium by introducing the new innovation, and (2) this disequilibrium in turn creates economic opportunities for further innovations leading to a wave of technological advance. Successful entrepreneurs, of course, generate profits, and the profit incentive of a market system is an essential condition for such entrepreneurial behavior, but Schumpeter never addresses the entrepreneurial decision process itself.

The only scholars to analyze entrepreneurial decision-making within the framework of economic analysis are those of the Austrian school. The work of Mises, Hayek, and, more recently, Kirzner and Rothbard provides an analytical framework for relating entrepreneurial behavior to technological change.[10]

An Austrian Analysis of Technological Change

The Austrian view of entrepreneurial decision-making begins with the concept of human action developed by Mises. Human action does not confine the decision maker to a framework of given ends and means, i.e., human action involves more than economizing decision-making in which the individual maximizes some set of ends with scarce means. Human action encompasses the very perception of the ends-means framework within which economizing decision-making is to take place. This opens up the possibility for alertness in discovering new goals and new resource possibilities, which the Austrians define as the entrepreneurial element in decision making. The individual is viewed as making a sequence of decisions in which each decision is comprehensible as the logical outcome of the previous decision. The pattern of change in an individual's decisions is the outcome of a learning process generated by the experience of decision making itself. In order to explain how one pattern of relevant means-ends is replaced by another, we must recognize the entrepreneurial element in decision making, in which the individual's alertness to new information generates a continuously changing sequence of decisions.

In a world of perfect knowledge and certainty, there would be no scope for the entrepreneurial element in decision making. Individual decisions could be explained in the economizing framework of neoclassical economics. Only in a world of imperfect information and uncertainty is the entrepreneurial element present in decision making. The unique characteristic of entrepreneurial decision-making is alertness to potentially worthwhile goals and available resources; the entrepreneur is alert not only to given market data, but also to possible changes in that data and to the potential impact of his own decisions on that data. The entrepreneurial element may be present in the decision making of consumers and resource owners as they attempt to maximize their welfare in a world of uncertainty. However, the pure entrepreneur is defined as a decision maker without means but with the ability to perceive unexploited economic opportunities.

The role of the entrepreneur is distinguished from that of the producer. The producer may be viewed as contributing a resource, i.e., the ability to organize and coordinate the various factors of production into a production team that converts resource inputs into a final output. These managerial resources may be offered in return for a price, which is, in turn, a cost to the firm hiring managerial services. The pure entrepreneur, on the other hand, provides no resource; the entrepreneurial decision occurs prior to the organization of resource inputs in the production process. The entrepreneurial decision may involve the discovery and exploitation of an economic opportunity at the point of contact between the resource market and the product market, but the managerial decisions involved in actually mobilizing resources to produce a final product are made subsequent to that entrepreneurial decision. Entrepreneurial profits accrue to individuals who correctly perceive and exploit economic opportunities. Such opportunities may exist in buying commodities in markets where they are selling for a low price and selling them in markets where they fetch a higher price. Entrepreneurial profits may emerge from the decision to introduce new or improved products, or improved techniques of production; they may also accrue to entrepreneurs who perceive a more efficient organization of the factors of production or other institutional arrangements. We can distinguish these pure entrepreneurial profits from the returns to factors of production, such as the salaries of managers, and the returns to capital. The functions of entrepreneurship, management, and the ownership of capital may overlap in the real world, but we must distinguish the role of the entrepreneur from these other functions if we are to understand the process of technological change.

The Austrian analysis provides a framework for relating entrepreneurial decision-making to the institutions within which those decisions are made. Some institutions are conducive to the perception and exploitation of economic opportunities, while other institutional arrangements are not. While this analysis is in its infancy, several inferences can be made regarding this relationship. First, it is clear that individuals are motivated to engage in entrepreneurial activity because that activity offers pure gain, interpreted broadly to encompass not only economic rewards, but also more esoteric benefits such as fame, power, prestige, and even the opportunity to engage in philanthropic activity. If the individual does not stand to gain from entrepreneurial activity, he is not likely to be alert to unexploited opportunities. Secondly, a free market is most likely to provide an institutional framework in which there is incentive in the form of personal gain for entrepreneurial activity. A free market system based upon a system of property rights and freedom of entry into a trade or business offers pure entrepreneurial profits as an inducement to entrepreneurial success. Further, the market system efficiently provides the information essential for entrepreneurial decisions. Unexploited economic opportunities are signaled by the price system, and individuals alert to these price signals respond by reallocating resources in such a way as to exploit these economic opportunities. Hayek refers to this as the discovery process of a competitive market system. The outcome of entrepreneurial activity in a market system is new and improved products; new methods of production; new forms of industrial organization, financing, and marketing—in sum, the process that we refer to as technological change.

Nonmarket systems, on the other hand, do not provide an institutional framework conducive to entrepreneurial behavior. In the great debate on economic calculation under socialism between the two world wars, this issue was never confronted. Oskar Lange argued that a socialist system could rely upon decentralized decisions by managers of socialist enterprises in response to centrally determined prices. But Lange never addressed the question of how prices would change in response to changes in consumer demand, resource availability, new products and production methods, etc. To assume that central planners could somehow simulate the complex discovery process of entrepreneurs in a market economy is incomprehensible. Central planners in a socialist system lack the information necessary to simulate such changes in the price structure. Further, the managers of socialist enterprises lack the incentive of personal gain that induces entrepreneurial decision-making in a market system. There is no reason to expect such managers to be alert to opportunities for a more efficient allocation of resources or to exploit such opportunities when they are recognized. To argue that socialist managers could retain entrepreneurial profits or that entrepreneurial decision-making could be open to everyone is, of course, to subvert the whole rationale of a socialist economic system. This is not to deny that an incentive system can be used to induce managers to produce more and even to introduce new products and production techniques. But this assumes a prior entrepreneurial decision by central planners, and we are back to the fundamental flaw that the planners lack the information generated by entrepreneurial behavior in a dynamic competitive market system necessary for an efficient allocation of resources.

We should distinguish between the technological change that emerges from entrepreneurial decision-making in a market system and change that occurs through government decision-making in a nonmarket system. Technological change in response to price signals in a market system is productive activity in the sense that it expands the total supply of goods and services desired by consumers. Successful entrepreneurial decisions will generate entrepreneurial profits, which, in turn, signal a reallocation of resources into those lines of economic activity. Losses accrue to unsuccessful entrepreneurial ventures, and these, in turn, will result in a reallocation of resources away from those activities. This market test is absolutely essential if resources are to be allocated efficiently into economic activities that improve the welfare of the society.

Technological change in a nonmarket system may or may not improve welfare in this issue. It is certainly possible for government planners to allocate resources so as to expand the supply of goods and services available in a nonmarket system. Whether or not that increases welfare depends upon several factors: Are the goods and services produced efficiently in terms of maximizing the output from a given resource base? Do the goods and services produced satisfy consumer demand? Are the government planners alert to new products that will satisfy the shifting tastes of consumers? Will those planners take advantage of new resources and production methods, and new methods of organizing and financing economic activities? We have sufficient evidence to conclude that often nonmarket systems fail in terms of each of these criteria. Technological change often does not occur in nonmarket economices or lags far behind that occurring in market systems. When technological change does occur in nonmarket systems, it is often accompanied by inefficiencies in the allocation of resources. The fundamental problem of technological change in nonmarket economies is the absence of a test for success or failure. Entrepreneurs who fail to introduce technological change, or who do so inefficiently, continue to thrive and become more firmly entrenched because there is no loss signaling that failure. Resources are not shifted to entrepreneurs that successfully introduce technological change because there are no profits signaling that success. Shadow prices in nonmarket economies do not signal success or failure, because the shadow prices reflect the prior decisions made by government officials as part of the planning process, not the dynamic discovery process that occurs in a market system.

At worst, the technological change that occurs in nonmarket economies merely transfers wealth and income from one group in the society to another. Interest groups with access to the government decision process influence planners to allocate resources so as to benefit that interest group. Technological change then occurs, but given the disincentive effects that usually accompany such transfer activities, the net results is often a reduction in total wealth, with adverse consequences for the welfare of the society.

The limitations of technological change in nonmarket economies such as the Soviet Union have been examined in several recent studies.[11] We lack comparable studies of the impact of government decision-making on technological change in Western economies such as the United States.[12] The following section explores this issue with references to the impact of government decision-making on technological change in the energy sector of the American economy.

Technological Change in the American Economy

The traditional analysis has failed to explain the rapid technological change that accompanied the industrial revolution in America during the nineteenth century, and also the recent retardation in the rate of technological advance. We are even further from an explanation for the pace and pattern of technological change in different industries over these time periods.

This literature suffers from some of the inherent limitations of the conventional wisdom in technological change discussed in the previous section. Scientific knowledge was largely irrelevant to improvements in technology during the early industrial revolution. Technological change in firearms, textiles, iron, machinery, and other industries was tied to the empirical knowledge gained by inventors and mechanics through the crude process of trial and error and experimentation. This is not to deny that scientific knowledge could have speeded up the process of technological change. However, the direct application of scientific knowledge as the basis for technological advance came rather late in the industrial revolution. By the second half of the nineteenth century, the limits of raw empiricism had been reached in a number of industries, and further technological change required the direct application of scientific knowledge to technical problems. Scientific advances in turn opened up opportunities for the development of new products and production methods in such industries as chemical fertilizers, metallurgical industries, electrical industries, etc. Yet throughout the nineteenth century, American science lagged far behind that in Europe. It is fair to say that scientific leadership was neither a necessary nor a sufficient condition for technological progress in the early phase of the industrial revolution. It is also fair to say that rapid economic growth and technological change in the nineteenth century opened up new opportunities for inventive activity and for developments in scientific knowledge linked to that inventive activity. However, we should not accept the deterministic view that the growth in demand induced these advances in science and technology automatically. There were substantial lags between the emergence of a demand and technical and scientific breakthroughs, and further lags in the innovation and diffusion of new technologies. In order to understand this process of technological change, we must understand the role of individual entrepreneurs in responding to the economic opportunities available in different industries and the institutional framework within which these entrepreneurial decisions were made. The nation's first energy crisis in the nineteenth century illustrates this process of technological change.

The Nation's First Energy Crisis

The first energy crisis in the United States occurred in the early nineteenth century.[13] The major source of artificial lighting in that period was whale and sperm oil, and there were no good substitutes for these fuels. As demand increased more rapidly than supply, the price of these fuels began to rise. Sperm oil rose from $0.43 per gallon in 1823 to $2.55 per gallon in 1866. Whale oil rose from a low of $0.23 in 1832 to $1.45 a gallon in 1865. Higher prices provided an inducement to producers to expand output of these fuels. From 1820 to 1847 the tonnage of whaling vessels increased by almost 600 percent, and numerous technological changes were introduced to increase the productivity of the whaling industry.[14] Whaling spread throughout the world and the increased allocation of resources into the industry expanded output more that 1,000 percent over that period.

This first energy crisis must be understood in terms of the unique characteristics of the whaling industry. The reason the growth in demand for whales and sperm oil outpaced the growth in supply is that whales are a common property resource. Since no individual whaler could claim private property in whales, there was no incentive to conserve the supply of whales. All the whalers had an incentive to kill off the whales as rapidly as possible, depleting the supply first in the North Atlantic and subsequently in other whaling grounds, forcing the whaling fleets into the Arctic and other distant parts of the ocean. Fortunately, whalers did not exhaust the supply of whales because the high price of whales and sperm oil provided an incentive for the development of our first alternative energy resource, kerosene.

In 1846 Dr. Abraham Gesner, a Canadian geologist, discovered that oil could be distilled from coal, and that kerosene could be drawn off and used as an illuminant. With whale and sperm oil selling for as much as $3 a gallon, entrepreneurs were quick to exploit the profit opportunities in producing the cheaper kerosene. Within a few years, a number of firms were extracting oil from shale to produce kerosene. The market signals also provided an incentive for discovering and exploiting new sources of oil. Benjamin Silliman demonstrated the potential value of oil found on marshy creeks in Pennsylvania for the Pennsylvanian Rock Oil Company. But it was left to a former railroad conductor and drifter, Colonel E. L. Drake, to discover oil in commercial quantities in Titusville, Pennsylvania, in 1859. When Drake's well produced 25 barrels a day at $20 per barrel, the petroleum era was born. By 1867, 300 firms were refining petroleum products, and kerosene quickly broke the sperm and whale oil market. By 1896 sperm oil had declined in price to $0.40 per gallon, cheaper than at any other time in the nation's history.

The solution to the nation's first energy crisis depended very much on the flexibility of prices in signaling producers to reallocate resources to expand the production of scarce sperm and whale oil and to develop alternative sources of energy in petroleum. That technological and scientific change did not occur automatically; there was a lag of almost half a century between the emergence of that energy crisis and the technological breakthroughs in petroleum that ultimately solved the crisis. That technological change in turn occurred through a series of entrepreneurial decisions in response to economic opportunities in the development of our energy resources over the second half of the nineteenth century.

John D. Rockefeller through the Standard Oil Company performed a unique entrepreneurial role in bringing about that rapid technological change in the petroleum industry.[15] The major technological change was the fractional distillation or cracking method of refining. That method of refining increased the scale of refineries from a few barrels per week to over 3,000 barrels per week by 1870. Larger scale in petroleum refining was related to changes in the transportation and storage of petroleum. Early methods of transport and storage were primitive and expensive, utilizing horse-drawn wagons and large numbers of barrels. Railroads substantially reduced the cost of transporting oil to the refineries; later, pipelines further reduced these costs. The storage of petroleum in barrels and individual retail storage tanks was replaced by a complex system of bulk terminals and road tank wagons.[16]

Standard Oil was not always the innovator of these technological changes, but Rockefeller was quick to copy successful innovations by competitors. For example, pipeline transport was first introduced by Tidewater Oil Corporation, but Standard Oil quickly developed its own pipeline facilities. Technological change permitted Standard Oil to lower its costs, and its savings in turn were passed along to consumers in the form of lower prices for petroleum production. The price of kerosene fell nearly 80 percent between 1870 and 1897.

By the 1880s, Standard Oil had captured 95 percent of the domestic petroleum market. Rockefeller had successfully exploited the opportunities for profit in expanding Standard's operations from petroleum refining into crude oil production, transportation, and marketing of petroleum on a worldwide basis. He brought revolutionary changes to the technology and organization of the petroleum industry. However, many writers attribute Rockefeller's success not to his entrepreneurial skills, but rather to monopoly power and predatory practices used by Standard to eliminate competition. These issues are crucial in understanding the entrepreneurial role in technological change.

One charge of abuse of monopoly power leveled against Rockefeller and Standard Oil was occasioned by the rebates they received from railroads. Rebates were a consequence of vigorous competition among railroads for the rapidly growing petroleum traffic. Transportation costs were a major cost to refiners and one way to reduce that cost was to obtain rebates or concessions on the "open" or published rates charged by railroads. Few shippers paid the open rates, and the actual rates paid varied considerably between refiners. As Standard increased its refining capacity, its bargaining position with the railroads improved. Rockefeller was able to negotiate agreements with railroads that assured them of a large and continuous supply of petroleum traffic, thus cutting the railroads' costs; the railroads then passed their cost savings along to Standard in the form of rebates. Other refiners were usually unable or unwilling to negotiate similar terms with the railroads and ended up with smaller rebates.

Standard Oil and several railroad companies then formed the South Improvement Company. Standard was to ship its oil exclusively on railroads that were part of the new company. In return, Standard was to receive a rebate of from 25 percent to 50 percent on freight charges—plus information on oil shipments by other petroleum companies. Formation of the South Improvement Company was proposed, not by Rockefeller and Standard Oil, but by Tom Scott of the Pennsylvania Railroad.[17] The railroad industry at that time was highly competitive, with frequent price wars. The railroads perceived, correctly, that an agreement providing for the shipment of petroleum at stable rates would protect them from the cutthroat competition that characterized the railroad industry. The object of the collusive agreement with Standard Oil was to introduce monopolistic control over the railroad industry. As might be expected, the other railroads soon discovered this collusive arrangement and placed embargoes on the shipments of oil over railroads participating in the South Improvement Company. Political pressure was used in the Pennsylvania legislature to revoke the charter of the South Improvement Company, and the proposed rebates never went into effect.

During the South Improvement Company episode, Standard acquired many of the refineries in the Cleveland area, and its share of the petroleum industry jumped from 4 percent to 25 percent. While the rebates proposed in the South Improvement Company agreement never went into effect, it is argued that the threat posed by the rebate scheme permitted Standard Oil to force its competitors out of business. This argument ignores the threat to competing refineries from improved efficiency and lower costs of the Standard Oil Company. There was excess capacity in the refining industry; while approximately 5.5 million barrels of crude reached the refineries in 1871, refinery capacity was over 12 million barrels.[18] Clearly, the small margin refineries would have been driven out of business even without the threat of rebates through the South Improvement Company. The total number of refineries dropped from 300 in 1863 to 100 in 1872; by the latter date Cleveland's daily capacity of 12,500 barrels was spread among just six refineries, including Standard Oil.

When Standard bought out competing refineries, it very often paid less than the original cost of the refinery. That should not be surprising in the case of small inefficient refineries, some of which were closed down following their acquisition. In some cases Standard paid more than the market value for refineries in order to reserve the talents of an exceptional management. For example, Clark, Payne and Company received $400,000 for refining properties appraised at $251,110, the difference being paid for good will and an agreement that Colonel Payne join Standard Oil's management.[19]

Another charge leveled against Standard was that it engaged in cutthroat pricing designed to drive out competitors. The recent literature challenges this view in several ways. There is little evidence that Standard Oil actually engaged in predatory price cutting and that this enabled them to eliminate competition to any significant degree.[20]

The trust form of organization was introduced into the petroleum industry in 1882 when 39 companies were joined together to form the Standard Oil Trust. It is important to point out that Standard had a controlling interest in these companies even before they were joined together to form the Standard Oil Trust. Standard captured most of the market for petroleum before it organized the Standard Oil Trust because it could produce petroleum at lower costs and sell it at competitive prices vis-á-vis its competitors.

The trust form of organization permitted Standard Oil to exert greater monopoly control over the petroleum industry. However, the explanation for this monopoly control was not so much predatory practices vis-á-vis competitors, but rather the efficiencies associated with the trust form of organization. In the view of Davis and North, Rockefeller's success was due to his "ability to acquire sufficient capital to innovate the new refining technology when his competition would not. . . . It was not his knowledge of oil refining, but his ability to present his firm as 'less uncertain' to the Cleveland (and later, New York) financial communities that was the basis of his successes."[21] In the relatively immature capital market of the second half of the nineteenth century, the access to capital often spelled the difference between success or failure for business enterprise. Rockefeller correctly perceived that the trust form of organization would effectively mobilize the capital required for large scale operations in the petroleum industry.

In addition to the trust, Standard Oil introduced various organizational innovations that made it a precursor to the modern twentieth century corporations. Standard developed sophisticated methods of recovering and analyzing information pertinent to its business. Modern accounting methods were introduced and private telegraphs installed so that management could efficiently control operations. The beginnings of the managerial revolution were evident in management by objectives and the utilization of special advisory committees. Standard was a pioneer in modern research and development activities that kept it on the frontier of petroleum technology. However, Rockefeller and Standard Oil did not have a monopoly on entrepreneurial ability—a fact that became evident after 1890.[22]

The crucial importance of entrepreneurial skills in the development of the petroleum industry is revealed by the trends in the industry after 1890. Table 1 shows that Standard's share of the market reached a peak of 95 percent in the 1880s and then declined continuously up to 1911, when it controlled 64 percent of the market. For some petroleum products Standard's share declined even more: kerosene (95 percent to 75 percent), fuel oil (85 percent to 31 percent), and gasoline (85 percent of 66 percent). This decline in Standard's share of the petroleum market preceded the antitrust suit and dissolution ordered by the Supreme Court in 1911.

Table 1

The Share of Refinery Capacity Controlled by Standard Oil

Year	*Percent*
1880	95
1899	82
1906	70
1911	64

Source: H. Williamson, R. Andreano, A. Daum, and G. Klose, *The American Petroleum Industry* (Evanston, Ill.: Northwestern University Press, 1959-1963), vol. 2, p. 7.

The explanation for the decline in Standard's share of the petroleum market prior to 1911 is that Rockefeller was less alert to the changing economic opportunities in the industry while other petroleum firms took advantage of those opportunities; in short, entrepreneurial leadership shifted from Standard to other firms. These firms opened up major new oil fields in the western region. Not only did Standard compete less successfully in the new fields, its position in the older fields in Appalachia declined as well. One Standard executive boasted that he "would undertake to drink all the oil that was ever produced [west of the Mississippi].[22,23] As a result of this attitude, Standard played little part in the rapidly growing oil fields of Texas and California. The demand for petroleum products shifted away from kerosene toward fuel oil and gasoline, but Standard failed to respond to this shift in demand, and a large share of these new, rapidly expanding markets was captured by its competitors. One author has described the deterioriation in Standard's position in the following terms:

> Standard's failure was primarily its own doing . . . the responsibility of its conservative management and lack of initiative. The American oil industry passed through a revolution from 1900 to 1920, and Standard failed to

> participate fully in it. . . . In a spiralling market for oil such as existed from the turn of the century on, Standard, conservative and technologically uncreative, was no match for the aggressive new competition.[24]

Given this decline in Standard Oil's position in the petroleum market prior to 1911, what was the impact of the Supreme Court's decision? One way to answer this question is to pose a counterfactual hypothesis that projects what Standard Oil's share of the market would have been in the absence of the decision requiring dissolution of the company. Assuming a continuation into the following decade of the trends in market shares prior to 1911, we estimate that Standard's share of the market for final products would have fallen from 64 percent in 1911 to less than 40 percent in 1919, and their control over the market for crude oil would have fallen by a comparable magnitude. Market competition would have eroded whatever monopoly control that Standard wielded in the petroleum industry, even in the absence of antitrust action against Standard Oil.[25]

The Nation's Second Energy Crisis

Earlier we traced the nation's first energy crisis in whale and sperm oil used for artificial lighting during the early nineteenth century. We showed how higher prices for these fuels provided an inducement for producers to expand output and eventually to find cheaper substitutes for these fuels in petroleum refining. The twentieth century has witnessed a sequel to the nation's first energy crisis in recent decades. A rapid growth in the demand for petroleum products has resulted in higher prices and periodic shortages of supply. This more recent energy crisis has not, however, brought a response from entrepreneurs similar to that which occurred during the nation's first energy crisis. In order to explain the current energy crisis, we must understand the changes in the institutions affecting entrepreneurial behavior. The institutional framework of the American economy has changed dramatically in the twentieth century, resulting in significant changes in the role of entrepreneurial decision-making and the pace and pattern of technological change. Beginning with the antitrust decision against Standard Oil, government policies have had an increasingly pervasive impact on the allocation of energy resources.[26]

Throughout most of the twentieth century the supply of energy more than kept pace with the demand for energy. From the standpoint of petroleum producers, the problem in the first half of the twentieth century was that the growth in supply outstripped increases in demand, resulting in lower prices for petroleum products. Despite continued efforts by private producers to establish a cartel to limit production, the industry was characterized by intense competition in which each producer attempted to lower price and expand production in order to capture a larger share of the market. The rapid growth in refining capacity and intense competition in the industry during the Great Depression led to the passage of the Petroleum Code as part of the National Industrial Recovery Act of 1933. This code enabled petroleum producers to use the coercive powers of government to limit production and maintain higher prices in the industry. The President was given the power to control interstate and international shipments of petroleum. He could establish prices and control production, imports, and withdrawals from crude oil storage. The nation was divided into eight refining districts within which controls were established over the sale of gasoline. Refiners were permitted to withdraw from their stocks of refined products only when current output was inadequate to meet demand, but the storage of gasoline in greater quantities was outlawed as an unfair practice. The code had the desired effect, as crude oil prices increased from a range of $0.69–$0.75 per barrel in 1932 to about $1 per barrel in 1933–35.[27]

After the Second World War, government controls over the petroleum industry were removed, and the nation's energy supplies expanded. The increasing demand for energy was reflected in higher prices for natural gas and petroleum products, but the prices for these energy products actually declined relative to the general price level. This meant that the real cost of energy declined, whether we measure this relative to the cost of other goods and services or in terms of resource costs per unit of energy produced.

In the 1960s the government again intervened in the energy sector to control prices and production. In 1961 the Federal Power Commission (FPA) imposed a price ceiling in natural gas at the wellhead for interstate sales of natural gas. In the 1970s a mandatory allocation program required some petroleum companies to sell their natural gas to pipelines in other parts of the nation at controlled prices. Following the imposition of price controls, the supply of natural gas failed to keep pace with rising demand. The number of natural gas producers dropped from 18,000 in 1956 to 4,000 by 1971. As demand for natural gas outstripped supply in the nonproducing states, consumers turned to alternatives such as fuel oil, liquefied gas from Algeria, and synthetic gas. In terms of energy yield, fuel oil on the average in the 1970s sold at twice the free market price of natural gas. Some firms relocated to states that produced and sold natural gas at the unregulated price. Both of these responses, i.e., reliance on alternative energy sources and relocation in order to assure a supply of natural gas, involved inefficiency and misallocation of resources.[28]

Without government regulation, the price of natural gas would have been driven up and supplies would have increased, displacing the more expensive substitute fuels. While interstate gas prices were regulated by the FPC, the intrastate prices fluctuated with market price. With the expansion of demand for gas, the unregulated price of natural gas in Texas increased from $0.75 in 1972 to a high of $2.20 in 1975. The higher price brought drilling rigs to Texas from all over the United States and Canada. In 1971, only 1,056 new wells were drilled, whereas in 1975, 2,275 new wells were completed. The expanded supply drove the price back down to $1.76. Even at this price, natural gas was a bargain; according to the FPC, the free market price for natural gas was 22 percent cheaper than liquefied natural gas, 31 percent cheaper than Alaskan gas, 44 percent cheaper than coal gas, and 46 percent cheaper than synthetic gas. This free market response occurred only with respect to intrastate gas, which was not regulated by the FPC; interstate gas supplied did not expand because the price set by the FPC was substantially below the free market price.[29]

Government regulations were also imposed on the oil industry. The price of petroleum products was controlled first by jawboning in 1969 and then by mandatory controls in 1971. This period witnessed the most rapid rate of inflation since the Civil War. As the real price of oil declined, the supply of domestically produced petroleum declined and the share of petroleum imports increased. At controlled prices, the earnings of oil producers declined, and there was little incentive to invest. By the time of the oil embargo of 1973, we had only one-half as many drilling rigs in operation in the continental U.S. as we had had twenty years before. Dependence on imported petroleum approached half of our total consumption.[30]

Although price controls on gasoline ended when the Arab embargo was lifted in 1974, the Federal Energy Agency (FEA) continued to maintain price controls on crude oil produced domestically. The price of old oil was controlled at about $5.25 per barrel. New oil from wells put into production after November 1975, plus output from old wells that exceeded the base period output levels, was controlled at a price of about $11 per barrel.[31]

At these controlled prices shortages emerged for domestically produced oil, and refineries relied increasingly on imported oil. Those refiners who had access to old oil had an advantage over refiners forced to pay market prices. The FEA responded with an elaborate system of entitlements and allocations among crude oil refiners. Each refiner was given a certain number of entitlements to domestic oil at controlled prices based on the total purchases of crude oil at uncontrolled prices.

The entitlements program placed a tax on domestic production of crude oil and subsidized refinery purchases of imported oil. The United States, in effect, paid a subsidy of about $3 for every barrel of oil imported. Needless to say, this policy discouraged domestic production of petroleum. By holding petroleum prices below the market price, the entitlements program led to wasteful use of petroleum resources and discouraged the development of alternative energy sources.[32]

The market has not solved the energy crisis in the twentieth century as it did in the nineteenth because the market has not been permitted to operate. Recent legislation calls for deregulation of prices of natural gas and petroleum products, but this does not mean a return to reliance on private enterprise to solve the energy problem. Private energy companies are threatened with windfall profits taxes and disfranchisement of their holdings. Regulatory controls limit exploration and expansion of production and increase the costs of producing energy products.

In short, private entrepreneurs today do not have the incentive to explore and expand production of existing energy products—and to find cheaper substitutes for energy—as they did in the nineteenth century.

The government has assumed a greater responsibility in solving the nation's current energy crisis by subsidizing private firms to develop alternative sources of energy. The U.S. Synfuels Corporation has become the vehicle for this expanded role for government in the development of alternative energy sources. The U.S. Synfuels Corporation was created by Congress in 1980 with authorization to spend $20 billion in government funds. After three years of operation, the Synfuels Corporation made its first award of financial assistance, $820,750, to a North Carolina peat-to-methanol project whose investors include former CIA director William Casey. It also awarded $120 million in price guarantees to a Cool Water Coal project in California. Most recently, the corporation has signed a letter of intent with Tenneco Shale Oil Company and Occidental Oil Shale, Inc., for the development of oil shale in Colorado. The proposal calls for $2.19 billion in guarantees, including $1.812 billion in loan guarantees and $378 million in price guarantees. Under the agreement, the private corporations would be guaranteed a price of $60 per barrel over a ten-year period from 1987 to 1997.[33]

The role of the government in the development of oil shale reveals the inherent failure of a government solution to the energy crisis. The guarantees between the Synfuels Corporation and private companies virtually assure that there will be no market test for an efficient allocation of resources in the development of oil shale. The Colorado project will proceed even though the market price for the final product falls below the guaranteed price. The loan guarantees assure the private corporations' access to loanable funds, even when the market interest rate on loanable funds signals that the project should not proceed. It is not clear that the subsidized corporation will advance technology, since the Colorado project will utilize a combination of processes for the production of oil shale already developed by private corporations.

After U.S. Synfuels had been in operation for three years, Senator Proxmire concluded,

> The Synthetic Fuels Corporation does not meet the basic standard of our capitalist system: the freedom of incompetent management to fail. Even worse, instead of assisting technologically sound and commercially promising projects, the corporation may be about to fund companies with neither the technical resources nor financial capability to use the money effectively.[34]

The U.S. Synfuels Corporation is forging ahead in the development of alternative energy, not because that is an efficient allocation of resources, but rather because it has a government mandate to spend $20 billion of the taxpayers' money. Senator Armstrong has estimated that the cost of the U.S. Synfuels Corporation could run as high as $88 billion.[35] Based on its track record thus far, the U.S. Synfuels Corporation promises to be the Teapot Dome scandal of our era, with far more devasting consequences to our welfare. Despite the opposition of Senator Armstrong and others in Congress, the U.S. Synfuels Corporation continues to expand its role in the development of oil shale and other alternative fuel sources.

More important than the misallocation of resources through the U.S. Synfuels Corporation is the negative impact of government policies on the private development of oil shale. The Mineral Leasing Act of 1920 limits private development of oil shale to no more than 8 square miles (5,120 acres). Government regulations also prohibit off-tract disposal of processed shale. A recent Rand Corporation study shows that these restrictions on the size of the tract and on off-site disposal significantly reduce the efficiency of shale oil development. Permitting off-site disposal of processed shale alone could increase the percentage of shale oil recovered on private lands from less than 20 percent to more than 60 percent.[36]

Antitrust policies have also had a negative impact on the private development of oil shale. Each developer is limited to one lease, and federal policies rule out joint processing ventures. The Rand study concludes that this combination of antitrust policies and land use policies has resulted in a fragmented industry of first-time developers. The report states, "Given the innovative processes required to produce shale oil, these developers may be unwilling to make large investments in a first of a kind plant."[37]

It should not be surprising that some corporations have chosen not to follow through on private shale oil projects. For example, the Exxon Corporation has withdrawn from its Colony Shale Oil Project in Colorado. Private corporations face an industry in which government land policies and antitrust policies have eliminated the profit incentive of large scale innovative technology in oil shale development. They are asked to compete with a government-subsidized corporation whose price and loan guarantees protect it from competitive market pressures. Government decision-making is virtually displacing private entrepreneurship in the oil shale industry.

Some studies, such as the Rand Corporation study cited earlier, maintain that this pattern of decentralized development of oil shale may not necessarily be bad. "An industry consisting of many small projects would be more competitive than a highly centralized industry." This perception of competition in the shale oil industry is based upon the static neoclassical model of competition, a perception that underlies the antitrust and regulatory policies affecting the industry. Despite overwhelming evidence that those very policies preclude the dynamic competition required to develop oil shale efficiently, we cling to this naive view of the nature of a competitive market.

Conclusion

There is a lesson to be learned from our experience in the development of oil shale. Government decision-making cannot replace the role of the private entrepreneur in bringing about technological change and efficient development of oil shale. Further, government policies based upon a static neoclassical model of competition introduce barriers to private entrepreneurial activity, thus inhibiting technological change and efficient development of oil shale. Before significant changes will take place in government policies, we must begin to understand competition, not in this static view but as a dynamic market process. The Austrian view of competition as a dynamic market process provides a framework for an entirely different set of government policies. The essential condition for this dynamic competition in the long run is freedom of entry. Private entrepreneurs must be free to enter the oil shale industry and to innovate new technologies and organizations. They must respond to market forces, not the government signals of price guarantees, loan guarantees, land use restrictions, and the threat of antitrust suits. In the long run, we would expect some firms to fail and some to survive this market competition. Some of the latter firms might achieve a scale that would permit them to exercise some monopoly control in the industry, and one firm could potentially exercise monopoly control over the oil shale industry comparable to that exercised by Standard Oil in the nineteenth century. To the extent that such monopoly control and the corresponding monopoly profits are a return to entrepreneurship, that is consistent with the Austrian view of competition as a dynamic market process. In the long run, we would also expect such monopoly control to be eroded as private entrepreneurs exploit market opportunities in the development of oil shale.

Many economists will respond that the inefficiencies and misallocations of resources that result from monopoly control in the short run are too great, and therefore we cannot afford to rely on dynamic competition in the long run. They maintain that we must have government intervention to limit the exercise of monopoly power in the short run. But such an argument must rest not upon some theoretical ideal of government policies to maintain a competitive market structure, but rather in the real world functioning of such government policies. We have sufficient evidence to judge these alternative approaches to government policy in the development of our energy resources. If we had applied the government policies currently in use in the shale oil industry to the petroleum industry during the early phases of its development, the outcome is clear: The development of petroleum resources would have been constrained by a fragmented industry with small inefficent producers, and there would have been little incentive for rapid technological change requiring large-scale capital-intensive methods of production. The alternative to Standard Oil and other large scale oil producers would have been a nineteenth century equivalent of the U.S. Synfuels Corporation. By now, such government bureaucracy would be as firmly entrenched in the petroleum industry as the U.S. Synfuels Corporation is in the oil shale industry. We did not introduce such a government bureaucracy, but the expanded role of government in the petroleum industry in the twentieth century has had a comparable impact. The overwhelming evidence is that the pervasive role of government in the petroleum, natural gas, and oil shale industries has had a negative impact on the rate of technological change and the efficient development of our energy resources. This displacement of private entrepreneurship by government decision-making is not unique to the energy industry, but is ubiquitous throughout the economy. It should be no surprise that massive government intervention in recent decades has been accompanied by retardation in the rate of technological advance and a slower rate of economic growth.

Notes

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3. Poulson, *Economic History,* pp. 443–95.
4. Jacob Schmookler, *Invention and Economic Growth* (Cambridge: Harvard University Press, 1966), pp. 180–81.
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11. For a discussion of technological changes in the Soviet Union, see also Joseph S. Berliner, *The Innovation Decision in Soviet Industry* (Cambridge: MIT Press, 1976).
12. There are some important exceptions. Edward Denison and John Kendrick provide important insights into the quantitative impact of government decision-making on technological change in American and other Western economies. For an Austrian analysis, see the following: Stephen C. Littlechild, *The Fallacy of the Mixed Economy: An 'Austrian' Critique of Economic Thinking and Policy,* Hobart Paper 80 (London: Institute of Economic Affairs, 1978); Israel Kirzner, *The Perils of Regulation: A Market Process Approach,* occasional Papers of the Law and Economic Center of the University of Miami School of Law, 1978.
13. The first energy crisis is discussed in Poulson, *Economic History.*
14. For a discussion of the whaling industry, see Teresa D. Hutchins, "The American Whale Fishery, A Short History" (Ph.D. diss., University of North Carolina, Chapel Hill, 1983).
15. For a discussion of technological change in the petroleum industry, see Poulson, *Economic History,* pp. 545–49; see also Harold F. Williamson and A. Darin, *The American Petroleum Industry* (Evanston, Ill.: Northwestern University Press, 1959), vol. 1.
16. P. H. Frankel, *Essentials of Petroleum* (New York: Kelley, 1969), p. 24.
17. Williamson and Darin, *American Petroleum Industry,* p. 346.
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19. Ibid., p. 355.

20. John McGee, "Predatory Price Cutting: The Standard Oil (N.J.) Case," *Journal of Law and Economics* 1 (October 1958):137–70.
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22. Ralph Hidy, *Oil's First Century* (Cambridge: Harvard Business School, 1969), p. 9; and Paul H. Giddens, *The Standard Oil Company* (New York: Appleton-Century-Crofts, 1955).
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34. News Release, Senator William Armstrong, from Armstrong-Proxmire Synfuels Press Conference, April 15, 1982.
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