"If evolutionary models are to be successful at all in the social sciences, it is in enhancing our understanding of technological and economic performance in the past. In this poineering work, Johann Peter Murmann does exactly that, and immediately establishes himself as one of the most innovative and bold scholars in the field. Using evolutionary theory and management science, this book sheds important light on the nineteenth-century chemical industry. This is one of the most methodologically original books in interdisciplinary history to come out in recent years."

JOEL MOKYR, Robert H. Stortz Professor of Arts and Sciences and Professor of Economics and History, Northwestern University

• • •

"Darwin not only set out his theory of biological evolution at some length but also provided as much empirical backing as was available at the time. In this remarkable book Johann Peter Murmann sets out a general analysis of coevolution and provides a detailed example to back it up – how quickly the discovery of synthetic dyes by an academic scientist gave rise to an industry that in turn influenced the development of academic science. Murmann provides a well-developed theory and evidence to support it. Who could ask for more?"

DAVID L. HULL, Professor of Philosophy (Emeritus), Northwestern University

• • •

"Johann Peter Murmann's book is a major contribution to our understanding of the interrelations between technological change and industry evolution. This comparative study of the emergence of the synthetic dye industry wonderfully illustrates how differences in public policy, university traditions, and industry context affect both technical as well as industrial change. Murmann's book will have a major impact on coevolutionary theory as well as industrial policy. It is a book for researchers as well as for policy makers."

MICHAEL TUSHMAN, Paul R. Lawrence, Class of 1942 Professor, Harvard Business School

• • •

"Murmann's admirable book provides the most persuasive account, to date, for Germany's early leadership and long dominance of the synthetic dye industry after the momentous, serendipitous scientific discovery by a young Englishman in 1856. It is an account that employs a sharply focused, coevolutionary lens upon the differing historical experiences of Germany, Great Britain and the United States. The book calls attention to the ways in which the earlier development paths of the German states had equipped them, much more effectively than their potential competitors, to exploit the specialized research tools of synthetic organic chemistry, upon which commercial success was to become heavily dependent."

NATHAN ROSENBERG, Professor of Economics (Emeritus), Stanford University

• • •

"Johann Peter Murmann's book shows convincingly that competitive advantage, especially in the knowledge-intensive industries, is firmly rooted in national institutions. Blending quantitative analysis and case study evidence over a period of decades, he makes a major contribution to the fields of strategic management, organizational theory, and technological innovation."

MAURO F. GUILLEN, Dr. Felix Sandman Professor of International Management, The Wharton School, University of Pennsylvania

• • •

Knowledge and Competitive Advantage

Entrepreneurs, managers, and policy makers must make decisions about a future that is inherently uncertain. Since the only rational guide for the future is the past, analysis of previous episodes in industrial development can shape informed decisions about what the future will hold. Historical scholarship that seeks to uncover systematically the causal processes transforming industries is thus of vital importance to the executives and managers shaping business policy today. With this in mind, Johann Peter Murmann compares the development of the synthetic dye industry in Great Britain, Germany, and the United States through the lenses of evolutionary theory. The rise of this industry constitutes an important chapter in business, economic, and technological history because synthetic dyes, invented in 1856, were the first scientific discovery quickly to give rise to a new industry. Just as with contemporary high-tech industries, the synthetic dye business faced considerable uncertainty that led to many surprises for the agents involved. After the discovery of synthetic dyes, British firms led the industry for the first eight years, but German firms came to dominate the industry for decades. American firms, in contrast, played only a minor role in this important development. Murmann identifies differences in educational institutions and patent laws as the key reasons for German leadership in the industry. Successful firms developed strong ties to the centers of organic chemistry knowledge. As Murmann demonstrates, a complex coevolutionary process linking firms, technology, and national institutions resulted in very different degrees of industrial success among the dye firms in the three countries.

Johann Peter Murmann is Associate Professor of Strategic Management at the Australian Graduate School of Management. He is on the editorial board of the *Journal of International Business Studies* and is the editor of *Evolutionary Theories in the Social Sciences.*

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Knowledge and Competitive Advantage

The Coevolution of Firms, Technology, and National Institutions

Johann Peter Murmann

Australian Graduate School of Management

CAMBRIDGE UNIVERSITY PRESS

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32 Avenue of the Americas, New York NY 10013-2473, USA

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9780521813297

http://johann-peter.murmann.name

First published 2003
Reprinted 2004
First paperback edition 2006

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Murmann, Johann Peter, 1967–
Knowledge and competitive advantage : the coevolution of firms, technology, and national institutions / Johann Peter Murmann.
p. cm. – (Cambridge studies in the emergence of global enterprise)
Includes bibliographical references.
ISBN 0-521-81329-8 (hc.)
1. Dye industry – Germany – History. 2. Dye industry – Technological innovations – Germany – History. 3. Dye industry – Great Britain – History. 4. Dye industry – United States – History. 5. Competition, International – Case studies. 6. Comparative advantage (International trade) – Case studies. I. Title. II. Series.
HD9660.D843G35 2003
338.4′76672 – dc21 2003043048

ISBN 978-0-521-81329-7 Hardback
ISBN 978-0-521-68415-6 Paperback

For the one who knows my gratitude

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Series Editors' Preface

By blending historical evidence with evolutionary economic theory, Johann Peter Murmann enhances our understanding of economic change and helps us see why firms and nations prosper or fall under the pressure of competitive capitalism. Central to this process in the Second Industrial Revolution was the ability to apply scientific knowledge to industrial processes in the electrical and chemical industries. Murmann surveys with great care the early development of one of those industries, synthetic dyes – an often-told story, but now placed in a new and exciting comparative context. Great Britain had the early lead in dyestuffs, but Germany parlayed a powerful scientific establishment and aggressive entrepreneurial firms into a successful challenge. Favored by its unique research institutions and patent laws, the German industry was able to lobby the government to strengthen its position even more. Coevolution of firms and national institutions was at the heart of a process that had important ramifications for the political economy of Europe and the United States in the nineteenth and twentieth centuries. Firms maintaining strong links to the relevant scientific networks prospered; their competitors gave way.

Murmann's dynamic model of this process should be of great interest to economic and business historians, economists, and scholars analyzing business management and strategy in the modern era. We are pleased to publish this innovative study as the second volume in our series, *Cambridge Studies in the Emergence of Global Enterprise*.

Louis Galambos, Johns Hopkins University

Geoffrey Jones, Harvard Business School

Author's Preface

Synthetic dyes represent the first time when a scientific discovery quickly gave rise to a new industry. In 1856, the nineteen-year-old William Henry Perkin serendipitously invented the first synthetic dye and successfully commercialized his discovery. Perkin, along with entrepreneurs from Britain and France, dominated the synthetic dye industry for the next eight years. Contrary to contemporary predictions, however, these firms were not able to sustain their leadership position in the new industry. By 1870, Germany had about 50 percent of the global synthetic dye market; Britain fell to second place. By 1900, Germany's worldwide share climbed to as high as 85 percent, where it stayed with relatively minor fluctuations until World War I. In the 1860s, American firms tried to be successful participants in the U.S. market, but they could not compete with German and Swiss firms before World War I and remained relatively small players or went out of business.

Adam Smith (1776) and David Ricardo (1817) and more recently Michael Porter (1990) and David Mowery and Richard Nelson (1999) are prominent examples of a wide array of social scientists who have tried to identify the factors that lead nations and firms to prosper. This book follows that tradition. In tracing the development of one industry within the context of three countries – Great Britain, Germany, and the United States – during the period from 1857 to 1914, I attempt to make a contribution toward formulating a much-needed dynamic theory of industrial leadership.

Frequently, enterprise, technological, and economic developments are examined in separate studies. In this book I bring together these different literatures and investigate an important chapter in business, economic, and technological history. I argue that a complex evolutionary process led to very different degrees of industrial success by dye firms in Britain, Germany, and the United States. Based on the empirical findings, this monograph articulates a dynamic model of competitive advantage that has at its center coevolutionary processes linking firms and national institutions.

The study identifies differences in educational institutions and patent laws as the key reason for the long-lasting German leadership position in this industry. When the German synthetic dye industry had pulled ahead of its foreign competitors, its superior performance allowed it to lobby government agencies to enhance educational institutions and patent regulations, creating a cumulative spiral of competitive advantage. To observe in greater detail how national institutions help or hurt the competitive position of domestic firms, I also analyze the performance of individual firms, examining the development of two synthetic dye companies (one successful and one unsuccessful venture) in each of the three countries. At the level of the individual firm, a key finding is what the winners in all three countries shared in common: In

contrast to the losers, they had strong ties to the centers of knowledge about organic chemistry.

Many activities compete for our scarce attention. Because not everyone will have the time to read this book from beginning to end, I have designed Chapter 1 to provide a summary of the entire monograph. The sections in the introductory chapter that present an outline of evolutionary theory are a bit technical for the general reader, but the empirical analysis presented in Chapters 2 through 4 will be readily accessible to a wide scholarly audience. Readers who are most interested in the national industry level of analysis can skip Chapter 4, which presents detailed case studies of six individual firms. In contrast, this chapter will be most valuable for management scholars and business historians who look for thick descriptions of how firms actually develop over time. Those who are mainly interested in my articulation of coevolutionary theory of industrial development may want to jump directly to Chapter 5, where I spell out in detail how the national synthetic dye industries of Britain, Germany, and the United States coevolved with dye technology and national institutions. My hope is that Chapter 1 or Chapter 5 will stimulate many a reader to work through the rich empirical study of the synthetic dye industry between 1857 and 1914 that I present in Chapters 2 through 4. Enjoy!

Some of the ideas and empirical facts presented in this book have been published previously in articles and book chapters. Part of the demographic data on national firm populations appeared in the *Journal of Evolutionary Economics* (Murmann and Homburg, 2001). Some facets of the evolution of synthetic dye technology were described in a section of a chapter on the institutional foundations of entrepreneurship published in the edited volume *The Entrepreneurial Dynamic: Origins of Entrepreneurship and its Role in Industry Evolution* (Murmann and Tushman, 2001). A less detailed comparison of the British and German educational systems from 1857 to 1914 was published in a section of a chapter in the edited book *Chemicals and Long-Term Economic Growth* (Murmann and Landau, 1998). More information on these and other of my publications can be found at http://johann-peter.murmann.name.

Acknowledgments

What started out as a dissertation project at Columbia University now lies in your hands as a substantially revised, expanded, and more sharply articulated book. Although only my name appears on the cover, I want to acknowledge here that many people aided me in the course of analyzing the synthetic dye industry, which served as my laboratory for understanding a bit better the role of organizations in the economy. I would like to thank all of you who helped me to tell the beginning of what I believe to be an important investigation of how one of the first science-based industries developed. In particular, I would like to express my gratitude to the people who were most directly involved in the creation of this study.

As anyone who is familiar with his work will readily discern, **Richard Nelson** has left the greatest mark on this book. My study undoubtedly is much better because of his advice and encouragement. He was a superb counselor in writing a book that crosses terrains of literatures that were previously separated by disciplinary boundaries. Thanks, Dick!

Charles Tilly thought that I had a very promising book manuscript when he saw an early version of my study. Tirelessly and with breathtaking speed, he made extremely helpful suggestions on how to reorganize the early manuscript and gave useful comments on new draft after new draft. He also shared with me much wisdom about how to go about publishing a book. Chuck, merci beaucoup!

I arrived in graduate school with a plan to study social sciences broadly, but with a particular focus on psychology. This focus on psychology quickly was pushed into the background of my attention when I began to immerse myself in the literature on technological innovation as I was taking in the second semester **Michael Tushman's** organization theory Ph.D. seminar. Together with Phil Anderson, Elaine Romanelli, and Lori Rosenkopf, earlier doctoral students in the Columbia management department, Mike had done important work on the impact of technological change on the fate of firms and industries. In the middle of the term, Mike invited me to work with him on a paper that would clear up a few loose ends in the literature on dominant designs and the technology cycle. For the paper we eventually published, *Dominant Designs, Technology Cycles and Organizational Outcomes* (Tushman and Murmann, 1998), I read many historians of technology and became convinced that detailed knowledge of how individual technologies and industries developed was necessary if one wanted to build reliable generalizations. Mike, many thanks for getting me started on this. Take this book as a follow-up on the term paper. There are still some "loose ends" but not the same ones as ten years ago!

Chance favors the prepared mind. I was very fortunate that an innocuous reference led me to **Ernst Homburg**, whose knowledge of the early synthetic dye

industry is unparalleled. The sophistication of the empirical analysis I offer in these pages owes a great deal to the computer databases Ernst and I put together on all the synthetic dye firms that existed between 1857 and 1914. As will become apparent throughout the text, when I refer to our correspondence, he helped me at every turn to get the history of the dye industry right. Thank you, Ernst. Now that the book is done, I look forward to analyzing with you in more detail the synthetic dye industry database we created. I am sure that when we publish the entire database on the Internet, it will be a treasure for other scholars.

It is a particular honor and delightful experience when a distinguished senior scholar with whom you have never interacted personally responds to your request for comments on a manuscript with, "I want to publish your study in my series at Cambridge University Press!" **Louis Galambos** helped nourish the infant manuscript into a grown-up book. I thank him in particular for helping me figure out how to write the concluding chapter in a way that it will be valuable for all three groups of scholars for whom this book is primarily written: management scholars and organization theorists, business and economic historians, and evolutionary economists. I also express my gratitude to **Geoffrey Jones**, who coedits with Lou Galambos the series in which this book appears. He was an enthusiastic supporter of the early manuscript and the need to subject it to substantially more work.Two original anonymous reviewers for Cambridge University Press did me the honor of pointing out how I could remove the shortcomings of an earlier manuscript. They pushed me to better situate my work in the literature on comparative business and economic history and to articulate more forcefully my theoretical arguments and the empirical support I found for them in the synthetic dye industry. A final anonymous reviewer prompted me to articulate more clearly the purpose of Chapter 3 in the overall architecture of the book and helped ensure that my claims in that chapter did not go beyond the data I could marshal for them.

Fellow comparativist **Mauro Guillén** went far beyond the call of duty in making superb comments on generations of drafts.

My arrival at Northwestern University in 1997 brought me in close physical proximity to **Art Stinchcombe** and **Joel Mokyr**. Art did me the great service of reading the manuscript with superb care, pointing out little tautologies here and there that needed to be fixed. His sharp and experienced eyes uncovered many opportunities to improve the manuscript. As you will find in Chapter 5, Art may have unwittingly sparked in my mind a key idea for making coevolutionary arguments work in the social sciences. It took a year for Joel and me to realize that we were both working on developing evolutionary models for the development of technology and industry.

Joel's comments on the manuscript and my conversations with him in the past years – especially when I visited him on the West Coast at the Center for Advanced Studies in the Behavioral Sciences during January 2002 – have been enormously beneficial in articulating the details of my coevolutionary theory.

Many colleagues did me the honor of reading at least parts of the generations of manuscripts that I circulated. **Howard Aldrich, Robert Aunger, Thomas Brenner, Guido Buensdorf, Bruce Carruthers, Frank Dobbin, Giovanni Dosi, Leonard Duddley, David Hull, Neil Fligstein, Martin Fransman, Jeff Furman, Gerald Hage, Rogers Hollingsworth, Paul Ingram, Gregory Jackson, Margaret Jacob, Mark Kennedy, Bill Kingston, Steven Klepper, Bruce Kogut, Ryon Lancaster, Arie Lewin, Ken Lipartito, Jim March, Stan Metcalfe, Keith Murnighan, Willie Ocasio, Nathan Rosenberg, F. M. Scherer, Andy Spicer, Max Voegler, Isabell Welpe, Ulrich Witt, Hagen Worch**, and **Ed Zajac** all helped improve the book. Besides commenting on an early manuscript, Jeff Furman convinced me that a timeline of the major events in the industry would come in very handy for the reader.

The "macro" colleagues in my department – **Bob Dewar, Bob Duncan, Ranjay Gulati, Paul Hirsch, Willie Ocasio, Mike Radnor, Huggy Rao, Alva Taylor, Brian Uzzi, Marc Ventresca**, and **Ed Zajac** – not only provided me with a sympathetic ear for my historical studies in our regular seminars on work in progress but also helped me figure out how to explain the importance of my study to an audience of organizational theorists. I have benefited from the collective brainpower that has been assembled in our department. Being surrounded as well by psychologists and social psychologists – **Jeanne Brett, Adam Galinky, Deb Gruenfeld, Vicki Medvec, Dave Messick, Keith Murnighan, Kathy Phillips**, and **Leigh Thompson** – has increased my awareness of the cognitive and social psychological influences on individual decision making.

I am grateful also to the two other members who, besides Richard Nelson, Charles Tilly, and Michael Tushman, served on my dissertation committee. **Jerry Davis** and **Rita McGrath** helped me think more clearly about an early version of this study.

I wish to express my gratitude to a few others who contributed significantly to the making of this study. I was fortunate to meet **Ralph Landau**, one of the successful American entrepreneurs in the chemical industry after World War II. On retirement from business, Ralph embarked on a second career as a prolific scholar. For almost four years I collaborated with this Renaissance man of the twentieth century on the book *Chemicals and Long-Term Economic Growth* (Murmann and Landau, 1998). Ralph shared with me his vast knowledge of the chemical industry, opened doors at synthetic dye firms, helped organize funding for this project, and invited me to many a lunch at 2 Park Avenue in midtown New York City, where we discussed the fine points in the development of the chemical industry. **Anthony Travis** was the first historian of the dye industry I met at a meeting of the Society for the History of Technology in Lowell Massachusetts almost a decade ago. He pointed me to many valuable sources of information for this study. **Kathy Steen**, whom I also met at that meeting, was an invaluable help in giving me sources on the American dye industry and sharing with me her fine dissertation on the U.S. synthetic organic chemicals industry, 1910–30. At the early stage of this project **Peter Morris** and **Robert Bud** of the Science Museum in London pointed me to the literature on the chemical industry.

Writing is, on one level, a deeply mysterious process. **Joy Glazener** was so kind as to read over the different generations of the manuscript to bring it closer to what Mr. Fowler would accept as the King's English. **Tom Wyse** and **Jean Schulz** helped in earlier versions to eliminate all the little mistakes that would distract the eye of the reader. At the beginning of the project, **Richard Tilly** commented on my study proposal, giving me confidence that I had the basic facts under control.

I received financial support from many institutions. I thank **Columbia Business School** for providing me with a four-year scholarship for their doctoral program. A travel grant from the **Chazen Institute** at Columbia Business School in 1994 got this project off the ground. The **Stanford Institute for Economic Policy Research** at **Stanford University** funded me for over a year to write a study of the development of the British and German chemical industries since 1850. The **Pine Tree Charitable Trust** gave me very generous support to collect data on the synthetic dye industry and complete my dissertation. The support of the **Kellogg School of Management** at **Northwestern University** allowed me to write this book when I was not teaching MBA students how to analyze and run organizations. I thank in particular Deans **Dipak Jain**, **Don Jakob**, **David Besanko**, and **Bob Magee** for their support. A sabbatical year in Germany that began in September 2001, first at the **Social Science Research Center (WZB)** in Berlin and later at the **Max Planck Institute for Research into Economic Systems** in Jena, provided the necessary time to finish the book. **Lars-Hendrick Röller** and **Jürgen Kocka** at the WZB and **Ulrich Witt** at the Max Planck Institute provided me with ideal conditions to bring this project to a closure.

Of the many people involved in putting my ideas into a physical book, I thank especially **Frank Smith**, **Catherine Felgar**, **Eleanor Umali**, **Virginia Marcum**, and **Bill Wondriska**. Frank Smith, my acquisitions editor at Cambridge University Press, skillfully managed this book from beginning to end and was a great partner in publishing a book we can all be proud of. A good copyeditor is worth gold; Virginia Marcum made sure my prose would not be an obstacle in communicating my ideas. Catherine Felgar at Cambridge and Eleanor Umali at TechBooks acted as competent production managers who kept the book on schedule. Finally, given that human beings take in most of the information they encounter through their eyes and the fact that this book deals with synthetic colors, this combination presented a once in a lifetime opportunity to produce a book that would be a feast for the eyes. Bill Wondriska's artistry turned this opportunity into reality.

Last but not least, I would like to thank especially **my family** for letting me go where curiosity would lead me and for supporting my endeavors in many ways over the years. Take this as the first report from my journey. Stay tuned for more.

Jorge Louis Borges (2000, p. 69) noted that "the concept of a 'definitive text' corresponds only to religion or exhaustion." Although I tried to remove all errors concerning the facts, any remaining mistakes will need to get fixed in a future text. I am confident, however, that the central empirical descriptions of how the synthetic dye industry developed can be relied on by generations of scholars to come. What may change are our theoretical interpretations that relate the facts in a web of causation and the relative importance of each of the causes. I urge the scholarly community at large to learn about my theory of coevolution and try it out in new arenas!

Timeline of Key Events in Development of the Synthetic Dye Industry before 1914

1856	Perkin discovers first synthetic dye, aniline purple (mauve), in London
1857	Perkin & Sons begins production of aniline purple
1858	The German firm Jäger enters the industry
1863	The German firm Friedrich Bayer enters the industry
1864	German immigrants form the British firm Levinstein near Manchester
1865	Professor Hofmann leaves London for Berlin
1866	Kekulé publishes his benzene ring theory
1868	The British firm Brooke, Simpson & Spiller (BS&S) is formed
1869	Graebe and Lieberman in Germany and Perkin in Britain develop synthetic alizarin
1874	Perkin sells his plants to BS&S and retires from the dye industry
1875	American Aniline is formed by German-born Victor Bloede
1877	All-German patent law is passed
1877	German Chemical Industry Association is formed
1879	The American firm Schoellkopf is formed in Buffalo, NY
1880	Professor Baeyer synthesizes indigo on laboratory scale
1881	Society for Chemical Industry is formed in Britain
1883	First patent for a direct azo dyestuff is issued
1883	Carl Rumpf hires the first three research chemists for the Bayer Company
1891	German patent office changes the application of patent law
1897	BASF produces commercially synthetic indigo
1905	Professor Baeyer receives the Nobel Prize in chemistry
1914	World War I disrupts German supply of dyes to the world market