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Finance and the Chemical Industry

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The chemical industry was born with a long-term horizon; that is, with a need to finance large and risky projects with a far-off pay-back horizon. This is because the industry's discoveries and advances have been the result of substantial research and development efforts, while the industry's production has been highly capital intensive. Thus, the availability of financial resources, and the conditions under which these resources are provided, has had a powerful influence on the features and outcomes of the chemical industry. It is then not surprising that the characteristics of a nation's financial system have often been a key factor in determining the competitiveness of individual firms and national systems.

Financial systems affect the development of industry through allocation and governance. Allocation consists of channelling funds from lenders to borrowers, which means choosing which projects and firms are worth financing, and under what conditions. There are different decision-makers for various sources of finance. Equities and bonds can be bought directly by final investors, or purchased by fund managers. A loan may be granted by a commercial bank officer or syndicated by an investment banker. The decision about the share of earnings to retain is made by a firm's own board of directors. These different sources of funds put different constraints on borrowers, and offer them different opportunities. Thus, each possibility implies for the firm different costs, obligations, and expectations of behavior, all shaped by the regulatory context of the financial system.

The financial system also provides a mechanism to govern firms, which is commonly referred to as "corporate governance." Ownership rights are the source of rights and duties which, again, differ across holders of different titles. Shareholders are the main claimants on their firm's decision making process, although their influence is mediated through a board of directors. Bondholders and banks, as lenders, may also have some voice in how a corporation is governed. Managers, as the insiders who make key decisions, set agendas, and gather and distribute information, also shape the process. The way ownership is structured affects how managers view firm's goals, strategies and performance. A private firm with strong family ownership will differ from a company whose ownership is dispersed among thousands of investors. Moreover managers enjoy different degrees of autonomy, and set different goals for themselves, according to how the interest of shareholders, bondholders and lenders are voiced.

This chapter discusses how allocation and governance, shaped by the economic and regulatory history of nations, affected the availability and conditions of external finance, thus shaping the evolution of the chemical industry. I approach these issues from an angle which is both historical and comparative. When looking at single firms, I explore how cash flow, capital expenditure, R&D intensity, and corporate strategies at large have been affected by the availability of funds. At the industry level, the key questions are how coordination, consolidation and restructuring have been influenced by financial markets. The first sections of this paper compare directly the evolution of the chemical industry in Britain, Germany and the United States at particular periods in time. Then, I treat Japan in a separate section, to account more properly for its idiosyncratic pattern of development.

FINANCING THE ENTREPRENEURIAL AGE

The British Decline

Synthetic dyes, the first science-based chemical industry, were discovered in Britain by Perkin in 1856. In 1862 there were nine British dye firms and seven (smaller) German ones (Beer, 1959, p. 30). For the rest of the decade the British firms enjoyed a first mover advantage, and dominated this rapidly

growing market. However, British firms showed little interest in developing technical capabilities; most never went beyond simple refinements of Perkin's methods. The British industry was thus soon overtaken by German competitors in the 1870s. For an overall discussion of the British and German chemical industries since 1850, see the chapter by Murmann and Landau in this volume. Here, I explore the particular question of how Britain's financial sector contributed to its falling behind in the chemical industry.

The British system of industrial finance developed in the first half of the 19th century during the Industrial Revolution.¹ Several of its initial traits proved long-lasting: minimal regulation; strong reliance on retained earnings for the finance of capital accumulation; "distant" borrower-lender relationships based on short-term loans and tradeable notes; and limited access to the stock markets for new firms. The first intermediaries to provide external finance for industrial ventures were small partnerships of wealthy merchants known as country bankers. They financed firms through short-term loans and by discounting "bills of exchange,"

trade-originated securities. This pattern of industrial finance required entrepreneurs to fund fixed capital themselves, or with kin and friends. Banks were constrained by law to be small. Until 1826, they could not have more than six partners, and limited liability was introduced only in the second half of the century. This was when joint-stock banks developed as centrally coordinated networks of local banks. They maintained the arm's length attitude to lending of country bankers, to which they added an emphasis on risk diversification.

By the middle of the 19th century, firms in railroads and utilities were able to raise large sums of external finance through British merchant bankers. However, industrial ventures raised much less. Industrial securities were regarded as speculative, and promoters and bankers were not equipped to appraise the idiosyncratic risks involved in screening firms and monitoring their management. City institutions developed their skills by floating public securities, but stayed away from giving financial support to new industrial firms. In Germany and the United States, specialized entities (Kreditbanken and investment banks) emerged for managing the processes of assisting firms in issuing securities. No such entities emerged in Britain. Instead, informal capital markets remained the main source for industrial finance in Britain for a long time. Thus, markets for industrial securities were slow to develop; indeed, no British chemical firm issued equity until the end of the century. Between 1882 and 1913, innovative industries like chemistry, engineering and electricity accounted for only 21% of domestic industrial and transport new securities issues, while breweries and railways accounted for 55%. Typically, incorporation was used by closely held companies to achieve limited liability, rather than to raise funds: as late as 1904, almost 90% of Britain's 3477 new joint-stock companies were private.

There is a longstanding debate on why British financial markets failed to provide capital to sustain domestic industrialization.² City financial institutions have been accused of irrationally preferring investment in utilities and foreign public bonds and turning down domestic industrial securities. But as Edelstein (1971) shows, British financial markets equalized risk-adjusted returns across different securities, and were thus investing rationally and efficiently. This sharpens the question of why Britain's financial markets did not offer much support to industrial development.

In my view, the explanation can be viewed as a self-reinforcing circle. Given banks' distant attitude, it was rational for firms to invest in low risk projects. In turn, given entrepreneurial focus on relatively simple projects, it was rational for banks to avoid involvement in long-term finance. If existing financial institutions had been able to select promising projects and skilled entrepreneurs and to provide them with long term support, it would have been profitable for industry to invest in more advanced technological capabilities. This failure to coordinate was at the heart of the British decline. Financial intermediaries have often served as an important catalyst for the early stages of industrialization. But investment in the necessary information-processing capacity and coordination skills is costly and risky. When firms adopt simple technologies, there is little that a bank can gain from developing close ties with such firms, and it does not pay for a bank to undergo such investment. Da Rin (1997a) offers a formal presentation of this argument which draws out some additional implications.

This argument helps explain the pattern of Britain's chemical industry and broader development in the 19th century. British firms successfully adopted a pattern of production which made use of simple technologies, and invested in easily redeployable assets. Banks engaged in distant, arm's length intermediation, circulating securities in impersonal markets. Once selected, the compatibility of these industry and bank choices made them self-sustaining and persistent. The earliest products of the British chemical industry, for example, included basic chemicals, acids and bleaching powder (alkalis). These products used simple technologies, which required little specific physical and human capital. Thus, British technology was complementary to British style arm's length financing.

The British financial system discouraged chemical firms from making innovative and risky product and process-specific investments, so that they failed to develop original and innovative technology and fell behind when innovative competitors arrived. Consider the evolution of the soda industry. Its firms started declining when they failed to switch to the Solvay process, retaining the obsolescent Leblanc process. In 1891 many Leblanc alkali producers merged into United Alkali, in an attempt to sustain prices by concentration. Predictably, United Alkali soon suffered competition from more efficient producers of electrolytic alkalis, and stopped paying dividends as early as 1896. By 1913 it had reduced its capital by 40% (Haber, 1971, p. 140). Its low rate of return on capital, around 2%, contrasted with the profitability of Solvay producers Brunner Mond, then around 15%. The main reason

for the surprising decline in Britain's chemical industry, after it had seemed a secure industry leader in the 1850s and '60s, was the reluctance to invest in research, chemists and experimenting. This pattern was not exclusive to the chemical industry. British mining, foundry and ship-building also developed with relatively little interest in technological research. Innovative industries like the electrical and electro-mechanical ones remained very small and more dependent on imports. Of course, the financial system was not the exclusive reason. British chemical firms were used to exploiting the large markets provided by the Empire, without the need to conquer new ones, which allowed them to thrive without cutting-edge technical excellence (Landes, 1969). Germany, on the other hand, had no such dominions (Kocka, 1988). Perhaps as a result, German firms were much more aggressive in setting up marketing branches in many countries. German firms also offered technical assistant to customers, hosting them for training on new methods of fixing dyes.

The only British success stories for this time period come from cartelized industries or consumer chemicals. For example, Brunner, Mond & Co., a producer of alkali by the Solvay process, was part of international cartel of Solvay producers. Brunner, Mond was founded as a partnership in 1873, and it faced severe financing problems for a number of years.³ The initial funds were provided by the two partners and by a friend. Banks, unable to understand its technology, were not attracted by such a risky venture, and only lent money against a mortgage secured by the Winnington property which hosted the plant site. The partnership also got short-term credit for small amounts from Parr's Bank in Warrington, whose manager was a friend of Brunner. Ernst Solvay himself provided credit at a critical time, and then became a shareholder. Most of Brunner, Mond's technology came from abroad, and cartel protection meant that the company felt little pressure to invest in research. In fact, Brunner, Mond still employed only four chemists in 1914 (Reader, 1970, p. 176). Nobel Industries, which produced explosives, is another example of succeeding through cartelization. The Nobel-Dynamite Trust, an international holding company, acted as an internal capital market which exerted strong control over its members (Reader, 1970, pp. 179-81). Necessary technology was developed abroad. Nobel Industries borrowed more from firms in the cartel than from banks, and was never in need to issue debt or equity. In both alkalis and explosives science played a lesser role, as in all inorganic chemicals. Given their protected status, it is not surprising that Brunner, Mond and Nobel lost little ground to innovative German newcomers.

Consumer chemicals are another area in which where research and technical investments mattered relatively less, and in which even Britain's chemical success stories reveal the shortcomings of its financial system. Courtaulds successfully shifted from leadership in natural silk to artificial fibers (Coleman, 1969) when it experienced a decline in profitability at the beginning of the century. In 1904, the company incorporated and issued preference shares and debentures. However, Courtaulds achieved its success largely because of marketing and efficient distribution to consumers, two areas in which British firms traditionally excelled, rather than because of technical skill. Two other successful consumer chemical firms, Lever Bros. and Crosfield, relied on internal finance for a long time before offering equity to the public (Musson, 1965; Wilson, 1968). Lever Bros. listed its preference shares on the stock exchange only in 1929. Crosfield did not issue securities until 1896, after the firm had relied on personal savings and retained earnings for more than 70 years.

The picture which emerges is that British chemical firms were discouraged by the financial system from investing in projects with a long-term payoff horizon. This meant little and unsystematic research activity, suboptimal plant size, and lack of diversification. This held true across industry sectors from the alkali companies (Haber, 1958, p. 154), to the producers of inorganic chemicals (Chandler, 1990, p. 357), and the dye makers (Haber, 1958, pp. 165-167). There was little interest in the systematic pursuit of science to improve productivity. It is telling that the most active British experimenters in alkalis were William Gossage, a druggist, Charles Tennant, a linen bleacher, and Walter Weldon, a journalist of fashion magazines (Lischka, 1985, pp. 63-5). Research and capital intensive fields like pharmaceuticals, intermediates and electrochemicals hardly developed.

Britain's financial system contributed to the underinvestment in technology. In the absence of an effective corporate governance system, able to assess the technological value of projects and managers, simpler technologies and reliance on established markets were the best response by entrepreneurs.⁴ In the absence of a way to coordinate their choices towards riskier but more productive investments, both firms and banks had little incentive to pay the costs and take the risks of changing their strategies.

The German Rise to Leadership

The relative decline of Britain's chemical industry was based on complementarities between industrial and financial strategies. A similar story, told in reverse, helps explaining the rise of Germany late in the 19th century as a power in the chemical industry.

Several features of the German financial system date back to its formation around the middle of last century: a close relationship between borrowers and lenders, the development of monitoring and control capabilities by large banks, and the dependence of capital markets on a few large banks. Industrial finance appeared with Privatbankiers, partnerships of private bankers with good knowledge of business opportunities.⁵ Privatbankiers established close ties with their clients and engaged in long-term as well as short-term finance. They were superceded by larger and better capitalized Kreditbanken, which pioneered "universal banking" by offering both commercial and investment banking services. In so doing, they developed the skills necessary for evaluating firms' long-term prospects and exerting control over management, and so were willing to provide long-term loans.⁶

Banks helped firms issue securities. Between 1882 and 1913, the four fastest growing industries -- chemicals, mining, engineering and electricity -- accounted for nearly 70% of new issues (Tilly, 1993). By the turn of the century five big banking groups (Konzerne) had developed around the Deutsche, Dresdner, Disconto, Schaaffhausen and Darmstädter banks. Yet the system remained rather competitive, with each group striving to enlarge its market share by attracting new customers in new regions and industries. These German banks became involved with emerging firms in "new technology" industries like chemical, electricity, machinery, and transportation.

The choices of German banks and firms had key complementarities. Banks upheld the specific, risky investments that German firms made at the beginning of industrialization. Banks used their skills for control and resolution of financial distress, and supported their clients. They lobbied government officials where necessary, or would even become directors or managers of firms.⁷ They also assisted firms in their export activities. Given this attitude of banks, it was rational for firms to choose risky but potentially very productive projects. In fact, the potential gains from such projects justified the cost to firms of developing close ties with banks. Tilly (1986) employs modern asset pricing analysis to show that returns to investment in different branches were on the efficient frontier.

To understand how the German system worked in practice, consider banks' influence on some well-known firms at early stages. BASF incorporated in 1865 with the contribution of the bank W.H. Ladenburg and Söhne (Kirchgässer, 1988, pp. 68-69). In 1862, Ladenburg had financed the Chemische Fabrik Sonntag, Engelhorn, Dyckerhoff und Clemm, predecessor of BASF, and the bank also financed also other chemical start-ups. Ladenburg retained 10% of BASF shares, and his partner chaired its board. The bank was also active in later capital increases (1873 and 1889), and in 1901 floated the first large BASF bond issue. Credit from the bank was strategically important. In 1868, it allowed the ailing BASF to hire Heinrich Caro as head chemist; in 1869 Caro (with others) received a patent for alizarin, which made the fortune of BASF. Another chemical firm, AGFA, was funded in 1867 with help from the banker Mendelssohn-Bartholdy, who became a partner. Its parent company, Kunheim, had ALSO been founded with the help of a banker (Haber, 1958, p. 48). DEGUSSA, later a leader in electrochemicals, received credit from Frankfurt financial houses to establish its own research laboratories (Beer, 1959, ch. 8).

Kreditbanken were not old-time venture capitalists; they preferred to deal with firms which had already shown some potential for growth. Several firms started being financed and assisted by Kreditbanken only when incorporating, like Hoechst and Bayer. Since Kreditbanken extended long-term credit as well as floating firms' bonds and shares, they effectively offered bridge loans that allowed firms to wait for low interest rates before issuing bonds. This encouraged German firms to incorporate and access capital markets early in their life, allowed them to raise very large sums of equity from the public and so to afford investing in capital- and research-intensive production techniques. The "universal" nature of these banks allowed firms to tap either debt or equity finance using the same financial intermediary.

Hoechst, for instance, incorporated in 1881 with a capital of 10 millions marks, of which 5.5 were sold through two Frankfurt banks, Hauck & Son, and J.I. Weller Sons.⁸ Between 1863 and 1908 it raised 36 millions marks of capital on the stock exchange, always with bankers as underwriters and providers of bridge loans. Together with 29 million marks of retained earnings, this allowed Hoechst an impressive cumulative investment of 65 million marks. Forty-two German chemical firms incorporated in the early 1870s with the bank help, and the

trend continued in the following decades (Riesser, 1911, p. 125). Of the 17 chemical companies which ranked among the largest 100 German firms in 1907, 15 had been founded early as partnerships and were later incorporated, (Kocka and Siegrist, 1979, p. 111). Grabower (1910) provides detailed statistics showing how relations with banks differed across the branches of the chemical industry.⁹ Early in a company's life, equity capital often accounted for more than 95% of financing. As firms matured, loans and bonds became more important. The involvement of bankers was substantial. Only about a third of the 223 joint stock companies he considers were founded without a banker. A striking difference with Britain was that capital increases were rarely reserved to existing shareholders, especially for larger and listed firms. When shares were offered to the public the involvement of bankers was essential, partly as brokers and underwriters, and partly to assure investors that they would get their money back.

The effects of the German financial system on firms risk-taking and systematic scientific research are clear. It was in Germany that industrial research departments were invented, and the chemical industry was most active in this, especially dye makers. For instance, in 1885 Bayer employed 24 chemists, which grew to 100 by 1896, plus 25 engineers, all at least graduates (Wrigley, 1987, pp. 171-3). German chemists perfected the knowledge and exploitation of organic chemistry, laid the basis of modern pharmacology, competed with the Americans in electrochemical processes, and created high pressure processes for synthetic fertilizers. The immense capital outlays required for capital investment and research far outgrew retained earnings. Both the initial support from banks and the subsequent access to capital markets were fundamental in building industry leadership. The combination of the complex scientific nature of organic chemistry and the need for huge financial sums present a powerful barrier to entry by new firms. In fact, the few chemical firms which emerged from the dyemaking industry in the 1870s are still prominent. For instance, the search for synthetic indigo cost BASF 17 years of research with with a cost of at least 18 million marks (Wrigley, 1987, p. 177). Such an investment required very patient, daring and forward-looking finance. Hoechst, which joined BASF in the race to the discovery, built five experimental plants to develop industrial production, spending about 15 millions marks (Haber, 1958, p. 175). Similarly, the exploitation of the fixation of nitrogen required two decades of costly research. Mittasch, in developing it with Bosch, performed over 6,500 experiments in three years, trying over 2500 substances for the catalyst (Haber, 1971, pp. 85-95). Bayer's profit rate until 1914

ranged between 20% and 30%, which brought to the accumulation of 145 million marks. Yet its balance sheets show that it had to raise an additional 45 million to finance its huge capital outlays.

The complementarities between long-term finance and research and development also allowed the chemical industry and the dye makers to use profits to open new lucrative areas of business, and thus to sustain their high profit rates. Indeed, the persistent success of Bayer, BASF, AGFA and Hoechst was due to their ability to keep ahead of competition in innovating and diversifying. BASF pioneered high-pressure ammonia, Hoechst pharmaceuticals, and Bayer rubber -- all very costly fields to enter. The contrast with the sparing research attitude of British pharmaceutical firms is striking (Liebenau, 1984). Hoechst established close links with the founders of chemotherapy, Knorr, Koch and Ehrlich (Baumler, 1968, pp. 33-6). Chemotherapy took several years to be recognized by the medical profession, and was a very risky investment. The profits from revolutionary drugs like antipyrin (1883), pyramidon (1896), and novocain (1905) repaid Hoechst well. Bayer soon followed suit, introducing phenacetin (1887) and aspirin (1897). Specialized pharmaceutical firms, like Merck, developed more slowly. For these firms, diversification into new products also helped dampen cyclical fluctuations.

Dyemakers were in a sense outliers, because of their fantastic profitability. Haber (1971) illustrates in detail the differences between dyes and other branches of the industry (heavy chemical, fertilizers), which had more and smaller firms and never reached such impressive profit and investment rates. But the general connection between German finance and science reached beyond chemicals to firms in other sectors as well. In electrochemicals, Chemische Fabrik Griesheim, Kunheim, and Alkaliwerke became world leaders at the end of the century, competing with American enterprises. Although the Germans failed to overtake the British in consumer chemicals, Henkel did challenge Lever by investing in advanced research and developing new electrochemical technology with DEGUSSA, a pioneer in the field. The story of DEGUSSA again illustrates how banks helped with restructuring and refinancing, a role repeatedly illustrated by Grabower (1910). In 1899 DEGUSSA formed Cyanid Gesellschaft to exploit the cyanamide process for the fixation of nitrogen. It was backed by the Deutsche Bank, which helped it promote its subsidiary Bayerische Stickstoffwerke. Consolidierte

Alkaliwerke set up a competing firm in 1904, with financing from the Metallbank, which also rescued it in 1911.

The strength of Kreditbanken was not positive for German industry in every way. For example, the Kreditbanken were also responsible for fostering the cartelization of the German industry, since that too, along with innovation, would support the financial stability of their borrowers. However, the benefits of the German financial system -- help in accessing capital markets, bridge loans for securities issues, and effective corporate governance in case of distress -- certainly had an overall positive impact. Calomiris (1995) has argued this might have offered German firms a lower cost of capital than in Britain or the United States, though this conclusion remains tentative for lack of systematic data.

The American Awakening

At the start of the 19th century, the United States was a relatively less developed economy. Through most of this century, there was little production of advanced chemicals in the United States; instead, inorganic chemicals were mostly imported from Britain, and organic chemicals from Germany. But the potential of the American economy soon became apparent. In terms of the U.S. chemical industry, the strongest force was the possibility of exploiting economies of scale in producing and selling to America's huge internal market (Arora and Rosenberg, this volume). Large producers of consumer chemicals, like Procter & Gamble and Colgate, emerged through consolidation only during the last two decades of the 19th century. Heavy and intermediate chemicals took longer. According to Roy (1990), in 1880 there were 1,324 chemical works, with 25,000 workers. By 1900 they were 1,331, with 41,000 workers, and by 1914 they became 1,987, with 78,000 workers. Their capitalization increased ten-fold. More concentration occurred in drugs: the 1,805 drug-makers of 1890, with 2,000 workers, became 416 by 1914, with 9,000 workers. Their capitalization also increased ten-fold. However, U.S. production of organic chemicals would not replace imports until after World War I.

In the 19th century, America's financial sector offered little support to its budding chemical industry. Even more than in Britain, the fragmentation of the banking system, and its short-term horizon, deprived firms from outside sources of funds. America has always caged its financial intermediaries in a web of regulations which constrained their development.¹⁰ The

result has been to fragment banking, to favor securities markets, and to separate commercial and investment banking, as Roe (1994) meticulously documents. The 1864 National Banking Act created a dual system of national and state chartered banks, in which banks were subject to capital requirements and federal supervision, and were prevented from equity ownership and branching.¹¹ The Banking Act introduced another lasting feature, preventing banks from lending more than 10% of their assets to a single borrower. Together with the absence of a central bank (the Federal Reserve system was not created until 1913) and a national money market, this forced banks to reduce their risk by restricting their lending to liquid short-term loans.

One consequence of the lack of available finance in the U.S. economy was that the consolidation of the chemical industry in the later part of the 19th century took different routes in the United States than in Germany. In Germany, the hundreds of firms making in organic chemicals in the 1860s and 1870s (Teltschik, 1994) were reduced to a few by competition but also by bank-managed mergers during the 1880s. While such concentration was most acute in dyes, it was common to all sectors (Grabower, 1910). In the United States, less reliance on external finance delayed greater concentration until the drop in transportation costs made it inevitable.

The similarity between the situation of British and American firms and banks at this time was strong, but with one major difference. British firms were largely reconciled with the way the capital market allocated capital; for example, there are no records of young British chemical firms trying to persuade banks to lend to them for long-term research and capital investment. However, American firms often applied for such financing and were refused. The small U.S. banks had little capability to understand technical processes -- especially when they were so innovative and risky as in chemicals. They preferred lending to safer and more established industries. Capital markets also provided very little support for science-intensive industries like chemicals, unlike for railways or other heavy industries (Michie, 1987). The result was to restrain technical development and investment in research.

Thus, the American chemical industry was in a situation where external finance was very limited, but it seemed clear to entrepreneurs that demand was rising and substantial profits could be made in this industry by firms which could endure long enough. Their strategy was a

frenetic wave of tinkering on plants and processes to find empirically viable solutions to immediate production problems. Little effort could be afforded on long-term, sophisticated basic R&D, but resources were put into adaptive process innovation, often based on foreign patents (Arora and Rosenberg, this volume). The main virtue of American inventors at this stage was indeed their ability to adapt and respond to market demand (Khan and Sokoloff, 1993).

Electrochemicals are a good example in this respect, as they represented the first big success of innovation in American chemicals (Moore Trescott, 1981). Aware of the country's enormous electrical power resources, like the area around Niagara Falls, several chemists started researching in the 1890s: La Sueur, Castner, Hall, and Dow. They adopted and improved discoveries made mainly in Germany and France, eventually producing processes of their own. From 14 firms in 1899, they grew to 34 by 1909, producing metals (aluminum), alkalis, and calcium carbide. In the 1890s they engaged in feverish activity, each racing to stay ahead. Virtually no external finance was raised. Only when some of these firms reached financial stability did they start engaging in systematic R&D.

The monumental work of Haynes (1954) illustrates the history of 219 chemical companies, and provides evidence on how firms were financed at this stage. Firms received little help from banks. Industrial securities became accepted only very slowly, and chemicals were regarded as very risky. Thus, most companies were financed out of the accumulated wealth of their founders, and relied almost solely on earnings to expand and survive distress. Chemical companies like Eastman Kodak, Dow Chemical, Monsanto, and Firestone Rubber survived because their tinkering and process improvements were successful. Interestingly, the most successful pioneers were rarely chemists (Hayes, 1939; Haynes, 1954). Also, the typical American drug companies -- Abbott Laboratories, Ely Lilly, Upjohn Co, and Squibb & Sons -- all started as small scale family start-ups, unlike in Germany, where pharmaceuticals were financed by the profits from dyes (Haynes, 1954).

Toward the beginning of the 20th century, U.S. chemical companies were still unable to rely on bank financing, but they began to be able to draw on securities markets. The reliance on securities for external finance became a distinctive American trait, especially after the spectacular boom of railroads bonds (Michie, 1987). Industrial securities took time to be

accepted on national stock exchanges, as they were considered too risky and speculative; by 1898 only 20 industrials were listed on the New York Stock Exchange (NYSE), but they grew to 173 by 1915 (Carosso, 1970, p. 79). Roy (1990) provides data on chemical firms listed on the New York stock exchange from 1899 to 1913. There were only three companies listed in 1899, with a capitalization of \$48 million. Of these, Du Pont was the first and by far the largest issuer. They became 17 by 1913, with a capitalization of \$367 million. Of those which would become major chemical companies, only four were listed in this period: Du Pont, Union Carbide, General Chemical, and Sherwin Williams. Fewer chemical companies were listed than from other industries. Other large chemical firms issued only bonds, usually when incorporating. Detroit Chemical Works, Dow Chemical, Merck & Co, Minnesota Mining and Manufacturing (better known as 3M), and U.S. Industrial Chemicals followed this pattern (Haynes, 1954).

Trading of securities became concentrated in New York. American investment banks, less hampered than commercial banks by regulations, established close links with both issuers and wealthy investors (Navin and Sears, 1953). They became investors' portfolio managers, and with the merger wave around the century started acting as directors in many firms (De Long, 1991). Houses like J.P. Morgan, Drexel, Kuhn Loeb, Kidder Peabody, First National Bank of New York, National City Bank, Lee Higginson, and later Goldman Sachs and Lehman Bros became extremely influential (Carosso, 1970). However, chemicals participated in the merger movement relatively less than other capital-intensive industries, retaining at this stage a high plant and firm dispersions (Arora and Gambardella, this volume). For that reason, investment banks played a lesser role in engineering chemical deals, a point made by both Haynes (1954) and Chandler (1990).

To get a feel for the impact of the U.S. financial system on the early development of the chemical industry, it is perhaps useful to look at the financial experience of some of today's major chemical firms. The case of Dow Chemical is most telling (Whitehead, 1968).¹² Herbert Dow was a genial improver of processes, but he had difficult relations with his financiers. In 1892 he founded Midland Chemical, financed by Cleveland manufacturer J.H. Osborne, but had to dissolve it for financial reasons two years later. Dow then founded Midland Chemical Co., again financed by Osborne and other Cleveland businessmen. This time the impatience of the investors, who had no clue of the technical problems Dow was facing, stopped him right

on the verge of success. In 1895, he involved the faculty of the Case School of Applied Sciences in founding the Dow Process Company. In 1897 it was incorporated, receiving small credit from a local bank. In 1902, Dow first issued bonds, secured by a mortgage on the plants, which was the start of Dow's traditional policy of high leverage. Since 1910 dividends rose steadily, and common stock paid ever increasing dividends.

John Queeny had to save from his salary to gather enough funds for founding Monsanto Chemical Company in 1901, since he was turned down by several banks (Forrestal, 1977). He started producing saccharin, but suffered from ruthless dumping by German firms, and had to diversify into vanillin and caffeine. His difficulties in obtaining capital were extreme. In 1903 the only financier he could convince was an old acquaintance. Other troubled capital increases occurred in 1907 and 1913. Success only came with World War I, when Monsanto achieved huge profits. These allowed Monsanto large investments in R&D, exploiting patents confiscated from the Germans. Monsanto became large enough to start exploiting economies of scale. At this point, finance became easier. Monsanto went public in 1927, selling about 30% of its capital.

Du Pont, founded in 1802, is a rare case of a venture financed by a substantial family wealth (Chandler and Salsbury, 1971). Its growth was due to the expansion of the explosives business: between 1870 and 1900 sales grew 250 times. The firm remained a partnership until 1899, when it was incorporated but still family owned. In the next three years Du Pont acquired 54 companies, and by 1905 controlled 75% of the U.S. explosive powder market. At this stage its products were developed through a trial-and-error process, but its Eastern Laboratory (1902) and Experimental Station (1903) were among the earliest U.S. industrial labs. An antitrust ruling then forced Du Pont to divest part of its traditional business. It spun off two companies, Hercules Powder and Atlas Powder.¹³ It then initiated a policy of vigorous diversification, which accelerated after the war. Du Pont's most profitable acquisition was the 23% stake in ailing General Motors, which it bailed out and reorganized (Haber, 1971, p. 183).¹⁴ As already mentioned, at the beginning of the century Du Pont pioneered the issue of industrial equity to finance its large investments. For example, of the \$3.5 million Dow invested in 1905-6, about \$1.0 million came from the sale of securities. Bank loans were not even taken into consideration.

The early U.S. chemical industry resembled the British in many respects: simple technology, small plants, little support from banks and capital markets. But the American experience was unique in several ways. At the turn of the century, U.S. investment banks were selling the industrial securities of large firms. Although the chemical industry was not at the forefront of this trend, securities finance was available to a number of leading U.S. chemical companies before World War I. Moreover, the growing American domestic market allowed firms to escape the "British trap" by generating internal funds sufficient to engage in technological innovation and sustain their effort over time. Astounding growth rates in certain sectors (explosives, alkalis and electrochemicals) made retained earnings a sufficient source of finance for continued growth. This allowed the U.S. producers to enter a German-style cycle in which large earnings supported huge research programs, which in turn secured future growth, through a combination of increased sales, acquisitions and diversification. However, the self-sustaining success of the U.S. chemical industry came only after the accumulation of profits had supported extensive research. The development of the industry was indeed held back by the the financial system. For many American chemical companies, the combination of large profits and large research laboratories could only be achieved after World War I.

FROM ENTREPRENEURIAL TO MANAGERIAL FIRMS IN THE CONCENTRATION ERA

Needs for explosives, intermediates, and drugs led to increased production of chemicals in all countries during World War I. Moreover, the disruption of foreign supplies led many chemical companies to a search for replacements -- in some cases, to new synthetic materials. A number of the today's largest chemical companies became firmly established during World War I. For example, from 1912 and 1918 the real assets of BASF rose by 70%; of Brunner, Mond by 120%; Dow by 210%; and Monsanto by an extraordinary fifteen-fold.

Wartime profits were generally employed towards two goals: increasing R&D expenditures and diversifying away from glutted markets to preserve profitability. The renewed research effort was pursued in large research laboratories, copied from those of the Germans. New fundamental discoveries soon were made: nitrogen fertilizers, nylon, polythene, synthetic materials (fibers, alcohol, and rubber), new drugs (sulfoaminides, penicillin) and paints, and many new intermediates. These inventions were less serendipitous than many earlier

discoveries; instead, they were the fruit of a coordinated effort of applying science to industry. They required resources which could be provided only by financially strong firms. Indeed, since the 1920s no chemical industry start-up has become a lasting major diversified player in the industry, which has shown a remarkable pattern of persistence in its leaders. The firms which most profited from the war and the boom of the 1920s gained a lasting advantage.

Another lasting consequence of the war was to increase industry capacity for existing products, which resulted in overcapacity after the war. By 1924, production of heavy chemicals in Britain, Germany and the United States was at 50% of industry capacity. Consolidation swept the industry on a global scale, seeking to achieve financial stability and protect national industries in an era of protectionism. The two leading examples were the mergers leading to the creation of ICI in Britain and I.G. Farben in Germany, both of which will be discussed further below. As entrepreneurial firms evolved and merged into managerial firms, they required a broader supply of external funds, and needed a different governance support, which meant changes in the interface between financial markets and industry.

The character of the British financial system, and its relation with industry, did not change substantially over this period. Consolidation of joint-stock banks proceeded steadily, and by World War I the "Big Five" -- Barclays, Lloyds, Midland, National Provincial, and Westminster -- dominated the banking system. The interwar period saw further consolidation of commercial banking and only a slightly wider use of industrial securities. The scarce support offered by financial intermediaries and capital markets continued. Bank credit was not very lavish, and only a very small, even decreasing, share of bank advances went to chemicals (Thomas, 1978, ch. 3). Underwriting procedures and practices slowly improved with time, and by the 1930s some merchant bankers had specialized in underwriting and marketing large domestic industrial issues. However, speculation in new industries, like films and gramophone, first deceived and then disillusioned investors, preventing the long-term development of venture capital institutions.

A trend toward consolidation and larger firms was observable in most branches of Britain's chemical industry in the interwar years. The war had been profitable for British chemical producers. Nobel, for example, more than tripled its capital from 1913 to 1919, and used these

resources to acquire 30 firms right after the war. Brunner, Mond also acquired several competitors in this period. This consolidated their industry positions. Courtaulds concentrated on fibers; Lever took over the entire soap industry, and Glaxo, Beecham and Boots emerged as leaders in drugs. However, chemicals remained a relatively small and fragmented industry. In 1905 there were only four chemical firms among the largest 50, in 1919 they were six, and in 1930 four (Hannah, 1976, p. 102, 187, 189).¹⁵ What remained distinctive in Britain was a pattern of closed family ownership (Chandler, 1990). Such coziness had an adverse impact on firms' strategic aggressiveness, probably because the lack of financial intermediaries with strong capacity for corporate governance allowed controlling families to divert funds for private use. Historical research has also stressed that Britain's industry leaders of the time viewed entrepreneurship as a way to achieve social status -- to spend their time at Ascot and Windsor -- not as a reward in itself. Since investors could still put their money in foreign public securities in the City, British firms were left without MUCH funding or outside governance. The fastest-growing firms began to express frustration with the lack of capital available to them, according to the Macmillan Committee, a feeling which had not been widespread before.

The creation of Imperial Chemical Industries (ICI) in 1926 illustrates many of these trends (Reader, 1970). ICI was the government-induced merger of two strong leaders -- Brunner, Mond and Nobel -- with two obsolete producers -- United Alkali and the British Dye Corporation -- which were saved from a very uncertain future. The merger allowed a remarkable concentration of financial resources and capital markets responded positively by providing large sums for equity issues. Centralization provided more resources for research, whose budget quadrupled within 4 years from the merger, reaching 1 million pounds -- nearly 2% of sales -- in 1930 (Hannah (1976), p.113). ICI discovered polythene in 1933, which sustained the company financially for many years. ICI was the largest spender on R&D in the British chemical industry. Courtaulds, for example, spent in R&D only around 1% of its sales (Coleman, 1969). Other firms in pharmaceuticals, like Glaxo, mainly kept improving marginally on foreign discoveries.

Yet despite these positive signs, ICI suffered from the fact that it was created with a diffused ownership, which failed to provide effective corporate governance and to induce an effective integration of constituent firms. Its inefficient central financial department failed to provide a

rigorous planning of resource allocation, both in capital investment and in research. ICI's R&D spending remained a smaller share of its sales than at I.G. Farben or Du Pont. Similarly, professional staff in R&D at ICI numbered 510 in 1941, about half that at Du Pont or I.G. Farben. The R&D to sales ratio at ICI was 1.3% in 1935 and remained at this level throughout World War II (Edgerton and Horrocks, 1994; see also Reader, 1970). But when sales halved during the depression, so did the research budget. By contrast, Germany's I.G. Farben did not cut its R&D significantly even during the depression. The depression also had a negative and lasting effect on ICI's capital expenditure, which dropped from about 30% of sales in the late 1920s to 2.6% in 1932, and remained below 10% throughout the war (Reader, 1975, appendix). ICI showed only a moderate profitability until World War II, and its return on capital fluctuated between 5% and 9%. Other than its discovery of polythene, ICI fell behind in developing new products and diversifying its product lines. Much of its revenue was indeed earned thanks to its protection from competition and easy access to large imperial markets.

The German chemical industry during the interwar period was very keen to embark on cooperation and cartelization; remember that Kreditbanken had long promoted a highly cooperative attitude among industry leaders (Da Rin, 1996). The 1905 cartel inquiry of the German Interior Ministry located 47 cartels in chemicals (Haber, 1971, pp. 267-9). In their role as creditors banks earn their profits mostly from the interest charged on loans. Therefore, their main interest is to keep their clients alive, rather than highly profitable. This is one reason why we tend to observe less competition in economies where large banks are major lenders to industrial firms, like in Germany or Japan.

Germany's Kreditbanken were badly hurt by the the German hyperinflation of the early 1920s, which shrunk the size of their financial assets. By 1927, no bank remained among the 10 largest firms. The banking industry was swept by a wave of mergers, which laid the foundations for the present system centered on the big three: Deutsche, Dresdener, and Commerzbank. However, even with the weakening of banks, an anti-competitive attitude persisted in Germany in the interwar period. Concentration of the German chemical industry reached its apex in 1926 when the big producers of organic chemicals consolidated into I.G. Farben, which took the form of "community of interests" (Interessengemeinschaften) (Plumpe, 1990; Haber, 1971). Concentration was a response of large dye makers to mounting competition from American firms. The capital of the firms which merged into I.G. Farben had

roughly doubled during World War I. Hyperinflation benefitted them, since their stocks of materials were increasing in value. For instance, in 1920 BASF stocks (in good part fertilizers) amounted to 80% of its assets. However, given the depressed state of the German economy, the liquidity of their assets shrank, so that another decrease in sales would trigger a financial crisis. Forming I.G. was a protection against that risk. Moreover, the assets of I.G. Farben grew at an average 3.5% per year in its first decade, faster than any other German chemical firm. Farben dwarfed its internal competition; it was ten times as large as the second-ranking firm, Deutsche Solvay.

The capitalization of I.G. was similar to that of ICI. One important advantage over ICI was the high depreciation rates allowed by the German commercial law, which could be very important to a capital-intensive industry. About half its initial capital was indeed funded this way. Between its enormous size and favorable depreciation treatment, I.G. was completely free from bank influence, and its base of investors was dispersed enough so that capital markets exerted little oversight. However, I.G. Farben engaged in a centralized and meticulous financial planning, which rationalized production and commercialization. Even more importantly, the firm engaged in a centrally planned effort of diversification through R&D and capital investment. I.G. Farben was far more dependent on exports than ICI, and apparently this dependence provided enough pressure on management that supplementary governance of financial intermediaries and capital markets was unnecessary. In the decade after their formation, the R&D to sales ratio was much higher at I.G. than at ICI: 9.9% and 2.4%, respectively (Haber, 1971). While in 1913 three product categories (heavy chemicals, pharmaceuticals and dyestuffs) accounted for 96% of the sales of the firms that were later to constitute I.G. Farben, by 1938 they only accounted for 51%. New products, like synthetic rubber, metals, rayon, fibers, new fertilizers and gasoline were introduced, and their development absorbed half of the capital investments from 1930 to the end of the war (Plumpe, 1991, p. 264). At this time, the German industrial research laboratories reached their fullest expression. Growing earnings sustained systematic diversification into new products, which in turn sustained further growth of earnings. As Herbert Levinstein wrote, ICI "depends for success on making comparatively few products extremely well and selling them at prices usually fixed by international agreement," whereas I.G. Farben "relies on making a large variety of substances constantly changing in the range as new products appear in the

laboratory and are taken up for large scale manufacture because they seem to have profit-making capacity" (Haber, 1971, p. 300).

It is revealing to compare the financial record of I.G with that of its leading competitors, ICI in Britain and Du Pont in the United States. The three companies were of very similar size; in 1929, the capitalization of I.G. was \$404 million, compared to \$464 million at Du Pont, and \$502 million at ICI. This ranking almost corresponded to the stock of capital equipment of the three: \$203 million at I.G., \$443 million at Du Pont, and \$ 240 million at ICI (Plumpe, 1990, p. 184-93). Du Pont and I.G. suffered from the depression in similar ways, losing about 11% of their sales a year in 1929-32, much more than ICI's loss of 1%. Later in the decade they grew at about 11% a year, while ICI at only 6%. What is most notable is that Du Pont could exploit a large and growing internal market in an era of increasing trade barriers, whereas I.G. still depended on exports for most of its sales. The creation of I.G. Farben, then, was a successful concentration of financial resources in a period of high uncertainty. Moreover, Farben then shows an ability to generate high earnings, which allowed a larger outlay of R&D.

By the mid-1930s, however, the pattern of research at I.G. Farben was increasingly dictated by the government. Investments were directed towards commercially unrewarding research, especially on high pressure chemistry for hydrogenation and for synthetic rubber. While the government subsidized the immediate costs of this research, the main loss was the shift in research focus away from fundamental research, which retarded the development of polymer science and the shift to oil as feedstock.

The American chemical industry established itself in the interwar period as the most dynamic in the world. More chemical firms entered the list of top 200 U.S. manufacturers in this period than any other sector (Chandler, 1990). Like the British and German chemical industries, the U.S. industry also profited from World War I. Sales at Du Pont, for example, increased ten-fold during the war. As in Europe, firms used these resources to expand through acquisitions, plant expansion and research, which induced a self-sustaining process. Acquisitions and new research allowed diversification. Diversification provided new profits. Profits upheld further growth, expansion, and research. The stability of profits earned the industry the reputation of being "recession-proof." Indeed, 38 of the largest 45 listed chemical

companies listed on the New York Stock Exchange continued paying dividends even during the Depression, and their R&D activities were not cut back substantially.

In fact, an increased R&D effort was the basis for the growth of American chemical firms. In 1930 they employed 30% of the scientific personnel in all of U.S. industry (Chandler, 1990, p. 171). Dow, Du Pont and Monsanto all spent between 2% and 3% of sales in R&D, increasing such sums with time. Each major firm developed fundamentally new products in the 1920s and 1930s, some of which, like polymer chemistry, revealed their full potential only after World War II. Du Pont developed the commercial potential of polyethylene (which had been discovered by ICI), and Dow invented and developed polystyrene. Both became huge earners.

The American chemical industry also saw a wave of mergers and consolidations in the 1920s. Haynes (1954) estimates that 500 mergers occurred in the U.S. chemical industry in the 1920s, which gave rise to at least two large firms, Allied Chemical and Union Carbide and Carbon. Dow employed its wartime profits to acquire smaller competitors who could help in exploiting its research on by-products of ethylene and benzene. As a result of this successful policy its assets quadrupled from 1918 to 1929. American Cyanamid and Monsanto also made a number of acquisitions during the 1920s.

Du Pont provides a vivid illustration of the cycle of profits, innovation, and diversification. Du Pont grew by exploiting the wartime profits of its explosive division, systematically diversifying into new fields (Chandler and Salsbury, 1971; Hayes, 1954). In 1913 it had \$75 million assets, and 97% of its income came from explosives. By 1940 it had \$935 million assets, and less than 10% of its income came from explosives. Du Pont developed a powerful R&D capability. In the 1920s, its nitro-cellulose know-how led to viscose and acetate rayon, cellophane, synthetic ammonia, ethyl gasoline and lacquers. Synthetic ammonia required an investment of \$27 millions and 10 years of research. In the 1930s major discoveries as nylon and neoprene followed, whose cost of development was respectively about \$4.3 million and \$2.5 million, based on its nitro-cellulose know-how.¹⁶ Between 1920 and 1939, Du Pont spent \$40 million in R&D, and in the 1930s it feasted on the fruits of its 1920s research effort. Du Pont also bought 23% of General Motors with wartime profits, which gained the company both an incredible stream of dividends and a crucial strategic alliance.

However, no concentration took place in the United States on a scale equal to that of ICI in Britain or I.G. Farben in Germany. America had passed antitrust laws to discourage or block such combinations. In addition, the sheer size of the market made it difficult for any firm to become hegemonic. Du Pont, the largest American chemical firm in 1930, ranked 12th in size among U.S. companies, and there were four chemical companies among the largest 50 firms. In Britain ICI, ranking 4th, was the only industrial chemical company among the first 50 in Britain. In Germany, I.G. Farben was the second largest company. Both ICI and I.G. Farben dwarfed their national competitors, unlike Du Pont, which faced competitors like Monsanto, Dow, Allied and American Cyanamid.

The American financial system contributed to these developments of the chemical industry. Between 1927 and 1934, U.S. financial regulation was completely reshaped, opening the way for impersonal market-based finance. Three new laws were particularly important (Perkins, 1971). The MacFadden Act (1927) de facto stopped the trend towards a wider use of branch banking. The Glass-Steagall Act (1933) barred commercial banks from dealing in securities, and introduced deposit insurance, a measure which helped smaller banks, which would otherwise have been riskier. The Securities Exchange Act (1934) instituted the Securities and Exchange Commission to regulate the securities markets and their intermediaries. The first two changes limited the influence of banks and the last encouraged the use of equity and bond markets.

Thus, the chemical companies began to raise money more aggressively in equity and bond markets. This reliance of U.S. firms on non-bank financial markets dates back to before World War I, but for chemical companies, its force became apparent in the interwar years. Du Pont was the first chemical firm to raise large sums on the stock exchange; it raised \$60 million in 1915, a huge sum for the time. Dow and Monsanto issued bonds and raised equity during the 1920s. The high profitability of chemical companies had always been known, but with the consolidation of the industry in the 1920s, its riskiness was lowered and firms could find the support of outside investors. Investors had two other sources of comfort, as well. The chemical companies still remained closely held by the founders" and their families, so that as they made the transition to being controlled by professional managers (Chandler, 1990), this continued to assure close supervision and dedication to long-term company growth. In

addition, the large and powerful investment banks played an important role in brokering securities issues, and their reputations reassured outside investors as well.

A capsule financial history of Dow gives a flavor of much of what was happening in the U.S. chemical industry at this time.¹⁷ During World War I, Dow accumulated hefty profits. It distributed extra dividends (between 10% and 65%) between 1915 and 1919. Its investment in technology was sustained, as the firm diversified on the basis of its electrochemical know-how. By 1932 Dow employed 600 engineers and 100 chemists in its works and labs. Over the 1920s the closely held equity was spread over a wider public through issue of new equity, and a keen effort in publicizing the company outside its home territory. In 1929 Dow distributed 4-for-1 shares to capitalize reserves, and in 1931 it distributed shareholders \$900,000 of surplus with an extra dividend, which was repeated in 1934 (50% extra dividend). Such lavish returns were instrumental in attracting the attention of investors towards this company. By 1939 its shareholders numbered 4,211, but Dow, like Du Pont, still remained under the control of the founders.

The picture which emerges from these three countries during the interwar period is one of deep change in the nature of the industry, with the ascent of managerial companies, greater sophistication of technology and fundamental scientific discoveries. However, European financial systems seemed to provide less oversight for management, although in some cases, like I.G. Farben, the pressure of global competition provided some substitute for oversight from the financial markets.

THE MATURATION OF THE CHEMICAL INDUSTRY

For the chemical industry, the period since World War II can be divided into two very different phases. During the first phase, beginning with wartime government subsidies which supported sustained capital investment, the chemical industry grew strongly up to the oil shocks of the 1970s. Then growth plummeted, and the industry suffered from accumulated excess capacity. Moreover, the industry's rate of innovation fell during the 1960s and 1970s. By one count, of the 63 major innovations in the chemical industry since 1930, only 20 were introduced in the 1950s and 1960s and a mere three in the 1970s and 1980s (Bozdogan, 1989, p. 20). New

products which created fortunes like dyes, rayon, nylon or plastics, have no longer appeared. This reflected in part industrial maturity, but also a slack in research intensity, and consequently profits. However, this trend seems to be reversing itself since the late 1980s.

Financing Growth After World War II

For the chemical industry, two decades of intense and widespread growth followed World War II, sustained by seemingly endless economic growth. Petrochemicals, pioneered by American firms, induced a revolution in both processes and products (Arora and Rosenberg, this volume). No new major firm has emerged in the chemical industry since the 1920s; today's large diversified competitors are those who came out of the Depression, and firms which were created during this period -- whether start-ups or firms specialized in commodity chemicals or new specialties -- have played only a marginal role. One reason for this lack of large new entrants has been the capital-intensity and research-intensity of the industry, which constitute formidable barriers to entry.

Naturally, the financial sector plays an especially important role in an industry which is capital- and research-intensive. Over this time, steady growth loosened the constraints on capital allocation. This coincided with a relaxation of corporate governance in the Anglo-Saxon world, as the increase in the size of companies was not matched by increased oversight skills by financial intermediaries. Share ownership became ever more dispersed in the United States, Germany, and Britain, and institutional investors were still to come. The reduced pressure from shareholders is likely to have contributed to the slowdown in research effort, which is the basic determinant of long-term growth. However, these forces were somewhat different across countries.

In the United States, the Bank Holding Companies Act (1956) reaffirmed the American penchant for preventing banks from becoming large and powerful. External financing for firms came mostly from issue of bonds and stock, as the securities markets increased their popularity. Institutional investors like mutual and pension funds or insurance companies appeared, but still intermediated on a very small part of savings. Chemical firms tended to rely more on retained earnings than on external finance than other industries, with the notable exception of Dow. Dow proceeded in its traditional policy of high leverage and continuous

expansion of its capacity. Its debt-to-equity ratio increased with time; it was about 0.7 in the late 1940s, surpassed 1.2 in the early 1950s, then declined to about 0.4 in the early 1960s, when income was very high. By the time the oil shock struck vigorous expansion had brought it back to more than 1. High debt was used by Dow to expand capacity and achieve low production cost in commodity chemicals. The low interest rates of this period made this a profitable strategy, and the later increase in inflation reduced the real value of debt. Dow also pursued a policy of relatively high dividends; for example, its dividends doubled between 1963 and 1970.¹⁸ Other firms were more conservative. Monsanto and Du Pont, for instance, rarely experienced a debt to equity ratio higher than 0.5. The formation of conglomerates in the 1960s was much less pronounced in the chemical than in other industries, probably because the profitability of expanding within the industry made diversification into unrelated businesses seem relatively unattractive.

This period also saw a shift in emphasis from fundamental research to product development and capital expenditure, mostly due to the high reward in perfecting petrochemical processes. For instance, at Dow the ratio between R&D and sales reached about 7% in the 1930s, but after World War II slowed down to between 4% and 6%, and eventually descended to 3% in the 1960s and 1970s. At Du Pont the ratio was 7.8% in 1960, and fell to 6.5% in 1970 and to 4.3% in 1980. The lack of innovations at this time is exemplified by the dismal experience of Du Pont and Monsanto in setting up "new ventures" programs in the 1950s and 1960s. These programs aimed at nurturing entrepreneurial ventures within the company (Du Pont), or at spotting them outside and providing finance (Monsanto). However, both projects failed to deliver satisfactory results and were repealed. The primary strategic reason for this failure was a lack of connection between new ventures and firms' operational divisions (as Chandler, Hikino and Mowery maintain in their chapter).

In Britain, ICI found itself facing both low productivity and the loss of its virtual monopoly over Commonwealth markets. Its profitability was correspondingly lower than U.S. firms: trade margin over sales at ICI averaged 13.6% in the 1960s and fell to 11.7% in the 1970s, compared to 13.0% at Du Pont and 17.1% at Dow (Pettrigrew, 1985, table 8). ICI was slow at upgrading its product portfolio and at building a petrochemical base (Pettrigrew, 1985, p. 217). The long-term research effort was lower than in the United States and Germany, as its R&D to sales ratio remained below 3.5% since the 1950s throughout the 1970s.¹⁹

ICI was slow in reacting to the challenges of increased competition. One reason for its sluggishness is the mild scrutiny that this widely held company received from its shareholders. In this, Britain and the United States were similar. At this time, ICI's chairmen served a fixed term and were not held accountable for performance. Also, hostile takeovers were rare until the 1960s, when diffusion of ownership, and increased transparency of accounting requirements made it possible for bidders to bypass a company's directors and appeal directly to its shareholders (Hannah, 1974).²⁰ ICI increased its capital by retaining reserves, rather than by issuing equity or debt. Only in the 1970s, when inflation made debt very attractive, did ICI make more use of capital markets: in 1969, its debt to equity ratio was less than 0.1.

The lack of discipline induced by British capital markets can also be seen in the research-intensive field of pharmaceuticals, which currently accounts for nearly one third of total R&D investment in the United Kingdom. Glaxo was the largest British spender in R&D in the industry after the war. In 1957 its R&D-to-sales ratio was 3.3%, compared to an average of 6.3% for seven U.S. large pharmaceutical firms. The trading margin at Glaxo was 39.9%, against an 64.9% for the U.S. firms. The U.S. firms also paid higher dividends: an average of 26.3% versus 9.2% at Glaxo (Davenport-Hines and Slinn, 1992, p. 169). A similar pattern continued well into the 1960s.

In Germany, the Allied powers reorganized the German industrial system after World War II. In the chemical industry, they broke up I.G. Farben into its main constituent firms: Bayer, BASF, and Hoechst. These were among the largest German firms, and their stock listing in 1953 was an important milestone for the German equities market. However, in the years after World War II the German financial system continued to be focused around banks. The "big three" -- Deutsche, Dresdener, and Commerzbank -- suffered increasing competition from commercial, regional and savings banks, which entered into industrial lending (Edwards and Fischer, 1994). Although stock ownership became widespread in Germany, banks retained power through proxy voting, and still had close ties with their clients. Also, they still controlled capital markets, issuing most bonds themselves and using the proceedings for long-term credit.

The corporate governance structure of chemical firms has been no exception to the general German pattern. When German companies raised new capital on the stock market, they did so with support from banks. For instance, Hoechst increased its capital several times in the 1950s, raising 1 billion marks (Baumler, 1968, pp. 355-69). Funds set aside to pay future pensions were another important source of funds. At BASF and Bayer, they accounted for between 25% and 45% of equity, at times being larger as a source of funds than bonds and loans combined. However, notice that this form of finance is managed directly by the company, thus making management less accountable to outsiders.

German banks have been the controlling proxy votes for the major chemical firms, constantly representing about two-thirds of shareholders, and the vast majority of the votes. Banks have thus shielded chemical companies from hostile takeovers. Moreover, Bayer and BASF have a 5% statutory limit on voting rights, also meant to discourage takeovers. However, in Germany, the lack of a market for corporate control does not seem to have supported managerial entrenchment at this time. Research and profits were both strong (the R&D to sales ratio was between 4% and 5%), though less than for American firms. Banks seem to have acted as reasonably efficient delegates of shareholders. Several studies of the German chemical industry have found a positive effect of bank closeness to firms during the postwar period (for example, Cable, 1995; Gorton and Schmidt, 1996).

By the 1960s, the pattern of finance started shifting somewhat in Germany, away from domestic bank loans and toward alternate forms of finance. BASF and Bayer exemplify the changing pattern. BASF started using bonds in the 1960s. Now their ratio of bonds to bank credit is nearly 1:1. When loans are received, they are now much more likely to be from foreign sources, or even in foreign currencies.²¹ While monitoring by banks worked fairly well for German chemical companies during the 1950s and 1960s, this does not prove that this mechanism is superior at all times and places. It is possible that bank governance is particularly effective in times of stable macroeconomic growth, when it is possible to push management without dramatic restructuring of the corporation. However, if restructuring measures are needed, the presence of banks may make adjustment less quick and thorough than would an active stock market.

Restructuring, Stagnation and Recovery

The 1973 oil shock hit the chemical industry with dramatic force and induced a restructuring whose pattern differed in each country (as described in the chapter by Arora and Gambardella). At about the same time, financial markets in all countries were going through regulatory changes, generally in the direction of liberalization and deregulation. The interplay of the economic shock and finance had two important effects: a reduction in cash flow and a change in corporate governance.

The sudden squeeze on cash flow was due to several factors, from increased competition to reduced growth and lower operating margins. This meant that research activities were temporarily reduced, and redirected towards incremental perfecting of existing processes, rather than the development of new products (Bozdogan, 1989). While firms could partially restore profitability in this way, it was at the cost of long-term competitiveness. The major players reacted by leaving less profitable commodity markets and diversifying into high value added sectors: specialties, pharmaceuticals, and advanced materials. Financing for this changes came in good part from the sales of existing plants for commodity chemicals. This evolution of the industry, separating commodity operations from more diversified firms, made strategic sense. Commodity chemical operations resemble mature manufacturing business, in that their profitability depends more on careful management than on substantial new research and capital expenditure. Indeed, their management typically has a financial, not industrial, upbringing. This contrasts with the research and planning effort necessary to make diversified firms successful in the long run, and with the specialized knowledge of niche markets. Here is where the national stories start to differ.

American firms restructured more quickly and thoroughly than firms in Europe and Japan (Lane, 1993; Lieberman, 1990). One reason can be found in the more active and liquid American capital markets. One major tool was the leveraged or management buyout, which grew from a combination of deregulation, increasing power of investment banks, and depth of financial markets. Using leveraged buyouts, newly formed companies could issue large amounts of bonds and buy plants. The resulting extremely high debt-to-equity ratios provide management with powerful incentives to perform in the interest of shareholders (Jensen, 1989), as the menace of default leaves little room for managerial slack. Companies like Cain Chemical, Huntsman, Sterling, Vista Chemical, Aristech and others were instrumental in turning over capacity in the chemical industry along these lines. Huntsman, for example,

bought polystyrene plants from Shell and Hoechst, and Cain bought polyethylene plants from Du Pont. About 50 high-leverage restructurings took place in the 1980s, mostly in commodity chemicals like ethylene, methanol, polyethylene, PVC, propylene, and styrene (Lane, 1993). In the first half of the 1980s, Monsanto, Dow, Union Carbide, and Du Pont sold plants and businesses. In 1985 alone, Monsanto sold \$900 million of plants, and wrote off a similar amount, and Dow divested \$1.8 billion. They also issued large amounts of equity to finance part of the acquisitions and new plants which completed the move into new lines of business. Dow, for instance, doubled its equity between 1975 and 1980, and again between 1985 and 1990 (also capitalizing reserves).

Leveraged buyouts are one main instrument in the market for corporate control. The other main instrument, takeovers, had less of an impact on chemical firms. There was an unsuccessful attempt to take over Union Carbide after the Bhopal tragedy (Eccles-Crane, 1988). Allied Chemical has also been involved in an attempted takeover which, while ultimately unsuccessful, caused the company to divest itself of many of its most profitable activities. Fear of a takeover bid prompted American Cyanamid and Celanese, for instance, to buy back shares as a way of keeping stock prices high and rewarding shareholders (Derdak, 1988).

The restructuring of the U.S. chemical industry has been very successful. Profitability has bounced back. In the late 1980s, the return on equity was about 5 points higher for the major chemical firms than for the average large manufacturing corporation (Bozdogan, 1989). Moreover, R&D intensity has increased steadily, reaching historical records. At both Dow and Monsanto, for instance, it is up to about 7% of sales in the early 1990s. Since 1986, Monsanto is spending more in research than in capital equipment, which is unprecedented.

The monitoring power of America's capital markets has been fostered since the 1970s by the increasing strength of institutional investors. Until the late 1970s, the so-called "Wall Street rule" held that institutional investors would vote for the incumbent management, and if not would sell their shares, thus "voting with their feet." Pension funds, mutual funds, and life insurance companies all operated under rules that required a very passive portfolio policy as a way of diversifying risk. A basic principle of American commercial law, the legal doctrine of "equitable subordination," has also greatly contributed to keep intermediaries away from

taking active stances in corporate matters. It implies that a creditor which becomes active when his debtor becomes financially distressed loses the seniority of its claims. Regulation of institutional investors underpinned this attitude. The 1974 Employee Retirement Income Security Act had a major impact in this respect.

However, the 1980s brought a large amount of deregulation to the U.S. financial industry (Khoury, 1985). True, the McFadden, Glass-Steagall and Bank Holding Company Acts continue to prevent banks from direct involvement in corporate governance, and thus help to preserve the autonomy of professional management. However, trading of securities has become ever cheaper and intense. Several changes in legislation have favored a more active representation of shareholders and bondholders (Roe, 1994), which started weakening the traditional power of American managers. Investment and pension funds, trusts, and insurance companies now intermediate the bulk of savings. Greater activism on part of ever larger institutional investors is transforming the nature of the U.S. financial system, though the outcome remains uncertain. All large chemical companies are widely held (except for the Du Pont family). It appears that America's active financial markets are working fairly well to provide managerial oversight.

In Europe, reorganization of the chemical industry has been much slower. Here, besides government intervention and labor market rigidities, an important factor has been the lack of accountability of firms to their shareholders. In Britain this problem has been endemic. In recent years, however, Britain's financial system has seen some degree of change. Concentration in commercial banking has proceeded further. Clearing banks have been reduced to six, and have retained their specialization in short- and medium-term loans and the focus on traditional industries, which have become sectors with relatively low growth. Domestic British banks have gradually given way to other intermediaries, like building societies, pension funds, and life insurance companies. Takeovers have become more common, as active intervention of fund managers on behalf of investors. Deregulation has made equity markets more similar to the American model, and the importance of institutional investors has increased. London became the host of the Euro-currency markets, and its stock exchange greatly increased its importance at the European level.

The impact of these changes can be seen in the recent experience of ICI. ICI accumulated losses until the early 1980s, when a far-reaching reorganization finally made it suitable for a more competitive world. ICI exited petrochemicals by swapping its polythene plants with British Petroleum PVC facilities in 1982. However, it remained slow in developing new product lines. Its R&D-to-sales ratio hovered about 3% throughout the 1980s, with no change over the two previous decades. In the early 1990s, ICI split its activities between life science and chemical units, spinning-off the former into a new company, Zeneca. This separated the dynamic, research and growth-oriented activities from the more traditional and capital intensive chemical ones. (Pharmaceutical companies spend around 15% of sales in R&D, against the 5% of heavy chemicals.) The change was induced by a takeover threat first posed by the Hanson Trust in 1991. From June 1992, when the split of ICI was announced, to December 1994, the equity of the two units appreciated by 57%, more than the double of the stock market index (Owen and Harrison, 1995), and by 1996 the appreciation had climbed to 70%.

Germany's bank-centered system, which excelled at sustaining growth until the 1970s, has been less effective at helping the chemical industry adapt and maintain a high level of competitiveness in the 1980s and 1990s (Cable, 1985; Gorton and Schmid, 1996). Among German chemical companies, BASF, Bayer and Hoechst are all widely held companies whose majority of active voting rights is exercised by banks and other institutional investors. Hoechst and BASF have a strong investor (the Kuwait Investment Office and Allianz, respectively). Chemical firms have then suffered the increasing loss of accountability allowed by the system, especially in the case of BASF (see the chapter by Richards). The transition out of commodity chemicals has been longer and less thorough than in the United States. Research expenditure has fallen and remained lower for longer. At Bayer, for instance, the ratio of R&D to sales remained around 5.5% throughout the 1980s, recovering to over 7% since 1991. At BASF it has yet to recover. The profitability of German chemical firms has not increased since falling in the 1970s.

However, there are signs of evolution even in Germany's financial markets. Pension provisions and reserves are starting to play a major role. Pension provisions rose from 5% of liabilities in 1970 to 25% in 1980, and 16% in 1990. Together with securities, which now account for about 10% of liabilities, this lowered the importance of bank credit, which has

considerably fallen from the postwar levels. At BASF, for example, pension provisions have greatly increased over the years. From 7% of liabilities in 1970, they have climbed to 15% in 1980, and to 18% in 1990. Retained earnings have also become quite large, now about half the value of equity.

German institutional investors are still underdeveloped. However, new financial intermediaries are appeared and thrived. Mutual funds have been recently introduced. By 1993, 62% of the equity in German market generally was held by institutional investors, and only 29% by individuals. Nearly half of the holdings was abroad. At BASF in particular, 60% of stock was owned by institutional investors in 1995. Given the increasingly international ownership structure of the large German chemical firms, foreign fund managers have however started voicing their discontent. Some changes in management style have appeared. Kaplan (1994a) shows that in the 1980s, the turnover of at the largest German firms was no less sensitive to performance measures than in the United States or Japan. The more substantive issues -- in particular, the need to follow ICI and the American firms in splitting the bio-science and chemical businesses -- is still pending. In early 1996, mere speculation that Hoechst and Bayer are planning such steps caused an increase of 40% to 80% of their stock (Die Zeit, July 12th, 1996), which shows how much behind they had fallen. Despite these changes, it is fair to note that the German system still does much to shield firms from takeovers, and a market for corporate control had not yet developed.

In America, Britain, and Germany, the nature of corporate governance has evolved towards more attention towards shareholder value. As the chemical industry has been reshaped in recent years -- particularly through the separation of commodity from specialty chemicals -- activism of investors has become extremely important. Globalization has affected both the competition between products and the financial markets, where large diversified companies compete for capital. In a shifting competitive environment, financial markets may prove even more important in shaping the chemical industry than they have been in the past.

THE JAPANESE PUZZLE

The Japanese chemical industry was very slow to develop; in fact, Japan relied almost exclusively on imports of chemicals until early in the 20th century. Only fertilizers achieved some importance before World War I. There were many small firms. They stayed small, at least in part, because of Japan's inefficiently regulated financial system. In the late 19th century, Japan's financial system consisted of a large number of small private banks. Securities markets were virtually non-existent. The existing banks financed mainly agriculture and trade. Their endemic weakness led to various attempts to create a system of commercial banks along the U.S. pattern.²² The most notable of these attempts was the 1890 Banking Act which brought about a dual system of unit local banks and few (branched) national banks. At about this time, the Industrial Bank of Japan (IBJ) was created to engage in long-term industrial loans and to serve as a conduit for attracting foreign capital, but for some years, its activity was purely nominal. Probably the most powerful source of finance was available through the zaibatsu, which were powerful industrial conglomerates centered around trading companies which had evolved into industrial concerns (Da Rin, 1997b).

The story of the first major success story in the Japanese chemical industry illustrates the characteristics of Japan's financial system. Two entrepreneurs, Noguchi Jun and Fujiyama Tsuneichi, pioneered the adoption of electrochemical processes and founded a company called Nichitsu. However, as the growth of Japan's chemical industry was slow, retained earnings were insufficient to allow a powerful accumulation of resources. So like the American chemical pioneers, Jun and Tsuneichi experimented and tinkered, raising finance in informal capital markets, among friends, acquaintances, and rich individuals. Banks and capital markets turned them down repeatedly. To keep their independence, they also refused finance from Mitsui, one of the most powerful zaibatsu. Only when the firm had become rather established, in 1910, was it lent substantial sums by the Industrial Bank of Japan (IBJ). Ownership of their firm was very concentrated: the ten largest shareholders controlled 70% of it, and Jun himself about a quarter. In its broad outlines, this story closely resembles that of Dow or Monsanto.

During World War I -- in which Japan did not take part -- the development of Japanese heavy industry required large financial sums. The powerful zaibatsu made recourse to internal capital markets, borrowing little from outsiders. They were among the few large issuers of securities, and accounted for the greatest share of industrial capital formation. Banks also helped

Japanese industry as a whole by recapitalizing and merging. However, the Japanese financial system remained fragmented and unique. It was different from the British in that credit was often given for the long-term. It differed from the American in that it made little use of securities. It differed from the German in that banks were not universal. World War I was very profitable for Nichitsu and the smaller Japanese chemical firms. Profits ranged between 10% and 30%. During the war, the Japanese government help allowed Nichitsu to issue bonds. After the war, Nichitsu -- still the only large chemical firm in Japan -- was powerful enough to become the center of a new zaibatsu. By the mid-'20s, Nichitsu assumed a holding company structure which allowed an internal capital market to substitute for external credit. In this period large profits allowed a sustained growth of the group. In 1930 Nihon Chisso, Nichitsu's most profitable subsidiary, ranked 6th among industrial firms. At about this time, two other Japanese companies also came to engage in electrochemicals, Dai Nihon Fertilizers, and Showa Fertilizers, both parts of industrial zaibatsu. Both were financed by their holding companies, with little involvement of banks.

Apart from Nichitsu, which could depend on retained earnings, and Dai Nihon Fertilizers and Showa Fertilizers, which were part of zaibatsu, most Japanese chemical firms in the interwar period were short of resources to invest in systematic research. The few resources spent on research went to understanding imported technology. Indeed, Japan's self-sufficiency in dyes, soda ash and ammonia remained below 50% until the late 1920s. Profits were generally low.²³

Without access to capital, firms like Asahi Glass or Nihon Soda were unable to expand to an optimal scale, which only reinforced their competitive difficulties and financial weakness.

In the 1930s, the rise of new industrial zaibatsu brought the older ones to respond and invest in other chemicals, mostly fertilizers. Their firms were depending on the mining parts of the conglomerates, as they exploited coal derivatives. They also catered mostly to clients within their holding group, a factor which kept their size relatively small. Mitsui, Sumitomo and Mitsubishi opened ammonia plants. An advantage of operating within a zaibatsu was that not only did it provide group finance, but it also opened the way to issuing securities on the stock exchange, though this was possible for only small amounts. In the late 1930s, with mounting profits, most zaibatsu started purchasing technology to enter into explosives, coal tar derivatives, and dyes. The largest chemical firm, Nihon Chisso, now ranked 6th among all industrial firms. There were five chemical firms among the largest 50, and nine among the

largest 100 (Fruin, 1992, appendix). As part of the Sino-Japanese war effort, the government played an important role in fostering investment in chemicals for war purposes. This greatly stimulated the capital outlay of the industry, and by 1940, there were 18 chemical firms among the 100 largest.

Japanese financial markets also evolved in several other ways during the 1930s. The zaibatsu firms began to use cross-shareholding to avoid diluting group ties and secure stable ownership. The IJB started developing its skills as an industrial investment bank, becoming the main long-term lender to modern industries. A money market was also created after the Depression, easing the liquidity needs of banks. The banking system consolidated substantially; the number of banks in Japan fell from 1,900 in 1921, to 418 by 1936, to and 61 by 1945.

Thus, the main traits of the struggling Japanese chemical industry until World War II were the dependence on zaibatsu and the difficulty of raising enough capital -- whether through retained earnings or financial markets -- to engage in fundamental research. It is worth stressing that belonging to a zaibatsu was a mixed blessing for a chemical company. It provided access to finance and oversight of managerial performance. However, intergroup trading also restrained growth as it pressured chemical firms to stay within the span of the zaibatsu.

The end of World War II brought major changes to Japanese finance and industry. After the war, the American occupation tried to dismantle zaibatsu and reshape the financial system along American lines. Other than installing an American-style separation of the banking and securities industries, they had little success. However, their efforts did induce a change from industrial zaibatsu to financial keiretsu. Where zaibatsu were centered on a trading company, keiretsu have their core element in a bank, and are more horizontal in structure. The financial and credit markets at this time were put under tight control of the Bank of Japan, which regulated them heavily (Ueda, 1994). Securities markets were repressed. For a Japanese chemical firm, being connected to a keiretsu proved very important, as the repressed securities markets in the postwar period meant that bank financing was of foremost importance.

The financial keiretsu system, which features cross-shareholdings of large numbers of firms clustered together is parallel to, but distinct from, what has come to be known as the "main bank" system of corporate finance and governance became established.²⁴ The main bank system had its heyday in the 1950s and 1960s. It rests on close relationships between a firm and its borrowers and shareholders, which are typically financial intermediaries and other firms. This gives rise to a complex corporate governance structure, whereby a firm borrows from several banks, one of which -- the main bank -- assumes responsibility for monitoring its financial situation and for disciplining its managers. The main bank takes the largest share of the firm's loans, and assumes the burden of losses should it default. Participation of many banks in many such pooled lending agreements assures that none is tempted to disregard its obligations and save on the cost of monitoring firms. These incentives are reinforced by supervision and enforcement on part of the Ministry of Finance and the Bank of Japan. The main bank structure rested on regulation which restricted firms' access to securities markets, and thus it forced them to obtain finance through banks. Thus, the Japanese system of corporate governance was a balance among several elements, including the main bank relationships between firms and their main sources of external finance, and the cross-ownership within keiretsu.

Belonging to a keiretsu was a mixed blessing, just as belonging to a zaibatsu had been. Membership helped to assure stable growth by providing an internal market for a firm's products and shielding it from competition. A keiretsu often seeks to develop industries which can absorb production of others in the group; for instance, Mitsubishi-Monsanto Chemicals was established to provide an intra-group market for the carbide produced by Mitsubishi Chemicals. On the other hand, groups pose constraints on the growth of their firms. A successful firm cannot easily displace others in the same group, which can hamper diversification and limit growth. In times of recession and contraction of production, belonging to a keiretsu limits the possibility to consolidate or terminate businesses. Cross-group merging of complementary firms is unlikely. Intra-group mergers are also made difficult by intra-group politics. The troubled mergers between Mitsubishi Petrochemicals with Mitsubishi Kasei, and of Mitsui Toatsu with Mitsui Petrochemicals after the oil shock, are two instances of this sluggishness.

The cooperative nature of Japanese industrial organization has also influenced the growth of firms. Nakatani (1984) examines a sample of 317 manufacturing companies, including 33 keiretsu chemical firms and five independent chemical firms. He finds that over the 1971-82 period, keiretsu companies had lower profits and grew more slowly, but with less variability than independent firms. Keiretsu firms were also more indebted, a sign of easier access to bank credit. Belonging to a group also hampers the possibility to diversify. Japan has only a few diversified chemical companies -- Mitsubishi Chemicals, Sumitomo Chemicals, Mitsui Toatsu, Showa Denko, and the smaller Ube Industries -- and even these have a much narrower span than Du Pont, Dow, Bayer and BASF. The keiretsu structure has prevented firms from integrating downstream, where other firms in the group were already active. So Japanese "all rounders" are mostly petrochemical businesses.

These pressures have led Japanese firms to being smaller than their competitors. In 1954 the largest chemical firm ranked 21st among industrials, and there were eight chemical producers among the largest 100 firms. In 1973 the largest chemical firm ranked still only 18th, and there were 10 among the largest 100 (Fruin, 1992, appendix). In 1995 the firm with largest capitalization was Mitsubishi Chemicals, which ranked 65th among all corporations, and only three firms ranked in the first 100 (Business Week, July 10, 1995). This fragmentation into separate groups contributed to the low profitability of chemical firms in several respects. First, it constrained their freedom to compete in the global marketplace. Second, it directed their technical capabilities away from the exploitation of scale economies and towards high customization of products (see the chapter on Japan by Hikino et al.).

It is interesting to notice that in both Germany and Japan, the two countries with bank-centered stable ownership, the system has performed much better in times of steady growth. In Japan, for example, the 1950s saw the entrance into petrochemicals of the first four companies -- Sumitomo Chemicals, Mitsui Petrochemicals, Mitsubishi Petrochemicals, Showa Denko -- with five more firms entering in the 1960s. The backing of a strong banks and the guidance of MITI achieved a formidable result, and helped coordinating the growth of these firms. No independent firm entered this business. By the time of the the first oil shock in the 1970s, Japan had 13 major producers.

Much less effective has been the attempt by group banks and MITI to favor restructuring and withdrawal after the oil shock. The protective role of groups in Japan, meant that rival keiretsu sought to uphold their respective companies. Within the same keiretsu, rivalry between chemical and petrochemical companies made combining them difficult. Wasteful competition among companies belonging to the same keiretsu is common. When the strategic decisions regard restructuring, downsizing and diversification, the Anglo-Saxon market-based systems appear to ensure quicker managerial action. The need to subordinate the strategy of single firms to the whole keiretsu group has then penalized the speed and response of the major Japanese chemical producers. Whether this should be considered a damage to the single firm or an efficient arrangement for the group is a difficult question.

The keiretsu ownership structure has some other features in common with the German pattern, as well. In both Japan and Germany, ownership is in part in the hands of other enterprises, unlike in America. In Japan, the limit for bank of share ownership of an industrial company was for most of the period set at 10%, reduced to 5% only in 1987. By putting together a few such participations, banks and insurance companies can exercise easily control over management. Indeed such ownership patterns can be found in most industrial companies. At the same time, since few financial intermediaries own sizeable portions of equity, firms are typically shielded from hostile takeovers.²⁵ The situation contrasts starkly with the more dispersed and less stable ownership of Anglo-Saxon firms, whose shareholders are both individuals and intermediaries with small holdings.

That Japanese firms are insulated from a market for corporate control, however, does not mean by itself that their managers are exempted from discipline. The willingness of Japanese banks to discipline underperforming managers has been convincingly documented. In particular, Sheard (1994) describes in detail the structure of bank interventions in case of financial distress, and gives examples for some chemical companies: Mitsui Chemical (1966), Nitto Chemical (1965), Maruzen Oil (1963-4). In these case replacement of incumbent management with bank officials, and revision of corporate strategies were enacted. Banks remain extremely important in the Japanese economy; for example, the the ratio of bank assets to GNP in 1990 was .39 in Japan, .36 in Germany, .08 in the United States (Fortune, August 26, 1991, pp. 174-6). However, Japan has also seen in the 1980s a marked trend toward deregulation of financial markets. Powerful banks by now coexist with developed securities

markets. The four large securities houses which emerged after the war -- Nomura, Daiwa, Nikko and Yamahichi -- have increased their activities and power with time. This has weakened the main bank system as large firms have gained access to new sources of finance, both domestic and foreign.

Unlike in the Anglo-Saxon countries, though, the deregulation of securities markets has not resulted in an increased contestability of corporate governance. Operations like takeovers or leveraged buyouts have been virtually absent from the Japanese economy. This combination of more decentralized ownership and little apparent contestability of corporate control raises a concern that the accountability of corporate management may be diminished. However, Kaplan (1994b) shows that although the turnover and pay of Japanese managers are less responsive to stock prices than in America, they are more sensitive to negative earnings. Comparing Japanese and American firms, Prowse (1990) finds support for the idea that the main bank system may solve agency problems better than the American stock market. Thus, in both Japan and Germany it seems that the steps taken toward deregulation have had little deleterious impact on managerial behavior in the the 1980s, but it remains an issue to watch in the 1990s.

CONCLUSIONS

Finance matters. It is especially important in the case of chemicals, where the two main sources of success, research and capital expenditure, both require an up-front investment and the passage of time to generate profits. However, the way finance exerts its influence is less straightforward. Several points emerge from the analysis.

First, the ability to tap diverse sources of external finance has always been important in the chemical industry -- and not only at the early stages of a firm's life. Firms which could rely on large cash flows have found it easier to retain their competitive edge. The profits made during World War I promoted the leadership of several American firms, like Du Pont. Firms which find it difficult to obtain funds may see their development slowed. Early U.S. firms developed more slowly than American domestic demand partly because they could not find external

sources of finance, and so had to wait to make large investments in technology. Early Japanese firms had a similar experience.

Second, availability of capital is not a guarantee of success. The effectiveness of corporate governance is equally important, as the failure of United Alkali in Britain illustrates. Another example is the experience of the large German chemical firms during the post oil shock period, who enjoyed stable earnings but apparently felt little discipline from their investors. The source of finance does not matter much for the effectiveness of corporate governance. Bank loans, bonds, or equity may all entail good governance, but need not do so. German Kreditbanken helped the rise of the German industry, whereas British banks did not. The governance features of a financial system also changes with time, mostly due to changes in regulations. The deregulated Anglo-Saxon equity markets, for instance, have become much more watchful of shareholder value in the last two decades than they were in the postwar decades. This has pushed American firms to pursue high-return strategies more relentlessly than their European or Japanese competitors. Public policy plays an important role in this respect.

Third, the most appropriate type of corporate governance may differ for firms at different stages of maturity. The early German dye makers benefitted from the support of German banks, which allowed them to bear the enormous risks of basic research. Similarly, U.S. biotechnology firms have benefitted enormously from finance by venture capitalists. However, more mature firms require less of an infusion of financial support and more discipline for their management. The relative decline of German versus American chemical companies seems to reflect that the bank-centered German financial system may be less effective than the equity-centered American financial system at this stage of the chemical industry's development.

Fourth, the hallmarks of a country's financial system tend to persist for a long time. Some examples include the arm's length attitude of British banks and the involvement in corporate governance of German banks. The American and Japanese system have undergone more frequent changes, due to sudden regulatory shake-outs. Nonetheless, one can point in America to a continuing desire to restrain banks from a role in corporate governance, and to depend on securities markets instead. In Japan, the persistent theme has been the importance of a group

industrial structure, whether in the form of zaibatsu, keiretsu, or main bank. However, in all four countries considered here, the last two decades have witnessed a trend towards deregulation and integration of world securities markets. We should then expect some degree of convergence toward a common pattern.

Fifth, finance must be considered in combination with other features of each economic system, especially other regulations that affect competitiveness. This is most clear in the case of Japan, where the early financing of chemical firms responded to the logic of a financial system dominated by integrated zaibatsu groups. Key characteristics of this financial system have persisted in the postwar era of financial keiretsu. Until World War II the German economy was hostile to the concept of competition, and fostered collusion, which was cherished by banks. In contrast, the American financial environment, where the individuality of firms was embedded in antitrust legislation from the start of the 20th century, developed quite differently.

Financial systems change continuously, along with regulations, technical change and overall economic development. Since no financial system is well-suited for all places and situations, it is important to encourage flexibility in the design of financial markets, so that they can evolve to support the changing needs of the economy.

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1. On the history of the British financial system, see Collins (1988), Cottrell (1980,1985), Kennedy (1987), Kindleberger (1984), Michie (1987), Nevin and Davis (1970), and Thomas (1978).

2. Collins (1991) surveys in detail the literature on the British industrial decline during the Victorian times. Kennedy

(1987, ch. 5) argues for a bias of British markets towards "safe" securities. He argues that capital market imperfections made it rational for investors to avoid securities whose riskiness could not be properly understood. However, he is less convincing in providing an explanation for why such system persisted and did not evolve into a more efficient one. Nor does he provide explicit evidence of credit rationing.

3. Lischka (1985) and Reader (1970, pp. 48-55) reconstruct the firm's financial history.

4. The size of the financial intermediaries may also have been relevant. In this respect. De Long (1991) argues that the large market share of J.P. Morgan in the United States made maintaining its reputation extremely valuable. The converse was true in Britain, where financial promoters were many and small, and had a high incentive to grab the money and run, a behavior which was frequently observed.

5. On the development of German industrial finance, see Balderston (1991), Da Rin (1996), Feldenkirchen (1991), Francke and Hudson (1984), Hardach (1984), Kindleberger (1984), Pohl (1984), Riesser (1911), Tilly (1967), and Wellhöner (1989).

6. Regulations were important in this respect. The Bank of England refused to extend refinancing to banks experiencing liquidity problems. On the contrary, the Prussian central bank adopted a liberal discounting policy, which helped German banks to offer long-term, illiquid loans.

7. Jeidels (1905, p. 170) reports data for 1903. The eight largest Kreditbanken had a total of 55 corporate directorships. Not surprisingly, seats were typically proportional to the funds borrowed from banks or raised as securities issues.

8. Baumler (1968) has a detailed account of the financial history of Hoechst.

9. From 1850 to 1906, the German chemical industry raised about 750 million marks of capital for joint-stock companies. They were evenly divided between about 100 firms in heavy chemicals, coal tar derivatives, dyes and fertilizers, and about 100 firms in rubber, explosives, organic colors and specialty chemicals.

10. On the American financial system, see for example, Carosso (1970), Fischer (1968), Goldsmith (1958), Nevin and Sears (1953), and Sylla (1975).

11. In 1900 there were 3,731 national banks and 4,369 state banks (White, 1983, p. 13), but only 87 had branches (Fischer, 1978, p. 35).

12. The following analysis is based also on the financial historical files conserved at Dow's Post Street Archives.
13. Hercules was formed in 1912 with an extremely high (1:1) capital-debt ratio. Debt was owned by Du Pont, and was reabsorbed in two years by issuing new equity. From then on the quick growth of Hercules was financed mostly from retained earnings (Dyer and Sicilia, 1990, pp. 76-7).
14. Hounshell and Smith (1988, app. III) have a complete list of Du Pont's acquisitions.
15. By comparison, at these dates, food and drink had 17, 9 and 17 firms among the largest 50, and textiles 12, 9 and 6 firms.
16. Hounshell (1988) provides a detailed study of Du Pont R&D strategy over time.
17. The following analysis is based on the financial historical files conserved at Dow's Post Street Archives.
18. Dow Chemical - PSA File 00624.
19. In a recent analysis (Department of Trade and Industry, 1996), Richard Freeman of ICI writes that UK companies and sectors of industry continue to underinvest in R&D compared with other industrial companies. The new ICI, for example, spent only 1.8% of sales on R&D, compared with what would normally be in the range of 3-4% for heavy chemical companies of this size in other nations. This has been historically true, going back to the days of ICI and I.G. Farben.
20. Ironically, ICI launched one of the first (unsuccessful) hostile bids in 1961, for Courtaulds. The bid alone made Courtaulds' shares appreciate by about 70%. However, the move was criticized as "un-British" by both firms' financial advisors (Morgan Grenfell and Barings), and by the Church Commissioners, a large shareholder of both companies.
21. Loans show the increasing internationalization of BASF, which by 1994 had obtained seven syndicated loans for 1.9 million marks, one loan for 60 million Swiss francs, and six loans for \$880 million. Ten loans were raised for \$1,320 million, one loan for \$40 million Canadian dollars, three loans for 300 million Swiss Francs, one loan for 100 million French francs, and three loans for 240 million marks.
22. For an in-depth discussion of the development of the Japanese chemical industry, see the chapter by Hikino et al. in this volume. In addition, the early development of chemicals in Japan has been carefully reconstructed by Molony (1990). Pressnell (1973) and Goldsmith (1983) provide a good account of the development of Japanese finance.

23. Miyajima (undated) reports the large losses of several firms -- especially in dyes -- during the 1920s. Dependence on exports was common to most sectors.

24. A complete and thorough analysis can be found in the collection of studies edited by Aoki and Patrick (1994).

25. The average of the top five holders for the 14 Japanese largest firms between 1967 and 1992 was 19% (Roe, 1993, table 3).