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Introduction

When World War II ended in 1945, the damage to German cities and industry had been so severe that most observers, whether Allies or Germans, realized that the country's economy was on the verge of collapse. Nonetheless, already in the 1950s commentators had begun to notice the West German *Wirtschaftswunder,* its ''economic miracle,'' which led to rapid growth into the 1960s; the West German economic performance since then has evoked both admiration and envy. Macroeconomic explanations for the miracle abound,[1] as well as for the continuing West German ability to compete in world markets. Yet decisions at lower levels – by politicians, bureaucrats, businessmen, consumers, and others – clearly had significant impacts on that macroeconomic performance, and we still know very little about the processes of economic and technological change that occurred at the level of the various industries, with the possible exceptions of coal and steel.[2]

[1] Much of the literature on the economic miracle is cited by Rolf Dumke, ''Reassessing the *Wirtschaftswunder:* Reconstruction and Postwar Growth in West Germany in an International Context,'' *Oxford Bulletin of Economics and Statistics* 52(1990):451–91.

[2] Studies of heavy industry include the following: Werner Abelshauser, *Der Ruhrkohlenbergbau seit 1945. Wiederaufbau, Krise, Anpassung* (Munich: Beck, 1984); Volker Berghahn, *The*

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The West German chemical industry deserves attention in this regard. Like other industries, it was severely affected by the war, but rebounded quickly from those effects. It performed especially well in export markets, which were essential bases for the economic miracle. Unlike the heavy industries, the chemical industry was research-intensive, like many others that helped account for the impressive West German economic performance in the postwar period.

Why was the West German chemical industry able to recover from the effects of the war and perform so well in world markets in the postwar period? Part of the explanation is institutional, because in the aftermath of the war the Allies divided the most important German chemical firm, Interessengemeinschaft Farbenindustrie Aktiengesellschaft (variously referred to as I.G. Farbenindustrie A.G., I.G. Farben, or the I.G.), into component parts that were much more rational and competitive.[3] But one of the most important factors in the success of West German chemical firms in the postwar period was a major technological change: their gradual transition from traditional, coal-based chemistry to modern petrochemical technology.

This book investigates the causes, course, and consequences of that major change in West German chemical technology, covering the period from the German defeat in 1945 through 1961, the year in which petroleum replaced coal as the industry's primary starting material, or feedstock. My major concern is to examine why and how the transition from coal chemistry to petroleum chemistry occurred in West Germany as well as the political, economic, and cultural impacts of that technological change. This book thus examines the factors that led key chemical firms to opt for petrochemical production, the basis on which the chemical industrialists chose among the competing technologies, the process of technology transfer (primarily from the United States and Great Britain to Germany, but also the reverse), and the trends in German research, production, investment, and marketing after the war. In addition, I argue that it is impossible to explain the technological developments in the chemical industry between 1945 and 1961 without exploring a number of other areas, including corresponding changes in the West German and worldwide political economies during the same period, as well as German traditions regarding technological change. Neither the changeover to petroleum-based feedstocks nor the pace of the transition was inevitable; rather, both depended on choices made by politicians and industrialists within the context of the political economy of the 1950s, as well as the context of prior German experience.

Few technological developments have had greater impact on the daily lives of people in this century than those in the chemical industry. Large-scale production of chemicals and new applications for plastics, coatings, adhesives, syn-

Americanisation of West German Industry, 1945–1973 (Cambridge University Press, 1986); John Gillingham, *Coal, Steel, and the Rebirth of Europe, 1918–1955: The Germans and French from Ruhr Conflict to Economic Community* (Cambridge University Press, 1991); Mark Roseman, *Recasting the Ruhr, 1945–1958* (New York: Berg, 1992).

[3] See Raymond G. Stokes, *Divide and Prosper: The Heirs of I. G. Farben under Allied Authority, 1945–1951* (Berkeley: University of California Press, 1988).

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thetic fibers, and a host of other products have literally transformed our material world. Proponents of the industry argue that all this has improved our standard of living by extending the range of products available and making them less expensive; critics point to the environmental costs of the industry's development and to the alleged cheapening of mass tastes. But neither side would deny that chemistry has fundamentally altered the way we have lived during the course of this century.

The startling expansion in the range and quantities of chemical products owed much to a change in the industry's preferred feedstock, from coal to petroleum. The first moves in that direction came in the early 1920s in the United States, when Carbide and Carbon Chemicals Company, a subsidiary of what later became Union Carbide Corporation, began production of ethylene glycol from ethylene. Expanded output of gasoline to meet the needs of the growing number of automobiles on U.S. roads led to an increase in the availability of olefins, which were by-products of the refining process and served as feedstocks for chemical manufacturing. Research by both chemical and oil companies led to new products and processes to utilize the increased output, and wartime demand for various materials such as explosives, synthetic rubber, and other substitute materials stimulated the petroleum-chemical industry still further. Postwar demand showed no signs of slackening. Between 1940 and 1950, the industry's output quadrupled. By 1955, more than 25 percent of all organic chemicals in the United States were produced using petroleum feedstocks, and they were being called "petrochemicals." On the eve of the oil crisis of 1973–4, the petrochemical share of the worldwide production of organic chemicals had grown to about 90 percent. What is more, by replacing coal with petroleum as its premier feedstock, the industry was able to produce goods in far greater quantities than would have been possible using only the traditional sources of coal-based feedstocks.

The German chemical industry, which led the world in output and technological sophistication through the 1920s, at first did not share in the new developments. Bound by tradition and (in the 1930s) by government policy to use their abundant supplies of domestic coal, German manufacturers, led by the giant combine I.G. Farbenindustrie A.G., fell far behind their U.S. counterparts in petrochemical technology. The German industry's relative technological backwardness ranked alongside the wartime destruction, the disruption of traditional production relationships (because of the division of Germany), and the breakup of I.G. Farben as key problems facing the industry during the immediate postwar years.

Still, West German industrialists representing the successors to I.G. Farben moved quickly during the 1950s and 1960s to replace coal-based feedstocks with petroleum-based feedstocks. By 1961, more than 50 percent of all organic chemicals in the Federal Republic of Germany were produced from petroleum, up from just 15 percent in 1950; in 1964, the proportion rose to 69 percent. As a result of that transition, West German firms regained a competitive position in international markets; by the 1970s, the I.G. Farben successors Badische Anilin- und Soda-Fabrik (BASF), Bayer, and Hoechst all ranked among the world's top

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five chemical producers. Its embrace of petrochemicals thus enabled the organic chemical industry to contribute substantially to West Germany's economic miracle and to the country's continuing economic success.

What would prompt the West Germans – or anyone else – to change from coal-based to petroleum-based feedstocks? Most commentators find the reason too obvious for lengthy comment. A. L. Waddams, for instance, in the third edition to his handbook on the petrochemical industry, put it simply: "the reason for the development of chemicals from a petroleum source as an alternative to, or at the expense of, other sources, is an economic one."[4] In his history of the rise of the petrochemical industry, Peter Spitz makes a similar point, stressing that all companies in all countries that wanted to remain competitive were forced to follow suit once U.S. pioneers in the industry began the transition:

> It didn't matter that coal, alcohol, crude oil, or natural gas could all be transformed into many of the same organic chemicals. The important thing was that this could be done most inexpensively from feedstocks derived from petroleum or from . . . natural gas. . . . When these materials became abundantly available, coal and alcohol chemistry was no longer economically viable for the production of commodity organic chemicals . . . [T]he future of organic chemicals was going to be related to petroleum, not coal, as soon as companies such as Union Carbide, Standard Oil (New Jersey), Shell, and Dow turned their attention to the production of petrochemicals.[5]

These and many other commentators on the industry's development have found the process of that technological change less interesting than the virtues of the new technology. For them, the move from coal- or alcohol-based chemistry to petrochemistry appears to have been preordained, given the overwhelming cost advantages of petrochemical production. There were some international variations in the adoption of the new technology, as well as differences between companies, but they had to do primarily with how quickly a country's industry or a particular company could accept and act upon the inevitability of the change.

In the long run, petrochemical production was indeed less expensive, in most cases, than coal-based chemical production. However, stressing this long-term conversion to the exclusion of shorter-term developments can obscure several significant factors, as a closer look at the West German case will make clear. For one thing, such an interpretation implies that the transition from coal-based to petroleum-based chemistry was inevitable and, furthermore, that the future development of the industry must already have been obvious in the late 1940s and early 1950s to any reasonably informed observer. But in fact, from the perspective of those years, the fate of coal chemistry was far from evident; even in the latter half of the 1950s it continued to dominate worldwide production methods and to provide apparently viable alternatives to petrochemicals. Even in the United States, where the petrochemical industry was most advanced, about three-fourths of all organic chemicals were produced using coal or alcohol feedstocks in the mid-1950s. Petrochemicals had made inroads primarily in what be-

[4] A. L. Waddams, *Chemicals from Petroleum: An Introductory Survey*, 3rd ed. (New York: Wiley, 1973), p. 295.

[5] Peter Spitz, *Petrochemicals: The Rise of an Industry* (New York: Wiley, 1988), p. xiii.

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came known as "commodity chemicals" (such as ethylene and propylene) and were especially important for the rapidly expanding plastics industry, but production in other areas, such as dyes, pharmaceuticals, solvents, and detergent intermediates, continued to be dominated by coal-based feedstocks, especially in Europe. Most European benzene, for instance, continued to be produced from coal through the mid-1960s.[6]

What is more, through the early 1960s there were alternatives to petrochemical production. Acetylene-based chemistry, for instance, was developed first and most extensively by BASF's Walter Reppe; it relied on carbide produced from coal, and it seemed particularly promising in the late 1940s and during the 1950s. Chemistry based on acetylene began its relative decline only in the 1960s, when U.S. chemical firms developed methods for producing acetylene from petroleum and found a number of alternative routes to manufacturing some of its products. In addition, another older German chemical process, the Fischer-Tropsch process, could use either coal or natural gas to produce chemical feedstocks. That process was modified during the late 1940s and 1950s and also seemed a promising alternative to petrochemicals.[7] In West Germany, Fischer-Tropsch plants continued to produce "petrochemicals" from coal into the early 1960s.

The persistence of Fischer-Tropsch plants, despite the inroads made by petrochemicals, brings up a second shortcoming of the interpretation that would stress the inevitable triumph of petrochemical technology. By focusing only on the success of petrochemicals, it neglects technological developments in the coal-chemical industry, in effect implying that it came to a standstill. In West Germany, however, innovations in coal-based processes continued throughout the 1950s and into the 1960s. Reppe chemistry remained vital to BASF's research effort into the 1960s, for instance. One of the Fischer-Tropsch facilities, in part owing to its research-and-development effort, was able to move into lucrative niche markets, producing those chemical raw materials and intermediates from coal that could not yet be produced from oil.

One key reason for the persistence of the coal-based chemical industry in the face of the apparently overwhelming superiority of petroleum-based processes was that coal chemistry was part of a distinguished industrial tradition in Germany. Producing petrochemicals would require that German chemists and industrialists begin to think in ways completely different than they had before. There were differences, for example, in terms of the optimal scale for an industrial plant, with petrochemical plants generally being much larger than coal-chemical facilities. In addition, the security of the feedstock supply became a much more difficult issue, because petrochemicals required reliance on overseas sources of oil, rather than on domestic coal. The Suez Crisis of 1956, occurring just as major West German firms were moving into petrochemical production on a large scale, brought home the potential dangers of such a course. Design traditions also had to change, because the new technology required that German

[6] Waddams, *Chemicals from Petroleum*, pp. 4–6.
[7] Melvin J. Astle, *The Chemistry of Petrochemicals* (New York: Reinhold, 1956), p. 5.

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designers – who were trained primarily as chemists – abandon their traditional regard for "elegance," that is, for processes in which the theory was well understood and the highest possible yields were obtained. Instead, they had to learn to concentrate on the most direct path to the final product (which often was poorly understood theoretically and yielded far less product), relying on recycling of part of the reactant to increase yields.[8] It took time to alter habits that had led to such success from the 1860s through the 1940s, especially when the new alternative did not yet appear suitable for all types of organic chemical manufacturing.

An additional shortcoming of the emphasis on economic determinism is that it simply assumes, rather than describing or explaining, the process of technology transfer. The focus here is, instead, on the existence of alternatives, which makes the details of the technology transfer more vital, because the range of choices is seen to have been so much wider. Again, concentration on the West German experience is instructive because it illustrates the complexities of the transfer process. Not surprisingly, key West German firms sought out British and American oil and chemical firms to supply them with petrochemical feedstocks and technology. For instance, in 1955, BASF, in cooperation with Shell, established the first plant in Germany dedicated entirely to petroleum feedstocks, and Bayer and British Petroleum (BP) opened their plant at Dormagen in 1958. Both firms sought out American engineering companies to help them begin petrochemical production.

What is surprising is the extent to which the transfer process operated in the other direction, that is, the degree to which German firms – which were behind their American counterparts in petrochemical technology – had something to offer foreign (especially American) companies. American petrochemical producers showed considerable interest in Reppe's acetylene chemistry, the products of which often proved impossible to reproduce when starting from the less expensive petrochemical products. Representatives of U.S. chemical companies, hoping to use natural gas rather than coal to produce acetylene, were therefore extremely interested in Reppe chemistry. In addition, U.S. firms, which had extensively automated the production of chemicals in their large-scale factories, used centralized laboratories for product analysis and hence were interested in the complementary plant-stream analyzers pioneered by the Germans to allow on-the-spot analysis of product.[9]

[8] Waddams, *Chemicals from Petroleum*, pp. 12–13. Waddams claims that, in general, those working for established chemical companies found it difficult to make the conceptual switch necessary for the new technology. Petroleum producers, in contrast, were relatively unencumbered by that traditional regard for "elegance." Peter Morris makes a similar point with regard to the choice of feedstocks for synthetic rubber at I. G. Farben in the late 1920s and 1930s: "The Development of Acetylene Chemistry and Synthetic Rubber by I. G. Farbenindustrie Aktiengesellschaft, 1926–1945" (dissertation, Oxford University, 1982), pp. 197–8.

[9] M. H. Bigelow (Plaskon Division of Libbey-Owens-Ford Glass Co.), a technical investigator who studied Germany's wartime technological advances in the aftermath of the conflict, conveyed the American excitement in "Reppe's Acetylene Chemistry," *Chemical and Engineering News* 25(1947):1038–42. Some firms later acted on the matter. Monsanto was one; material on their negotiations with BASF is in BASF Unternehmensarchiv, Ludwigshafen (hereafter, BASF),

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The ability of West German firms to offer technology that would appeal to their U.S. counterparts even during the 1950s brings up another important point. On account of this, West German companies possessed substantial bargaining power vis-à-vis foreign corporations, and the evidence indicates that they used it to wait for the best available deal. Bayer managers, for instance, were able to keep BP waiting in the wings on a proposed joint petrochemical deal while they negotiated with Esso. When, in 1954, after a number of years, the Esso deal fell through, BP was still waiting and quickly came to terms with Bayer on a joint venture. Shell's representatives sought out cooperation with BASF in the petrochemical field as early as 1948, but BASF managers chose to wait until 1952 to engage in the detailed negotiations that led to the creation of a joint venture in 1955.

This exploration of the competing technologies, the possible alternative paths of development, and the complex process of technology transfer draws evidence from a wide range of sources and speaks directly to a number of issues raised in several different but complementary bodies of literature. This book focuses, for example, on technological change, and in the process addresses a number of questions central to the history of technology. How decisions are reached on competing technologies, the role of the state in technological change, the process of technology transfer, the acknowledgment of real alternatives in the face of apparent technological determinism – all of these aspects of the "cultural ambience" of technological development are themes both in the contextual history of technology and in this book.[10] Various aspects of this study are also linked to themes and approaches dominant in business history, particularly in the work of Alfred D. Chandler, Jr.[11] Five of the book's chapters center on the

B4/1395 and F9/248. On acetylene chemistry's potential to produce goods that petrochemical technology at first could not, see Walter Reppe, "Die Bedeutung der Acetylenchemie für die Industrie der Kunststoffe im Vergleich mit anderen Grundstoffindustrien," *Chemische Industrie* 3(1951):602; BASF Patentabteilung, "Bericht über den Besuch der Herren Wilson und Menke der Monsanto Chemical Co. vom 15., 16. und 19 März 1951," March 29, 1951, 6, BASF, B4/1395. On plant-stream analysis, see B. Sturm, "Betriebskontrolltechnik in den USA und in Deutschland. Eine vergleichende Betrachtung über den Stand der Automatisierung," *Chemische Industrie* 7(1955):19.

[10] On competing technologies, see W. Brian Arthur, "Positive Feedbacks in the Economy," *Scientific American* (February 1990):92–9; and Arthur, "Competing Technologies, Increasing Returns, and Lock-in by Historical Events," *The Economic Journal* 99(1989):116–31. For a historical example of competing technologies, see Ian Inkster, *Science and Technology in History* (New Brunswick, NJ: Rutgers University Press, 1991), esp. p. 20. On nonlinear science more generally, see Alan Beyerchen, "Nonlinear Science and the Unfolding of a New Intellectual Vision," in Richard Bjornson and Marilyn Waldman, eds., "Rethinking Patterns of Knowledge," *Papers in Comparative Studies* 6(1988–9):25–50. The concept of competing technologies is related to, but is analytically distinct from, that of failed innovations. On the latter, see Hans-Joachim Braun's "Introduction" to a special issue of *Social Studies of Science* 22(1992):213–30. The term "cultural ambience" comes from John Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (Cambridge, MA: Society for the History of Technology and MIT Press, 1985), esp. pp. 121–61.

[11] See, for instance, Alfred D. Chandler, Jr., *The Visible Hand* (Cambridge, MA: Belknap Press, 1977); and Chander, *Scale and Scope: The Dynamics of Managerial Capitalism* (Cambridge, MA: Belknap Press, 1990).

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individual firm as the locus of inquiry and employ a case-study approach, which allows in-depth study of the decision-making process regarding technological change and technology transfer, while highlighting the similarities and differences in the experiences of individual firms.

Finally, because all too often historians of technology and business historians deal with particular technologies or firms, with little or no regard for the context in which technological changes and business decisions take place, this book relies heavily on certain issues and approaches defined in the rapidly growing literature on the history of post-1945 Germany.[12] Among the central themes that scholars in this area have identified are the following: the problems of continuity and change in German history; the origins and impact of the decision to divide Germany; the origins, unfolding, and effects of the *Wirtschaftswunder,* or economic miracle; European integration; and the changing role of the Federal Republic in the international political order.

Besides drawing from the historiography of postwar Germany, this study attempts to make a significant contribution to it. There have been few intensive investigations of the development of a single industry in West Germany since 1945, and this is one of the first to stress the role of technology in postwar German history.[13] It makes use of previously unavailable archival sources to test and refine some of the existing broad hypotheses regarding German political and economic history. The story of the changes in the chemical industry between 1945 and 1961 is particularly appropriate for this task. As mentioned earlier, the persistence of coal-chemical technology was in some respects a concrete manifestation of the persistence of ideas from pre-1945 German history that stressed economic self-sufficiency. In addition, the steadily deteriorating position of coal-based technology vis-à-vis petroleum-based technology mirrored heavy industry's steadily eroding position of power in West Germany during the 1950s and 1960s. Furthermore, coal chemistry, with its secure domestic supplies of raw materials, shared a state of tension with petrochemical technology, whose

[12] Among the large and growing literature on this subject, see, for instance, John Gimbel, *The American Occupation of Germany* (Stanford University Press, 1968); Gimbel, *The Origins of the Marshall Plan* (Stanford University Press, 1976); Werner Abelshauser, *Die Wirtschaftsgeschichte der Bundesrepublik Deutschland* (Frankfurt: Suhrkamp, 1983); Alan Milward, *The Reconstruction of Western Europe, 1945–1951* (London: Methuen, 1984); Berghahn, *The Americanisation of West German Industry;* Ludolf Herbst, *Option für den Westen. Vom Marshallplan bis zum deutsch-französischen Vertrag* (Munich: DTV, 1989); Christoph Buchheim, *Die Wiedereingliederung Westdeutschlands in die Weltwirtschaft 1945–1958* (Munich: Oldenbourg, 1990); Gillingham, *Coal, Steel, and the Rebirth of Europe;* Hartmut Kaelble, ed., *Der Boom 1948–1973. Gesellschaftliche und wirtschaftliche Folgen in der Bundesrepublik Deutschland und in Europa* (Opladen: Westdeutscher Verlag, 1992).

[13] Among the industry studies to this point are the following: Abelshauser, *Der Ruhrkohlenbergbau seit 1945;* Berghahn, *The Americanisation of West German Industry;* Gillingham, *Coal, Steel, and the Rebirth of Europe;* and Roseman, *Recasting the Ruhr, 1945–1958.* One of the few full-length studies centering on technology is by John Gimbel, *Science, Technology, and Reparations: Exploitation and Plunder in Postwar Germany* (Stanford University Press, 1990). A review of recent literature on the subject is available: Raymond G. Stokes, "Technology and the West German *Wirtschaftswunder,*" *Technology and Culture* 32(1991):1–22.

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adoption would mandate a Germany committed to export, to an integrated world economy, and to reliance on Anglo-American oil firms for supplies of feedstocks. Both the old, coal-based and the new, petroleum-based technologies were vital to the origins and unfolding of the *Wirtschaftswunder.*[14] At the same time, the ultimate ascendancy of petrochemicals is part of the reason the Federal Republic of Germany has performed so well in the international economic arena – and the political arena – since 1945.

This study combines approaches drawn from the history of technology, business history, and political and economic history. It therefore deals with a variety of issues, including German technological traditions, the traditions within individual firms, and their impact on the decisions made after 1945 in both Germanies; technology transfer in its political context; the roles of economic determinants or constraints in technological choice; and the role of the state in shaping technological development. These themes are covered in four parts, which are divided chronologically. Part I (Chapters 1 and 2) establishes the background. Chapter 1 outlines the connections between politics and technological excellence in Germany between 1860 and 1945, focusing on the organic chemical industry, and identifies some of the key elements of the German technological tradition. Chapter 2 covers the period 1945–9, when the Allies at first tried to hold Germany at a standstill politically and technologically, and then slowly moved away from such policies. Part II (Chapters 3 and 4) deals with the political economy of technological change between 1949 and 1955, when the Korean War, the negotiations on rearmament, and the reorganization of European coal and steel production gave West Germany a much stronger bargaining position not only in foreign policy but also in negotiations with foreign firms to transfer technology. At the end of that period, the Federal Republic had regained virtually full political sovereignty, and the first large-scale petrochemical facility began production.

Part III (Chapters 5–9) compares and contrasts the varied paths to petrochemical production taken by major German firms: the experiences of the major West German successors to I.G. Farben, two of which entered into partnerships with major oil producers, while a third developed petrochemical technology and feedstock production on its own; the experience of the former I.G. Farben subsidiary Hüls, which borrowed extensively from American firms for rubber production while relying heavily on the West German state for guidance in technological change; and the experiences of non-I.G. coal-chemical producers in West Germany. Part IV (Chapters 10 and 11) covers the parallels between the consolidation of the new technological regime between 1957 and 1961 and the consolidation of the new political regime, especially noticeable because of what seemed to be the increasingly obvious permanence of the division of Germany. It also surveys the importance of those changes and explores the study's main themes and conclusions.

[14] Stokes, "Technology and the West German *Wirtschaftswunder.*"

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Part I
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