

Knowledge and Competitive Advantage in the Synthetic Dye Industry, 1850–1914: The Coevolution of Firms, Technology, and National Institutions in Great Britain, Germany, and the United States

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It is London 1856. William Henry Perkin serendipitously invents the first synthetic dye while he is trying to synthesize quinine, a medicine for malaria. The nineteen-year-old Perkin leaves the Royal College of Chemistry and quickly commercializes his aniline purple dye, launching the synthetic dye industry. From that time on, the industry continues to dazzle the eye with ever new and appealing dye colors. Perkin, along with entrepreneurs from Britain and France, dominates the synthetic dye industry for the next eight years. During this period, British and French firms introduce most other innovative synthetic dyes onto the market, and they hold the largest global market share.

Contrary to contemporary predictions, however, these firms are not able to sustain their leadership position in the new industry. German firms such as Bayer, BASF, and Hoechst (some of the largest firms in the global chemical industry today) gain in market share. By 1870, Germany has about 50 percent of the global synthetic dye market. Britain falls to second place. By 1900, Germany's worldwide share climbs as high as 85 percent where it stays with relatively minor fluctuations until World War I. In the 1860s American firms try to be suc-

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cessful participants in the U.S. market but cannot compete with German and Swiss firms before World War I; they remain relatively small players or go out of business.

Any explanation of the shift in industrial leadership from Britain and France to Germany quickly becomes mired in an intriguing puzzle in which the obvious suspects have surprising alibis. Possessing cheaper raw materials or a larger home market cannot explain why German firms left British and U.S. firms in the dust, because both had more raw materials and a larger home market than Germany. Why, then, did Britain lose its leadership position? Why did the American dye industry remain so small before 1914? This dissertation takes a new tack to resolve the puzzle by engaging in a detailed historical analysis of the causes of this transition in industrial leadership.

Trying to solve the puzzle of why industrial leadership shifted during the first fifty-seven years of the synthetic dye industry contributes to two important intellectual agendas pursued by scholars in a number of different fields. Adam Smith, David Ricardo, and, more recently, Michael Porter, David Mowery, and Richard Nelson are prominent examples of a wide array of social scientists who have tried to identify the factors that lead nations and firms to prosper.¹ For economists and management researchers the question of how economic success is generated remains a key intellectual challenge.² In tracing the development of one industry within the context of three countries, I hope to make a significant contribution toward formulating a much-needed dynamic theory of industrial leadership. At the heart of the theory lies the concept of 'coevolution,' which has been employed with great success by researchers of biological³ and cultural⁴ change. Recently, ideas of coevolution have been introduced in the

1. Adam Smith, *The Wealth of Nations* (1776; New York, 1937); David Ricardo, *The Principles of Political Economy and Taxation* (1817; London, 1911); Michael E. Porter, *Competitive Advantage of Nations* (New York, 1990); and David C. Mowery and Richard R. Nelson, eds., *Sources of Industrial Leadership: Studies of Seven Industries* (New York, 1999).

2. Bruce Kogut and Udo Zander, "What Firms Do? Coordination, Identity and Learning," *Organization Science* 7, no. 5 (1996): 502–18; and David S. Landes, *The Wealth and Poverty of Nations: Why Some Are So Rich and Some Are So Poor* (New York, 1998).

3. Stuart A. Kaufmann, *The Origins of Order: Self-Organization and Selection in Evolution* (New York, 1993); John N. Thompson, *The Coevolutionary Process* (Chicago, 1994).

4. William H. Durham, *Coevolution: Genes, Culture, and Human Diversity* (Stanford, Calif., 1991); Charles J. Lumsden and Edward Osborne Wilson, *Genes, Mind, and Culture: The Coevolutionary Process* (Cambridge, Mass., 1981).

discourse on industrial leadership,⁵ technological change and economic growth,⁶ and the development of firms.⁷ What we need now is a theory that does more than explain industrial leadership at a particular time. I believe a coevolutionary theory that models firms as interacting with their social environment takes a significant step toward explaining how industrial leadership is gained and lost and how small initial differences in performance translate, in some instances, into large differences over time.

In placing national institutions and technology at the center of my analytical framework, I continue a neglected tradition that flourished around the turn of the century. Prominent social scientists such as Thorstein Veblen saw national institutions and their effects on technological development as a key to understanding why Germany, for instance, achieved higher rates of economic growth than Britain in those years.⁸ More recently, scholars from a variety of disciplines have relied on institutional accounts to explain Japan's rise to economic leadership after World War II.⁹ Nobel laureate Douglass North has argued in his recent book for the important role of institutions in shaping economic performance.¹⁰ For a long time, however, institutional arguments have been given scant attention in economic analysis. I want to help move them, once again, onto center stage and to focus attention on a critical missing piece in institutional analysis: namely, how institutions are created in the first place.

I also hope to contribute to a second important line of work that concerns itself with the rise and development of the large managerial firm as a new economic institution. The business historian Alfred D. Chandler, Jr., who has pioneered the study of the large managerial firm that appeared on the scene in the second half of the nineteenth century, identified this new organizational form as a key source of

5. Richard R. Nelson, "Co-Evolution of Industry Structure, Technology and Supporting Institution, and the Making of Comparative Advantage," *International Journal of the Economics of Business* 2 (1995): 171–84.

6. Joel Mokyr, *Neither Chance nor Necessity: Evolutionary Models and Economic History* (Princeton, N.J., forthcoming).

7. Kathleen M. Eisenhardt and D. Charles Galunic, "Coevolving: At Last, a Way to Make Synergies Work," *Harvard Business Review* 78 (2000): 91–101; Arie Y. Lewin, Chris P. Long, and Timothy N. Carroll, "The Coevolution of New Organizational Forms," *Organization Science* 10 no. 5 (1999): 535–50.

8. Thorstein Veblen, *Imperial Germany and the Industrial Revolution* (1915; New Brunswick, N.J., 1990).

9. W. Mark Fruin, *The Japanese Enterprise System: Competitive Strategies and Cooperative Structures* (New York, 1992); Michael Gerlach, *Alliance Capitalism: The Social Organization of Japanese Business* (Berkeley, Calif., 1992).

10. Douglass North, *Institutions, Institutional Change, and Economic Performance* (New York, 1990).

economic growth over the past century.¹¹ On the Chandlerian model, large firms—those run by professional managers rather than owners—came to dominate industrial activity in modern industrialized economies because they operated more efficiently by exploiting scale and scope economies made possible by cheap transportation (railroads) and communication (telegraph). The sociologists Neil Fligstein and William Roy have argued that Chandler's analysis is incomplete because it leaves out the political context in which large managerial firms originate.¹² I attempt to integrate the writings in business history and in sociology on the rise of the large managerial firm by focusing on how collective action on the part of firms molded the social and institutional environment in which firms operate. I marshal considerable evidence to show that the rise of the large managerial firm required the construction of an institutional regime that would favor such firms over other forms of organization. We shall see that German firms in the synthetic dye industry were much more successful in molding their institutional environment than their British and American counterparts. In Chandler's writing on large firms in Germany, Bayer figures prominently as an example of how a sophisticated managerial hierarchy was created that could organize more efficient production than smaller firms.¹³ Bayer could realize its economic advantage precisely because it became a key player in lobbying efforts to create a favorable institutional environment. Bayer's leaders sought prominent roles in the chemical industry trade association and participated in collective action to improve the German education system in chemistry as well as to change German patent laws to give large firms an advantage over foreign competitors and smaller domestic rivals.

One of my key propositions is that the creation of German dominance in the synthetic dye industry before World War I cannot be understood without coming to terms with successful and unsuccessful efforts regarding patent law, science funding, and tariff lobbying in the three countries.

My analysis of the synthetic dye industry shows that we need to rediscover scholarship that recognized the importance of lobbying in industrial development, such as Louis Galambos's *Competition & Cooper-*

11. Alfred D. Chandler, Jr., *Strategy and Structure: Concepts in the History of American Industrial Enterprise* (Cambridge, Mass., 1962); *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass., 1977); *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge, Mass., 1990).

12. Neil Fligstein, *The Transformation of Corporate Control* (Cambridge, Mass., 1990); William Roy, *Socializing Capital: The Rise of the Large Industrial Corporation in America* (Princeton, N.J., 1997).

13. Chandler, *Scale and Scope*, 474–81.

ation: *The Emergence of a National Trade Association* and Paul Hirsch's *Organizational Effectiveness and the Institutional Environment*.¹⁴ Comparing the fates of firms in the three countries shows that firms depended on their social environment for resources with which to prevail against foreign competitors. German firms were able to obtain more resources from their social environment than their British and American counterparts. My analysis of why German firms overtook their foreign rivals and then cemented their leadership draws on Jeffrey Pfeffer and Gerald Salancik's resource dependence theory, which highlights the political nature of creating successful organizations.¹⁵ One of the critical resources that firms in the synthetic dye industry needed to obtain was access to organic chemical knowledge and dye innovations. Because these resources were heavily concentrated at universities in the early period of the synthetic dye industry, firms needed to develop ties to university professors and their students. By examining the dependencies of a dye firm through Ronald Burt's more formal, network version of resource dependence theory, it becomes apparent that firms were competing for access to the leading organic chemists of the day.¹⁶ Those firms that were able to maintain ties to the best chemical talent out-performed rivals that were not as well connected. After working in a professor's university laboratory, chemists often moved from academia to industry, from one firm to the next, and sometimes back to a university position. This created an informal network of ties that connected players in industry and academia. Mapping the network on a worldwide scale for the period before World War I reveals not only that this informal network was overwhelmingly populated by Germans, but also that the central positions were occupied by players who came from Germany. Explaining the shift in industrial leadership in the synthetic dye industry is intimately bound up with being able to account for the strong and weak ties in what I call the academic-industrial knowledge network.

The informal network assumed a second function beyond simply transferring chemical synthetic dye knowledge. It served as a mechanism for organizing collective action. German firms engaged in significantly more successful collective action to shape domestic patent laws and university policies in part because they could rely on a much

14. Louis Galambos, *Competition & Cooperation: The Emergence of a National Trade Association* (Baltimore, Md., 1966); Paul Hirsch, "Organizational Effectiveness and the Institutional Environment," *Administrative Science Quarterly* 20 (Sept. 1975): 327–44.

15. Jeffrey Pfeffer and Gerald R. Salancik, *The External Control of Organizations* (New York, 1978).

16. Ronald Burt, *Structural Holes: The Social Structure of Competition* (Cambridge, Mass., 1992).

stronger network of actors, spanning industry, academia, and government. To be effective in orchestrating lobbying efforts, ties to high-level government officials enriched the informal academic-industrial network. Where this industrial-academic-government network was large and close-knit (Germany), collective action on behalf of the dye industry tended to succeed; where the network was small and distant (Britain and the United States), collective action was more likely to fail.

To provide empirical support for a coevolutionary view of industrial leadership, I use as units of analysis not only national industries but also individual firms. To observe in detail how national institutions helped or hurt the competitive position of domestic firms, I examine the development of two companies (one successful and one unsuccessful venture) in each of the three countries. At the level of the individual firm, a key finding is that the winners in all three countries shared one thing in contrast to the losers: they had strong ties to the centers of organic chemistry knowledge. The German firm Bayer, which was closer in social space to the central nodes of the university knowledge network, was able to establish the strongest ties to leading researchers in organic chemistry and thereby assured itself more timely access to new chemical knowledge and talent to run the firm's operations.

I am presently completing a book about my research on the synthetic dye industry before World War I, where these arguments are developed in much more detail. In chapter 2, to provide convincing evidence for my coevolutionary arguments, I analyze how differences in national institutions caused divergent economic outcomes in the synthetic dye industry of Britain, Germany, and the United States. Besides the aforementioned differences in national higher education systems and patent practices, I examine other supporting institutions such as professional chemistry organizations, trade journals, and the state. In chapter 3, I compare the strategies and the performance of the six companies, which are drawn from a newly collected data set of 379 firms. I expand the Chandlerian view of the rise of the managerial firm to include political processes stressed in the writings of Fligstein and Roy in chapter 4. In chapter 5, I assess the adequacy of existing theories to explain Germany's long dominance of the synthetic dye industry. The weaknesses in current theoretical arguments provide the basis for chapter 6, where I develop a theory that deals with both the national industry and the firm level. To avoid making coevolutionary arguments a catch-all label for the analysis of organizational and environmental change, I argue that we need to know specific mechanisms that characterize coevolution. In the final chapter, I present broad conclusions and ideas about future research on industry evolutions and firm strategy, as well as a discussion of the methods needed to go beyond our present understanding of the causes of industrial leadership.