Chemical Industries after 1850

Article for the
Oxford Encyclopedia of Economic History

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May 17, 2002

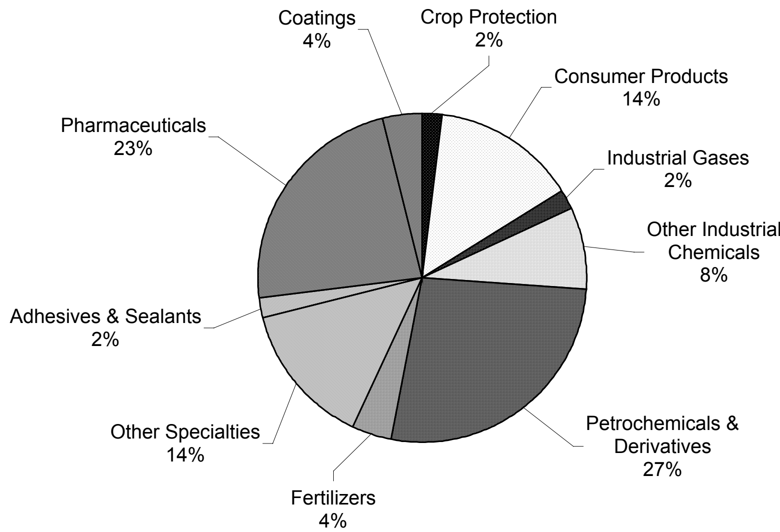
Economic Significance

At the turn of the 21st century, the chemical industry is one of the largest manufacturing industries in the world, selling products worth more than $1.67 trillion and employing over 10 million people. The U.S. produces approximately 28% of the global chemical output, Japan 13%, Germany 6%, France 4%, and the United Kingdom (Great Britain) 3%. About 30% of this output is traded internationally. The chemical industry is the largest manufacturing industry in the United States, the second largest in Europe after food and kindred products, and the second largest in Japan after electrical machinery. On a value-added basis, it is responsible for about 11.3 percent of total U.S., 10 percent of total European, and 13.8 percent of total Japanese manufacturing.

In all leading national economies, chemical production represents a strikingly similar share of Gross Domestic Product (GDP), 4.1% in the U.S. (2 % in terms of value-added), 4.4% in Japan, 5.4% in Germany, 3.6% in the United Kingdom, and 5.5 % in France, suggesting that chemicals are an indispensable part of large economies. Mikolaj Piskorski's data on exchange relationships between industries in the U.S. confirm the central role of chemicals in a modern economy. When the entire U.S. economy is classified into 77 distinct industries, the chemical industry ranks number 9 in terms how important it is to the functioning of all other industries in the economy. Not surprisingly the wholesale sector leads this centrality ranking, followed by government enterprises and new construction—all of which exchange significant output with virtually all other sectors in the economy. If one counts only relationships in which a focal industry exchanges goods with another industry that amounts to 5% of the focal industry's output, the chemical industry sells to or buys from 50 different industries. By contrast the average U.S. industry sells to or buys from 41 industries. (For details on how these calculations were made, go to http://johann-peter.murmann.name/chem-industry.htm.)

The major supply industries for chemical production at the beginning of the 21st century are wholesale (accounting for10% of inputs), electricity (8%), petroleum (7%), and natural gas (6%). The major buyers of chemicals are the health care (accounting for 21% of outputs), plastics (16%), textile (8%), paper (5%) and rubber industries (5%). A look back to the middle of the 19th century reveals that the most important inputs and outputs of the chemical industry have changed dramatically over the last 150 years. In 1850, the main inputs were coal, salt, pyrites and sulfur. The main outputs, in turn, were alkalis and acids. Demand for these heavy chemicals increased dramatically over the course of the 19th century because alkalis and acids played an important supporting role in the first industrial revolution as inputs to the rapidly expanding textile, soap, glass, and steel industries (see article on *Chemical Industry before 1850)*. Aside from these high-volume inorganic chemicals, the industry produced in the middle of the 19th century only a few pigments and a small number of low-volume organic chemicals. One of the central characteristics of the chemical industry is that it experienced a continuous stream of process and major product innovations over the next 150 years and thereby acquired a very diverse product portfolio of well over 70,000 different chemical substances. The main product categories at the beginning of the 21st century range from the traditional acids to food additives and preservatives (see Figure 1).

Figure 1: Global Chemical Production by Segment, 2000



Source: American Chemical Council *Guide to the Business of Chemistry*, 2001

The constant expansion of the industry's product portfolio has led to a dramatic growth in chemical output since the middle of the 19th century (see Table 1). At the turn of the 21st century chemical production in the United States, for example, is approximately 3730 times larger (in constant dollar terms) than in 1850. At that point, Great Britain had the biggest economy in the world and was by far the largest producer of chemicals. Her output of 304,000 tons of soda in 1867 and 590,000 tons of sulfuric acid in 1870 was much larger compared to Germany's 33,000 tons of soda and 43,000 tons of sulfuric acid. British production of these two heavy chemicals—they represent a rough proxy for overall economic activity during the 19th century just as semiconductor production serves as such a proxy for the leading industrial countries at the turn of the 21st century—was respectively 11 and 17 times higher on a per capita basis than that of Germany. In 1870, the United States produced only 93,700 tons of sulfuric acid, 10 times less than Britain on a per capita basis, and imported most alkalis from Britain. But the German and U.S. chemical industries subsequently grew much faster than the British one. German growth was fueled to a considerable extent by developing new chemical technologies whereas the U.S. until around 1930 developed her own chemical industry largely by importing European chemical technologies and adapting to the American context.

By 1910 Germany produced around 500,000 tons of soda, thereby reducing Britain's lead on a per capita basis to about 2.3 to 1. With an output of 1,600,000 tons of sulfuric acid in 1913, Germany surpassed British production by 350,000 tons and even pulled ahead when measured on a per capita basis (1.05 to 1). Parallel to the growth of her overall economy, the U.S. by World War I had become the largest sulfuric acid producer in the world with 2,200,000 tons of output. On a per capita basis this was nearly as much as Britain (0.9 to 1). Britain, however, still produced approximately 20 times as much sulfuric acid as Japan, reflecting the relative underdevelopment of the Japanese economy at the time. Although the synthetic dye industry had been pioneered in Britain, Germany's production of 137,000 tons of highly valued dyes in 1913 gave her about a 19 to 1 lead on a per capita basis when compared to a British output of 5,000 tons. With a world market share of about 85 percent in synthetic dyes and the largest share in new pharmaceuticals, the German chemical industry had captured a dominant position in organic chemicals similar to the one Britain half a century earlier had enjoyed in soda.

Table 1: Production of Chemicals in Billion US $ and Country Shares

Year	USA		Britain		Japan		Germany		France		World Total
1850	0.005										
1860	0.0047										
1870	0.0194										
1877							0.6	20%			3
1880	0.0386										
1890	0.0594										
1895							1				
1900	0.0626										
1905	0.0921										
1913	3.4	34%	1.1	11%	0.15	2%	2.4	24%	0.85	9%	10
1927	9.45	42%	2.3	10%	0.55	2%	3.6	16%	1.5	7%	22.5
1935	6.8	32%	1.95	9%	1.3	6%	3.7	18%	1.6	8%	21
1938	8.0	30%	2.3	9%	1.5	6%	5.9	22%	1.5	6%	26.9
1951	71.8	43%	14.7	9%	6.5	4%	9.7	6%	5.9	4%	166
1970	49.20	29%	7.60	4%	15.30	9%	13.60	8%	7.20	4%	171
1980	168.34	23%	31.77	4%	79.23	11%	59.29	8%	38.60	5%	719
1990	309.10	24%	44.70	4%	162.80	13%	100.50	8%	66.30	5%	1248
2000	460.00	28%	50.70	3%	218.40	13%	100.00	6%	73.00	4%	1669

Notes: The second column for each country indicates the world production share for the particular country.
Figures are on billion US $ except:
1870, 1913, 1927, 1935, 1939 in billion Reichsmark
1951 in billion German Mark
Because the statistical definition of the chemical industry was not always the same in each country, the numbers in this table need to be interpreted as estimates rather than exact figures. The U.S. share in 1913 is exaggerated because it includes petroleum refining, which is not included in the European figures. Haber (1971) puts American production in 1913 at around 1.53 billion Reichsmark (my calculation), placing it about half way between Germany and Britain. Figures for Germany between 1951 and 1990 refer to West Germany.
Sources: Chemische Industrie, Volume IV, October 1952 (pp. 890-891)
Haber, 1958 & 1971
VCI *The German Chemical Industry in Figures*. Historical summary 1977
CEFIC *Historical Sequence*
American Chemical Council *Guide to the Business of Chemistry*, 2001

Because of her undisputed leadership in organic chemicals, Germany by 1913 possessed the largest chemical industry in the world and was also the largest exporter with a 40.2% global share (see Table 2). But since chemicals proved to be such an important strategic asset in 20th century warfare, the United States, Britain and France in the wake of World War I would never again allow themselves to become as dependent on German organic chemicals as they had been on the eve of the war. With the rapid development of the American chemical industry in the first half of the 20th century, of the Japanese chemical industry in the second half of the 20th century, and more recently the growth of East Asian economies, the British and German share of world production and exports have decreased substantially since World War I, but Germany at the turn of the 21st century continues

Table 2: Share of Chemical Exports (in %) by Country of Origin: 1899-2000

Exports from	1899	1913	1929	1937	1950	1959	1990	2000
United Kingdom	19.6	20.0	17.5	16.0	17.9	15.0	8.4	6.6
France	13.1	13.1	13.5	9.9	10.1	8.6	9.1	7.8
Germany [1]	35.0	40.2	30.9	31.6	10.4	20.2	17.7	12.1
Other Western Europe [2]	13.1	13.1	15.3	19.4	20.5	21.1	31.7	32.0
United States	14.2	11.2	18.1	16.9	34.6	27.4	13.2	14.1
Canada	0.4	0.9	2.5	2.9	5.2	4.4	1.8	1.6
Japan	0.4	1.0	1.8	3.0	0.8	3.1	5.4	6.1
Other	4.2	0.3	0.4	0.3	0.5	0.2	12.8	19.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total in billion $ U.S.	0.26	0.59	1.04	0.98	2.17	5.48	309.2	566.0

[1] West Germany between 1950 and 1990.
[2] Belgium, Luxembourg, Italy, Netherlands (except in 1899 and 1913), Spain (only 1990 & 2000) Sweden, and Switzerland.
Sources: A. Maizels (1963) *Industrial Growth and World Trade, Cambridge University Press, UK,* and American Chemical Council *Guide to the Business of Chemistry* (2001).

to be the 2nd largest chemical exporter in the world after the United States. Furthermore, Germany still has the largest positive trade balance in chemicals ($ 22.8 billion), followed by Ireland ($ 17.3 billion), the Netherlands ($ 11.2 billion), Switzerland ($ 8.3 billion), and the United States ($ 6.3 billion). Building on two centuries of cumulative technological innovation, Western Europe continues to have a strong positive trade balance ($ 68.2 billion), North America a small negative one ($ -8.5 billion), and Asia Pacific a larger negative one ($ -27.8 billion). Over 35% of contemporary world trade in chemicals is intra-firm in nature because the large companies increasingly invest in all major markets in the world and sell output to their international subsidiaries. More and more, prices for commodity chemicals are determined by global supply and demand because the diffusion of petrochemical technology through Specialized Engineering Firms, which build turnkey plants, has created a slew of new producers close to the sources of the oil and gas.

Technological Developments and their Importance to the Industry

One can distinguish three types of innovations that have recurred throughout the history of the chemical industry. The first type involves the creation of processes for making chemical substances that are also found in nature but occur naturally in limited quantity or are cheaper to produce in an industrial plant. The Haber-Bosch nitrogen fixation process (1912) and synthetic indigo process (1897) are cases in point. The second type of innovation involves the substitution of an existing industrial process for a more efficient one such as the Solvay ammonia soda process (1864), which replaced the Leblanc soda process. Such new processes often work with raw materials that are cheaper or produce by-products that are more valuable in the market. The third type of innovation involves the creation of chemical substances that do not naturally occur on earth. The vast majority of synthetic dyes, including the first one—mauve—invented in 1856 by William Henry Perkin (1838-1907), as well as the majority of modern pharmaceuticals, fall into this category. The 118 chemical elements found in the universe to date can form many more stable combinations (the so-called molecules) than were present on earth before human beings acquired sufficient chemical knowledge to deliberately create synthetic compounds. It is this sheer limitless number of possible molecules that has provided the opportunity for continuous product innovations in the chemical industry.

The steady growth of the chemical industry since the middle of the 19th century came about because all three types of innovations appeared in regular frequency. Some innovations have provided a particularly large boost to the growth of the industry; and it is therefore customary to identify the stages in the development of the chemical industry with the most important new products or process technologies—organic chemistry, electrochemicals, high-pressure technologies, polymer chemistry, petrochemicals, plant protection chemicals, rational drug design and the like. The development of the Solvay ammonia soda process, the Haber-Bosch high-pressure ammonia process, synthetic indigo, and the polyester fiber processes collectively provide a window on the challenges that need to be overcome in developing a commercially viable chemical technology.

Since the early 19th century a number of people have tried to develop an ammonia soda process, but nobody had been able to solve the problem of recovering a sufficient amount of ammonia in the process to make it economically viable. After much additional trial and error, Ernst Solvay (1838-1922) succeeded in removing the final technical obstacles to the creation of an ammonia soda process that could compete with the Leblanc process. Solvay patented every stage of his process. Later he sold licenses to his process around the world and forced his licensees to share their technical improvements with him. The efficiency of the process was increased substantially in the decades after the original plant was built. When at the turn of the 20th century chlorine could be manufactured electrochemically, the Leblanc process, which as a side product also made bleaching powder and caustic, had lost its final advantage and henceforth all new soda plants would work the 25% cheaper Solvay process.

Much of the innovative work in chemical technology is concerned with taking a product that can be made on a laboratory scale and developing a process that works on an industrial scale. Because the problems of scaling up a laboratory reaction to an industrial process are substantial, an entire academic discipline of chemical engineering designed to master these technological challenges has developed since the late 19th century. Professor Adolf Baeyer (1835-1917) synthesized indigo in 1885, winning in 1905 the Noble prize in chemistry for this work. Nevertheless it took 17 years of research and development that involved intensive collaboration between many academic and firm chemists before BASF had a commercially viable process. Without innovations in inorganic chemicals, such as the new contact sulfuric acid process that could deliver a hitherto unavailable strength of the acid, synthetic indigo would not have been able to wipe out all indigo plantations within a short period. Germany dominated the chemical industry in 1913 because it had the strongest scientific base in chemistry from which firms could draw in their innovation efforts. In terms of its economic impact, the single most significant academic-industrial collaboration was the one between the physical chemist Fritz Haber (1868-1934) and the BASF chemist-engineer Carl Bosch (1874-1940). Their high-pressure catalytic process to synthesize ammonia directly from nitrogen and hydrogen gave the world a cheap source of fertilizers and won both men independently the Nobel Prize in chemistry, Haber in 1918 and Bosch in 1931. The fixation of atmospheric nitrogen had been on the agenda of chemists for decades, and many different approaches had been tried unsuccessfully since 1780 before the Haber-Bosch process emerged. Unlike many other chemical processes that do not survive for very long because a better one is developed, the Haber-Bosch process continues to be the chief source of ammonia in the world. The high-pressure technology developed by Bosch was later employed in the synthesis of methanol and hydrogenation of coal to petroleum.

Early in the 20th century chemists in Europe and the United States began to study the science of long-chained molecules (polymer chemistry) that would later provide the founding for plastics, synthetics fibers, and rubber. Signaling the beginning of American technological leadership in the chemical industry, Wallace H. Carothers (1896-1937) and his team at DuPont developed the first artificial fiber, nylon, in the 1930s. Of the hundreds of synthetic fibers studied during the 20th century, only about a dozen have the properties to compete successfully in quality and price with the natural fibers such as cotton, wool, silk, and flax. The most economically significant synthetic fiber to date is polyester, which was originally developed in 1941 by John Rex Winfield (1901-1966) and J.T. Dickson in England. For polyester to become the second most important textile fiber after cotton, much additional research money and manpower had to be invested on the part of the makers of the petrochemical raw materials, the chemical companies producing the fiber, the dye firms, and the textile and apparel makers. The successful introduction of a chemical invention more often than not is a large collective process (For more details, see articles on the *Synthetic Fibers Industry*).

Market Structures

Market structures have changed dramatically in the chemical industry since 1850. Given that thousands of different products compose the industry, it is impossible to identify a general trend in development of market structures. Except for the period between World War I and War II, when most major chemical markets with the exception of the U.S were cartelized—often with one large company such as I.G. Farben in Germany and ICI in Britain taking a dominant position—, the industry was at least moderately competitive. (The formation of I.G. Farben was orchestrated by Carl Bosch and Carl Duisberg [1861-1935] while the merger of all large British chemical firms into ICI was led Sir Harry McGowan [1874-1961, later Lord McGowan] and Sir Alfred Mond [1868-1930, later Lord Melchett] to counter the competitive threat posed by I.G. Farben.) Monopolies typically existed only for limited periods of time when a firm acquired a patent that guaranteed a legal monopoly for not more than 20 years.

A large number of other chemical markets have been characterized by an oligopoly because entry barriers either in the form of large amounts of capital or technical and organizational know-how required to operate at a competitive scale were substantial enough to keep new entrants away. The German dominance in the synthetic dye industry was built in large part on the ability of such firms as Bayer, BASF and Hoechst to exploit economies of scope in dye production and marketing. For many chemicals, large-scale production increases the efficiency of a chemical process. Since Ralph Landau's (1916-) Scientific Design developed in 1953 the petrochemical ethylene oxide, the scale at which new plants for this chemical are built has increased at least twenty fold. Chemical engineers long worked with the rule of thumb that capital costs only increase by 60% of the increase in a chemical process plant's capacity.

Many of the early firms that became successful in the chemical industry such as BASF and DuPont have remained leading players by investing substantial capital every year into research and development (R&D) and diversifying into new product lines. The R&D laboratory as a routine function of the corporation was invented in the German dye industry and gave those firms that pioneered this new organizational form a large advantage over their rivals. To adapt chemical technology to American conditions and later to develop genuinely new technologies such as polymer chemistry, U.S. chemical firms before 1950 created R&D laboratories in larger numbers than any other sector in the U.S. economy. 516 or 26% of the total of 2,303 R&D labs created in the U.S. before 1950 were formed in the chemical industry. This provided the basis for the countless U.S. chemical innovations after World War II. One significant determinant of the market structure in the petrochemical segment of the industry after World War II was that many of the key petrochemical processes were acquired (and sometimes even developed) by Specialized Engineering Firms (SEFs) such as Kellogg, the Lumus Company, Foster-Wheeler, Stone & Webster. These firms licensed their technologies all over the world allowing many countries such as Japan to build significant domestic chemical industries. By facilitating entry into the petrochemical industry, the SEFs have made the industry more efficient, but overcapacities in the commodities sector have also eroded profit margins and led to significant restructuring of the industry since the 1980s. The Japanese chemical industry has found it more difficult to restructure because the large business groups such as Mitsubishi, Mitsui and Sumitomo, which dominated Japan during the 20th century, were reluctant to sell or merge their chemical business with that of rival groups. Hence Japanese chemical firms have generally achieved lower profits in recent decades compared to the large American chemical firms.

Environmental & Work Safety Regulation

Many chemical manufacturing processes create waste products that can be harmful to the environment and human health when not properly handled. Without careful planning and monitoring, chemical plants also harbor significant risks to the life of workers and the population in its vicinity. This has been true from the very beginning of the industry and not just in recent decades marked by a number of disastrous chemical accidents. With the dramatic growth of the British alkali industry after 1850, more and more complaints were filed by people who had property in the vicinity of alkali plants and who suffered from the noxious fumes the factories released. This led to the so-called Alkali Act in 1864 that regulated how much hydrochloric acid fumes plants could release into the atmosphere. When companies complied with the act by channeling much of their waste products into rivers, the British legislature passed another act that regulated the discharge of polluting wastes into rivers. Early synthetic dye production also caused significant environmental hazards. Fuchsine, which was invented in 1858, was originally manufactured with the help of substantial quantities of arsenic acid. Two years later, Jakob Müller-Pack (1825-99) became the second fuchsine manufacturer in the city of Basle, but his business was bankrupted in 1864 by the compensation it had to pay to victims of the arsenic water poisoning caused by his plant. Following scientific recommendations of three chemistry professors, the government then outlawed the use of arsenic acid in dye production and required that all dye factories build pipes to carry their waste away in the Rhine River. In the early days of the synthetic dye industry it was also common for firms in Switzerland and Germany to settle disputes by making cash reparation payments to neighbors who complained that the fumes from the dye factories ruined white laundry drying in open air on adjacent properties. As these examples illustrate, the chemical industry from the beginning had to cope with environmental hazards, but in the 19th century only government officials and those who lived in the vicinity of plants generally perceived these hazards.

While the chemical industry in the first half of the 20th century enjoyed the general reputation of being a high-tech sector that improved life considerably, a number of accidents in recent decades shocked the general public and extensive media coverage cemented the negative image that the chemical industry had acquired starting in the 1960s. The most prominent accidents took place in 1976, 1984 and 1986. First, dioxin, one of the most toxic chemicals known to date, escaped from a chemical plant just north of Milan, Italy. Wind carried the toxic cloud to the municipality of Seveso, where about 37,000 people were exposed to chemicals, some of which came down with health problems only a few hours later. 4% of local farm animals died and the remaining 80,000 were killed to prevent contamination from filtering up the food chain. In 1984, the leakage of toxic chemicals at a Union Carbide plant in Bhopal, India, resulted in the death of 3,800 people and led to $470 million in compensation payments. Only two years later a fire at a Sandoz plant in Switzerland caused significant pollution of the Rhine River and together with the Seveso accident came to symbolize in the public mind the dangers of chemical production in densely populated Europe. The leakage of toxic chemicals that had been buried for decades in the Love Canal forced the evacuation of local residents in 1980 and galvanized the U.S. public to address the nation's toxic waste problems.

Over a century of unprecedented economic growth in all sectors of industry had created pollution levels by the1960s that turned many rivers in industrialized countries into poisonous streams and the air over large metropolitan areas into a significant health hazard. Many a scientific committee warned about a possible environmental collapse. At this point the public at large became very concerned about the living conditions on the planet. The rise of the environmental consciousness of the general population produced unprecedented levels of new regulations in all industrialized countries during the second half of the 20th century to protect air, water, and soil. Governments also created environmental protection agencies to coordinate state policies in cleaning up and protecting the environment. As a result of a slew of tougher regulations, average environmental spending in the chemical industry rose from about 3% of total operational investment in the 1940s to more than 6% in the 1960s and reached about 20% by the early 1990s. Initially the chemical industry in the industrialized countries tried to resist many regulations because they would increase the cost of production. In recent years, however, the industry has learned that it is to its advantage to be proactive about regulations and to engage also in self-regulation through such initiatives as *Responsible Care*® that commits members of all the major chemical industry trade associations around the world to continually improve health, safety and environmental performance. Since 1970 the American chemical industry, for example, has spent $36 billion for pollution abatement and control. Thanks to stringent government regulation and in recent years industry self-regulation chemical industry emissions in the U.S. are down by 65% percent, although industry output is up by 30%. From an environmental point of view, the globalization in the chemical business is likely to aid the environment because companies from industrialized countries tend to build plants that meet the same environmental and safety standards as the plants back home.

In the major industrialized countries, governments, and trade unions have been active for over a hundred years in improving the working conditions in chemical plants. An investigation of death rates at the end of the 19th century brought to light the fact that the chemical industry had the highest rate of all industries with 98 per 1,000 compared to 57 per 1,000 for all occupied males. A century later working conditions in chemical plants of the industrialized world have improved dramatically. In the U.S., which can be taken as representative for all major chemical producer countries, the occupational injury and illness rates (per 100 full-time employees) are less than half of the manufacturing sector as a whole (4.4 versus 9.2). Aside from eliminating many hazardous jobs and implementing effective safety programs, another reason that significantly fewer labor accidents occur in chemical plants at the turn of the 21st century is that plant employees are less prone to fatigue. Twelve-hour shifts common in the mid 19th century have been reduced to about 8 hours in the chemical industries of the major industrial countries. Workers in some departments of British alkali plants put in as much as 84 hours per week until 1889 when the introduction of additional shifts reduced the work hours significantly. Across the channel, the workweek of an average plant employee in the German chemical industry decreased continually from 72 hours per week in 1872, to 62 hours per week in 1900, to 57 hours per week 1913, and to an average of 37.5 hours at the turn of the 21st century.

Sources of Industrial Leadership

Between 1850 and 2000 leadership positions in the chemical industry have changed from Britain to Germany and later to the United States as radical product innovations created entirely new branches of the industry, as large markets opened up in North America and Japan, and as petroleum replaced coal as the key feedstock for organic chemicals. But there is also much continuity in industrial leadership. Many of the companies that dominated the industry at the turn in the beginning of the 20th century—BASF, Bayer, Dow and DuPont— continue to be the largest chemical enterprises in the world because, as first movers, they have continually invested in new technologies and built large capabilities in management, production, and distribution. Significant competitive advantages were created and lost by national industries—but not overnight. Industrial strength in the chemical industry is in essence the product of long-term investments. The economic history of the chemical industry is also consistent with Dennis Mueller's general findings (Profits in the Long Run, Cambridge and New York, 1986) that only companies which are able to introduce new innovations time and again, such as Merck, or companies which establish a particularly strong brand in the mind and hearts of consumers such as Coca Cola® can achieve above normal returns in the long run. Chemical innovations that were at one point reaping large profits—synthetic dyes, fertilizers, petrochemicals—are no longer sources of abnormal profits because market forces have brought them down to normal levels. However, companies that develop a stream of new therapeutic substances, for example, continue to reap above normal returns.

Pharmaceuticals, plastics, artificial fibers, and synthetic dyes are only the most visible products of the chemical industry that have made modern life more enjoyable on a physical level. Even when we take into consideration the environmental damage that chemical production has caused at various times, chemicals are in large measure the reason that citizens of the industrialized world need no longer claim that life is poor, nasty, short and brutish.

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Useful Websites

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Chemical Industries Association (Britain). http://www.cia.org.uk/

European Chemical Industry Council. http://www.cefic.be/

International Council of Chemical Associations. http://www.icca-chem.org/

Search Engine for Chemical Industry Information. http://chemindustry.com/

Synthetic Dye Industry Project. http://johann-peter.murmann.name/dye-project.htm