British 'Decline'

the 'Particular-Skill'-Thesis,

and the Case of Synthetic Dyes 1856-1914

Master thesis

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AUTHOR'S PREFACE

Two years ago I started working on a thesis that turned out to be centred on 19th century chemical industry and chemical history. This knowledge was difficult to breach for a non-chemist and I would like to thank Anthony Travis, Carsten Reinhardt and Peter Morris for immeasurable help in providing answers to difficult questions. I would also like to thank Ernst Homburg for answering questions related to his work, and allowing a small piece of it to be included into this thesis. Lastly, a great thanks to Simon Niziol for tightening up the writing to sharpen its impact. Special thanks to students and staff at the University of Bergen: my tutor Harm Schröter for two years of guidance and support, Håkon Haugland for reading and correcting an early draft of the thesis, and Camilla Brautaset for help beyond the call of duty.

TABLE OF CONTENTS

1 Introduction 3

1.1 Developing a research question 3

1.2 The field of study 6

1.3 Method and contributions 10

1.4 Plan of the thesis 13

2 The case of the British synthetic dyestuffs industry 15

2.1 Perspectives 15

2.2 Anthony Travis and Carsten Reinhardt 16

2.3 The continuation of knowledge 18

2.4 Early developments 23

2.5 The decline of the British synthetic dyestuffs industry 27

2.6 Summary 33

3 Historiography 35

3.1 John Joseph Beer 35

3.2 L. F. Haber 38

3.3Maurice Fox 43

3.4 Summary 49

4 Educational institutions and crucial skills 51

4.1 Robert Bud and Gerrylynn Roberts 51

4.2 Johann Peter Murmann and Ernst Homburg 57

4.3 Summary 64

5.0 The study of the British 'decline' 66

5.1 The concept of economic rational behaviour 66

5.2 Broadberry and British Higher education 68

5.3 David Edgerton and the British 'decline' 69

5.3 Tom Nicholas and the entrepreneur 79

5.4 Summary 82

6 Concluding remarks 83

Glossary 87

Bibliography 90

Appendixes 94

1 Introduction

1.1 Developing a research question

The second industrial revolution took place during the second half of the 19th century, and represents one of the greatest economic changes in modern times. The economies of Western Europe and North America reached maturity, and a new concept of 'modernity' was introduced. Mechanisation had become commonplace over the previous 100 years and had helped turn Britain into the 'workshop of the world'. However, during the second half of the 19th century and the early 20th century, Germany and the United States were to challenge Britain's leadership. Germany and the USA would in fact not only challenge, but forge ahead of Great Britain between 1870 and 1914.

Although there are no more than sketches of the historiography of how Britain's relative economic and industrial position was weakened,[1] explanations have centred on Britain's manufacturing industries, which slowed down compared with progress made by other countries. A 'declinist' tradition in historical writing in the 1950s considered British industrial performance between 1870 and 1914 as on the wane. In the 1960s perceptions changed, and the 'decline'[2] was seen as relative rather than absolute: it was not so much that British industry declined, but that German and US industry had caught up. Britain's position as the undisputed industrial leader was challenged even though the country's industrial output increased in the period. Recently Stephen N. Broadberry, Professor of Economics at Warwick, observed that most writers on Britain's relative economic decline offer the explanation that both Germany and the United States caught up with and overtook Great Britain in terms of comparative labour productivity at the aggregate level.[3] Since the productivity of the work force in Germany and the USA exceeded that of Great Britain according to calculations based on the entire work force, conventional literature has indicated that something similar was happening in the manufacturing industries. Broadberry has suggested that this is not the case and that Germany and the USA overtook Britain largely by shifting resources out of agriculture and improving their relative productivity in services rather than in manufacturing.[4]

A group of new manufacturing industries that based on the new technologies of the 19th century: the chemical, electrical and optical industries, shows a different pattern.[5] One of these, the chemical industry, was the first major new-technology industry in which Britain was

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[1] Edgerton 1996: 6.
[2] Glossary.
[3] Broadberry1998: 375.
[4] Broadberry1998: 375.
[5] Schröter, 1998: 95.

overtaken by Germany.[6] How this happened, and how the industry of one country was overtaken by the same industry of another country is extremely complex, and has, so far, defied satisfactory explanation.[7] A common hypothesis is the 'catch-up' effect. According to Moses Abramovitz, Professor of Economics at Stanford University and one of the pioneers in the study of America's economic growth, the catch-up hypothesis asserts that being backward in levels of productivity carries a *potential* for rapid advance.[8] The central idea is that because Germany had less technology embodied in her capital stock than Britain, then the leading country, Germany used new technology to 'catch up'.[9] The case of the British organic chemical industry, however, cannot be explained solely in terms of catch-up mechanisms. The German organic chemical industry did not merely catch up, but forged ahead of its British counterpart. The study of the industry has not, however, been an integral part of the larger study of the British 'decline', which, since the early 1990s, has questioned whether the British manufacturing industries declined at all.[10]

This thesis suggests that it is the type of explanations used in the historical accounts of the British organic chemical industry, or more precisely the synthetic dyestuffs industry, that have caused its under-representation in the more far-reaching study of the British 'decline'. A second observation is that more recent contributions on the 'decline' of the British synthetic dyestuffs industry that offer new explanations have not been integrated into the recent contributions to the broader study of the British 'decline'. The objective of this thesis will therefore be:

a) to analyse the literature on the British synthetic dyestuffs industry in order to consider what type of arguments are employed to explain one of the industrial branches that 'declined' between 1870 and 1914,
b) to question how the historical example of the British synthetic dyestuff industry, 1856-1914, became a neglected study of the broader British 'decline,
c) to analyse the literature on the British 'decline' to consider the positions of synthetic dyestuffs industry as a ***case study***.

The synthetic dyestuffs industry emerged in Britain around 1860. William Henry Perkin, a young Englishman, in 1856 had discovered the first synthetic dye, mauve. A year later, Perkin

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[6] Schröter, 1998: 95.
[7] Schröter, 1998: 95.
[8] Abramovitz 1986: 385. His article titled *Catching Up, Forging Ahead and Falling Behind* is currently the second-most cited among all papers published by the *Journal of Economic History*.
[9] Abramovitz 1986: 385.
[10] Edgerton 1996: 67; Broadberry 2004: 57; Magee 2004: 75; Broadberry 1998: 375.

succeeded in commercializing his product on an industrial scale. Britain had established itself as the first mover in a race for artificial colours, but other countries were not far behind: France (1858), Germany (1858), and Switzerland (1859) followed soon after.[11] France, although a significant player in the early years of the synthetic dyestuffs industry, and Switzerland have been regarded of less importance in explaining the decline of the British dyestuffs industry, and those two countries will appear in this thesis only insofar as they are portrayed in the literature. Switzerland was more important than this suggests before 1914. A fifth country that is discussed in the literature, but only played a marginal part in the history of the organic chemical industry prior to the First World War is the USA.[12]

The time period of this thesis will be restricted to the surveyed literature, which is generally from 1856 to 1914. However, the synthetic dyestuffs industry did not emerge in a vacuum, and to ensure that arguments appear in proper context they are given in the literature it is necessary to include the two decades before Perkin's discovery in 1856. The study of the British 'decline' is considered from two perspectives: a questioning of British economic performance between 1870 and 1914, and how Britain has performed in the period from 1870 to 1970 and beyond. British industrial performance over the latter period will be discussed in this thesis only when it is of direct relevance to interpretations of British economic performance between 1870 and 1914.

In 1914, Europe was cast into a war that significantly altered the conditions of trade, and acted as a natural closing point for studies researching the emergence of the synthetic dyestuffs industry and how Germany came to dominate the industry by the end of the 19th century. Since this paper primarily analyzes arguments concerning the shift in the centre of gravity of the synthetic dyestuffs industry, an adjustment needs to be made. The late 1860s and early 1870s saw a continuous increase in Germany's relative share of the world market in dyes. It is these two decades that represent the climax of a process that would eventually given German companies a near world monopoly in producing and selling dyestuffs. This thesis is not a survey of literature that discusses how Germany came to dominate the world's trade in dyestuffs prior to the First World War, but an analysis of an under-represented discipline that tries to answer how Britain did not.

The subject of the synthetic dyestuffs industry will be approached historiographicaly, and can be understood to mean the history of the organic chemical industry prior to the First World War. In approaching the subject, two recent accounts offering an explanation of how Germany and not Britain came to dominate the trade in dyes in the 1856-1914 period will be the main

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[11] Murmann and Homburg 2001: 178.
[12] Travis 2004.

focus. There is one major advantage to this approach. Recent, as opposed to historiographical explanations – that is time- and place-sensitive, will be used as the empirical footing of this paper. In such a way, the arguments to be analysed against the general arguments concerning the British 'decline' will be representative of the frontier of the discipline, rather than a more piece-by-piece consideration of the contributions of different commentators. Since the reliance on two accounts would only arguably be representative of a discipline, it is necessary to examine the borders of the chemical history discipline and introduce a short historiographical account of the study of the 'decline' of the British synthetic dyestuffs industry.

1.2 THE FIELD OF STUDY

The contributions to the study of the synthetic dyestuffs industry are numerous but not substantial. There are only a handful of accounts that question and offer explanations of why Germany and not Britain came to dominate the trade in dyes; that is an indication of the way the subject has been considered *terra incognito*. The publications within the field of study of chemical history are not restricted to industrial matters, but also deal with chemical technology, environmental issues, and the science of chemistry. The history of chemistry also involves itself with more particular matters, such as the industrial research laboratory or business histories. Whether or not a publication is meant to be a contribution to the history of chemical science or the chemical industry, or published as a contribution to the more general study of the British 'decline', has off course a lot to do with the author's purpose. But how the contribution is received is a different matter entirely, one that will be taken up in this paper.

What can be said is that the question of industrial overtaking[13] is an integral part of both the study of the British synthetic dyestuffs industry and of the British 'decline'. The British synthetic dyestuffs industry was, however, a chemical industry. More precisely it was an organic chemical industry and the study of the organic chemical discipline is very difficult to separate from the study of chemical science. This is because the synthetic dyestuffs industry represents one of the first instances in which scientific research led directly to a new commercial product.[14] This happened in 1856 and organic chemistry and synthetic dyestuffs were at the time a frontier science. But as the industry grew and new products was developed the synthetic dyestuffs industry drove the science of organic chemistry forward.[15] That the organic chemical industry and science were, to a great extent, uncharted territory at the time makes it a very difficult area of industrial history.

[13] Glossary.
[14] Murmann and Homburg 2001: 178.
[15] Stoltzenberg 2000: 57-91.

Chemistry today operates with some sense of common ground. The categorization of atoms and molecules is, for example, more or less universal. The atomic weight of atoms is known, not to mention how to break apart and piece together different atoms to make a molecule. The organic chemical industry was the place in which such knowledge was, for the first time, important to the discovery and synthesis of new industrial products. Yet, in 1856 organic chemistry was a frontier science. At the outset knowledge was gained by empirical testing and had little scientific foundation. No common system of chemical reference existed until the last third of the 19th century. Historians wishing to study the emergence of the synthetic dyestuffs industry would therefore find themselves in a haphazard and confusing environment. It is after all the less visible aspects of the product that were important in an industry that strived to create artificial variants of natural dyes, aspects such as constitutional formulae, chemical structure and method of production.[16]

A second historical problem is the unevenness of sources. There exists hardly any quantitative evidence of the early years of the British and French chemical industry, the period from 1856 to the 1870s. The German synthetic dyestuffs industry is, however, much more documented, especially by archival sources. An explanation for this unevenness is that German companies were required by the state and local authorities to keep records of their enterprises. A second explanation is that the German industrialists were perhaps more aware of their destinies in wielding together a new nation based on science and technology. They recorded in detail the plans, negotiations, and outcome of their enterprise. A third explanation is that some of the German companies that were founded in the 1860s still exist today and have preserved their company archives. [17]

The first publication that dealt with overtaking in the synthetic dyestuffs industry was John Joseph Beer's 1959 Ph.D. thesis, *The Emergence of the German Dye Industry*. One year earlier L.F. Haber published his *Chemical Industry During the XIX Century*. The first edition of Haber's work was, however, a study of both branches of the chemical industry and only partially dealt with the 'decline' of the British synthetic dyestuffs industry.

During the 1960's and 1970's little extensive work on the decline of the British dyestuffs industry was published, but the two major German chemical companies, the *Badische Aniline & Soda Fabrik (the BASF)* and *Farbwerke Hoechst,* made exceptions to publish documents from

[16] Travis 1993: 17.
[17] Travis 1993: 17.

their company archives, shedding additional light on the comparatively well-documented German synthetic dyestuffs industry.[18]

The late 1970s saw Maurice Fox finish his manuscript of *Dye-Makers of Great Britain 1856-1914*, but the author died in 1982, leaving the publication of his work to his colleagues at Imperial Chemical Industries (ICI). In 1987 they published an extensive but uncritical account, offering several reasons why Germany and not Britain came to dominate the trade in dyes, with a focus on two of the companies that were to merge into ICI after the outbreak of war in 1914. It was not until the 1980s that there was a significant increase in the number of publications focussing on the synthetic dyestuffs industry.[19] Ernst Homburg's 1983 publication *The Influence on Demand on the Emergence of the Dye Industry: The Roles of Chemists and Colourists* can be considered a link between the generalized arguments on the inadequacy of British educational institutions (Beer, Haber), and the nuanced view that such arguments are much too general.

The 1990s witnessed conferences on the examination of the history and development of chemistry, and a book series, *Chemists and Chemistry*, was published by the participants, who included Ernst Homburg, Carsten Reinhardt and Anthony Travis.

Travis is deputy director of the Sidney M. Edelstein Center for the History and Philosophy of Science, Technology, and Medicine at the Hebrew University of Jerusalem. Ernst Homburg is a professor at the Department of History, University of Maastricht. Carsten Reinhardt is Prof. Dr. of the Institute for Science & Technology Studies (IWT), University of Bielefeld. The overall arch of chemists & chemistry is above that of a single branch of industry, but represents the most important collection of contributions to the history of chemistry and the chemical industry and the German overtaking of the British dyestuffs industry is one of the most debated questions. Of the most significant interpretations is the downplaying of the relative size of the synthetic dyestuffs industry, and an increasing recognition that the dyestuffs industry had primarily a strategic, rather than a commercial advantage for the host nation. In addition, *Chemists and Chemistry* is a series of publications aimed at a better understanding of the

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[18] Höchst: Hoechst AG. *Dokumente aus Hoechster Archieven*.Heft 3. Frankfurt: Hoechst, 1965. Heft 26 was published by 1967. BASF: Zimmerman, Paul A. *Über die Grenzen hinaus*. Ludwigshafen/Rhein. 1971; Schuster, Carl. *Wissenschaft und Technik*. Ludwigshafen. 1976; Nagel, Alfred von. Fuchsin, Alizarin, Indigo. Der Beginn eines Weltunternehmens. Ludwigshafen: BASF, 1968. The most extensive business history of the Badische Aniline & Soda Fabrik is the publication of Werner Abelhauser (Bielefeld University), Wolfgang von Hippel (University of Mannheim), Jeffrey Allan Johnson (Villanova University) and Raymond G. Strokes (University of Glasgow), *German Industry and Global Enterprise BASF: The History of a Company*. Cambridge University Press. 2004.

[1919] In the 1970s several books were in fact published, but mostly on single companies or significant persons in chemical history or business histories, such as Abrahart, E.N. 1976. *The Clayton Aniline Company Limited, 1876-1976*. Manchester; or Reader, William J. 1970 (1975). *Imperial Chemical Industries: A history,* 2 vols. Oxford.

relationship between science and industry, of which the synthetic dyestuffs industry is perhaps the best example.

The series *Chemists and Chemistry* does not, however, provide a thorough account of the synthetic dyestuffs industry itself. It is more of a forum for debate not far removed from a journal.[20] Three commentators that have published recently and widely in both the series and on the history of the synthetic dyestuffs industry prior to the First World War are the above-mentioned Travis, Reinhardt and Homburg. The first extensive publication of Travis on the synthetic dyestuffs industry that also provides a hypothesis of how Germany and not Britain came to dominate that trade prior to the First World War is *The Rainbow Makers* (1993). In 2000 Reinhardt and Travis co-authored *Heinrich Caro and the Creation of Modern Chemical Industry*, which goes well beyond the ostensible object of that book, that is the life and times of the German chemist Heinrich Caro. The book relates Caro's upbringing, education, apprenticeship and inventive streak to the evolution of science-based technology, at first in England and then in Germany.

Ernst Homburg participated in a Dutch research team in the 1980s, investigating the synthetic dye industry before the First World War. Homburg also co-authored with Johann Peter Murmann[21], a specialist in evolutionary economics and the simulation modelling of the paper, *Comparing evolutionary dynamics across different national settings: the case of the synthetic dye industry, 1857–1914.* The paper was published in the *Journal of Evolutionary Economics* in 2001 (11: 177–205). The paper is the first part of a larger study on evolution of the first science-based industries from 1857 to 2000 that has not yet been published. The authors have provided an updated version (5.4) of that paper (10/24/07) with allowances.[22]

Since Travis' *The Rainbow Maker* is the publication that more specifically deals with industrial overtaking it will form the empirical backbone of this paper.[23] Travis's thesis

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[20]Another forum for discussion *is CHEM-HIST: History of Chemistry, Electronic Discussion Group*, which is an international electronic forum and news bulletin set up to carry information and discussion related to the history of chemistry and chemical industry. The list is open to anyone with an interest in any facet of the history of chemistry. Stable URL: https://mailman.uni-regensburg.de/mailman/listinfo/chem-hist

[21] J.P Murmann is Associate Professor of Strategic Management and Head of the newly formed School of Strategy and Entrepreneurship in the Australian School of Business. A second publication, namely *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions* (2003 that compares the development of the synthetic dye industry in Great Britain, Germany, and the United States through the lenses of evolutionary theory, is another source of entry into Murmann's reasoning.

[22] Appendix II.

[23] Travis has published extensively on the subject, and other papers such as the one published in Boston *What a wonderful Empire is the Organic Chemistry* [to be published in the *Bulletin for the history of*

necessarily contrasts with others publication both in method, argument and conclusion otherwise it would be bereft of novelty. What is attempted here is an identification of common ground, and to this end, *Heinrich Caro and the Creation of Modern Chemical Industry* will be integrated into Travis's reasoning. Homburg and Murmann are tested using Travis and Reinhardt's reasoning later in this thesis to determine if the views of these two authors can be generalized as representative of the understanding of the 'decline' of the British synthetic dyestuffs industry in chemical history.

The contributions that will be considered in the historiography of the synthetic dyestuffs industry prior to the First World War are those of Beer, Haber and Fox. These three are the only ones that question, in a systematic and thorough manner, why Germany and not Britain came to dominate the trade in dyes in this period.

I should mention that I am not a chemist. In order to avoid any misinterpretation or error due to a lack of chemical understanding, Anthony Travis, Carsten Reinhardt, Ernst Homburg and Peter Morris[24] have been most helpful in correcting me and helping me to understand different aspects of nineteenth-century chemical history and chemical industry.

1.3 Method and contributions

Adopting a historiographical methodology that considers only secondary sources would to a great extent circumvent the historical problems of the subject and make a very large study relatively smaller and comprehensible. Historiography allows a trace of how historians have interpreted a given historical topic over time rather than contributing new evidence or arguments on the topic. Although there is sometimes a large benefit in tracing the historical topic chronologically, this will be attempted only partially here. I have chosen to address the three research questions as separate entities, because what is of most interest is not to show how arguments and new evidence have functioned over time to alter the course of a discipline, but how the discipline itself has become neglected.

It is a difficult undertaking to allow each author his own separate entity and at the same time make allowances for the context appropriate to each argument without running the risk of being too much like the original source. This can to an extent be remedied by meta-textual interference. Yet, it is a ambition of any student of history to form a narrative of his own and in such a way piece together different histories of that particular piece of the past that was, at least

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chemistry, 2008]will, along with some very helpful and clarifying conversations by mail, show and explain Travis's thesis.

[24] Peter Morris is the Manager of Research and Residencies at the Science Museum, London, and was awarded the 2006 Sidney M. Edelstein Award for Outstanding Achievement in the History of Chemistry.

for a short time, very important. Any errors that have been made in this quest to form a narrative are my own.

The inclusion and sometimes exclusion of contributions has been difficult. This is because of the potential worth of many publication rather than questions of reliability and credibility. It is the methodological abstraction that is a problem for this type of history writing. There are several different tools to interpret a set of data and most publications use different ones. It has been attempted to 'under-communicate' the methods applied here to make this thesis accessible to most readers but not without a certain cost.

The works of two groups of historians are used in this paper, those who write on the history of the synthetic dyestuffs industry prior to the First World War, and those who write on the British 'decline' between 1870 and 1914. It has been necessary to exclude many publications especially on the latter because of their vast number. As a result valuable arguments and explanations, not to mention debates, have been excluded from this paper. Authors' credentials are generally discussed when the publication is first introduced in the main body of text in this thesis.

Valuable works on the synthetic dyestuffs industry that for different reasons have not been used in the main body of this thesis include: H. van den Belt, E. Homburg and W. J. Hornix, (ed)., *Development of the Dye Industry*, 1985; E. Homburg, *The Emergence of Research Laboratories in the Dyestuffs Industry, 1870-1900*, 1992; And C. Reinhardt, *Forschung in der chemischen Industrie. Die Entwicklung synthetischer Farbstoffe bei BASF und Hoechst. 1863-1914,* 1997.

Works on the British 'decline' that have not been used include: B.C. Beaudreau, *The economic consequences of Mr. Keynes: How the second industrial revolution passed Great Britain by*. 2006; Stephen N. Broadberry, *Comparative Productivity in British and American Manufacturing During the Nineteenth Century*. 1994; *Anglo German Productivity Differences 1870-1990: A Sectoral Analysis*. 1997; and works by D.N. McCloskey, *Did Victorian Britain Fail*? 1970; (ed) *Essays on a Mature Economy: Britain after 1840*. 1971; and *Enterprise and Trade in Victorian Britain*. 1981.

Most regrettably is the exclusion of D.N. McCloskey, who provides most interesting interpretations on British economic rational behaviour. McCloskey does, however, appear briefly in section 5.1. As for Broadberry, one of his latest papers has been included in this thesis, but only as a reference to a group of scholars. Broadberry has in addition analysed British education over time, which is the backbone of most studies that question industrial performance. Also worth mentioning is Leslie Hannah in the field of business history, who discussed the temporal and relative significance of the corporation in British manufacturing in

The rise of the corporate economy, 1976. Also absent, but beyond the scope of this paper, are comparative studies of other new-technology industries such as I.C.R. Byatt, *The British electrical industry 1875-1914: The economic returns of a new technology*. 1979. The list could go on.

Accounts on the synthetic dyestuffs industry during 1856-1914 that have been included in the main body of this thesis are: Anthony Travis *The Rainbow Makers.*1993; John Joseph Beer *The Emergence of the German dye industry*. 1959; Carsten Reinhardt & Anthony Travis *Heinrich Caro and the Creation of Modern Chemical Industry.* 2000; Johann Peter Murmann and Ernst Homburg *Comparing evolutionary dynamics across different national settings: the case of the synthetic dye industry, 1857–1914.* 2001; Maurice Fox *Dye-Makers of Great Britain 1856-1976*. 1987; and L. F. Haber *Chemical Industry During the XIX Century.* Second ed. 1968*.* Other publications that have been used but not in separate entities include: *Chemists & Chemistry* vol. 17, 18; Fred Aftalion *A History of the International Chemical Industry.* 2000; and Ernst Homburg *The Influence of Demand on the Emergence of the Dye Industry*. 1983. Robert Bud and Gerrylynn Roberts *Science versus Practice*, 1984, is the only publication that has been included that deals with applied science and the educational institutions in Victorian Britain in particular. Another relevant publication is *Representations of Applied Science: Academics and Chemical Industry in Late Nineteenth-Century England,* 1986, by J.F. Donnelly. The exclusion of this last publication is regrettable but would include a questioning of the relevance of a curriculum to the chemical industry that is best discussed elsewhere.

In the third part of this thesis studies of science and technology and British industrial performance have been included. As the study of the British 'decline' is highly researched, included are publications that are representative of the debate on British industrial performance. *Science, technology and the British industrial 'decline' 1870-1970* (1996) by David Edgerton, Professor at Imperial College, is highly relevant in this context. His publication included a rich but short historiography that, in a general tone, deals with British industrial and economic performance. A second publication by Tom Nicholas, *Clogs to Clogs in Three Generations? Explaining Entrepreneurial Performance in Britain Since 1850*, has been selected as he questions the causal empiricism of explanations of the British 'decline'. Lastly Stephen N. Broadberry has been included as he is representative of those historians who attempt to show British long-run economic performance and argue that British educational systems were adequate prior to the First World War. Studies that has been partially included to substantiate arguments include Johan Peter Murmann's *Knowledge and Competitive Advantage : The Co-evolution of Firms, Technology, and National Institutions* (2003) and Dr. at the Technische Universität München Ulrich Marsch's *Business strategies and research organization in the German chemical industry and its role as exemplar for other industries in Germany and Britain* (2000).

A number of journals have also been included. This is primarily because arguments applied by different authors often place themselves in a debate. The debate on the British 'decline' is relative to the area of analysis and operates with different time scales. Most relevant to this thesis are publications on the British industrial 'decline' between 1870 and 1914. This would, however, include the de-industrialization of Britain in the 1970s, because the debate has in recent years turned away from a focus on failure in the past to a questioning of British performance in the long run. The following journals have been included in this thesis to provide such a perspective: *The Economic History Review*, New Series, Vol. 44, No. 3, 1991; *The Business History Review*, Vol. 71, No. 2, 1997; *The Historical Journal*, Vol. 42, No. 1, 1999; *The Accounting Review*, Vol. 54, No. 1, 1979; and *The Journal of Economic History*, Vol. 59, No. 3, 1999. These journals are created to keep members of an academic society abreast of the latest thinking on a subject.

1.4 Plan of the thesis

The disposition of this thesis can be said to centre on several accounts published by a small nucleus of authors. The second chapter attempts to provide a basis of knowledge of the synthetic dyestuffs industry, in combinations with a presentation of Travis and Reinhardt's arguments of how Germany and not Britain came to dominate the trade in synthetic dyestuffs.

The third chapter of this thesis attempts to show in chronological order what arguments have been employed over time by historians to explain the 'decline' of the British synthetic dyestuffs industry prior to the First World War. Also addressed will be what type of arguments have been employed, since this might have explanatory value as to why the industry have been a neglected one in general studies. A selection of three accounts has been used to test this point.

The fourth chapter substantiates Travis and Reinhardt's reasoning by considering British educational output. This is important because of the nature of the synthetic dyestuffs industry, which by 1868 required another type of expertise because of the evolution of the industry and new chemical theory. The second part of chapter four introduces the potential of skill to function as a barrier against entry into a business. Because the account is a case study of the British synthetic dyestuffs industry it will be used to test the reasoning of Travis and Reinhardt.

In the fifth chapter the synthetic dyestuffs industry will be tested against the general arguments that are employed to explain British industrial performance between 1870 and 1914. What is seen is that the more recent scholars that have tackled the British 'decline' analyse British performance over a much longer perspective: from 1870 to present, and that there is little overlap between explanations employed to explain the decline of the synthetic dyestuffs industry, and the industrial performance study of which it is a case study.

Even though most of the publications referred to frequently in the paper can be considered historical accounts, several publications require some presupposed knowledge: i.e. a knowledge of chemistry. To communicate such studies and at the same time value the accessibility of historical studies it is necessary to introduce several concepts and terminology, techniques, products, and arguments in a proper context. To help the reader along, a process and product timeline of the synthetic dyestuffs industry has been included.[25] In addition a glossary, including definitions, is provided.

[25] A double timeline is available in the appendix I.

2 The case of the British synthetic dyestuffs industry

This chapter will give an account of Travis and Reinhardt's thesis. It will be followed by a short and direct analysis of the technological evolution of the synthetic dyestuffs industry. It attempts to show how the skill supply problem in British industry - concentrating around the availability in 1865 of drawing structural formula of aromatic organic chemicals that is the single most important component of Travis and Reinhardt's account. In the following chapter Reinhardt and Travis' publications will be contextualised within the historiography of study of the synthetic dyestuffs industry.

2.1 Perspectives

By the middle of the 19th century Britain was established as the industrial leader of the world, the greatest trading nation of the world, and the ruler of a vast empire. The British economy is often considered to be synonymous with the country's industries, which showed such promise in she proudly declared herself the workshop of the world.[26]

Germany, on the other hand, had for centuries been little more than loose federations and principalities to be played with by the great powers of Europe. The 19th century brought change and Germany established herself in the heart of Europe, emerging from the oppressive shadow of the Austrian Empire to the east. After winning a war with France in 1870-71, acquiring Alsace and Lorraine, the recently unified Germany was the most populous country in Europe, a demographic strength France was the first nation to recognize.[27] Great Britain on the other hand, would not only find that her products became increasingly hindered by German tariffs, but that British industries lost market shares to their German counterparts, and nowhere more so than in the new-technology industries of the 19th century. By the time the century was at its close, Germany had established herself as the foremost industrial country on continental Europe.

In the great scheme of things a branch of industry can seem of lesser importance, and perhaps at first glance the colouring industry of Britain and Germany had little to do with national supremacy. But here are a few facts: the synthetic dyestuffs industry was the first industry to employ a large customer support service and employ large-scale production processes based on research that were to become significant strategic advantages to any

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[26] Broadberry 2004: 56.

[27] After the Franco-Prussian war, France recognized that she had lost the population advantage that she had enjoyed in Europe for more than a thousand years, and demographical studies became established in France as a response to the German demographic threat.

industry.[28] The organic chemical industry drove chemical science, and vice versa.[29] The same industry was the first to establish the great industrial laboratories as we know them today, and synthetic dyes were the first scientific discoveries that led rapidly to a new industry.[30] The ability of great powers to embark on military adventures or engage in world wars during the first two decades of the twentieth century "has to be measured in terms of production of chemicals."[31]

Besides the importance of the synthetic dyestuffs industry to students of business, economic, and technological history, it also forms an important chapter in the understanding of the 'decline' of the British manufacturing industries, and the rise of the German synthetic dyestuffs industry culminating in the last third of the 19th century. The synthetic dyestuffs industry has for well over a century been cited as the supreme example of industrial rise and fall, even though the mechanisms that made it happen has been hidden from the history books.

2.2 Anthony Travis and Carsten Reinhardt

In 1993 Anthony Travis published *The Rainbow Makers: The Origins of the Synthetic Dyestuffs Industry in Western Europe*. It is a thorough account with emphasis on the early years of the British synthetic dyestuffs industry. The book traces technological change in the synthetic dyestuffs industry, with the greatest focus on the shift in the centre of gravity from Britain to Germany. In such a way *The Rainbow Makers* offers a treatise on how Germany and not Britain came to dominate the global synthetic dyestuffs industry.

A comparative study of the German overtaking of the British dyestuffs industry would have to overcome a historical problem: the unevenness of source material. This makes a measurement of the event, which went against economic prediction,[32] an especially problematic area of study. Because of the almost total lack of quantitative sources on the early years of the industry, Travis took an alternative approach: the overtaking by Germany as seen through scientific and technological developments, and in particular the 1877 German patent law, which both provide a guide to the changeover.[33]

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[28] Abelhauser, W., *et al*. 2004: 31.
[29] Travis 1993: 229.
[30] Murmann 2003: 5.
[31] Schröter 1998: 95-120. Marsch 2000: 217-241.
[32] See section 3.1.
[33] Appendix II.

The novelty of Travis's thesis is that it follows the changing technology to show how various phases and types of invention and innovation[34] may be identified, and how they were manipulated in laboratories, factories, courthouses, and board rooms.[35] Travis concentrates on production processes and the working environment of scientists, inventors and entrepreneurs, in order to suggest what the driving forces that led to new innovative activities were, and also to show how industrial practice and organization responded and adapted during the changeover from craft-based to science-based innovation around 1870.[36] In other words, Travis offers a treatise of how the British synthetic dyestuffs industry introduced the formal application of science to industry, that is, the foremost characteristic of the second industrial revolution.

The same argument structure and a more thorough account of the craft-based innovation have been taken further in Reinhardt and Travis' *Heinrich Caro and the Creation of Modern Chemical Industry* (2000). It is important to stress that even though technology stands at centre of Travis's method and argument, a single and categorical reasoning cannot be extracted. The in-house strengths and weaknesses of multiple companies of multiple nations have to be considered in different national settings.

The two most important external factors in Travis's reasoning is the adoption of a comprehensive patent law in Germany in 1877, which enabled German companies to secure markets through the novelty of their products and processes, and the educational institutions that provided the scientists required when the chemical industry had reached a level of complexity that the colourist in the dye and print works could not meet. Much of Travis's research concentrated on Roberts, Dale & Co. of Manchester, probably due to his extensive research into the life of Heinrich Caro, who spent seven years there as a colourist, but also because Caro provided a rich account of his career, and especially his Manchester years.[37] Travis also makes frequent references to Simpson, Maule & Nicholson, L. I. Levinstein & Co., Read Holliday & Sons, and Perkin & Sons.

There are some assumptions to Travis' reasoning that is empirically and not theoretically founded that contrast previously published literature: First, incompetence on the part of the British manufacturer, which could be seen in unison with the study of meritocracy; i.e. studies of

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[34] Glossary.
[35] Travis 1993: 14.
[36] Travis 1993: 14-15.
[37] *"Fortunately, it is this creative English period for which we have access to the most detailed archival sources, held mainly with the Caro Nachlass. These sources include trade literature, recipes, laboratory and accounts notebooks for the period 1862-3, trade and scientific correspondence 1860-67, and transcriptions of retrospective accounts written by Caro and other Germans who spent time in Manchester.* " (Reinhardt and Travis 2000: 49-50.)

the social origins of 19th century British business leaders.[38] In the 1998 edition of *Chemists and Chemistry* the incompetence of British companies is argued against by Travis, and because of the method adopted, not given its own emphasis in *The Rainbow Makers.* Conventional literature on the British synthetic dyestuffs industry contrasts with this view. Also, how industrial practice and organization responded and adapted during the changeover from craft-based to science-based innovation, contrasting with previously published accounts of the reliance on craft-based innovation in the early years. This has been used by Travis as the main explanation of a scientific and technological overtaking. The German scientific excellence that is often seen as gradual with Germany as a second mover (second movers advantage)[39] is by Travis portrayed as much more immediate. It was the German chemist August Friedrich Kekulé von Stradonitz's discovery in 1865 of the *benzene rings*[40] that was critical to the understanding of how the structure of aromatic organic compounds could be drawn, enabling an understanding of how molecules could be broken apart and pieced together again. In such a way, Travis's thesis has a much larger resemblance to path dependence, where both the starting point and 'accidental' events (Kekule's benzene theory) can have significant effects on the ultimate outcome, even though Travis does not elevate his thesis to a theoretical level.

2.3 The continuation of knowledge

"[…] a smooth blend of craft, industrial experience, and scientific knowledge […]"

Reinhardt and Travis[41]

It was an Englishman, William Henry Perkin, who discovered the first synthetic dye mauve by researching the different components of coal tar[42] at the Royal College of Chemistry in London. Perkin abandoned his academic studies and left the Royal College in 1856 to set up the manufacture of his novel invention. The novelty of Perkin's discovery has often led to the conception that the required knowledge to set up the manufacture of the dye must have had its origin at the frontier of science: the educational institutions. Forerunners to Perkin's aniline

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[38] Nicholas, Tom .1999. *The Myth of Meritocracy? An Inquiry Into the Social Origins of Britain's Business Leaders Since 1850.* London. On the case of the synthetic dyestuffs industry; Schröter 1998: 95-120.
[39] The concept of a second mover to be in an advantageous position to learn from the faults of the first mover and to employ modes of production and systems of organization that is thought to be the best is questioned in recent economic literature. The general idea is, however, that a second mover is in a position to imitate and employ existing technology reducing cost and risk.
[40] Glossary.
[41] Reinhardt and Travis 2000: xv.
[42] Glossary.

purple were of vegetable origin. They were isolated from roots, leaves, and other plants, whilst Perkin's dye was manufactured from the aniline, made from coal tar benzene, an aromatic organic compound, on an industrial scale.

Perkin received tuition is organic chemistry at the Royal College of Chemistry, and Perkin's mauveine (mauve) and its successors were, like all the synthetic dyes, aromatic organics. An important question is therefore whether organic chemical teaching was a requirement for entry into the business, or alternatively, whether organic chemical teaching was only partially required for entry into the synthetic dyestuffs trade. This is especially important because skills can be used to explain competitiveness over time, whereas crucial skills can deny entry into a business, or severely reduce competitiveness.[43] There is a consensus in conventional literature that the Royal College in particular provided the necessary skills required by industry in the early years (1856-1868) when innovation was empirically based rather than science-based. In those years the synthetic dyestuffs trade was firmly in the hands of British and French companies.

At the middle of the 19th century there was no established chemical discipline suited to the needs of the dye industry at the university level. This is, according to Travis, "demonstrated on the training grounds of the main contributors, mainly technical colleges or private teaching laboratories, where research in chemistry, including studies on dyes, was also conducted."[44] The Royal College was such a private teaching laboratory and August Wilhelm Hofmann[45] was the man who had introduced courses of organic chemistry with emphasis on coal tar. Conventional literature suggests that by the time Hofmann left the College in 1865 and especially during the following decade, much of the impetus for organic chemical teaching was lost and the Royal College could not keep up with its German adversaries. That the Royal College and other teaching institutions failed in providing skills in organic chemistry, has led commentators to focus on government and private initiatives in the area. Travis and Reinhardt argue that there was an adaptation of existing dye-using technology that made possible the fast growth of the new synthetic dyestuffs industry.

Reinhardt and Travis' argument is generally that the roles of the colourist and the chemist were overlapping and that the existing natural dye industry and chemical technology have much to do with the growth of the synthetic dyestuffs industry. Such a view cannot be attributed to Travis alone, in that *Heinrich Caro and the Creation of Modern Chemical Industry* to

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[43] More on this note in section 4.2.

[44] Travis 1993: 25.

[45] Hofmann had just recently earned a doctorate's degree at the Giessen laboratories under Justus von Liebig.

a great extent appreciates the applications of chemistry to calico printing[46] and colouristic endeavours.[47]

At the centre of the book is the young German chemist Heinrich Caro, who in October 1852 entered Berlin's Königliches Gewerbeinstitut, the leading trade school of Prussia.[48] Caro had early in his life been attracted to the chemical science and two years earlier the school had introduced a chemistry course, one that catered for young men intending to pursue careers in local industries.[49] The emphasis of the course was, according to the authors, on chemical technology, analysis and laboratory work, which Caro supplemented by also enrolling in a chemistry course at the University of Berlin.[50] Caro's teachers were aware that the German textile industry, then in its first phase of large-scale expansion, needed chemically trained colourists and suggested that Caro should take an interest in calico printing and dyeing.[51] In 1855, after some difficulty finding a job, Caro entered the factory of C. & F. Troost, a calico-printing factory in Mülheim. He was assigned manual and analytical work, and would initially make limited use of his scientific knowledge. The analytical job at Troost provided plenty of opportunities for learning about the range of chemicals employed in calico printing, and for meeting suppliers of dyers and other textile chemicals.[52]

Some years later, in 1859, Caro arrived in Manchester and was employed as a private assistant to John Dale, of Roberts, Dale & Co. This enabled him to build further upon his training as a colourist in Mülheim. Caro referred to himself as an "analyst", because it signified a colourist with a high level of training in chemistry.[53] Analytical work was the principle task of trained chemists in industry at that time. In a factory laboratory close to Manchester, Caro investigated dyeing using French madder, an alizarin preparation garancine[54], dyewoods, and other natural products. Not long after, Caro discovered a new route to Perkin's mauve, and the product was probably made on a small scale during 1861.

Reinhardt and Travis suggest that the application of chemistry to calico printing and colouristic endeavours was to become relevant to Caro's career in the synthetic dyestuffs

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[46] Glossary.
[47] Reinhardt and Travis 2000: 26.
[48] Reinhardt and Travis 2000: 25.
[49] Reinhardt and Travis 2000: 25.
[50] The chemistry course at Berlin's Königliches Gewerbeinstitut was also attended by Ivan Levinstein, later the leading dye manufacturer of Manchester. (Reinhardt and Travis 2000: 25.)
[51] Reinhardt and Travis 2000: 26.
[52] Reinhardt and Travis 2000: 38-39.
[53] Reinhardt and Travis 2000: 52-53.
[54] Glossary.

industry. Reinhardt and Travis exemplified this by placing the main emphasis on the madder[55] dye and its commercial forms, the processes for indirect printing on textile fabrics, and methods for detecting adulteration of dyes. There was an ongoing application of chemistry in calico printing, and the craft enabled Caro, drawing on his chemical education, not only to become an important asset at Robert, Dale & Co., but also to eventually change the course of the history of dye technology.[56] His work at Robert, Dale & Co. in Manchester from 1859 and at Troost in Mülheim is ample evidence of the overlapping expertise between the colourist and the chemist, according to Travis and Reinhardt.

Another prominent person in Reinhardt and Travis' publications is Perkin. Perkin became familiar with the laboratory techniques involved in converting coal tar hydrocarbons into their nitrogen bases at the Royal College. Furthermore Perkin set up his own private laboratory.[57]

Perkin committed himself to his discovery, and soon after conducted experiments on cotton dyeing. The result was that no suitable mordant [58] for the colouring of cotton was available and only a pale shade of colour remained on the fabric. These however, were admired, but Perkin would find himself short of customers for his product. In the last months of 1856, Perkin tried to find a cheaper method to produce his dye, and continued to work on its application. In doing so took on the role of a colourist, according to Travis. But as was the case with synthesizing organic chemicals, there were few or no precedents, and the state of the art was whatever the inventors made it.[59]

Calico printing was where the real money was to be made by Perkin, and it presented enormous technical difficulties because of the absence of nitrogenous material in the cotton fibre. This is where a mordant was required. The solution was to find a satisfactory 'animalised', or nitrogen-containing, coating for cotton that would adhere to both fibre and dye in the printing areas.[60] Since the creation of a marketable product relied on knowledge of prices for the necessary solvents and reagents, as well as on the state of the competition, Travis writes that it is "pertinent to ask how William Perkin and his family partners established the cost of introducing the new dye as well as the selling price, and made comparisons with existing products."[61] The aniline purple mauve was a high-value-added material according to Travis, and

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[55] Glossary.
[56] Reinhardt and Travis 2000: 38.
[57] Travis 1993: 35.
[58] Glossary.
[59] Travis 1993: 31-40.
[60] Travis 1993: 40.
[61] Travis 1993: 41.

whatever the difficulty Perkin faced in commercialising his product, he knew one thing, and that was the great cost of natural dyes. If Perkin could succeed in making mauve fast on cotton, and not only on silk, and scale up the production of his product, it would be a rousing financial success.[62]

The ability of Perkin to set up production of his mauve can be measured in terms of the 1850s chemical technology that enabled the production of picric acid (a brilliant dye but one that suffered from poor light fastness) by nitrating phenol[63] under similar conditions to those employed for preparing nitrobenzene. Picric acid production picked up when the commercial production of phenol from coal tar yielded a good product in 1847. Other such developments were also made in chemical technology and in chemical products. Yet, in Britain, the study of coal tar and its derivatives in the organic chemical science was frontier knowledge and solutions to problems were found in the testing, and not by scientific thinking.

Having secured a suitable factory site at Greenford Green near London, building began in 1857. Owing to the prohibitive high cost of nitrobenzene (made in Paris and Manchester) its large-scale manufacture from benzene was tackled first.[64] Nitric acid strong enough to nitrate benzene was also too costly to buy, and Perkin made it in-house from readily available Chile saltpetre and sulphuric acid, for direct reaction with benzene.[65] Having secured the supply of raw material and viable production processes for the necessary intermediates, Perkin was on the verge of manufacture.

Travis's micro study of the use of existing knowledge has explanatory value for the understanding of the later decline of the British synthetic dyestuffs industry. Travis and Reinhardt provide examples of how important the colourists were to the early years of the synthetic dyestuffs industry by tracing the education of Caro, and the continued application of science by the colourist and the natural dye trade. A second example is that Perkin realized the commercialisation of his novel invention by approaching his scientific technical problems as much in the traditions of the great British craft industries as in the rigorous and exact methods of Hofmann's German-style training.[66]

That organic chemical teaching was only partially crucial in terms of entry into the business is the first important component in Travis's argument structure. Second is the advantage gained by German companies in aromatic chemistry, something that will form the second part of this chapter. It should be mentioned, however, that the availability of cheap raw

[62] Travis 1993:40-41.
[63] Glossary.
[64] Travis 1993: 47.
[65] Travis 1993: 47.
[66] Travis 1993: 62.

material in bulk was one of the currents that allowed the synthetic dyestuffs industry to grow in the first place. The raw material, coal tar, was a by-product of the gas works[67] that by 1820 were being built in increasing numbers, especially in England.[68] The distillation waste, especially coal tar, was quickly becoming a nuisance, and the disposal of coal tar was quickly becoming a problem. Thus, when Read Holliday, the founder of Read Holliday & Sons[69], decided upon renting a site for his business, it was within easy reach of abundant raw material and of his potential customers in the neighbouring textile mills.[70] Within walking distance of the Huddersfield Registered Gas Light Company (founded 1821) Read Holliday erected a distillation unit for the production of ammonia. He was allowed 'for the taking' just as much coal tar as he wanted.[71]

2.4 Early developments

The manufacture of synthetic dyestuffs from coal tar aromatic hydrocarbons, mainly benzene, naphthalene, and anthracene, grew rapidly after 1860.[72] In 1858, or early in 1859, the prototype of a new range of dyes was obtained in France.[73] The business of Francisque and Joseph Renard (Renard Frères), not only produced Perkin's purple, but also developed a second aniline colour, a red dye called fuchsine in France and magenta in Britain.[74] It would be the most successful aniline dye.

French companies were also to manufacture Perkin's mauve and did not have to circumvent Perkin's patent, which had been declared invalid in France 'owing to a mistake as to date'.[75] Just as chemists had sought ways of imitating Perkin's process, they now turned to new ways of preparing the red fuchsine from aniline.[76] At first the coal tar dyes struggled to compete with colorants from natural products, but soon ways were found of fixing them to cotton, the basis of the fastest-growing sector of the textile industry.[77] British and French investigators found better ways of producing fuchsine, and the best process, to be favoured for over a decade,

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[67] Gas works made coal gas for illumination.
[68] Fox 1987: part II 62.
[69] See more on Read Holliday & Sons in section 3.3.
[70] Fox 1987: part II 62.
[71] Fox 1987: part II 62.
[72] Reinhardt and Travis 2000: xi.
[73] How Verguin discovered the product, and the exact date and place is clouded by uncertainty. On this Travis offers three different stories. (Travis 1993: 68.)
[74] Travis 1993: 67.
[75] Beer 1959: 26.
[76] Travis 1993: 69.
[77] Reinhardt and Travis 2000: xi.

was that of the British chemical company Simpson, Maule & Nicholson.[78] Nicholson himself filed a patent in London on 25 January 1860, but his application was not completed as Henry Medlock, another of Hofmann's earlier students at the Royal College, had filed an application one week earlier. S.M. & N. were eventually to acquire Medlock's patent, which specified the use of dry arsenic acid, in October 1860.[79]

In France, the possibility of making magenta by different routes (processes) led to an important law suit.[80] The patent law of July 1844 protected the product rather than the process, which according to Beer knocked the pins from under chemical discovery. "*There are dozens of ways of synthesizing a single compound and the crux of industrial chemical invention is to find the quickest, cheapest method to do this*."[81] Beer goes on to state that "if, for instance, as happened in the early dye industry, Renard frères & Franc's fuchsine was protected by patent, no other French manufacturer could make that compound without that firm's permission even though he had a process that was far more efficient." [82] It was no small wonder that the improved arsenic process for making fuchsine was perfected and applied outside France, despite being a French discovery in the first place. French patent law stood in the way of progress by guaranteeing monopoly to inefficient producers.[83] In comparison, the German patent law of 1877, which protected process and not product, induced German companies to discover all routes to a dye to secure a monopoly, creating a severe restriction on any manufacturer wanting to get into, or compete in the synthetic dyestuffs industry by investing heavily in R&D[84].

Perkin's mauve was also to be produced by rival companies, such as Roberts, Dale & Co., as English patent law permitted the filing of different processes for the same product. Caro, at Roberts, Dale & Co, discovered a new route to mauve in 1860. [85] It has even been argued that by 1864, the number of dye manufacturing firms had out grown the number of dyes manufactured at regular commercial levels in Britain.[86]

In the beginning of the 1860s, synthetic dyestuffs had become a European industry. The International Exhibition of 1862 revealed one Swiss manufacturer, seven Germany and Austrian

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[78] Travis 1993: 70.
[79] Nicholson's aniline red was generally named magenta in Britain, after the June 1859 battle of that name in which the French had repulsed the Austrian army, reflecting where the British sympathies lay. Nicholson's company, however, preferred the trade name roseine. (Travis 1993: 70-71.)
[80] Haber 1969: 82.
[81] Beer 1959: 35.
[82] Beer 1959: 35.
[83] Beer 1959: 35.
[84] Research & Development; Glossary.
[85] Reinhardt and Travis 2000: 54.
[86] Fox 1987: part I 11.

companies combined, nine from Britain, and twelve from France.[87] During the early 1860s the four major German synthetic dyestuffs companies would be founded. These companies were the Badische Aniline & Soda Fabrik (BASF), Farbwerke Hoechst, Aktiengesellschaft für Aniline Produksjon (Agfa), and Bayer & Co. Farbwerke Hoeckst was initially set up in 1862 by Eugene Lucius in a joint venture with two dealers, Wilhelm Meister and Adolf Brüning, to manufacture aniline dyes at Hoechst near Frankfurt (as Teerfarbenfabrik Meister, Lucius & Co).[88] BASF developed from the association in 1861 of a businessman and tar distiller, Friedrich Engelhorn, with two chemists, the Clemm brothers, to build a fuchsine and aniline plant at Mannheim. Bayer & Co. set up trading in Barmen in 1863 and was a joint venture between a dye merchant, Friedrich Bayer, and the cotton trader Johann Friedrich Westkott. Bayer & Co. started off with only one employee.[89]

In some respects, this early period in the production of synthetic dyes represented little break with the past, since, according to Reinhardt and Travis, the new synthetic dyes relied on prior science and technology in the processing and application of natural products.[90] Even though a scientific understanding of the products and processes was still a few years off, the industry picked up pace, and the number of firms in Britain, France, Germany and Switzerland all increased, and would continue to do so, until 1865. By 1867, the number of companies in France, Britain and Switzerland was dropping.[91] France was the first industry to lose out, and the only industrial sector to experience something similar to a shakeout.[92]

The early 1860's was also a period in Britain when academic chemists from technical institutions were brought in to provide scientific explanation to industrial problems.[93] Hofmann at the Royal College discovered the important range of fuchsine-derived violets (Hofmann's Violets) and determined the nature of the reactants for aniline red.[94] Travis considers the establishment of a direct relationship between the red, blue and violet aniline dye by Hofmann not long after as the point in time when chemical manufacture began to turn from craft towards science. Structural formulae were not available for aromatic chemicals at this time. However,

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87 Travis 1993: 74. See also Appendix III Fig 3.
88 Aftalion 2001: 41.
89 Travis 1993: 74.
90 Reinhardt and Travis 2000: xv.
91 Appendix III Fig 3.
92 Homburg and Murmann 2001: 182.
93 Travis 1993: 86.
94 Travis 1993: 86.

they can be represented by constitutional formulae based on simple types of groupings of atoms, which enable Hofmann to discover his violets in May 1863.[95]

An important feature in the early years of the synthetic dyestuffs industry was the scaling up of production. From experiments conducted on a laboratory scale, apparatus was erected that had to take into account the generation of heat, the corrosive nature of acid etc. There are several indicators that show that the British companies held the advantage there, at least for a while. For example in 1868, Perkin remarked that overseas producers did not originally appear to have succeeded well in the manufacture of nitrobenzene and continued to use earthenware vessels for some time. In Britain, iron apparatus for large-scale manufacture with ordinary nitric acid and concentrated sulphuric acid as the nitrating mixture was available through the work of Simpson, Maule & Nicholson in 1861. S.M., & N. would also make a major advance by introducing high-capacity closed-iron reactors driven by steam engines around 1860. Travis, in relying on a contemporary source, tells how this type of reactor did away "with the dangers of explosion and fire, and has converted a perilous operation, which seemed as if it would never get out of the domain of pure science, into one of the easiest and most elegant of manufacturing processes."[96] Nicholson's style of equipment was to be imitated by the French and the Germans.[97]

The quality of British engineering can also be understood from the business achieves of BASF, which obtained from 'the much more technically versed W.H. Perkin' the purification of anthracene and the manufacture of anthraquinone from this substance in 1870.[98]

The reactor designs, according to Travis, shifted from the crude and makeshift to the large-scale equipment to distillate coal tar hydrocarbons up to the mid-1860s. From the late 1860s large, airtight, efficient and reliable reactors fitted with steam-powered mechanical agitators became commonplace for many operations.[99] The necessary process equipment for intermediates in the production of dyes and oxidation "evolved empirically and continued to benefit from the latest techniques used in the construction of steam engines and in heavy engineering, requiring the same tools and equipment."[100] By 1871, the annual production of aniline in Europe had reached 3500 tons, though by this time the greater part of manufacture and consumption was in Germany.[101] It had much to do with a German imitation of British

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[95] Appendix II.
[96] Travis 1993: 92.
[97] Travis 1993: 92.
[98] Abelhauser, W. *et al*. 2004: 27.
[99] Travis 1993: 102.
[100] Travis 1993: 102pp.
[101] Travis 1993: 103.

products and processes, which implies that the technological shift happened after a shift of industrial output.

2.5 The decline of the British synthetic dyestuffs industry

The foremost characteristic of the second industrial revolution was the formal application of science to industry, and few commentators have doubted its impact on the growth of the German industry in the last third of the 19th century. The prelude to scientific and not empirically based innovation was the availability of Kekulé's novel benzene theory in 1865. Previously elusive structural formulae could be drawn for the coal tar aromatic compounds and their derivatives. It was so successful as the servant of the coal tar dye chemistry that the benzene ring became an essential component of academic organic chemistry, according to Reinhardt and Travis.[102]

Tab 1. Estimated increase in production of aniline dyestuffs in Western Europe 1862-72.[103]
(five year intervals)

Year	Value *Marks (millions)*	Production *(1862=1)*
1862	7.5	1.0
1867	22.5	15.0
1872	30.0	40.0

From 1862 to 1872 the estimated relative production of synthetic dyestuffs in Western Europe increased as much as 40 fold. That the value of production in the same period 'only' quadrupled shows that there was a general price drop relative to output in the period, a strong signifier of fierce competition as well as improved production processes.

The English market was the largest market in Europe for synthetic and natural dyes. During the first half of the 1860s Britain imported dyes from France, and sometimes the origins were hidden in order to avoid patent infringement.[104] Imports from France declined after the collapse of *La Fuchsine*, a joint-stock company set up by Renard Freres & Franc, which monopolized production of fuchsine in France.[105] By the middle of the 1860s, imports from Germany started to grow.

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[102] Reinhardt and Travis 2000: xv.
[103] Travis 1993: 149.
[104] Appendix II.
[105] Travis 1993: 116. Appendix II.

As for British manufacturers, Perkin established his business and started producing his mauve in 1857. Simpson, Maule & Nicholson of London produced aniline red (magenta) and its blue and violet derivatives. Levinstein began production in Salford in 1864, and then moved to nearby Manchester in 1865, and traded under the name of L.I. Levinstein & Co. He benefited from the removal of the SM&N monopoly by the House of Lords in a legal dispute with Read Holliday & Sons of Huddersfield. Holliday also suffered from the SM&N monopoly, at least until 1865 when the Medlock patent was declared 'ill and void at law'. Although only a cluster of companies, these were the main producers of aniline dyes. Read Holliday & Sons and L. I. Levinstein & Co. were by far the largest British manufactures in this period, having established their position in Britain during the mid-1860s.[106]

Both L.I. Levinstein & Co., and Read Holliday & Sons' hiring record of scientists reveals that Hofmann, the teacher whose advice Perkin was ignoring when he resigned from the Royal College of Chemistry to set up a dye manufacture, was but one of many highly qualified German individuals playing a part in the new but growing synthetic dyestuffs industry. Indeed, it would be easier to count the British companies that did not employ a German scientist that those who did, and continued to do so.

The product range in synthetic dyes, which Beer traces by relying on source material from the London Exhibition of 1862 and that of Paris in 1867, shows that four coal tar dyes had disappeared completely from the market. [107] The consumption of mauve and imperial violet diminished considerably, while fuchsine and aniline blue greatly increased their markets though their price fell drastically.[108] During this same period eleven new colours were introduced, of which iodine green, Hofmann's violet, aldehyde green, and aniline black proved to be the most important.[109] Product turnover time in the following years was to diminish and the product range was to increase dramatically into a full rainbow of colours.

In the decade after 1859, the starting hydrocarbon remained benzene. Later, toluene-based[110] dyes were developed to overcome the monopoly Renard's had gained in fuchsine production.[111]

The year 1865 was one of the most significant in the development of the coal tar dyestuffs industry in Britain, according to Travis.[112] Two important patent cases had finally been

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[106] Travis 1993: 134. More on cross national company population in section 4.2.
[107] Beer 1959: 32.
[108] Beer 1959: 32. More on this note in section 3.1.
[109] Beer 1959: 32.
[110] Glossary.
[111] Travis 1993: 157.
[112] Travis 1993: 135.

resolved, and an invention was seen to be immaterial if the specification was misleading. This would make the important synthetic dyestuff fuchsine virtually free game in Britain, ensuring competition and a lower price.[113] That same year August Wilhelm Hofmann resigned from the chair at the Royal College. During his twenty-year stay in London he had trained the pioneers of the industry and had been an important figure not only at the College, but also at the crossroads of laboratory and industrial research.[114] Travis claims that around this year the British market experienced the first organized invasion by the German manufactures. Travis identifies that novelty in product (and process) were still a British phenomenon, rather than German.[115]

A hydrocarbon that was present in very small amounts in coal tar would be a critical component in bringing about a geographical change in the novelty of product. That hydrocarbon was anthracene, which played a critical role in forging the link between technology and science in the 1870s.[116]. The understanding of structures of many simple aromatic products, though not of immediate value, followed from Kekulé's Benzene theory. Then new discoveries provided new directions to chemical technology, and the greatest change happened in Germany, where German companies appreciated and adapted to the new way of using knowledge, whilst British companies would perhaps experience too little change and carried on as before.[117]

Travis considers the period 1868-1880 as one of a changeover from science-based empiricism in the dye industry to a pursuit in which a sound theoretical basis encouraged the design of total synthetic pathways.[118] Kekulé's six-carbon benzene ring of 1865 was the key scientific concept in this endeavour and "provided a visualization of structural formulae that were reasonably approximations of the desired products."[119] Kekulé's theory was immediately applicable to resolving problems of molecular architecture. Not long after, in 1868, Carl Graebe, a Heidelberg student in chemistry, and Carl Liebermann, who had qualified under Bayer at the Gewerb Institut, found that the natural product alizarin is a derivative of the aromatic hydrocarbon anthracene, and established the partial structure of alizarin and a route to its synthesis. This was the first synthesis of a complex natural product in the laboratory,[120] or the first instance of industrial replication of an organic molecule found in nature.[121]

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[113] Travis 1993: 136. See also 'The Medlock case', sections 3.2 and 3.3.
[114] Travis 1993: 136.
[115] Travis 1993: 163.
[116] Glossary.
[117] Travis 1993: 159.
[118] Travis 1993: 163.
[119] Travis 1993: 163.
[120] Reinhardt and Travis 2000: xii.
[121] Travis 1993: 164.

Travis acknowledged there was a major English contribution to the alizarin story. This was made by Perkin. Drawing on Kekulé's published theory, Perkin set out researching the synthetics of alizarin. Other developments occurred simultaneously, amongst others by Adolf Bayer, who took his Ph.D. in Heidelberg before moving on to research with Kekulé. Bayer's studies were to be very much related to industrial problem solving. While Hofmann's students in London had become masters of aromatic nitration and reduction in developing the synthetic methods crucial to the production of aniline dyes, Bayer and his students in Berlin became masters of the art by tearing apart industrially important molecules and, from the information they revealed, by designing ways of putting them together again. This began in 1865. Bayer started research into the constitution of indigo, and though he would soon experience setbacks, his studies played an important role in the alizarin research brought to fulfilment by Carl Graebe. Graebe and Libermann embarked in a course of patent protection that encompassed France, Austria, Russia, Prussia, and several other German states, and most important, because of the strength if its patent law and the enormity of its textile industry, Great Britain. The British patent was registered on 18 December 1868.[122]

BASF, a German dyestuffs company that by 1865-66 had a total turnover of about one million Marks, experienced some problems due to the high level of competition, and found survival to be a matter of new product developments and improving existing processes. August Clemm, who with his brother Carl had founded the BASF in partnership with Friedrich Engelhorn, was in charge of the dyestuffs section. At the time the company possessed neither research facilities nor a 'scientific chemist'.[123] To remedy this Heinrich Caro was hired as a deputy technical director, and soon afterwards Caro began discussions with Graebe and Libermann over ways to improve the yields of their patented process. An announcement of their synthesis – but not their method – was made in January 1869, spurring chemists in Germany, France and Britain to take up research into the matter.[124]

In Britain, Perkin also attempted to synthesize alizarin. On 24 August 1869 Perkin's patent was sealed, while the German patent awaited the results of further experiments on their renewed patent filed on the following day. Having secured his patent one day in advance of his German competition, Perkin and the Germans found the situation delicate and uncomfortable. The BASF Prussian patent of 12 September 1869 was turned down, and from then on there was no monopoly on the manufacture of alizarin in Germany, making the British patent all the more important for the BASF. The BASF was worried, however, that Perkin & Sons could well be a

[122] Travis 1993: 167-176.
[123] Travis 1993: 177.
[124] Travis 1993: 179.

powerful competitor on mainland Europe. The solution was that Perkin would monopolize the manufacture of alizarin in Britain, while the BASF would dominate the European mainland trade, without interference from Perkin & Sons Perkin soon developed a second process that was found to be more valuable, and was joined in the cross-licensing agreement.[125]

Soon production began in Germany and Britain. German companies aimed at optimizing the conditions under which synthetic alizarin might be produced, and called for new strategies of company restructuring involving divisional and individual responsibilities in company organization.[126] The BASF reorganization was the most far-reaching. By the end of 1869 the number of scientific personnel had increased from four or five to the then high figure of seven.[127] Similar developments can also be seen in other German companies such as Bayer & Co. Although slower to adapt than BASF in the total number of chemists employed, the Bayer Company also sought to sponsor research whose primary aim was the discovery of new colours during the latter half of the 1870s. [128] Hoechst also entered the alizarin trade, though production was brought a halt in August 1870 because of the Franco-Prussian war, and the construction of new facilities was not completed until the middle of the following year.[129]

In Britain, after overcoming the difficulties of scale up production and supply of the feedstock anthracene, Perkin begun production late in 1869 and produced a ton before the end of the year. The next year Perkin & Sons produced 40 tons of synthetic alizarin (as a 10-per cent paste), 220 tons in 1871, 300 tons in 1872, and by 1879 2000 tons annually. The figures Travis employ for the manufacture of alizarin in Germany by 1880 is 12,000 tons.[130] The individual contributions are, however, uncertain. For example estimates have been provided only for BASF for 1870, when 1 ton was produced, and 1871, when 100 tons were produced.[131] The company history of BASF (2004) shows that by 1875 alizarin dyes constituted more than 40% of total sales turnover, and in that year the value of the trade in alizarin dyes was about 5 million marks (£250,000)[132].[133]

Synthetic alizarin would also have an important impact on entrants into the synthetic dyestuffs trade between 1869 and 1876. According to Homburg and Murmann the second entry

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[125] Travis 1993: 182-183.
[126] Travis 1993: 184.
[127] Travis 1993: 184.
[128] Beer 1959: 78.
[129] Travis 1993: 186.
[130] Travis takes several sources into account in making his estimates. (Travis 1993: 195.)
[131] Travis 1993: 195.
[132] A 20:1 estimated currency exchange rate by Haber that does not take purchasing power into account. (Haber 1969: 195.)
[133] Abelhauser, W. *et al*. 2004: 93.

wave, which occurred between 1871 and 1873, provides a good example of the consequences of such a major scientific breakthrough as the synthesis of alizarin.[134]

The synthesis of alizarin in 1868 opened up the huge market that was formerly served by the natural dye makers and the madder root. Murmann and Homburg suggest that firms entered the industry to take advantage of the alizarin market.[135] In 1869 Hoechst, BASF and Perkin & Sons started to make synthetic alizarin. Soon new companies were founded as specialized alizarin producers and table 2 shows that from 1873 alizarin producers averaged close to 30% of total firms.[136]

According to Travis, the most important consequence of the alizarin synthesis is that from 1868 onwards the synthetic dyestuffs trade picked up pace and relied on science-based innovation in Germany, whilst British producers were increasingly left behind. The 1870s were a period of adjustment and stabilization as more power fell into the hands of the market leaders. The revenues from the alizarin trade enabled Germany to account for over 50% of the world sales in synthetic dyestuffs. Then as the decade drew to a close, the discovery of the azo dyes[137], protected by the German system of patent protection, forced new research strategies upon the German dye industry, which possessed a greater body of relevant knowledge than its British counterpart.[138]

The further developments of the industry are regrettably beyond the scope of this paper. After 1870 the survival of the empirical approach, the size of the companies, and the exceedingly large scale of production all require a considerably larger study. It is necessary, however, because of the arguments employed later in this thesis to produce a short fulfilment of the reasoning of Travis and Reinhardt.

The foundation of modern science-based industry and industrial-academic collaboration had been laid by the discovery of alizarin. Artificial alizarin heralded the downfall of the natural dye industry, and the start of the age of science-based invention, or what is often known as the second industrial revolution. As the pace of invention, innovation, and competition accelerated, many of the new artificial dyes were themselves threatened with obsolescence. Product turnover times became shorter and shorter, and the range of new products expanded incessantly. To keep up with these developments, firms had to implement strategies for long-term survival. This called for new modes of organization, including collaboration with academic

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[134] Homburg and Murmann 2001: 182.
[135] Homburg and Murmann 2001: 122.
[136] Homburg and Murmann 2001: 182pp. Entry and exit patterns see section 4.2.
[137] Glossary.
[138] Travis 1993: 207.

chemists, and the establishment of industrial research laboratories where new products were invented and the products of competing companies were carefully screened and analysed.[139]

In 1874 the academic chemist Adolf Baeyer, at Strasbourg, and industrial chemist Heinrich Caro, at BASF, jointly published the chemical structure of alizarin. The same year Perkin retired from the industry.

The German technological achievements, such as the introduction of azo dyes in 1875, which contain the atomic grouping -N=N-, had a tremendous impact on the protection of intellectual property rights for chemical discoveries, and led to the calls for the reform of patent systems, particularly in Germany. In 1877 a comprehensive patent law was introduced in Germany. It was the most advanced system in the world for protecting chemical inventions.[140]

According to Beer the most immediate concern for those engaged in dye manufacture in Germany was the patent question. It became a matter of vital importance to the German dye industry to have a workable, efficient patent system without which it was useless to invest heavily in a research programme, and without a research programme the continued prosperity of the colour business was unthinkable.[141]

One of the most quoted successes of industrial and academic collaboration was the 1883 discovery, by Adolf Baeyer at Munich, of the structural formula for indigo. By 1897 BASF and Hoechst in Germany commenced the manufacture of synthetic indigo that eventually led to the collapse of the natural indigo trade.

In 1889 a Central Research Laboratory opened at the BASF Ludwigshafen factory and the industrial research laboratory became a formal business unit.

By 1914, the German synthetic dyestuffs industry accounted for 90% of the world's trade in dyestuffs.[142]

2.6 Summary

How then can the new contributions offer an altogether new understanding of the decline of the British synthetic dyestuffs industry? Travis's thesis is a milestone in that the British manufacturer of the dye plants operated in accordance with market conditions: rationality or social origin, two of the most common explanations of the general 'decline' of Britain's manufacturing industries, had little to do with the decline of the British synthetic dyestuffs industry.

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[139] Reinhardt and Travis 2000: xii.
[140] Reinhardt and Travis 2000: xii.
[141] Beer 1959: 105.
[142] Marsch 2000: 217-241.

Travis's thesis has not, however, been hailed as a milestone outside the chemical history community even though it singles out a particular technical skill to the relief of British ingenuity and enterprise. To explain why new explanations of how the British synthetic dyestuffs industry 'declined' have been poorly received, if received at all, it is necessary to consider what explanations have been used in the historiography on the subject.

3 Historiography

The study of the emergence of the synthetic dyestuffs industry in Britain in 1856, and the evidence of its 'decline' more than two decades later, is approaching its 50th anniversary. This industry has, for the greater part of that period, been under-documented, partly because a definite account has still to be written. To illustrate that point three publications of 1959, 1968 and 1987 have been selected here. These publications were the only ones to consider the 'decline' of the British dyestuffs industry in this period until the more recent publications of the 1990s.

The object of this chapter is to give an understanding of what arguments have been employed over time to explain how Germany and not Britain came to dominate the world's trade in synthetic dyes prior to the First World War. What little reference has been made to the synthetic dyestuffs industry in the family of studies that comprise the British 'decline' comes from these publications. The historiography of the synthetic dyestuffs industry is therefore important in understanding how this industry has become a neglected case study of the British decline, something that will be discussed in chapter 5.

I have attempted to assign each author to separate entities, only pointing out trends or continuities, to address how the decline of the synthetic dyestuffs industry has been a largely unsolved matter. The increasing awareness of skill and the inadequacy of Britain's educational system in terms of supplying chemical expertise are crucial for the understanding of the historiographical evolution of the study of the history of the synthetic dyestuffs industry.

3.1 John Joseph Beer

Beer was one of a few capable historians with a knowledge of chemistry, and (initially, his Ph.D. thesis) *The Emergence of the German Dye Industry* (1959) focussed on technological achievement. Some of the critics of the work claimed it was thorough only on the surface and lacked in-depth analysis.[143] There was a particular lack of company archives, which would have been useful to survey how German companies would come to dominate the global synthetic dyestuffs industry. Beer backed up his arguments by relying on the German synthetic dyestuffs company Bayer, one of the four major German companies alongside B.A.S.F., Hoechst and Agfa. As a result, Beer did not earn the most favourable reviews. I.N. Lambi, at the University of Toronto, concludes his review of the work with a few well-chosen words: "But he [Beer] has raised more problems than he has solved. A definitive account on the subject remains to be

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[143] Redlich 1960: 515-516.

written."[144] Still, equipped with the marvellous language of a 1950s history student, in a way that has caught the awareness of multiple students from different disciplines, Beer sets out and succeeds in communicating a historical problem that was no longer acute by the time he wrote his book.

When John Joseph Beer published *the Emergence of the German Dye Industry* in 1959 it was a timely attempt to explain how Germany achieved the pre-eminent position of being the foremost industrial power on the continent by a case study on the synthetic dyestuffs industry. Published not more than a generation after the end of the Second World War and at the beginning of a long run of continuous and high growth rates in Western Europe lasting into the 1970s, Beer isolated the German system of education as the cause of growth. The synthetic dyestuffs industry contributed mightily to educational reform at the university level, helping to make Germany's scientific and engineering education system the finest in the world. Beer goes on to state: "the dye industry also did much to help bring about a change in the social structure of society. It did so by employing large numbers of academically trained chemists in its plants, and this it set an example to other industries by showing them first the usefulness and later the indispensability of this type of employee."[145] But I will not go on pointing out to small and formal issues. In Britain, on the other hand, the industrial scientist and engineers carried little prestige in intellectual circles and in society at large.[146]

By mid-century Britain had achieved industrial supremacy primarily for its efforts in the coal, iron, cotton and textile industries, in addition to colonial trade. Since Britain's wealth was greater than that of its continental rivals, Beer proposed that British capitalists had the pick of the work market, and that Britain's wealth stood in the way of the development of the dye industry.[147] It could be mentioned that wealth had not stopped Britain from becoming pre-eminent in the global trade of natural dyes. Beer claimed it was not that Britain had achieved no advances in the fields of organic chemistry and chemical technology, but that the country had not advanced rapidly enough. He claimed the reason why the British failed to match the German scientific developments and, as a result, declined as a dye-manufacturing country was complex question and worth quoting at some length:

"*Certainly she had a commercial and industrial base for supporting a dye industry far superior to that of France. No country in the world had a potential market that could compare with Britain's, none had greater financial resources for backing new industries, none had such a well-developed coal industry which produced tar in abundance; nor was there a nation whose output of heavy chemicals was comparable. She had been the*

[144] Redlich 1960: 515-516.
[145] Beer 1959: 149.
[146] Beer 1959: 44.
[147] Beer 1959: 44.

first to embark on the dye-making venture and, when one considers all these points in her favour, she should have continued to lead the way."[148]

Beer's identification of no less than six points in Britain's favour leads him away from the more common economic variables, to an attempt to trace technological achievement.

Beer identifies the decline of Britain's dye industry as beginning in 1873. Beer explains this by considering the national products shown at the International Exhibitions of 1873, even though he does not provide an analysis of cross-national product range, but rather relies on contemporary reports. He finds that if no signs of a shift of power existed at the International Exhibition in 1867, things were different by 1873. By 1873 eminent German chemists had left the British Isles, which according to Beer, was the start of the decline for the English dye industry. Beer did not believe that the departure of German chemists was a cause, but rather a symptom of Britain's failure to keep up with Germany.[149]

The state of organic chemistry in Britain was backward and by the 1870s the country could no longer attract German scientists of such exceptional quality as August Wilhelm Hofmann, Heinrich Caro, and Maurtius, who all wanted desired a sympathetic attitude from business and government backed by money, and lots of it. Unfortunately, no one in Britain was ready and capable of granting such requests. In Germany however, the situation was almost reversed. There, industries and schools were eagerly gathering large numbers of chemists for whom such splendid working conditions and salaries were being provided that it became impossible for the chemists employed in England to resist the call to return home. [150]

In Britain, little investment was made for the benefit of the chemical discipline, or the synthetic dyestuffs industry. Instead, Beer finds that the British banks had ample opportunity to put their money into ventures with whose risks and potential they were already familiar. They could afford to let their foreign colleagues take the incalculable risk of financing a business that depended entirely on scientific and technological discovery. Apart from the unwillingness of English capitalists to back chemical research and set up, or bring pressure on the government to set up, schools for the training of organic chemists, there was still another and perhaps more fundamental factor responsible for Britain's lack of industrial scientists and engineers. Those professions carried little prestige in intellectual circles and in society at large and, as a result, industry found it hard to obtain them. Science as an end to itself was prestigious; to get one's

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[148] Beer 1959:44.
[149] Beer 1959:42.
[150] Beer 1959:43.

hands soiled by industry was not. Cultural arguments, such as this one from Beer, are typically associated with the group of historians who, in the 1950s, tackled the British 'decline'.[151]

Beer's last point is that scientific advances made in Britain were exposed to foreign imitation. Since no comprehensive patent law existed throughout the German principalities (see more below), German companies could file a patent in Britain to protect their product, but British companies could not do the same to protect their products.[152] Up until the 1870s, German companies were not very innovative and relied on acquiring foreign technology. Beer claimed the British patent law, which might be thought to exist to protect British enterprise, did little of the kind. [153]

According to Beer, inadequate industrial research, added to England's free-trade policy and a long delay in requiring foreign companies to work their protective patent on British soil, caused the decline of the British dye industry to be as drastic as that of France, which was the only industry to experience a shakeout.[154] As a result, by 1914, 80% of Britain's annual dye consumption, valued at £2 million, came from abroad. The remaining 20% was made in England by foreign-owned subsidiaries from imported intermediates.[155]

3.2 L. F. Haber

"The history of the British dyestuffs industry is a disappointing story of initial success followed by a long but irresistible decline." L. F. Haber [156]

Haber's *Chemical Industry During the XIX Century* was first published in 1958, but it is the second edition of 1969 that is considered here. The general conclusions have remained unchanged but alterations in emphasis and amendments have been made. As opposed to Beer, Haber's book is not a question answering publication, in the sense that it is published as an effort to come to terms with a question or problem of a given research area. Rather, Haber offer a treatise; a systematic and extensive written discourse on the chemical industry during the 19th century. Haber is primarily concerned with four products on the inorganic side of manufacture: sulphuric acid, soda ash, caustic soda and bleaching powder, and dyestuffs on the organic side of manufacture. Haber's two books, *The Chemical Industry during the Nineteenth Century: A Study of the Economic Aspect of Applied Chemistry in Europe and North America* (Oxford 1958 second ed.

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[151] Beer 1959: 44; See chapter 5.
[152] Beer 1959: 49.
[153] Beer 1959: 49.
[154] Beer 1959: 47.
[155] Beer 1959: 48.
[156] Haber 1969: 162.

1969) and *The Chemical Industry 1900-1930: International Growth and Technological Change* (Oxford 1971) are still considered to be the standard treatments of the entire chemical sector during this period.[157] Because the book also includes the inorganic side of manufacture, Haber (unlike Beer) includes the early part of the 19th century.

Haber, like Beer, traces the organic chemical teaching at the Royal College of Chemistry through Hofmann to Liebig and the institute at Giessen to conclude that "most of the impetus that he [Hofmann] had given to British chemical education was lost with his departure, for Liebig's British disciples were not animated with the same pedagogic zeal."[158] This argument is typically in order with the general picture of British technological achievements created by history students of the 1950s. Haber reaches this conclusion after a narrow survey of Hofmann's career at the Royal College.

Haber does, to a greater extent than Beer, offer a survey of chemical institutions in Britain and a few statistics to accompany them. Overall, Haber places an emphasis on Liebig's teaching and Liebig's chemical principles, rather than an interpretation of the training in a special skill to be pursued as a trade. *"A remarkable new feature at Giessen was the careful fostering of an spirit de corps between student and teacher*."[159] Thus, even though Haber gives a treatise of the organization of scientific advance in England prior to the establishment of the Royal College of Chemistry, he does not capture the specific nature of the chemical education (aromatic chemistry) required by the synthetic dyestuff industry around the time Hofmann left the Royal College, something that has been noted by other commentators:[160]

"[Haber]*fails entirely to show the profound difference between the kind of science that could only gradually become applicable in the heavy-chemical field and the compound-spawning activities of the organic chemists employed in the laboratories of the German dyestuffs firms[.]*"

Haber's quantitative estimates of skill supply are therefore misleading in that he indentified general skills on a particular case. Despite dealing with the state of scientific education in England and other countries over two chapters, Haber fails to show the profound difference between the kinds of science that could only gradually become applicable in the compound-spawning activities of the organic chemists employed in the laboratories of the German dyestuffs firms. In *Chemical Industry During the XIX century* there seems to be "an assuming of the relationship between science and technology that in fact did not begin to become significant

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157 Pence 1999: 164-165.
158 Haber 1969: 69-70.
159 Haber 1969: 64.
160 Travis 1993: 164,166-169; Reinhardt and Travis 2000: 109-10; Schröter 1998: 100.

until the century was in sight of its close."[161] It is therefore hardly surprising that Haber reaches the conclusion that German chemical education was simply better than British chemical education.

Haber's seeming unawareness of the multitude of industries illuminated by chemistry and the different utilities of practical science is made evident by his interpretation of Henry Roscoe's admiration of science for its own sake (pure science), " […] a love for science and knowledge for its own sake is much more seen in those [German] universities than it is in ours" which Haber interprets as a general love in Germany for science shown by high numbers of students enrolled in German universities.[162] Haber interestingly offers the view that there was a decline of the standard of teaching in Britain, but does not stress the nature of the teaching, and relies on numbers of incumbents.[163]

In the case of the synthetic dyestuffs industry Haber argues that the retirement of Nicholson in 1868, Perkin in 1874, and Greville Williams in 1877, left Britain virtually bereft of chemist-businessmen, with the notable exception of Ivan Levinstein.[164] There was also a notable lack of chemists with a superior knowledge of the hydrocarbon derivates and especially the coal tar colours.[165] This was due to the fact that the only place the subject organic chemistry was taught properly was in Manchester, and then only from the 1880s onwards.[166] Haber uses wage data to illustrate the inferior status of chemists. The salaries earned in Britain were only in rare cases comparable to what the German chemists earned in their home country. But neither in purchasing power nor prestige could the British and German posts carrying these salaries be compared.[167] A career, therefore, in industrial chemistry held out little inducement for the youth anxious to earn a good living to the neglect of industrial chemistry in Britain. The directors of chemical firms were "not, however, wholly bereft of scientific assistance."[168] The services of consultants became more important in the second half of the nineteenth century in Britain, and they were drawn mainly from academic circles.

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[161]Hardie 1959: 291-294.
[162] Haber 1969: 71.
[163] Haber 1969: 75.
[164] Haber 1959: 188.
Read Holliday, manager of Read Holliday & Sons, was also listed as an inventor of dyes, but not nearly to the same extent as Levinstein. Rather, his son Thomas and other near relatives did much of the inventive work at Read Holliday & Sons until the end of the century. (Fox 1987: Appendix IV.)
[165] Argued by Ivan Levinstein, quoted by Haber 1969: 190.
[166] Haber 1969: 190.
[167] Haber 1969: 190.
[168] Haber 1969: 191.

The influence of patent law on the development of the organic chemical industry was, according to Haber, great and lasting. “Perhaps no other single factor determined to the same extent the decline of dyestuffs manufacture in England and France and conversely its growth in Germany and Switzerland.” [169] What led Haber to come to such a conclusion were two patent cases filed in 1860 by Henry Medlock, a chemist at Simpson, Mauve & Nicholson, and the other in 1869 filed a by a group of German chemists the day before a British chemist, Henry Perkin, filed his patent for the same product.

Medlock’s patent was considered badly drafted and declared ‘bad and void at law’ by the House of Lords in 1865. Owing to the prevailing ignorance of organic chemistry in the early 1860s, it was difficult to draw up patents as watertight as possible, a requirement by the final judgment in the Medlock case. To avoid patent infringement, a patent needed to specify the step-by-step process of manufacture accurately. Medlock’s patent covered the process of producing fuchsine by using arsenic acid, and after the judgment fuchsine was produced by many manufacturers and its price fell steeply.[170]

The second case was the patent application for alizarin in 1869. Both Perkin and a group of German chemists filed the patent in England, which led to a cross-licensing of each other’s processes and Perkin became the sole manufacturer of alizarin in England.[171] In this instance the Germans had not been able to prevent the manufacture of a dye in England; soon, however, the number of British patents taken out by Germans increased, whilst their willingness to grant licenses decreased.[172] As long as inventiveness had been a characteristic feature of British dyestuffs manufacture, the problem of working foreign patents was unimportant. However, it was growing more urgent every year, for British manufactures made fewer discoveries of immediate commercial value and so lost business; as they were also unable to secure licenses from German and Swiss inventors they lost further business.[173] Haber goes on to show that the French patent system applied a hindrance to unjust monopoly because a patentee was deprived of his privilege if he did not to begin manufacturing within two years of the date when the patent was filed in the country where it was filed. Haber suggests that if such a system had been applied

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[169] Haber 1969: 198.
[170] Haber 1969: 199.
[171] Haber 1969: 199.
To the benefit of the reader it should added (though excluded from the argument) that the German group of scientists had filed their patent a day in advance of Perkin, but Perkin’s process was superior. For that reason an agreement was made to allow Perkin to monopolise the production of artificial alizarin on the British market, whilst German companies monopolised the continental European market. (Travis 1993: 180pp.)
[172] Haber 1969: 199.
[173] Haber 1969: 199.

in Britain, British companies would not have been excluded from competition by their own patent law. A second consequence would be that if a foreign company took out protection for a production process in Britain it would be forced to produce the protected product on British soil.[174]

Prior to the unification of Germany in 1871 no common system of patent protection existed throughout the German principalities. It was not until 1877 that a law that covered the entire geo political space of the 'Reich' was passed. This was according to Haber, an exceptionally favourable juncture as far as the dyestuffs industry was concerned. "Up to the early seventies that industry has been imitative rather than original and relied on copying foreign discoveries which were not patented in the different states."[175] In light of Haber's previous argument it meant that German companies would be protected by law if they filed a patent for a product in Britain, whilst British companies would have no such system of protection for their products, abroad or at home, with the notable exception of British competition.

Haber's third point is government intervention in the chemical industry.[176] Haber finds that during the second half of the 19th century "chemical manufactures found that their freedom was being circumscribed by legislation specifically directed against them".[177] Britain did for example specify the natural colouring matter grown in India, instead of the synthetic colouring matter made in Germany for army uniforms. The questioning of British government is another feature that is associated with a 'declinist' history tradition of the 1950s.

Partly evident in Beer but most notable in Haber is the relative size of the synthetic dyestuffs industry. In Haber's fourth point; free trade and tariffs: their effect on the chemical industry, he questions the relative size of the synthetic dyestuffs industry and why Germany should not be allowed to purchase tar distillates from Britain to produce a good the British market required when they sold it at a competitive price. The decline of the synthetic dyestuffs industry did after all occur at a time when Britain produced three times as much coal and iron as

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[174] Haber 1969: 199-201. A new patent bill was introduced in 1883, but it was not until 1907 that the Patents and Design Act forced the patentee to work his invention on British soil.
[175] Haber 1969: 292.
[176] Outside the scope of this paper, Haber identifies the taxation of industrial alcohol in Britain as a hindrance to the development of the chemical industry. Haber relies on a committee report on alcohol and finds that adjustments had been made in the early 20th century, but that it was believed to be of little actual importance to the manufacture of dyes. Fox picks up this point to comment that L.I. Levinstein & Co., was prevented from making the dyes Victoria Blues, Auramine, Malachite Green, Brilliant Green, and the Methyl Violets by the crippling duty on (industrial) alcohol. (Fox 1987:13 part I.)
[177] Haber 1969: 204.

Germany and France combined.[178] At the end of the nineteenth century, Britain was still the most important trading nation of the world, and was also the leading exporter of heavy chemicals. Beer studied the synthetic dyestuffs industry as a case study of Germany's rise to become the foremost industrial country of the European continent with a focus on technological achievement. Haber, on the other hand, identifies that towards the end of the 19th century, Britain's position as the leading industrial country was being challenged by Germany, and that the challenge was most effective in the field of applied chemistry. Haber's approach is much more quantitative and that of an economic historian, and has a stronger focus on the British experience during the second industrial revolution than Beer, whose primary objective was to consider the German rise to fortune. A common characteristic of both Beer and Haber is the appliance of cultural arguments that have been questioned by recent publications on the British decline. Another observation is that the empirical findings of Beer and Haber are questioned not only by recent contributions to the history of the synthetic dyestuffs industry, but by students of the British decline as well.

The next thorough accounts that discuss the decline of the British synthetic dyestuffs industry were published during the 1980s. Two commentators, Maurice Fox and Ernst Homburg [179] (1984) would be the first to consider the term 'aromatic chemistry' in relation to the British rise and fall in the synthetic dyestuffs industry, and so act as a link between Beer and Haber and the more recent publications. Homburg was the first to argue major difference between Germany and Britain cannot be explained just by looking at the relative numbers of organic chemists, but by looking at the aromatic chemists the difference become more plausible. It would be Fox, however, who was the first to consider aromatic chemistry in a publication on the rise and fall of the British synthetic dyestuffs industry in particular.

3.3 Maurice Fox

Maurice Fox's book Dye-Makers of Great Britain 1856-1976 was published by the enterprise Imperial Chemical Industries (ICI) in 1987. Fox died in 1982, but not before completing a full manuscript sometime between 1979 and 1982. Fox's publication is substantial but uncritical,[180] and it should be remembered that the publication is in the main a history of the two main

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[178] In 1870, the output of iron ore in metric tonnes was: UK 14,602, Germany 2,919, France 2,614, Italy 89. The output of coal in metric tons in 1870 was: UK 112,203, Germany 26,398, France 13,330, Italy 59. (Mitchell 1980: 385-409.)
[179] Treated as a single entity in section 4.2; Appendix II.
[180] Schröter 1998: 100.

companies that were the original nucleus from which grew into the largest dye-making organisation in the Commonwealth, the ICI.[181]

Fox regretted the absence of any comprehensive book dealing with the history of dye-makers in Great Britain before setting out to compile his own book. Fox, a long-time employee at ICI, chose to pay greatest homage to the two British chemical companies, Read Holliday & Sons, and L.I. Levinstein & Co., managed by Read Holliday and Ivan Levinstein respectively, to which he devoted the lion's share of attention in the part of the work dealing with the 1856-1914 period. Other companies such as Perkin & Sons and the British Alizarin Company Ltd., were also the subject of separate sections.[182] Fox included in his work nine company histories and several biographies of the men involved in the industry. He also provided illustrations of some of the chemical plants in the 1856-1914 period.

Part I of Fox's publication is on the family and chemical company of Ivan Levinstein, and Levinstein's services to industry and state through his campaign to alter the existing educational system in Britain. Ivan Levinstein setup business in Salford in 1864, then moved to nearby Manchester in 1865, and started producing synthetic dyestuffs under the name of L.I. Levinstein & Co. The company, although Ivan Levinstein himself showed significant ability as a dye inventor, was to hire continental chemists. In the late 1870s the German chemist Dr Adolf Liebmann and the Swiss Dr Arthur Studer were the first of a long line of Continental dye chemists to come to Blackley, near Manchester. Prior to this event there is no indication anywhere showing that Levinstein had employed a graduate chemist. The majority of the foreign chemists came from Germany, and occasionally Switzerland, and made very positive contributions to Levinstein's company either by invention or process improvement. Fox brings up the low stability of Levinstein's staff. That chemists employed by L.I. Levinstein & Co. were not well paid, added to Levinstein autocratic style of management, explains the short stay of his foreign staff.[183]

Levinstein was, according to Fox, a ceaseless campaigner for improved technical education in Manchester, and there were those who said that he wished to have ready-made experts fed to him for too little in the way of adequate financial recompense. Contemporaries thought that this spoiled the image of an otherwise enlightened and capable chemical manufacturer. Nevertheless, Levinstein was unhappy about his need to hire a foreigner, and in fact openly decried those Englishmen who did so. Fox argues that Levinstein wished for the

[181] Fox 1987: author's preface.
[182] Fox 1987: author's preface.
[183] The Blackley works used the name Levinstein & Co Blackley by 1866, and Ivan Levinstein's brothers in London used the trading name of Levinstein & Co., whilst it is thought that by 1873 L.I. Levinstein & Co. had been adopted as the trading name in Manchester. (Fox 1987: 13-14 part I.)

provision of men "trained in applied science so that the country could become self-generating in the matter of trained brains and expertise".[184] Levinstein himself found it surprising that the first commercial country of the world does not possess a single journal that dealt with the practical appreciation of chemical science to different branches of industry. In an attempt to remedy this, Levinstein founded the 16-page monthly journal *The Chemical Review* in 1871.[185]

Starting in the 1870s and lasting well into the 20th century, Levinstein engaged himself in debates over practical and utilitarian views on education. Levinstein's speeches raised much opposition from academic circles, from the likes of Henry Roscoe, Professor of Chemistry at Owens College. Levinstein claimed that the British decline and the German sovereignty had much to do with Germany's educational system.[186]

"*The British are content with simply acknowledging the ever increasing amount of experimental research in Germany, without making the slightest effort to overtake their opponents, save perhaps by the demand for increased expenditure in technical education or endowments for research*"[187]

Fox supplements Levinstein's point by stating that increased expenditure in technical education or endowments for research was leading nowhere fast.[188] Roscoe's reply was that "no one who knows anything about the subject would support the proposition that the object of teaching technology is to qualify a man completely to manage an alkali works, an alizarin works, or a printing works, or a blast furnace, when he leaves technical school. Such an idea was according to Roscoe absurd on the face of it and needed "no further demonstration to a society like ours."[189] It becomes increasingly self-evident that Fox disagreed with Roscoe's idea that the teaching of general principle, or pure science, was the best way to qualify the student for the different trades. Fox argued that few would deny that Roscoe and others of Victorian Britain had contributed much to the advancement of scientific knowledge.[190] In this, Fox shows an awareness of his own position as a 1980s history student who had begun to question the British industrial 'decline'. Levinstein, the typical British industrialist, with a great depth of perception of the times added to his extensive and well-informed knowledge of what was happening in Germany having studied there himself, was thus fully justified in his campaign. In such a way,

[184] Fox 1987: 14 part I.
[185] Fox 1987: 14-26 part I.
[186] Fox 1987: 26pp part I.
[187] Fox 1987: 28 part I.
[188] Fox 1987: 28 part I.
[189] Fox 1987: 28 Part I.
[190] Fox 1987: 28 part I.

Fox uses the running debates of the time to stress the educational requirement of the synthetic dyestuffs industry, and the British failure to *this* end, whilst the industrialist escaped clean. [191]

On explaining the instability of diazonium compounds[192], the next important segment in the patter of dye-making after the aniline period of dyes, referred to as the *azo* class of dyes, Fox introduces Fredrich Kekulé's benzene ring theory. Kekulé's benzene ring theory makes it possible to draw the structural formulae of aromatic chemicals.[193] Fox goes on to state that systematic advance in azo dye chemistry was quite slow to develop because Kekulé's hypothesis had not advanced sufficiently far to enable chemists to even begin to clarify or even understand the factors of the combining ratios of the reactants. Self-coupling of diazo components, the importance of temperature and what was much later recognized as Ph[194], were still great mysteries. In addition, ice[195] was not yet manufactured and for a number of years after azo dyes had become quite well established in manufacturing, they could be produced satisfactorily only during wintertime.[196]

Kekulé's benzene ring theory have not been mentioned or paid any importance by neither Beer nor Haber. Fox, on the other hand, takes up Kekulé's theory and its significance to the azo dye chemistry. He does not, however, afford aromatic chemistry any special relevance to the skill supply problem experienced in Britain. Neither does Fox mention its significance in that the possibility of drawing structural formula represented a change from empirically based to science-based innovation. Instead Fox goes on to comment the progress made by Levinstein in producing the azo class of dyes by 1878. Fox suggests that Levinstein may have given away a few trade secrets by claiming that his company had developed improved routes that avoided the formation of unwarranted tarry matters, and enabled Levinstein to use cast-iron vessels rather than the extremely expensive and imported enamel-lined autoclaves in production.[197]

By the end of the 1870s L.I. Levinstein & Co. had started shipping intermediates to Germany instead of a common bulk shipment of raw material. Levinstein found it a much more lucrative business, and Fox comments that it is sad no other manufacturer supported him in this,

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[191] Fox 1987: 28 part I.
[192] Glossary.
[193] It was necessary to include some of Travis's writing here to be able to explain diazonium compounds and the importance of Kekulé's benzene ring theory. It should, however, be excluded from Fox's reasoning.
[194] Ph is a measure of the acidity or alkalinity of a solution.
[195] Ice was in fact manufactured at the time, but artificial ice was thought of as distinct from natural ice in that the artificial variant was not thought to display the same qualities.
[196] Fox 1987: 17 part I.
[197] Fox 1987: 17 part I.
The British mastery of engineering has been picked up by Murmann and Homburg in their examples of capacities of reactors and will be taken up in section 4.2.

to the continued hurt of the country's economy and the growth of German power in the industry.[198]

Fox, like Beer and Haber, considers patent law and patent cases important to the evolution of the British dyestuffs industry and brings up the BASF vs. L.I. Levinstein & Co. case of 1881. The German chemical company BASF brought legal action against Levinstein for alleged infringement of their British Patent No. 786 of February 1878. In 1887 the case had reached the House of Lords and according to Fox a sad and seemingly unfair decision was pronounced against Levinstein. Levinstein denied infringement of the patent on the grounds that the German chemist Heinrich Caro, who had worked out the process detail, built upon material already published prior to BASF' s application for the patent. Despite the fact that BASF had probably not produced a single ounce of the compound specified and that the patent that protected four routes would be incapable of yielding a dye that was sufficiently homogenous to have a single structural formula assigned to it, Levinstein lost the case. Considerably poorer in terms of hard cash and unable to produce a profitable dye, Levinstein eventually set up manufacture of the dye in Holland. Fox goes on to state that such was the damage sustained by British patent law, which imposed such crippling restrictions and allowed foreign patentees an unfair monopoly at the expense of British enterprise and ingenuity. [199]

In the eyes of contemporary organic chemists and businessmen, Ivan Levinstein's actions, and especially his reactions to the situation that had arisen on the final judgment of this case, brought him enormous respect and admiration in England, but unfortunately no financial investment in his Blackley concern was forthcoming. At this time, just when Levinstein needed to break the stranglehold of German competition in the home dye-consuming market, and, when he was busy planning further expansion at Blackley, he found himself overburdened by the high costs of litigation. He was unable to raise the necessary capital for his business; the mood of investors in Britain was lethargic to the interest of what was seen as a failing industry. Levinstein thus, according to Fox, in desperation turned to his technical and commercial adversaries, the German chemical companies, for help. The move resulted in a commercial alliance in production with BASF. Both parties benefited from this deal: Levinstein immediately boosted his product range and BASF received production technology.[200]

Another manufacturer of significance in Fox's publication is Read Holliday. Initially setting up a distillation work for ammonia from waste, Read Holliday & Co. became the largest

[198] Fox 1987:18 part I.
[199] Fox 1987:17-20 part I. Fox also argue on the 'Medlock case' the alleged infringement of Medlock's patent worked by S.M.,&N., who brought legal action against Read Holliday & Co.
[200] Fox 1987:20 part I.

distiller of coal tar in northern England. Located on the doorstep of the largest concentration of English textile dye houses, Read Holliday found himself in an advantageous position.[201] Read Holliday's Turnbridge works near Huddersfield quickly exploited the cheap and abundant waste from English gas companies, coal tar, to make dyes in the spring of 1861. What was to become the second largest British dyestuffs company in trade volume and inventiveness before WWI, after L.I. Levinstein & Co., quickly proved its ability to produce and invent dyes. Despite accusations of litigation by S.M. & N., Read Holliday & Co. grew throughout the early period up until 1870s, but was to suffer from the German competition. By the mid-1870s virulent sales competition from the German dye-makers brought a reduced turnover at the London office of Ivan Levinstein's company, an experience shared by other dye manufacturers in the period.[202]

Fox's *Dye-Makers of Great Britain* is rich on detail and includes a list of patents for products and processes taken out by British companies. The record in discovery in the field of dyes and intermediates for dyes, judged by the number of patents taken out by L.I. Levinstein & Co in Britain alone, presents a picture of excellent merit matched only by the performance of Read Holliday & Sons.[203] Despite clearly finding the decline of the British synthetic dyestuffs industry a sad chapter in British industrial history, Fox produced a substantial publication. Fox has not, however, provided an answer why the British synthetic dyestuffs industry declined that has been received with approval. What evidence Fox forwards is primarily on the British educational failure, and the government's lack of interest in improving the prevailing patent situation.

Lastly, Fox was a long-time employee at ICI. His work was amongst others related to dyestuffs, and Fox could, needless to say draw from his profession when writing his book. The attention to detail is greater in Fox's publication than in that of Haber and Beer, especially that which is related to chemistry. It has been shown in this chapter, which can be extended to include Travis and Reinhardt's publications, that the attention to detail is important in understanding what caused the 'decline' of the British synthetic dyestuffs industry, and there is an increasing attention to skills in the historiographical evolution of the study. All contributors have related the 'decline' to skills, but the required skills have been refined from chemistry to organic chemistry and lastly to aromatic chemistry. The increasing awareness of skills can be considered related to the increased specialist knowledge of the contributors when one adds to the equation the fact that Reinhardt and Travis are not unfamiliar with chemistry. In fact, both

[201] Fox 1987:65 part I.
[202] Fox 1987:14 part I.
[203] Fox goes on to state that some 80 patents were taken out in the Levinstein name and a high proportion of these was in the single name of Ivan Levinstein. (Fox 1987:17 part I.)

have extensive knowledge of the subject. Reinhardt's master's thesis was on the history of chemistry. His later education and academic employment centred on the history of science. Travis, as already mentioned, is deputy director of the Sidney M. Edelstein Center at the Hebrew University of Jerusalem. This institution was established in 1980 to encourage advanced research in the history and philosophy of science, technology, and medicine, and in particular it fosters research based on the Edelstein collections on the history of dyeing and chemical technology.

3.4 Summary

Beer was the first commentator to carry out a case study on the synthetic dyestuffs industry by studying technological achievement. But instead of making the 'decline' of the British synthetic dyestuffs industry the focus of investigation, Beer tried to answer how Germany came to be the foremost industrial power on the continent by using the German dye industry as a case study. In so doing, Beer offered several explanations to why it was Germany and not Britain that came to dominate the synthetic dyestuffs trade. Beer focussed on the educational capabilities of Britain and Germany. Because the change in the centre of gravity went against economic prediction, Beer can be said to have identified what has later become the primary area of research. Beer does not, however, provide any analysis of educational institutions or the skills required by industry over time, and rests on the assumption that the teaching of organic chemistry became neglected in Britain, especially after Hofmann left the Royal College of Chemistry, compared to Germany.

Much the same argument can be extracted from Haber, only that it is the number of incumbents and the financing of educational institutions that made the difference in the supply of skills to industry. Haber does not add to the equations the demographic differences between Britain and Germany when dealing with rough aggregates. Instead, Haber, and to a lesser extent Beer, suggest that the dyestuffs industry was a minor industry and not comparable to the big four of coal, iron, textile and cotton, neglecting the fact that similar patterns of decline are found in the new electrical and optical industries. In this, Haber succeeds in under-communicating the experience of the technology-intensive industries during the British 'decline'.

Both Beer and Haber recognise that the manufacture of synthetic dyestuffs had been empirical from the start until the end of the 1860s when the synthetic dyestuffs industry had become a scientific undertaking.[204] In addition, both commentators place the start of the decline in the very last years of the 1860s and the beginning of the 1870s. They mention but do not pay

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[204] Haber 1969: 81.

any special attention to, the fact that at that time the synthesis of madder was achieved, and that it opened up a huge market.

Fox is the only of these three commentators to mention the performance of British companies after the 1870s and it can be seen that the actual output of the British synthetic dyestuffs industry did not necessarily decline, as Read Holliday & Sons. and L. I. Levinstein & Co expanded well into the 20th century. Fox is also the only commentator to introduce aromatic chemistry to the study of the synthetic dyestuffs industry, but not its relevance to the 'decline' of the industry.

During the second half of the 19th century formal knowledge was applied to industry, which was the foremost characteristic of the second industrial revolution. The technology-intensive synthetic dyestuffs industry experienced this change as much as any other manufacturing industry, in that research into new products became increasingly science-based. The capacity of companies to compete therefore relied increasingly on scientific expertise. Since the relatively poor performance of the new industries – including the synthetic dyestuffs industry – has been cited as an example of Britain's 'decline', there is potentially explanatory value in considering the synthetic dyestuffs industry in relation to other new industries. What little work on this has come from Beer, Haber and Fox, who are among the historians who offer cultural explanations for the British 'decline'.

In the next chapter the British educational system will be questioned. This is because the particular skills required by industry were not provided by the British educational institutions, but also because historians concerned with the British 'decline' suggest that such skills were provided by other mechanisms.

4 EDUCATIONAL INSTITUTIONS AND CRUCIAL SKILLS

The first current of Travis thesis was that there was a continuation in knowledge from the natural dye trade in the appliance of craft knowledge in a trade that at first was characterized by empiric rather than science-based innovation. Another study, Robert Bud and Gerrylynn K. Roberts's *Science versus practice,* which traces chemistry in Britain through the Victorian age, shows how chemistry was a multi subject discipline with an academic society that envisaged the study of general principle as the most fruitful approach to the vocational expectations of chemistry. The importance of teaching general principle and comments on the vocational importance of chemistry will be explored first in this chapter. It is worth mentioning, however, that when one is dealing with a set of higher educational institutions, one does not capture the total educational output in Britain, which ranges from primary and secondary education to apprenticeship systems and more.

When a crucial discovery, namely the innovation of artificial alizarin, resulted in a increased industrial pace and required new modes of organization to display a competitive edge in the business, British industry was becoming stagnant, according to Travis. Whether Travis' thesis can be upheld in general is a point that will be tested and substantiated by Murmann and Homburg in the second part of this chapter.

4.1 ROBERT BUD AND GERRYLYNN ROBERTS

Bud and Roberts provide an analysis of British formal teaching in their *Science versus Practise* (1984). Although the organic chemical industry is only one of a great many branches that is dealt with by the group of historians that tackle the British 'decline', it is a special case in that it is British higher education that is being questioned. Such training, again, is not only of consequence to the organic chemical industry, but other new technology industries in particular.

Chemical research started on a small scale. In Britain, the number of practitioners or papers in the chemical discipline over the decade of the 1830s was still measured in the tens.[205] It would take more than 40 years before the number of papers published or the number of chemical patents were to be counted in the thousands.[206] By the 1830's 'professional chemists' such as Humphry Davy could earn a living through teaching and consultancy.[207] Particularly in London did opportunities emerge, and it was in London that the School of Mines, Kings Cross, and the Royal School of Chemistry were established in the following decades. Chemists were

[205] Bud and Roberts 1984: 14.
[206] Bud and Roberts 1984: 15.
[207] Bud and Roberts 1984: 25.

soon appreciated by industry and agriculture, and in the North of England, a new urban industrial culture of consumers of science developed. In 1851 Owens College, a private institution, was founded in Manchester.

Arguably, in the early nineteenth century a very broad range of northern industries was assisted by chemistry; the soap industry, Calico printing, and new industries such as the bleaching powder and Leblanc soda industries. The chemical discipline had already proved its relevance to some extent. At the outset, Thomas Thomson, Professor of Chemistry at Glasgow between 1818 and –1852, was optimistic of the discipline's future. Thomson wrote in 1817 to Robert Jameson, the Edinburgh Professor of Natural History, of his intention 'to establish a real chemical school in Glasgow and to breed up a set of young practical chemists."[208] 12 years later Thomson published an article in the *Edinburgh Review*, 'History and Present State of Chemical Science', which sharply attacked British chemistry:

"About twenty-five years ago, at least thirty individuals might have been reckoned in Great Britain actively employed in chemical investigations; now we can scarcely recon ten. Some cause must exist for this retrogradation, so different from what is exhibited in the Continent, especially in France and Germany".[209]

It seems that despite the progress made in Britain in chemical science at the turn of the 19th century, by the 1830s the country was trailing its continental rivals. One of the German pioneers of industrial organic chemistry was Justus von Liebig[210].[211] Liebig founded in Gießen the first chemical training centre of rank.[212] Its laboratory was one of the German cells of the recent subject of chemistry, in which scientists received their experimental analytic and synthetic training.[213] The Liebig scholars consisted of pupils of the like of Hofmann, Carl Remigius Fresenius and August Kekulé. Both Kekule and Hofmann have already been presented in this paper, but they stood in the forefront of the many German chemists highlighted in the literature for the value and nature of their research for industry. The notion that the German institutions had a focus on the practical, that their institutional training was to be applicable to industry, and was not only to function as a mere research science can be traced back as far as to William von Humboldt in 1799.[214] Humboldt desired and worked towards the development of commerce, and was in a position to direct the educational institutions towards this aim. Liebig did, however,

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[208] Bud and Roberts 1984: 37-38.
[209] Bud and Roberts 1984: 41.
[210] Further reading on Liebig's research and publications is available in Haber 1969: 63-68.
[211] Teltschik 1992: 3; Fox 1987: 94.
[212] Teltschik 1992: 5.
[213] Teltschik 1992: 5.
[214] Schuster 1976: 11.

alter his emphasis from the essential practical utility of chemistry, to the notion of science as an end to itself,[215] a trait that echoed that of Henry Roscoe's teaching in England in the 1840s at the Owens College, a private institution.[216]

In Great Britain one of Thomson's pupils, Thomas Graham, published '*Elements of Chemistry: Including the application of Science to the Arts'* in parts between 1837 and 1842. In Graham's *Elements of Chemistry* one finds 149 pages on physical phenomena and 455 pages on the preparation and properties of inorganic compounds.[217] If Graham's publication gives any indication of the nature of teaching or the progress of the science as a whole (with respect to Graham's capacity),[218] then the teaching of organic chemistry was more of a frontier science in Britain than it was in Germany, at least in terms of the standing of coal tar research.

In October 1845 the College of Chemistry opened and was soon to win royal patronage. At the outset, the scheme was the personal project of two entrepreneurs, John Lloyd Bullock and John Gardner, who envisaged two distinct but linked teaching institutions and the College of Chemistry was meant to be teaching practical chemistry.[219] The position of the academic elite, however, was that the best method of promoting practical improvements is to "encourage scientific research", and that "purely scientific education is generally the best", and is more certain to lead to improvement in practise that the most laborious experience in any one manufacture, gained as it generally is, at the expense of general principle".[220] The idea of teaching general principle instead of qualifying a man to work, for example as an industrial chemist, would two decades later become a barrier to British ingenuity and enterprise.

The original plan for two institutions collapsed, but plans for the establishment of a teaching institution with departments especially for the study of chemistry's many applications were to bear fruit, and Hofmann was hired to teach. That the institution at the outset had differing principal interests, is made clear by Bud and Robert, who divide it's more than 700 supporters into three categories: medicine, the landed interest and manufacturers and engineers.[221] [222] The financial supporters of an educational institution, as Bud and Roberts recognise, give valuable insight into what needs that institution is meant to fill. Medical

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[215] Bud and Roberts 1984: 85.
[216] Bud and Roberts 1984: 85.
[217] Bud and Roberts 1984: 41.
[218] The About the same time, the Swedish Baron and chemist Jons Jakob Barzelius strongly criticised Liebig when the latter attempted a publication on what was proved to be Liebig's strong side, inorganic chemistry and nitrogen fixation.
[219] Bud and Roberts 1984: 51.
[220] Bud and Roberts 1984: 52.
[221] Bud and Roberts 1984: 53-63.
[222] Bud and Roberts 1984: 53-63.

reformers argued that organic chemistry should be part of the curriculum, as did the expanding hazardous coal gas industry, which required that "every gas works employ a chemist, both for its own benefit and for that of the public."[223] As to practical chemistry, analytical chemistry was a prerequisite for industry, as it was required by the inorganic branch of chemical industry and the more 'businesslike agriculture', which sought the aid of chemistry to sold the problem of costly fertilisers.[224] Bud and Roberts are very time-sensitive in their approach, and very careful in describing the vocational importance of science as shifting (much more so than Haber).[225] Coal-tar research was at the cutting edge of science by the time the Royal College was established, and other financial interests were well established long before any demand came from the organic chemical industry. The skill supply response to the demands of Perkin's discovery, as is argued by Travis and Reinhardt & Travis,[226] often derived from a skilful adaptation of existing dye-using technology. Nevertheless, Bud and Roberts do give credit to the Royal College's establishment as something beneficial to the trades.

John Joseph Beer, on the other hand, saw a stronger bond between the College and the trade, and linked Perkin's discovery to Germany. At the Royal College of Chemistry, which followed the salutary German practice of retaining the service of its ablest graduates in the capacity of laboratory assistants, all, except for the Frenchman August Cohours, came from Germany or were Englishmen just back from the study of chemistry at one of the leading German universities. Beer lists the likes of Hermann Bleibtreu, David Price, John Blythe, John Stenhouse, Peter Griess, Adolph Wilhelm Kolbe, James Sheridan Muspratt, Otto Witt, Carl Alexander Martius and Henry Medlock.[227] When the college opened its doors in October 1845, twenty-six was enrolled and there were some whose name became inseparably linked with dye chemistry and the manufacture of organic chemicals; Warren de la Rue, Frederick Abel, and Edward Chambers Nicholson being the most notable. The class which was enrolled the subsequent March contained Frederick Field, Charles B. Mansfield, and George Merck of Darmstadt. Perkin entered only in 1854.[228] Beer goes to some length to state that the Oxford Street laboratory stayed abreast of the latest chemical thinking on the Continent, and with their help the school became, after a decade of operation, "the most productive organic chemical

[223] Bud and Roberts 1984: 61.
[224] The bulk of the financial support was derived from the landed interest. (Bud and Roberts 1984: 62.)
[225] Haber 1969: 28-36, 68-71.
[226] See sections 2.2 and 2.3.
[227] Beer 1959: 23. British dyestuffs manufacturers show a similar foreign influence, as can be seen from the hiring records of Robert, Dale & Co., L. I. Levinstein & Co., and Read Holliday & Sons Ltd.
[228] Beer 1959: 21.

laboratory in the world next to Giessen."[229] Beer also gives Hofmann and his teacher Liebig as much of the credit for Perkin's discovery as Perkin himself.[230] That the institution at Giessen had taken the lead in organic chemistry was generally appreciated, and few failed to stress Justig von Liebig's teaching, when telling of the emergence of the dyestuffs industry. However, Beer does not capture the fact that the tuition Hofman received in organic chemistry, and the inevitability of the discovery of the first synthetic dye, took place when there was little initial interest within the academic community to work for the benefit of a specific trade.

As early as June 1874, according to Fox, the education of chemists in Britain was rightfully criticised by Ivan Levinstein for the scarcity of trained chemists suitable for dye research but also for the ulterior motive that the 'foreigner' could pick up British trade secrets.[231] The lack of English chemists is evident in the record of employees for Levinstein & Co Ltd.[232] Levinstein, himself an immigrant from Germany, engaged himself strongly in educational issues, for what he felt was a key concern for the dye industry, and was himself the manager for a dyestuffs-producing company that enjoyed both longevity and expansion, a trait that was fairly uncommon for such companies in Britain.

In contrast to Levinstein, Heinrich Caro, a German chemist, who industrialised the process of synthesising alizarin from anthrazene applauded the inventive genius and spirit of enterprise in England and the scientific and industrial progress that created such a fame-rich era starting with Perkin's discovery of the first aniline colouring material.[233] Haber, in his 1969 publication of quantitative estimates of skill supply, reached the conclusion that German chemical education was better and produced more graduates than its British counterpart. Haber fails, however, to show what skills the industry required. The number of educated scientists was also an area of increasing attention. Henry E. Roscoe, Professor of Chemistry at Owens College until 1883, who later succeeded Levinstein as the chairman of the Manchester Section of the

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[229] Beer 1959: 23.
[230] Beer 1959: 24-5.
"[...] *as the first thorough analyst of coal tar, he*[Ernest Sell sent a bottle of light coal oil to Liebig] *made possible the isolation in pure form of various of its constituent compounds, while his study if the chemical properties of these substances made feasible their eventual use as dyestuffs precursors*". (Beer 1959: 10.)
[231] Fox 1987: 29.
[232] Fox 1987: part II 228-230.
[233] „*In England haben erfinderischer Genius und Unternehmungsgeist eine neue Ära wissenschaftlichen und industriellen Fortschritts geschaffen. Dieser ruhmreiche Zeitabschnitt eines früher unbekannten „Zusammengehens von Wissenschaft und Industrie wurde durch Perkins Entdeckung des ersten Anilinfarbstoffs eingeleitet.*" (Zimmermann 1971: 9.)
Note also that according to Travis there was a deliberate refashioning of history, especially in retrospective accounts written between 1885 and the 1920s, which tended to be prejudiced and highly selective to suit a new context. (Travis 1993: 18.)

Society of Chemical Industry, boasted that by the time he retired, he had taught 2,000 students![234] According to Bud and Roberts, between 1850 and 1870 thousands of students passed through the leading schools,[235] but up to 1870, only fifty students took the specialist honours in chemistry, which would be damaging to chemistry as a pure science.[236] It seems that if Roscoe's numbers are indeed accurate, Levinstein's argument could apply only to the manner of which British chemists were taught, and not their numbers, i.e. a very special group of scientists. By 1863 there were twenty-one full-time professors of chemistry in London.[237] Their teaching however, covered the total field of study chemistry: including inorganic applied science, which was the prerequisite for industry, medicine, agriculture, pharmacy, and organic chemistry concering the nature of living organisms.[238]

More to the point is the contemporary English chemist Raphael Meldola (1849-1915).[239] Meldola gave a lecture in 1886 before the applied chemistry and physics division of the Society of Arts, a lecture that was "a much more forcible idea of the true state of the coal-tar colour industry in this country than hitherto has been attempted."[240] Travis comments that "Meldola showed how the German synthetic dye industry that relied on research had displaced its main rival, Britain that relied on improvisation."[241] The foremost characteristic of the second industrial revolution was the formal application of science to industry, and few commentators have doubted its impact on the growth of the German industry in the last third of the 19th century. Those historians who have tackled the British 'decline' have, for a long time, considered Britain's adaptation a failure, and this is why the 'new' industries of the 19th century are so interesting. The prelude to scientific rather than empirically based innovation was the availability of Kekulé's novel benzene theory in 1865. Previously elusive structural formulae could be drawn for the coal-tar aromatic compounds and their derivatives. Reinhard and Travis stress that the benzene ring became an essential component of academic organic chemistry.[242]

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[234] Bud and Roberts 1984: 86.
[235] Bud and Roberts 1984: 86.
[236] Bud and Roberts 1984: 80.
[237] London still enjoyed an incomparably high density of institutions teaching chemistry in England, even though Owens College in Manchester and regional universities took up the discipline in the following years.
[238] The original definition of organic chemistry came from the misperception that these compounds were always related to life processes. N and H formations can, however, also occur inorganically.
[239] In 1885 Meldola left the dye industry and took up an appointment as Professor of Chemistry at the Central Technical College, Finsbury, London. (Travis 2007: 14.)
[240] Travis 2007: 12.
[241] Travis 2007: 15.
[242] Reinhardt and Travis 2000: xv.

4.2 Johann Peter Murmann and Ernst Homburg

Because the historiographical evolution of the study of 'the decline of the British synthetic dyestuffs industry', offers a number of explanations of the rise and fall of that sector, a recent account will be explored in for the purposes of comparison with the causes and explanations suggested by Travis. What is seen is that the two different accounts operate at different levels (micro and macro), and the generalised approach to industrial evolution differs in points from Travis's study of technological evolution. This implies methodological abstraction rather than empirical disagreement. In terms of content, the two studies retain only information that is relevant for their particular purposes. Secondly, Murmann and Homburg suggest that entry and exit patters in the case of the synthetic dyestuffs industry is much related to skill.

Of the two authors, Johann Peter Murmann, is the more experienced in evolutionary economics, and also in the simulation modelling of the paper. A second publication, namely *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions* (2003), which compares the development of the synthetic dye industry in Great Britain, Germany, and the United States through the lens of evolutionary theory, is another source of insight into Murmann's reasoning.

Ernst Homburg at the Department of History, University of Maastricht, who was part of a Dutch research team investigating the pre-1914 synthetic dye industry, provided the specific historical data in the paper. Because Homburg has published several accounts on different aspects of the subject, other contributions will be used to supplement areas of uncertainty. *Comparing evolutionary dynamics across different national settings: the case of the synthetic dye industry, 1857–1914* will take centre stage in this section, because it was the first paper to create and apply a total company and plant database, and in such a way provides new quantitative evidence.

Comparing evolutionary dynamics is a highly theoretical paper based on a simulation model, yet it revolves around factors such as availabilities of crucial skills, economies of scale and scope, and positive feedback mechanisms between firms and national institutions that were likely to produce national differences. Economies of scale and scope are, however, beyond the scope of this paper in that German companies displayed this strategy near the end of the 19th century, more than two decades after the change in the centre of gravity. No doubt, the German achievement of scale and scope economies was important in understanding the continued acquisition of market shares, and was something that few British companies could claim, but it was not a business strategy during the critical years of industrial overtaking as the industry did not yet display the necessary criteria.

What is interesting is that Homburg and Murmann identify crucial skills, and apply the term 'crucial' instead of the more mainstream 'skill –requirement' as a signifier of industrial evolution.[243] Although the authors seeks to demonstrate that "Instead of trying to construct models that hold true for all times and places, we believe that useful models of industry evolution will incorporate important contextual features",[244] i.e. to identify key factors behind industrial evolution to make the exercise of modelling long-term industry dynamics a useful one, they do so by looking into the dynamics that marked the industry, such as the synthesis of alizarin.

The paper analyses at a national level, based on a quantitative and qualitative database of all firms and plants in the synthetic dyestuffs industry across the five major countries (the USA being the fifth) before WWI, how German firms came to dominate the industry. Although, they make no mention of aromatic chemistry, Murmann and Homburg argue for positive feedback mechanisms between firms and national institutions that were likely to produce national differences.[245] The outcome of a path dependent process will often not converge towards a stable situation in which forces cancel one another out, such as prices when adopting similar grand scale production processes which is the main treatment in economic theory, but instead reach one of several stable situations. This is often thought originating from positive feedback mechanisms such as the educational system. They claim the most important institutional interaction on the market was patent law as it was decisive in the rise of the German dye industry and in the case of alizarin.

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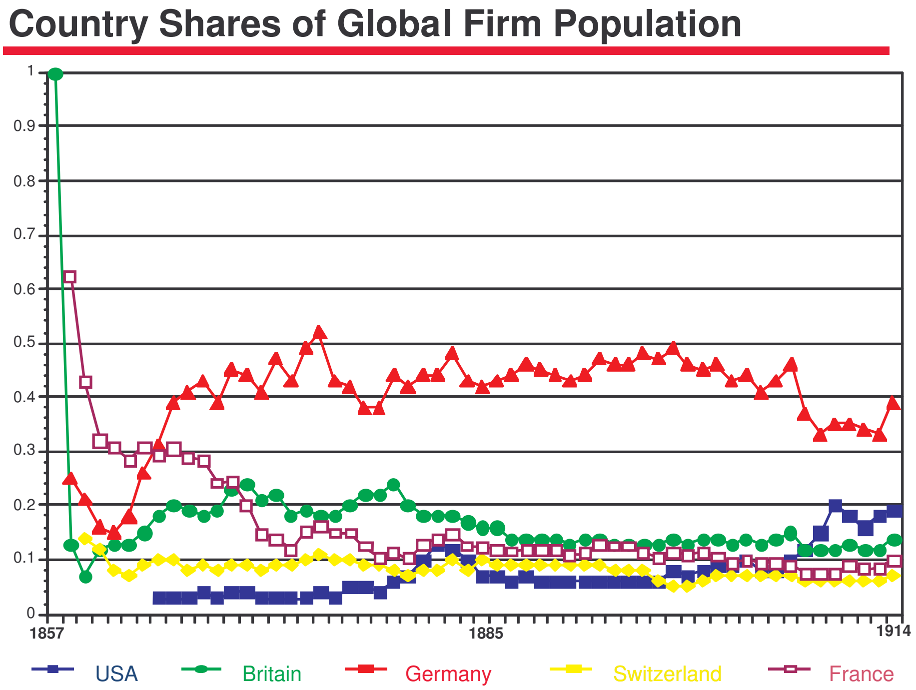
[243] Murmann and Homburg 2001: 177, 181, 186.
[244] Murmann and Homburg 2001: 204.
[245] Murmann and Homburg 2001: 177.

Fig 1.[246]



The database of all companies and plants allows Murmann and Homburg able to establish that the French country share of global population indicates that the French synthetic dyestuffs industry played a more significant part in the early years of the industry. *"Existing historiography emphasizes that Britain was the leading country in the early synthetic dye industry, with France closely following and Germany far behind (Beer, 1959; Travis, 1993). Our data show, however, that France was not trailing at all."*[247]Murmann and Homburg reach this conclusion by looking at country company shares of global population (Fig 2) and the number of dye firms by country (Fig 1)[248]. The data show clearly that the number of French companies exceeded that of the British in both total share and national share by a large margin from 1857 onwards. From 1857 to end of the 1860s, however, the two graphs show two distinctly different patterns: the number of British companies is increasing, whilst the number of French companies is decreasing. The number of firms is, however, only an indicator of production output, and not a main signifier in itself. Secondly, the emphasis Travis attributes to the early years of the British synthetic dyestuffs industry is novelty, not output, and he takes care to mention the French contribution of fuchsine and its derivatives. At the time when French companies outnumbered the British, they also produced Perkin's mauve and fuchsine and its derivatives but Murmann

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[246] Murmann and Homburg 2001: 190. There is a problem with the caption in the figure; German share of global firm population is shown by red squares and red triangles.
[247] Murmann and Homburg 2001: 189.
[248] Appendix III.

and Homburg go further in assessing the French importance in the early years of the industry. The best production process to produce fuchsine was developed by the British company Simpson, Maule & Nicholson, whilst fuchsine was a French discovery. The promising nature of the French synthetic dyestuffs industry was halted early by the restraints of the French patent law, and as a result little novelty came out of the French synthetic dyestuffs industry after the discovery of fuchsine and its derivatives and other discoveries made prior to 1870.[249]

Two general trends characterised the market penetration of synthetic dyes after the creation of the first synthetic dye, according to Murmann and Homburg: "(*1) unremittingly falling prices and (2) the continual invention of new classes of synthetic dyes.*".[250] Another way of arranging this reasoning would be to argue on a company level and state that because prices were falling unremittingly and because there was continued invention of new classes of synthetic dyes, a company that merely relied on an existing product portfolio would face increasing competition in price for its products, which in any case would only be on the market for a few years. This is why novelty is of importance.

Reaffirmed by Murmann and Homburg is the fact that "for the first 8 years, until the middle of the 1860s, British and French firms were clearly market leaders".[251] Murmann and Homburg go on to state that "But in the second half of the 1860s German firms caught up and surpassed their British and French rivals. Around 1870, German firms were responsible for 50% of world production."[252] How German companies achieved the 50% production share is very time-sensitive in that for example alizarin, within a very few years after 1870, opened up a huge market (more below). Besides that note, it was the absence of a patent law throughout the German principalities that enabled German companies to imitate British and French products and processes, according to Murmann. This is also argued by Travis, Beer, Haber and Fox. Although not providing any estimate of output in the paper, which surely stems from the studies of Homburg,[253] the years around 1870 are also reaffirmed as the time when German companies came to surpass their British (and French) adversaries.[254]

Although Murmann and Homburg, as mentioned above, argue that national institutions were the likely cause of national differences they did not take patent legislation into consideration when discussing the rapid entry of firms between 1858 and 1864 and the price drop because of the competition. Murmann and Homburg argued that the rapid entry was

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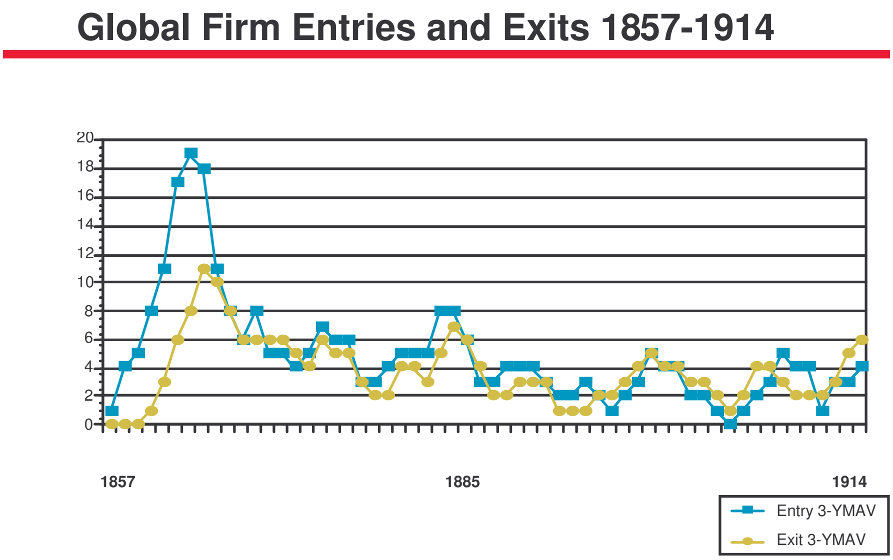
[249] Chapter 2; 3.1; 3.2.
[250] Murmann and Homburg 2001: 182.
[251] Murmann and Homburg 2001: 183.
[252] Murmann and Homburg 2001: 183.
[253] Murmann and Homburg 2001: 204-205.
[254] Argued by; Reinhardt and Travis chapter 2; Beer 3.1, Haber 3.2 and Fox 3.3.

propelled by a strong demand for aniline dyes, especially in the field of luxury textiles (silks) and highly priced fashionable designs. "The number of synthetic dye producers rose so quickly that the intensifying competition soon led to falling prices for the new dyes. By 1864, the price of fuchsine (aniline red), for instance, had fallen to about ten percent of the 1860 levels (Morris and Travis, 1992, p. 65)."[255] As was mentioned in chapter 2, Perkin's mauve was also produced by British and French companies. A comparable price drop to that of aniline red was never experienced by mauve, although it never reached the same popularity as aniline red.[256]
Murmann and Homburg do, however, take patent systems into account when dealing with company entries. In asking why the entry rate in the early years was higher in Germany than in Britain even though Germany's textile industry was about 23 times smaller than that of Britain the authors reach the conclusion that the most important reason seems to lie in the patent system: "In Britain dyes were protected by patents, whereas in Germany no such protection existed because the customs union (Zollverein) eliminated any effective patent protection."[257]
When Murmann and Homburg place an emphasis on skills in the probability of entry into the trade, they claim it was aided by a lack of a patent law in Germany. [258]
Fig. 2[259]



[255] Murmann and Homburg 2001: 180.
[256] Beer 1959: 26; Haber 1969: 199.
[257] Murmann and Homburg 2001: 194.
[258] Murmann and Homburg 2001: 194.
[259] Murmann and Homburg 2001: 181.

The second entry wave, which occurred between 1871 and1873, provides a good example of the consequences of a major breakthrough, according to Murmann and Homburg.[260] The authors argue that "every single major breakthrough led to new waves of entry in the synthetic dye business."[261] As they go on to claim: "The development of synthetic alizarin in 1868 opened up a huge market that was formerly served by natural dye makers."[262]As can be seen in Fig. 2 the German synthetic dyestuffs industry strengthened its position relative to global company population in this period. Murmann and Homburg show that the proportion of alizarin producers among the entrants by 1870, Hoechst, BASF and Perkin & Sons had started to make alizarin, rose steadily, from 2 out of a total of 7 (28.6%) in 1870: "in 1871, 20% of 10 entrants made alizarin, in 1872 75% of the 4 entrants did, and from 1873 to 1876 between 33% and 66% of the new entrants were founded as alizarin producers."[263] This is important in comparison to Travis's reasoning, because Murmann and Homburg suggest that when a new industry emerges, the number of entrants in a particular social environment appears to be limited by the number of people in that environment who have the skills to carry on the business.[264] They go on to state that not every person in the five countries was in the 'risk set'[265] of starting a dye business and the "knowledge of organic chemistry was an important skill that entrepreneurial ventures needed to possess."[266] The authors conclude their argument by stating that because Germany had many more trained organic chemists than Britain, Germany possessed many more potential entrants than Britain once Perkin showed that synthetic dyes were commercially feasible. "*The availability of core skills, in turn, was partly a result of public policies taken toward education and the training of the workforce*."[267] It is very important given industry's requirements to recognize the skill as a particular one, as opposed to the arguments on the British 'decline' where skills are not-time sensitive or particular.[268]

Since the authors deal with the question of likelihood and probable entry into the synthetic dyestuffs industry, over a period of time that lasts into the 1880s, there is no mention of aromatic chemistry, but instead organic chemistry alone. Yet, Homburg in his *The influence of demand on the emergence of the dye industry* (1983) finds that the general argument used in the

[260] The first entry wave is the 1858-1864 period and can be seen in Fig. 3 as the first high rate of entry.
[261] Murmann and Homburg 2001: 182.
[262] Murmann and Homburg 2001: 182.
[263] Murmann and Homburg 2001: 182.
[264] Murmann and Homburg 2001: 201.
[265] "*On average, entrepreneurs will seek out an industry where they believe they have a reasonable chance of succeeding*." (Murmann and Homburg 2001: 201.)
[266] Murmann and Homburg 2001: 201.
[267] Murmann and Homburg 2001: 201.
[268] 5.2, 5.3, 5.4.

debate (Beer, Haber), that the German chemical education was better than British chemical education and that there were simply more chemists in Germany, could not be upheld in general. He claims it was the difference in aromatic chemistry that is striking between Germany and Britain.[269]

Although their primary object was to find promising candidates for key causal forces of industry evolution (of which they find six), their identification of skills in the context of that *"the same causal forces did not operate throughout the entire period from 1857–1914"*[270] shows their awareness of crucial skill even if they do not state it as critical in the years around 1870.

In addition Murmann and Homburg found support for the proposition that firms entered the industry to take advantage of the alizarin market by comparing the product portfolios of all synthetic dye producers.[271]

An interesting feature in their reasoning is the concentration processes that occurred within national industries after the 1860s: "*In all major countries output became increasingly held in the hands of a few firms*."[272] Although Britain, Germany, and the USA illustrate this trend only Germany will be used as an example here. In Germany the top three producers BASF, Hoechst, and Bayer[273] accounted for 55% of the domestic dye production in 1883, worth 60 million marks.[274] In 1883, there were 33 dye companies in Germany according to Murmann and Homburg. Partly, the concentration of the industry is explained by Murmann and Homburg in terms of country share of global share (and top five country aggregate) population. Considering that 30 companies accounted for the remaining 45%, their average domestic market share would be 1.5%. The average market share, if one were to include the fourth major German player Agfa, for the remaining 29 companies would be closer to 1%.[275] Given Germany's world market share the same argument applies for concentration processes versus total country share of global company population.

What is more, the authors acknowledge that out of "6102 firm-year observations in our database – 2522 observations until 1886 and 3580 observations after 1886. The vast majority of firms (87%) are single-plant firms in both periods."[276] What is seen is that the total company estimates do not reflect the country market share. The authors do consider that large firms such

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[269] Appendix II.
[270] Murmann and Homburg 2001: 200.
[271] Murmann and Homburg 2001: 182.
[272] Murmann and Homburg 2001: 184.
[273] BASF had a market share of 23.3%, Hoechst of 16.7% and Bayer of 15%. (Murmann and Homburg 2001: 184.)
[274] Murmann and Homburg 2001: 184.
[275] Abelhauser, W. *et al*. 2004: 129-133.
[276] Murmann and Homburg 2001: 187.

as Bayer possessed an important competitive advantage, but discuss this in terms of the production of intermediates.[277] Since the paper does not include an exit and entry graph for individual countries, the top five aggregates show little in individual country behaviour, the geographical centre of innovation and thus novelty. What the paper gains by focusing on industrial evolution it loses in capturing the importance of novelty and the ability to innovate. The reverse applies to Travis's thesis.

The paper does, however, give weight to the belief that as the German companies increased market share in the alizarin period, and by adopting new modes of organisation, they denied entry to companies primarily from Britain and France after 1870. Since economies of scope and scale applied not only to production but to R&D as well, according to Murmann and Homburg, large investments in R&D were required to compete with the German companies. "*In the era where firms' R&D laboratories replaced university laboratories as the main source of new dyes, large-scale experimentation and testing of dyes reduced the cost of finding competitive new dyes.*[278] The authors write that in 1906, 2,656 new chemical compounds were synthesized in Bayer's research laboratories but only 36 ever reached the market.[279] They illustrate the point by stressing that if a company employed only a single research chemist his efforts would be unlikely to yield a new dye, but "if a firm employed a large team of chemists who would synthesize thousands of new compounds, the odds were much better that a firm would be able to come up with a competitive product before fashion trends changed."[280] Both the unit cost and the likelihood of novelty are important in this context. Not only would research enjoying the economicies of scope & scale reduce the unit cost of research per dye, but would also increase the likelihood of inventing a new dye in the first place. This is important in understanding how German companies solidified and in fact strengthened their position after 1870, and most likely the only reason why aggregate numbers of 'scientists' could explain country differences.

4.3 Summary

The most notable evidence to emerge from Murmann and Homburg's database is the skill requirement to compete. In the case of alizarin they argue that German companies could enter the trade because of a lack of a German patent law, but it was skill density that caused high country shares of global company population. The companies known in the literature for adopting new modes of organisation, and came to dominate the global trade in dyes with a

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[277] Murmann and Homburg 2001: 186.
[278] Murmann and Homburg 2001: 184-5.
[279] Murmann and Homburg 2001: 184-5.
[280] Murmann and Homburg 2001: 185.

market share of twenty per cent each, BASF, Höchst and Bayer, had been established a decade earlier. But again, what made these three companies able to gain that market share was the organisation of innovative ability that rested on the shoulders of the industrial chemist.

Although there is differences in interpretation of empirical evidence, such as the importance of France in the early years of industry where Murmann and Homburg go somewhat further than Travis and Reinhardt, there is conformity in areas of empirical scrutiny. A distinct difference between the authors is the level of abstraction. Travis and Reinhardt are much more empirically based than Murmann and Homburg, who argue in general terms.

5.0 The study of the British 'decline'

"If by 'theory' one means the neoclassical apparatus then one has to admit [...] that it is a fairly blunt instrument." M.G. Morrissey[281]

This chapter will discuss how the synthetic dyestuffs industry is *thought* to have endured the 1856-1914 period by two different groups of historians; those that have tried to tackle the British 'decline', and a selected group of historians that have tackled the 'decline' of the British synthetic dyestuffs industry. Important in this context is the recognition that the empirical evidence applied in the history of the chemical industry is only in rare cases referred to in the broader studies of the British 'decline'.

The arguments of Travis and Reinhardt on how the British synthetic dyestuffs industry 'declined' were shown in chapter 2 and again in chapter 4 to centre on an increasingly particular skill, and were measured as a technological shift away from Britain. The German patent legislation protected the new products and prevented British imitation. New modes of organization were adopted in Germany, but the British industrialists were denied entry. The performance of the industrialists has, on the other hand, been portrayed in cultural and entrepreneurial literature on the British 'decline' as mediocre. Generalized arguments on industrial performance, entrepreneurship, social origin and the economic rationality of British business leaders have as their empirical foundation in case studies of various industrial branches. How the synthetic dyestuffs industry is thought to have endured the years from 1856 to 1914 is therefore a case study of how the entire British industrial sector endured the same period. Since patterns can often be distinguished between branches, the synthetic dyestuffs industry might be considered as one of the new-technology industries of the 19th century, alongside the optical and electrical industries. This is not generally the case, however, as those who tackle the British 'decline' usually concentrate on manufacturing.

First, a short mentioning will be made of economic rationality in a historical context, to assist the understanding of how and why rationality is portrayed.

5.1 The concept of economic rational behaviour

Professor Emeritus Edwin M. Epstein and Professor Emeritus Dow Votaw , both at the Haas School of Business, Berkeley, introduced the concept of rationality in their co-authored publication *Rationality, Legitimacy, Responsibility* as bringing an end to the magical character of

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[281] Morrissey 1974: 146.

medieval life and reorienting almost all aspects of society.[282] Rationality as a generalized characteristic of economic behaviour has become one of the most important pillars of economic theory. One of the most fundamental outcomes of the Methodenstreit in Austria around 1900 was the establishment of the metaphysical impossibility of empiricism i.e. the view that experience, especially of the senses, is the only source of knowledge.[283] If one desires to utter any opinion one necessarily excludes, if even by the restraint inherent in language as a structure. The outcome was, among others, that American (particularly) and British economic theory (generally) sought generalized explanations, and generalized explanations especially with the introduction of applicable mathematics in the 1930s (or mathematical economics)[284] sought generalized pillars to construct upon.[285] One of those pillars was rationality. Rationality became, according to Epstein & Votaw, both the philosophical basis and the practical justification for the market society, for capitalism depended upon rational conduct and the rational organization of labour and other productive resources such as the inputs of labour, natural resources and capital used to generate new goods and services.[286] The poor manufacturer than loses out in business and does not respond to market changes, such as investing in machinery or equipment when the cost of labour grows too high, and thus displays irrational behaviour.

When British business lost out to the German competition in industries based on organic chemistry, the British manufacturer was supposed to have displayed a pattern of bad decision according to the market conditions, and British investors failed to react to the potential of the new-technology industries of the 19th century, according to the historiography on the subject.[287] Chapter 2 provided an account of the skill requirement of the synthetic dyestuffs industry over time. After the critical year of 1868, folloing the discovery of a process to produce artificial alizarin based on scientific empiricism, British manufacturers were increasingly denied entry into the synthetic dyestuffs industry because they did not possess the skills to compete in new classes of dyes. This was because of the scientific, structural and institutional build up in Germany. Travis was introduced as a milestone in that his interpretation of the German overtaking of British manufacturing industry had little to do with the British businessman. Since it was the knowledge of how to break apart and piece together again aromatic hydrocarbons

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[282] Epstein and Votaw 1978: 1.
[283] Hodgson 2001: 27-28, 79pp.
[284] There was a debate over economics and mathematics before the end of the 19th century. (Backhouse 2002: 190pp.)
[285] This was especially a trait of American educational institutions, particularly Harvard. (Hodgson 2001: 184.) During the same years the German and Austrian economic thinking declined in importance. (Backhouse 2002: 172pp.)
[286] Epstein and Votaw 1978: 1.
[287] See sections 3.1 and 3.2.

that allowed the German synthetic dyestuffs industry to outpace its British counterpart, it necessarily calls into question the British educational institutions, and perhaps the financiers of educational institutions, but not the industrialist.

5.2 Broadberry and British Higher education

The presentation in this thesis of a lack of necessary skills provided by higher education in Britain is often considered in light of other developments in education. As was mentioned earlier in this paper, Broadberry points out that manufacturing industry had little to do with the fact that both Germany and the United States caught up with and overtook Great Britain in the long run.[288] Labour productivity levels were stable compared to Germany and the USA. Since education and training are considered one of the most important variables to secure such industrial performance in conventional literature, the requirements of a high-technology industry are highly important. Broadberry's findings are that British long-run industrial performance was backed by adequate educational institutions and training. The synthetic dyestuffs industry, on the other hand, was an industrial branch among other new technology industries in which Britain performed comparatively worse between 1870 and 1914.[289] The question of educational adequacy must therefore be considered in relation to the argument that Britain can be considered as falling between the US emphasis on formal educational and the German emphasis on vocational training.[290]

Broadberry is among the group that Edgerton has labelled the neo-classical economists.[291] In 1998 Broadberry published a paper where he argues that in the 1870-1990 period the changes in total factor productivity also reflect changes in comparative total factor productivity related to technology and organization.[292] In this paper Broadberry suggested that there is no best technological way; Britain must not necessarily be compared to other countries in terms of the type of institutions that is perceived to be the best. Productivity levels would, however, be misplaced on the synthetic dyestuffs industry in that such estimates would not show the cross-national difference.

What is interesting is that in his contribution to the *Cambridge Economic History of Modern Britain* (2004), Broadberry argue that although Germany had gained an advantage in formal education by 1870, Britain had largely closed the gap in primary education by 1914. On the question of British technical training, Broadberry writes that recent publications offer a

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[288] See chapter 1..
[289] See chapter 2.
[290] Broadberry 2004: 62-73.
[291] See section 5.3.
[292] Broadberry 1998: 375.

balanced view. In part this is because Britain adopted a 5-to-7-year system of apprenticeship to provide the key framework for skill acquisition in modern factory industry.[293] Broadberry goes on to recognise that "the persistence of a flourishing apprenticeship system is not inconsistent with shortages of particular skills at particular point in time."[294] Broadberry acknowledges that some historians stress the shortcomings of the apprenticeship system in the provision of particular technical skills during the second industrial revolution, especially in chemistry and electrical engineering. However, he dismisses this view, citing another group of historians who argue that it would be a mistake to think of technical training in Britain as a static system immune to changes in the provision of technical skills and their shortages.[295] The problem with the latter view, one that has been identified in this thesis, is not the potentially dynamic nature of the British apprenticeship system, but its need to respond to change in the first place. What is particular about the second industrial revolution is that the formal application of science to industry ensured that businesses, particularly late entrants, would face an increasingly modern competition even if they trailed by only a few years. So if the British system of apprenticeship training was indeed adequate over time it would still require a massive investment to regain a competitive edge. Such an investment did for example occur in the case of the synthetic dyestuffs industry during the First World War. Ulrich Marsch argues that in no other industry did the British government go so far in intervening as in chemicals. It did so by setting up a new large firm, the British Dyestuffs Ltd., with substantial state-guaranteed loans.[296]

5.3 David Edgerton and the British 'decline'

Economic rationality has been shown to function as one of the explanations used in the historiography of the study of the synthetic dyestuffs industry, but not in recent publications. Economic rationality is also a part of the historiography of the study of the British 'decline', although in a broad framework. David Edgerton's *Science, technology and the British industrial 'decline'* (1996) questions the rationale of British manufacturers as an explanation and provides a short but rich historiographical account of the British industrial 'decline'. In addition, Edgerton questions the perception of Britain's mediocre technological performance compared to that of Germany and the USA. Edgerton also contributed to the study of the British 'decline' in historical and business reviews that will be added to this thesis, and has published extensively and widely on the British 'decline'.

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[293] Broadberry 2004: 62-73.
[294] Broadberry 2004: 62-73.
[295] Broadberry2004: 62-73.
[296] Marsch 2000: 217-241.

In the *Historical Review* Edgerton wrote that one of the most original points taken up was that 'declineism' could be, perhaps was, in itself a cause of economic underperformance, and especially in its resistance to structural change.[297] Imperialists argue that the loss of empire meant economic as well as geographical decline. In other words, many publications on the 'decline' were published in a period of underperformance in Britain, often by British scholars. This is one among many categorisations or groupings of scholars that tackle the British 'decline'. Another organisation of groupings can be found in the influence of key contributions.

In the *Business History Review* (1999) Edgerton wrote an article on the 'decline of declineism'.[298] Here Edgerton argues that the whole issue of decline as a historical explanation needs rethinking. In the context of 'declinist' scholars Edgerton brings up Alfred Chandler who created a model of US business, such as the employment of upper, middle, and lower management, and historians has compared British business unfavourably with this model.[299] In *Scale and Scope: The Dynamics of Industrial Capitalism* (1990) Chandler himself produced a picture of a clearly deficient British business according to Edgerton.[300] He claims that the image of British industry as deficient in a number of interlocking respects is closely connected to explanations of those deficiencies.[301]

Alfred D. Chandler, Jr., was Isidor Straus Professor of Business History at Harvard Business School. In his Ph.D. thesis *Strategy and Structure: Chapters in the History of the Industrial Enterprise* (1962) Chandler found that managerial organization developed in response to the corporation's business strategy, which is, for example, not unfamiliar with the managerial build up of BASF in the 1868-1914 period.[302] Chandler's emphasis on the importance of managers as the backbone of an organization to organize and run large-scale corporations was expanded into a 'managerial revolution' in *The Visible Hand: The Managerial Revolution in American Business* (1977). He pursued that book's themes in *Scale and Scope: The Dynamics of Industrial Capitalism* (1990).[303] The thesis of each of these works is that during the 19th century the development of new systems based on steam power and electricity created a second industrial revolution, which resulted in much more capital-intensive industries than the first industrial revolution of the previous century.[304] The thesis of *The Visible Hand* is that counter to

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[297] Edgerton 1999: 313-314.
[298] Edgerton 1999: 313-314.
[299] Richard 1997.
[300] Edgerton 1999: 313-314.
[301] Edgerton 1999: 313-314.
[302] Abelhauser, W. *et al.* 2004:19pp.
[303] Supple 1991: 500-514.
[304] Supple 1991: 500-514.

previous thought on how capitalism functions, administrative structure and managerial coordination, as the title implies, replaced Adam Smith's "invisible hand" i.e. market forces as the core developmental and structuring impetus of modern business.

The reason why Chandler is important to the study of the British 'decline' is that Chandler in a way created a model in which British business was dysfunctional, but he also portrayed two models that were, on the other hand, highly functional. This is not far removed from Broadberry's argument that Britain is considered as falling between an emphasis in the US on formal educational and a German emphasis on vocational training. In comparison to the German cooperative capitalism and US competitive capitalism the British personal capitalism, is easily identified in a managerial revolution as dysfunctionalIt is this individual capitalism, to which is added to a negative portrayal of the British elite, hostile to change and technology, educated in the arts and classics, if at all, that Edgerton considers a poor depiction of British capitalism. [305] What is argued is that Chandler's model has caused a search for that personal capitalism. The British synthetic dyestuffs industry could, for example, be used to support such a proposition, which is in fact not far removed from the reasoning of Beer and Haber. Such findings would, however, neglect the problem of adopting new managerial structures, which in the case of the German organic chemical companies came about as a result of a process, and was not culturally inherent.

Apart from the influence of Chandler upon the study of the British 'decline', one of Edgerton's main themes in his book is the distinction between 'relative' decline and doing badly.[306] He claims the extensive literature on the British economy has long invoked failings in technology as evidence of economic failure, and as a cause of economic failure.[307] He argues that economic literature has often centred on a 'declineist' version of British history to the neglect of the complex interrelation between science, technology and economic performance. He attempts in his pamphlet to come to terms with some of the explanations of this technological and economic British failure and provides two examples: that the German economy was more efficient than the British before 1860, and that investment in innovation is the main determinant

[305] Edgerton 1996: 8.
[306] Edgerton 1996: 4.
A perspective is that Britain is much less powerful today compared to other countries, than it was in 1870, 1900, 1920 and 1950. (Edgerton 1996: 4.)
[307] Edgerton 1996: 5.

of rates of growth and has explained a supposed lack of science and technology using dubious cultural comparisons; individuality vs. corporate.[308]

In the debate on the British ‘decline’ there is a distinction between those publications that attempt to analyse a ‘decline’ from 1870 to 1914 and a ‘declinist’ tradition of historians seeking to explain recent relative weakness by finding failures in the past. The most recent publications in the latter category attempt to analyse the British decline from 1870 to 1970, or to the present. These categories are not mutually exclusive.

The ‘declineist’ tradition arose in the 1960s, according to Edgerton, whilst the 1970s saw a greater emphasis on British industrial strength. The 1980s saw a surge in the condemnation of British technology, followed by a new defence of British technology in the early 1990s.[309] Of course, Edgerton is one of those defendants of British technology who arose in the 1990s. Likewise, Beer and Haber were part of the early ‘declineist’ tradition.

Edgerton divides literature on the relationship between science, technology and economic performance at the global level into four categories: technocratic, neo-Schumpeterian, neo-classical and neo-Marxist, which parallels the classification of the debate on the British ‘decline’. The single most important tradition of the four is the technocratic, which is most centrally concerned with the relation between science and technology and economic performance.[310]

The technocratic historical grouping (as defined by Edgerton) has as its most important analytical tool the degree of science and technological expertise to be found in government, business and social elites. Its central claim is that the presence of a properly trained elite, and consequent investment in science and technology, determine economic performance. This has, in the case of Britain, caused a critique of elites for not being sufficiently scientific and technological. Edgerton states that the British elite is depicted as being ‘generalist’ and ‘amateur’ and educated, if at all, in the classics or arts.[311] Whether or not classical education is good or bad for businessmen is actually taken up by Prof. Dr. H. Berghoff of the University of Göttingen in that “So far no one has really proven that a classical education always has a negative effect on

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[308] Edgerton 1996: 5. Presumably the Harrod-Domar and Solow model of economic growth which rests on the famous macroeconomic balance equation savings (s) = investment (i) over time (t): S(t) = I(t) (Ray 1998: 54.)
[309] Edgerton 1996: 6.
[310] Edgerton 1996: 6-7. The technocratic category includes, amongst others, C. Freeman’s *Technical Innovation and British Trade Performance* (1978), which Edgerton himself criticized in his 1994 publication, *Research, Development and Competitiveness*. This challenged Freeman’s hypothesis that British industry founded less R&D than Japan and Germany during the 1950s and early 1960s. (Edgerton 1996: 85.)
[311] Edgerton 1996: 8.

non-classical careers."[312] Edgerton is, however, questioning the general picture painted more than the actual worth of a classical education to non-classical careers.

The group of economic historians labelled neo-Schumpeterian, which reflects the analyses of modern capitalism made by the Austrian economist Joseph Schumpeter, puts innovation at the centre of their accounts. They argue that the British economy declined relatively, especially that Britain lost industrial leadership and ceased to be the major site of innovation and consequent qualitative changes in technology. This was explained in terms of entrepreneurial failure during the late 19th century. One of the key charges against British business, according to Edgerton, is that they failed to develop in-house R&D facilities, such as was the case in the synthetic dyestuffs industry until early in the 20th century. Notable to the entrepreneurial failure of the 1870-1914 period is the interpretation, especially argued by D.N. McCloskey, that the 'failure' was in fact a rational response to economic conditions (economic conditions set by the neo-classical group of historians), which can also be concluded from the study of the synthetic dyestuffs industry.[313]

Edgerton goes on to question the general picture of the overall structure and performance of British science and technology since 1870. Therefore, he argues, one must be aware of the complex relationship between historical actors' accounts and those of historian. It is vital to treat each separately and to note that historians both sometimes draw too uncritically on actors' accounts, and also fail to put actors' accounts into their proper historical context. Although highly critical of historical writing on the subject, Edgerton's point that historians sometimes draw too uncritically on actors' accounts is, for example, shown in the case of Fox.[314]

Another problem identified by Edgerton is the poor quality of international comparisons. Too often, Edgerton writes, is a comparison is not made with an actual other country, such as can be argued for Beer in that his arguments of German performance never reach a critical stance, and is misleading in that German companies, by virtue of their scientific excellence, responded vigorously to any challenge.[315]

Another conception that Edgerton questions is that many historians have condemned British industrialists for continuing to use old equipment, and for failing to develop new industries. One of the explanations was that there was a failure of British entrepreneurship, and British businessmen, especially between 1870 and 1914, did not innovate, or adopt new techniques, with the alacrity of their foreign competitors. Edgerton quotes D.N McCloskey in that

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[312] Berghoff 1990: 153.
[313] Edgerton 1996: 8-9; chapter 2.
[314] See section 3.3; Edgerton 1996: 11.
[315] Edgerton 1996: 11-12.

in “case after case that given the raw materials available, existing market conditions, and costs of labour and capital, British capitalist behaved exactly as capitalists were expected to: they took on new processes when they were profitable.” [316] Edgerton isolates this argument to the neo-classical grouping, whilst the neo-Schumpeterian argues that the British economy behaved exactly as neo-classical economists would expect. It was a highly competitive and successful economy before 1914. But this was exactly the problem because Britain had many perfectly rational entrepreneurs concerned with static efficiency, but it had few real entrepreneurs concerned with dynamic efficiency. [317]

British entrepreneurs did not, according to Edgerton’s interpretation of the neo-Schumpeterian critique of the neo-classical approach to understanding the economy, make the qualitative changes in technology, work organization, and firm structure that were required to increase productivity in the long run. British capitalism remained stuck in an older form of competitive, individualistic capitalism. Edgerton concludes by stating that the general argument is that British businesses were too beholden to the market, and did not develop the powerful true ‘invisible hand’ of modern corporate capitalism. Edgerton does not consider the ‘new’ 19th century industries or the synthetic dyestuffs industry in particular against these arguments but includes these branches by the general tone of the argument. [318]

Still with a general tone Edgerton introduce skills and knowledge as something that was changing in Britain between 1870 and 1970. Whilst some skills and knowledge disappeared, new skills and knowledge were created and diffused. Edgerton states that while hardly any graduates were employed in industry in 1870, by 1970 they represented a small but significant proportion of the work force. According to Edgerton, historians have long considered that this process happened much too slowly in Britain, and it has been linked to the allegedly poor record of British industry in modernizing old industries and creating new ones.[319]

Edgerton claims the picture of a dismally backward technical education was challenged by 1972. He goes on to state that ”what needs to be explained is not the decline or even the non-emergence of technical education but its rapid expansion.”[320] To look at 1870 is misleading, according to Edgerton, because then there was indeed little going on, whilst twenty years later, and especially forty years later, the picture was transformed. By 1910, states Edgerton, 14,330 students graduated from English higher education institutions in science and technology, excluding Oxford and Cambridge. Edgerton makes the point that one should not conflate skill

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[316] Edgerton 1996: 16.
[317] Edgerton 1996: 17.
[318] Edgerton 1996: 16-18.
[319] Edgerton 1996: 18.
[320] Edgerton 1996: 21.

and expertise with education especially before 1914.[321] Travis, Reinhardt, Murmann and Homburg point out that one should.[322]

In addition, Edgerton points out that there have been many complaints about the low number, low status, power and authority of technical experts in British industry. He argues that resent research suggests that the number of formally-qualified scientists and engineers working in British industry before 1914 has been seriously underestimated by historians.[323] An example is provided of the much-cited estimates of between 180 and 225 graduate chemists employed in industry by 1902. Recent accounts question this estimate and suggest that there was at least that number engaged in research and development alone. Between 1884 and 1901, writes Edgerton, no less than 71 Honours graduates in chemistry entered industry from Owens College in Manchester. Another example is that by 1920 ICI alone employed about one thousand chemists.[324]

Firstly, it is necessary to comment that there is a distinction between organic (mostly dyestuffs before 1900) and inorganic (heavy) chemical industry, which was a less innovative industrial branch than the organic. Secondly, by 1884 the organic chemical industry had become stagnant and in a much inferior position compared with the German organic chemical industry, which in 1889 had developed the first Central Research Laboratory at the BASF Ludwigshafen factory. The industrial research laboratory became a formal business unit in Germany, not Britain.[325] As argued in chapter 3 and section 4.1, the chemical discipline had a far-reaching industrial utility, and general arguments on institutional output must take care to mention which area of that spectrum the chemists are meant to occupy. Lastly, what is seen from ICI's rival German companies, the BASF, Höchst, and Bayer (merged into I.G. Farben at the time) is that the percentage of chemists employed skyrocketed, whilst the number of chemists working on the development of, for example, new dyes become an ever more marginal fraction. As such, the number of chemists employed covered a variety of different occupations within a single company.

When Edgerton writes that one could draw up an impressive list of British inventions and innovations since 1870, which would serve a useful purpose in highlighting the technical creativity of British industry since 1870, Edgerton loses the fluctuations and the frequency of those creativities. In the synthetic dyestuffs industry during the 1870-1914 period, according to

[321] Edgerton 1996: 21.
[322] Another point of view can be added in that the vocationally based German system of education benefited industrial performance. (Marsch 2000: 217pp.)
[323] Edgerton 1996: 25.
[324] Edgerton 1996: 26.
[325] See chapter 2.

conventional and recent literature most of the novelty came from abroad. Yet, in part, Edgerton is accurate in that according to Travis there was a key area of knowledge that were missing in the synthetic dyestuffs industry, not a total area of knowledge, and the organic chemical industry might be only a marginal case.

Edgerton, in taking up the case of the synthetic dyestuffs industry, dismisses its importance because of its relative trade, value without explaining what the trade value was in fact relative to.

"A still notorious case was the British innovation of synthetic dyestuffs, which was taken up by the German chemical industry. The failure of British firms to develop and produce synthetic dyestuffs for the giant British textile industry has long been condemned, despite the fact that the total value of such dyestuffs was small."[326]

That Edgerton dismisses the organic branch of chemical industry in such a way is striking, as it is primarily its strategic, and not its commercial significance that has been highlighted in recent literature on the subject. In dismissing a branch of industry in a publication that among other things discusses management structure, it should be mentioned that the synthetic dyestuffs industry is one of those industries where such a form of organization was created. A few additional comments: the German chemical industry did not take up synthetic dyes, rather, Germany in the 1860s established companies that came to dominate the world trade in dyes. The organic/inorganic distinction is a very important component in chemical history, as they are not the same thing. In 1914, when Germany controlled 90% of the world production of dyes, synthetic dyestuffs were in 11th place on the list of German exports in terms of value. Although it ranked below, for example, beet sugar, the German synthetic dyestuffs industry was renowned for paying high dividends, as high as 30%. These numbers have, however, met with some scepticism. Marsch argues that dividends do not reflect the real value of these firms and should probably be cut in half.[327] Then again, to take the longer view, BASF and Hoechst were during the 1990s ranked among the top 20 richest companies in the world. In 1948, the second largest British company, with an estimated market capitalisation of £197.5 million, was Imperial Chemical Industries.[328] In 1958 ICI's turnover in the U.K. and exports had from £17.5 million £50.7 million, and by 1968 the turnover in the dyestuffs division alone was £110.8 million.[329] That Britain in the longer run was to prove its innovative ability in the field of synthetic dyes can be noted by the fact that in 1956, 'on the occasion of the 100th anniversary of the discovery of

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[326] Edgerton 1996: 29-30.
[327] Marsch 2000: 221.
[328] Hannah 1976: 190.
[329] Fox 1987: part I 217.

mauve', ICI could announce 'the first fibre-reactive dye (Procion range) that forms a chemical bond with fabric'.[330] Little new of such similar value to a business was produced in that branch of industry between 1870 and 1914. Yet there is little doubt that most of the British chemists and innovation in chemistry to which Edgerton earlier referred in the long run happened at the ICI, and some of those even in the dyes product group.

As to organized research and development around 1870, Edgerton claims it was practically unknown. But before 1914 'we' know of 20 British firms doing R&D. What is seen is that Edgerton more or less identifies that sometime between 1870 and 1914 British firms adopted R&D, but not in great numbers. Edgerton also provides a table showing aggregate numbers of the percentage of British and German businessmen with higher education during the 1870-1914 period. The table shows that there is only a minor difference between those born after 1860.[331] That British businessmen were highly educated is of course an important indicator against their alleged irrational behaviour, also dismisses the previously mentioned argument that they were educated, at all, in the classics or arts.

Edgerton's conclusion is that literature on British science and technology is consistently different. The technocratic literature was shown by Edgerton to be misleading in that technical experts were few in number and low in status. [332] The neo-Schumpeterian work on the other hand has overstated the significance of innovation on national economic performance, whereas the neo-classical analysts have helped to change 'our' picture radically.[333] Historians of science and technology have been trying to explain something that was not the case, that Britain was behind Germany, or that British industry was short on capital, and that economists have shown that innovation is not the main determinant of different of rates of economic growth.[334] The main determinant to be able to compete in the synthetic dyestuffs industry was innovation according to Murmann, Homburg, Travis and Reinhardt. This caused Britain to lag behind Germany between 1870 and 1914. There is little sensitivity to this educational and technological period of relative decline from Edgerton and Broadberry. It has been dismissed either because of the dynamic response of the British apprenticeship system or for being a minor case.

A last comment on the sensitivity of historians who tackle the British 'decline' can be illustrated by Edgerton's own argument that the Leblanc process for the manufacture of alkali was phased out in 1914-1918:[335] The United Alkali, the largest chemical company in the world,

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[330] Appendix III.
[331] Edgerton 1996: 54.
[332] Edgerton 1996: 67.
[333] Edgerton 1996: 67-8.
[334] Edgerton 1996: 68.
[335] Edgerton 1996: 15.

was a merger of all major British manufacturers of alkali by the Leblanc process.[336] The Leblanc-process turned into a fiasco once a new alkali process appeared, the Solvay process, an ammonia-soda process, and the profitability of all the Leblanc by-products was later lost.[337] The Solvay process was available during the 1860's, and the United Alkali needed over fifty years to adopt a new and better process, if the Leblanc process was only phased out in 1914-1918.

As shown in sections 3.1 and 3.2, Beer and Haber discussed the potential low status of scientist, or more particularly the industrial chemists, in Britain between 1856 and 1914. Such arguments are not exclusive to the British synthetic dyestuffs industry but, rather, inclusive to the total manufacturing industries of Britain prior to the First World War. The archetypical British investor was from the elite of the British society and more concerned with imperial matters, colonial trade, coal, steel and cotton than any new technology that he is often perceived to be hostile towards.[338] Another trait is the government indifference towards the needs for science and technology.[339]Edgerton's description of the common perception of Britain and technology is worth quoting at some length:

"*We think of technology as something especially important to the twentieth century, and to the very recent past in particular. There was a time, however, when world and British technological history were much the same thing. Early nineteenth century Britain was the high seat of the Industrial Revolution; it was the workshop of the world; and, it had appropriately heroic entrepreneurs, inventors and engineers. By the end of the nineteenth century, world and British technological history diverge. For the period since the 1870's we have a picture of rapid technological development in the world economy and technological decline in Britain."*[340]

Certainly there is a general tone in Edgerton's introduction to his book that puts most argument on the 'technological decline' in a stark perspective.

In introducing his conclusions, Edgerton writes that "once we recognize that the relative decline of Britain is not to be equated with doing badly, the conclusions arising from this pamphlet will not appear so surprising."[341] What might come as a surprise then, writes Edgerton is that "until the 1960s Britain was the second richest large industrial economy in the world. And it has science and technology to match".[342] There is little evidence in recent literature that the 'decline' of the British synthetic dyestuffs industry should be equated with doing badly as was seen in chapter 2. In chapter 3, however, both Beer and Haber were used as examples of

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[336] Schröter 1998: 105.
[337] Schröter 1998: 105.
[338] Edgerton 1996: 1.
[339] Edgerton 1996: 1.
[340] Edgerton 1996: 1-2.
[341] Edgerton 1996: 67.
[342] Edgerton 1996: 67.

commentators on the British synthetic dyestuffs industry who portrayed such a view. In dismissing the synthetic dyestuffs industry as an example, Edgerton is in all probability dismissing the views of Beer, Haber and the like and not the more recent publications because they are not included. However, the British synthetic dyestuffs industry does not match Edgerton's profile of British industrial performance between 1870 and 1914, but Edgerton is probably more correct in a longer 1870-1970 perspective. The dismissal of a perceived absolute low-point of British industrial performance and 'declineist' arguments might have caused the neglect of, or an unawareness of the case of the British synthetic dyestuffs industry. A similar pattern is found in a treatise of British entrepreneurial performance.

5.3 Tom Nicholas and the entrepreneur

In 2001 Tom Nicholas[343] wrote *Clogs to Clogs in Three Generations? Explaining Entrepreneurial Performance in Britain Since 1850.* [344] It was published in the *Journal of Economic History*, and for example cited in *The Cambridge Economic History of Modern Britain* (2004). Nicholas attempts to show the benefits of using a new method known as lifetime wealth accumulation on a study of culture and entrepreneurship in Britain.

Previous studies have according to Nicholas been dominated by causal empiricism. Nicholas notes that most references to inheritance and entrepreneurship in the economic history literature cite David Landes's[345] influential account of European industrialism, which describes late-nineteenth-century Britain as plagued by nepotism, i.e. the act of favouring relatives because of their relationship rather than because of their abilities, tradition, and inflexibility. It is the British ownership structure that is said to have created complacency and conservatism, while the pursuit of social and political distinction caused an entrepreneurial lack of vitality or energy, or lethargy. Nicholas writes that the persistence of family capitalism supposedly delayed the efficient administrative and organizational structures, such that the British firms fell behind their competitors, in Germany and the USA, in terms of both capacity and efficiency. Nicholas concludes that a lacklustre that a enterprise culture that lacks brilliance or vitality is seen as a primary obstacle to economic growth. Amongst the publications Nicholas considers to have such a cultural thesis is Alfred Chandler's *Scale and Scope*.[346]

Nicholas has painted a picture of culture and entrepreneurship studies in Britain as 'declineist', but question the evidence of this failure. He makes no mention of the chemical

[343] Tom Nicholas is a British Academy Postdoctoral Fellow, Economic History Department, London School of Economics.
[344] Nicholas 1999: 688-713.
[345] Landes 1960.
[346] Nicholas 1999: 688-713.

industry, but states that such judgments of performance typically rest on case studies that are not sufficient either to refute or confirm more general hypotheses of weak British entrepreneurship. Nicholas recognises that instances of success as well as failure are plentiful, also among companies that were built around the founding family rather than new management structures.[347] In comparison to the synthetic dyestuffs industry, it should be mentioned that family companies existed, and in the middle of the 19th century there was off course no British synthetic dyestuffs company that displayed features of the new management structures. The British companies were, however, equally advanced in this field as the German companies until new modes of organization were employed in the 1870s and 1880 as a response to market conditions. The three German companies that were each to produce twenty percent of the world's dyestuffs by 1883 were founded as family businesses.[348] That the British companies did not change accordingly had little to do with a lacklustre enterprise culture, as was seen in chapter 2.

Nicholas states that in the economic history literature, the use of economic theory to assess entrepreneurial performance is confined almost exclusively to the application of the neo-classical paradigm. Nicholas recognises that the debate has largely centred on the issue of whether entrepreneurs active in British industry were economically rational in their choices of technology, although not pointing out that in a cross-national setting there is no conformity that there is one best 'technological way', even within the neo-classical paradigm.[349]

Nicholas argues that advances in growth theory have important implications for research on economic rational behaviour. By allowing that investment decisions might have been influenced by market conditions, resource flow, and technological spillovers, "endogenous growth theory may offer additional lines of defence for those wishing to absolve British business of any failure". On this he cites N.F.R. Crafts.[350] In endogenous growth models the pace of growth is determined from within the model and is not simply attributed to exogenous technical progress, or progress outside of the model.[351] What is "inside" the model is of course determined by the variables used in the calculation. . Then again, a model such as Harrod-Domar would in fact be the first example of an endogenous growth model, according to Debraj Ray, Julius Silver

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[347] Nicholas 1999: 689.
[348] As for example noted in chapter II, the Bayer Company, which started off with one employee, did in fact respond to the challenge of other German companies in changing its management structure. (Beer 1959: 57pp.) Another example is the BASF. (Abelhauser, W. *et al*. 2004: 36pp.)
[349] Broadberry 2001: 394.
[350] Crafts 1998: 193-210.
[351] Ray 1998: 103.

Professor of Economics, New York University, although is it not renowned for its realism.[352] Nicholas is rather discussing the inclusion of human capital, and especially skilled labour in growth theory. However, Nicholas does not take this any further because of the critique that the sources of the British economic decline remain beyond the narrow competence of the economist. It could be noted that most economists are often perceived as considering people all over the world as intrinsically the same, trying to figure out why economies are not, whilst the historians are often perceived as buried in detailed knowledge. Nicholson attempts in this article to bridge the gap between these two worlds.[353]

In doing so Nicholas discusses the neoclassical assumption of free entry and exit of entrepreneurial labour. As seen in section 4.2, Murmann and Homburg recognised that this was not the case and that in the synthetic dyestuffs industry Germany held an advantage in the number of trained chemists in organic chemistry, and aromatic chemistry in the alizarin era. The idea is simple. The entrepreneur cannot enter the trade without the skill. So when Nicholas assumes in his model that over *n* years of entrepreneurial activity, *r,* the rate of return, will depend on the entrepreneur's ability to exploit opportunities and generate returns on initial wealth (because $r= W_t+1/W_t+y_t-c_t$)[354], the equation does not encapsulate the probability of entry in the first place. This is a special case where at the outset Murmann, Homburg, Travis and Reinhardt would agree with Nicholas that in the case of the synthetic dyestuffs industry, rationality had little to do with the 'decline'. Yet, the calculation model of Nicholas would not fit the simulation model of Murmann and Homburg or the explanations of 'decline' proposed by Travis and Reinhardt. What is more, Nicholas's data set of individuals ranges from 1789 to 1937 (birth) and 1868 to 1993 (death). In other words the timeline from 1856 to 1914 that Murmann, Homburg, Travis and Reinhardt make use of could show highs and lows that are not as easily detected in a longer perspective. This possibly suggests that Nicholas might be accurate in trends in the long run; the British synthetic dyestuffs industry did for example grow significantly during the First Worlds War because of government subsidy, but so might be the case for

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[352] Ray 1998: 103pp.
[353] Nicholas 1999: 688-713.
[354] t connotes time, W = Wealth, C= consumed or saved profit, Y= entrepreneurial income that equals profit. It is worth extracting from the model that the rate of return would decrease, i.e. entrepreneurial activity, according to capital earned on products already on the market. An economy that performs well would have proportionately less entrepreneurial activity than an economy that performed comparatively worse. This is especially interesting because Broadberry have identified the high end of the Kuznets curve (Kuznets curve is the graphical representation of Simon Kuznets's theory that economic inequality increases over time, then after a critical income is attained, inequality begins to decrease) in Britain around 1850 implying high rate of return in Britain between 1870 and 1914.

Murmann, Homburg, Travis and Reinhardt who indirectly point out a entrepreneurial low point around 1870.

Nicholas does, however, recognize that his data set in biased towards the inclusion of successful entrepreneurs and entrepreneurs active in manufacturing and mineral extraction.[355] He concludes that the industries covered are those that frame the debate on culture and entrepreneurial performance in Britain. This is precisely my point. The industries covered are arguably highly representative of the debate on the culture and entrepreneurial performance in Britain, but do not include a industry where the findings are in stark contrast to the findings of studies on the British decline. However, one is probably in agreement, that rationality and social origin had little to do with the 'decline' of the British synthetic dyestuffs industry *or* the British 'decline'.

5.4 Summary

The authors that have been discussed in this chapter all revise the poor display of British industrial performance between 1870 and 1914. Broadberry argues that manufacturing industries and the skill requirement by industry more or less match German performance in the long run. Broadberry as well as Edgerton and Nicholas are, however, not sensitive to the performance of the British synthetic dyestuffs industry in their approach on several accounts. The clearest example is the deviation in literature on the treatment of industrial skill requirement and skill supply. Edgerton's main emphasis, however, that the British 'decline' should not be interpreted as doing badly, is on the other hand clearly supported by the case of the synthetic dyestuffs industry. The general revision of the cultural type of arguments is evident by both groups of historians. But it remains clear that the case of the synthetic dyestuffs industry is not taken up to support such an argument as Nicholas illustrates clearly: The British synthetic dyestuffs industry is not well represented as a case study of British industrial performance between 1870 and 1914.

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[355] Nicholas: 1999: 688-713.

6 Concluding Remarks

The Rainbow Makers and *Heinrich Caro and the Creation of Modern Chemical Industry* have been used in this thesis to generalise the new evidence of the 'decline' of British synthetic dyestuffs industry. The 'decline' had much to do with the cross-national density of a very particular chemical knowledge: aromatic chemistry. German scientists became able, though not overnight, to break apart and reassemble aromatic chemicals. The first instance of industrial replication of an organic molecule found in nature was in 1868, when Carl Graebe and Carl Liebermann discovered a route to the synthesis of alizarin. A huge market was opened up, one that only a single British chemical company took part in, and that was Perkin & Sons, the company founded by the man who had started off the industry in the first place. German chemical companies, in response to the competition of other German companies, deployed new modes of organization. The British companies became stagnant. It seems that structural change was not a viable strategy had not science-based innovation been achieved first.

In the historiography of the study of the history of the British synthetic dyestuffs industry prior to the First World War a different type of explanation was employed. Cultural explanations were used to describe the poor performance of British entrepreneurs and the industrialist's poor display of economic rationality. Such explanations were, however, second to the inadequacy of British educational institutions and British governmental initiative. Distinct from a questioning of the general worth of British institutions compared to German institutions, as evident of the historiography on the subject, is the more narrow approach by Reinhardt and Travis. What can be extracted from the historiography of the history of the synthetic dyestuffs industry is that it shows similarities to the evolution of the study of the British 'decline'.

The British synthetic dyestuffs industry did not decline in absolute terms as was thought by Beer. It did, however, experience a shift in the centre of technological gravity away from Britain and France. Industrial output in all likelihood increased throughout the entire period from 1857 to 1914. So did the number of innovations and discoveries. The difference, however, lies in the fact that Germany not only generated more in terms of technology and product, but vastly more, in an industry that at the outset was market by British innovative ability and one in which the British had every potential to compete. It was not before the British government made a huge investment that the British synthetic dyestuffs industry arguably regained a competitive edge.

A peculiar problem when dealing with the synthetic dyestuffs industry as a case study is that the deficiencies of British industry are not closely connected to explanations of those very deficiencies. Edgerton asks that the British 'relative' decline should not be associated with doing badly and the explanations used by the historians who deal with the British synthetic dyestuffs industry do not employ such characteristics. At least, the recent contributions cannot be accused of this. But the case study in question has not been used as an empirical foundation to support such arguments: rather, the case has been dismissed as of little importance. There are two likely explanations to this:

A. Chemistry is in itself hard to grasp for a non-chemist. The confusing and misleading nineteenth-century chemistry and chemical industry are even more difficult to penetrate. The intrinsic difficulty of the empirical data has, however, been carried into the publications on the subject by Travis and Reinhardt. Certainly, it has been attempted to remedy this shortcoming by explaining things a time to many and in a way that most would understand to make the publication accessible. Such attempts do, however, fall short of the normal requirements of a historical study. Most are able to follow the reasoning of the authors, but only few are able to question it. The intrinsic difficulty of the subject is also a problem that faces these audacious historians who endeavour to communicate the study to a wider audience. It would come as no surprise if one of the reasons why the history of the synthetic dyestuffs industry has become a neglected case was because the increased empirical scrutiny has made it more of a study of chemical history than of the chemical industry and thereby removed from the group study of the British 'decline'.

B. The second explanation is that the scholars who tackle the British decline perceive the British educational and training system to be adequately up to the task of providing particular skills to high-technology industries. Because of this the explanations reviewed here that question this view have not been dealt with. But in dismissing such arguments recent scholars have considered and dismissed the opinion of the 1970s history students, not the more recent contributions, which is highly questionable. Lastly, the synthetic dyestuffs industry has been dismissed as being of minor importance. Such an explanation would require a comparison with the electrical and optical industries, but this has not been proven. On the contrary, similar patterns are thought to exist between skill supply and demand in the whole cluster of new-technology industries between 1870 and 1914.

This thesis deals in general terms with how a branch of industry is argued to have endured a period of time that is associated with poor British industrial and economic performance. The synthetic dyestuffs industry did not decline in absolute terms, but it experienced a relative decline, according to Travis and Reinhardt. This relative decline was not measured in terms of output, although German industry was to control 80% of the world's trade in dyes by 1913, but in a shift in the technological centre of gravity away from Britain and France. How this happened has, in recent publications, been explained in terms of the availability of aromatic chemistry.

The historians who tackle the British 'decline' have on the other hand in recent years questioned the standard negative portrayal of British industrial performance. Among the explanations that have been subjected to empirical scrutiny are the inadequate educational institutions, the persistence of family capitalism, and the act of favouring relatives because of their relationship rather than of their ability, not to mention the industrialist in pursuit of social and political distinction rather than entrepreneurship.

The 1870s brought change towards economic maturity and modern business. The explanations proposed for the 'decline' of the British synthetic dyestuffs industry are very much connected to that change, in that the second half of the 19th century was when the formal application of science to industry created modern business. The 'decline' of this new-technology industry had little to do with complacency or conservatism or the persistence of family capitalism. It had much to do with the availability of a crucial skill that was located in a higher density in Germany than in Britain. It was German industry that could benefit from the availability of aromatic chemistry, not Britain, which was forced into stagnation, proving the significance of the case.

The historiography of the history of the synthetic dyestuffs industry painted a negative picture of the industry, and the explanations that were employed were typically associated with 1950s 'declinist' historians. Those explanations did not unravel the mystery of why Germany and not Britain came to dominate the trade in dyes and did contain poor depictions of the British industrialist, the British elite and British educational institutions. In fact, the arguments forwarded by Beer and Haber have been dismissed by both groups of historians discussed in this paper. What is striking is that new explanations forwarded by Travis, Reinhardt, Murmann and Homburg, that is the representatives of recent contributions of the group of historians studying the history of the synthetic dyestuffs industry prior to the First World War, have not replaced older explanations.

Two arguments of Broadberry have been considered in this paper. He argues that British labour productivity levels in manufacturing industry compared to Germany and the USA have remained remarkably stable over the last 150 years or so. The case of the synthetic dyestuffs industry shows that the fluctuations between 1870 and 1914 are not captured in such a view. The second argument was that the British apprenticeship system did provide technical skills adequately. This has been shown to not be the case in this thesis.

The diversity of the industry's skill requirement was argued by Bud and Roberts, who showed that the teaching of general principle was thought to be better in qualifying a student to an industrial occupation. The requirement of the synthetic dyestuffs industry again rested on a skill provided by higher educational institutions by the apprenticeship system. The importance of the skills to industry was argued by Travis and Reinhardt, and again Murmann and Homburg. The adoption of a comprehensive patent law in 1877 protected German industry against imitation.

A pattern is that the synthetic dyestuffs industry does not overlap with the explanations used on long-run British industrial performance. In the case of British industrial performance between 1870 and 1914 Edgerton was brought in. He dismissed the importance of the case of the synthetic dyestuffs industry as a minor value industry. The relative 'decline' of this industry was not questioned by Edgerton, but little importance was paid to the fact that although German industry was to control 80% of the world's trade in dyes by 1913, the shift in the centre of gravity was measured as a technological shift. Edgerton does not take this into consideration when arguing that Britain had the technology to match her industrial performance. Although he provides several examples to support his view, there is little match between Edgerton's findings and the finding of the group of historians studying the synthetic dyestuffs industry, by an author who asks for historians to be sensitive in their approach in the first place. This is despite the fact that these recent contributions are hard to place within 'declinist' history thinking.

It is always difficult to assess the importance of a single case in what is in fact a discussion of British economic performance between 1870 and 1914. The extent to which the synthetic dyestuffs industry shows the whole problem of industrial decline and overtaking can only be partial. What is of interest is whether the case of the synthetic dyestuffs industry is representative of other new-technology industries of the 19th century. This is because industrial performance must be understood in terms of skill shortages in the case of the synthetic dyestuffs industry.

GLOSSARY

Agfa: Aktiengesellschaft für Anilinfabrikation**.**

Alizarin: The red coloring matter of the madder plant, *Rubia tinctorum*. It is manufactured from the aromatic hydrocarbon anthracene.

Aniline: An aromatic chemical that contains the atomic grouping of two hydrogen atoms and one nitrogen atom (the amino group).

Anthraquonine: Quinone derivative of anthracene, used in dye manufacture.

Anthracene: A crystalline, aromatic hydrocarbon obtained from coal tar distillation.

Aromatic chemicals: Hydrocarbons and their derivatives in which certain carbon atoms are arranged in six-membered hexagonal rings. The simplest aromatic hydrocarbon is benzene.

Azo dye: An organic compound containing the azo grouping -N=N-.

BASF: Badische Anilin- & Soda- Fabrik or the Badische. Other used abbreviations; B.A.- & S.F. and B.A.S.F.

Basic innovation: The commercialization of new discoveries such as the wheel, the microchip and synthetic dyes is distinguished from any innovation in that a basic innovation is the first of a whole range of products or processes.

Calico printing: textile printing; the process for (indirect)[356] printing on textile fabrics (narrow) or; preparing and fixing dyes and creating designs and patterns particularly on cotton fabrics (wide definition with a focus on the job of a colorist).

Caustic soda: A caustic metallic base, forming a strongly alkaline solution when dissolved in a solvent such as water. An alkali is a basic, ionic salt of an alkali metal or alkaline earth metal element. Alkalis are best known for being bases (compounds with pH greater than 7) that dissolve in water.

Coal tar: The waste of coal gas works, in which coal was destructively distilled to afford a gas suitable for lighting (1820's), and later for heating. It is also a byproduct from the manufacture of coke.

Constitutional formula: A partial representation of the arrangement of the atoms in a molecule. Known groupings of atoms are separated from others for which only the ratio of atoms is known.

Decline: A condition inferior to an earlier condition.

Diazonium compounds: A primary amine is converted to a diazonium compound. Diazonium compounds or diazonium salts are a group of organic compounds sharing a common functional group with the characteristic structure of $R\text{-}N_2^+ X^-$ where R can be any organic residue such

[356] Printing with madder was achieved indirectly. (Reinhardt and Travis 2000: 27.)

alkyl or aryl and X is an inorganic or organic anion such as a halogen. Diazonium salts was developed as important intermediates in the organic synthesis of dyes. The preparation and reactions of diazonium salts were discovered in 1858 by Peter Griess working at Allsopp's brewing in Burton-on-Trent.

Dynamic efficiency: To this paper, the individual or group ability to cope with industrial evolution, when the requirements of the business changes over time**.** Or in general terms: An economy that appropriately balances short-run concerns (static efficiency) with long-run concerns (focusing on encouraging R&D).

Garancine: Garancine is prepared by steeping madder root in sulphate of soda and washing.

Innovation: Introduction of a new idea into the marketplace in the form of a new product or service, or an improvement in organization or process.

Intermediate: A chemical used in organic synthesis that contains at least one functional group, such as the amino group in aniline. Intermediates can be converted into other intermediates and final products, such as dyes and drugs.

Kekulé benzene theory: A structural theory based on six-membered rings of carbon atoms that is applicable to aromatic chemicals.

Madder: From the madder root, an organic substance, to produce Turkish red.

Magenta: An aniline dye also known under the name of fuchsine or roseine.

Mordant: A substance used in dyeing to fix the coloring matter.

Out-compete: To compete against in a manner that exceeds and may overpower.

Phenol: A white, crystalline compound derived from benzene.

Range (product range): All dyes and shades derived from one organic compound or grouping such as the azo, aniline and alizarin class of dyes.

Relative Decline: Interpretation of the 'decline' of British manufacturing industry between 1870 and 1914. It was not as much British industry that declined, but German and US industry that caught up.

Research and Development: (R&D): Basic or applied research for the purpose of creating new, or for improving existing materials, devices, products or processes; or to include strategy more heavily, R&D comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this knowledge to devise new applications. Research and development is a component of the broader innovation process. Industry founded R&D is differentiated from government-founded R&D and Industry-founded R&D, and it is the first type of R&D, the industrial effort to discover new products that is considered in this thesis.[357]

[357] Edgerton 1996: 70-71.

Sales[358] turnover: The volume traded (income and expenses), or level of trading, over a specified period, usually daily or yearly.

S.M & N.: Simpson Maule & Nicholson.

Static efficiency: an economy that concerns itself primarily short-run concerns.

Structural formula: The representation of the arrangement of all the atoms in a molecule.

Toluene: Also known as methylbenzene or phenylmethane is a clear, water-insoluble liquid. It is related to another aromatic hydrocarbon, benzene, and is today widely used as an industrial feedstock and as a solvent.

Total synthetic pathways: A total synthetic pathway is a multistep production method, and a formal understand of how to synthesize a product by producing every component required to 'building' that product.

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[358] There is no standard definition of 'sales'.

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APPENDIXES

Appendix I

Timeline for the synthetic dyestuffs industry

1840. After 1840 high levels of mechanization existed in calico printing (color printing on fabrics) in Manchester region, cheapening calico goods so such an extent that output grew to four times that of France.
1857. William Henry Perkin's factory at Greenford Green start production under the company name of Perkin & Sons. The major market for mauve was the printing and dyeing of cotton.
1858. The problem of attaching mauve to cotton was solved, and Perkin could justifiably claim that one pound of his solid purple dyed two hundred pounds of cotton.[359]
1858-9. Fuchsia. Uncertainty as to date, but application filed in as early as February 1858 by François Emmanuel Verguin. Much later in the year or perhaps early in 1859 Verguin treated aniline with anhydrous stannic chloride, and obtained a red colorant, the prototype of a new range of aniline dyes.
1859. Mauve reached its height of popularity at the end of 1859. It remained in fashion for another four years.
1859. The problems concerning truly large scale manufacture of the two intermediates (aniline from nitrobenzene) required to make mauve were resolved by Edward Chambers Nicholson, a former student of Hofmann, and partner in Simpson, Maule & Nicholson (established in 1853)
1862. Roberts, Dale & Co starts production of mauve by a different route discovered by Heinrich Caro as only other British producer of Mauve.
1862-63. Read Holliday & Sons listed as color manufactures.
1864. Ivan Levinstein set up business in Salford in 1864, then moved to nearby Manchester in 1865, and started producing synthetic dyestuffs under the name of L.I. Levinstein & Co.
1869. Perkin & Sons start producing alizarin.
1870s: The emergence of a major German synthetic dyestuffs industry.
1880. Natural products had, with the exception of indigo, almost given way to synthetic color.

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[359] "*The problem of compensating for the absence of nitrogenous material in the cellulose containing cotton* (the nitrogen containing protein in silk and wool gave good attachment properties to dyes) *was the great challenge presented to all colorist- in particular those who wished to succeed in using aniline colors*". (Travis 1993: 55.)

Timeline of the synthetic dyestuffs industry by Anthony Travis.

1856: The teenaged William Perkin in London, discovers the aniline dye from 1859 known as mauve. Aniline is an aromatic chemical, made from benzene.
1858: A red dye is made from aniline. It is later known as magenta, fuchsine, etc., and in 1861 is converted into a blue dye.
1863: Structural formulae are not available for aromatic chemicals. However, they can be represented by constitutional formulae based on simple types of groupings of atoms. This enables A. Wilhelm Hofmann to discover the Hofmann's violets in May 1863.
1865: Friedrich August Kekulé announces his benzene ring theory. This makes it possible to draw the structural formulae of aromatic chemicals.
1868: Carl Graebe and Carl Liebermann find that the natural product alizarin is a derivative of the aromatic hydrocarbon anthracene, establish the partial structure of of alizarin, and a route to its synthesis. This represents the first synthesis of a complex natural product in the laboratory.
1869: Heinrich Caro at BASF and William Perkin independently discover commercial routes to synthetic alizarin. Patents are filed in London during June 1869. Manufacture begins in England and Germany during 1869-70, and leads to the decline in cultivation of madder. This lays the foundation of modern science-based industry and industrial-academic collaboration.
1874: Academic chemist Adolf Baeyer, at Strasbourg, and industrial chemist Heinrich Caro, at BASF, jointly publish the chemical structure of alizarin. Perkin retires from industry.
1875: Introduction of azo dyes, that contain the atomic grouping –N=N-.
1877: Comprehensive patent law introduced in Germany. It is the most advanced system in the world for protecting chemical inventions.
1883: Adolf Baeyer at Munich draws the structural formula for indigo.
1889: Central Research Laboratory opened at the BASF Ludwigshafen factory. The industrial research laboratory becomes a formal business unit.
1897: BASF and Hoechst in Germany commence the manufacture of synthetic indigo. This leads to the collapse of the natural indigo trade.
1914: Germany and Switzerland are the leading dye-making countries, and control most of the world market. Some intermediates for dyes are important in the manufacture of explosives. Following the outbreak of World War I, the British dye industry is revived, and large-scale manufacture is taken up in the United States.
1956: On the occasion of the 100th anniversary of the discovery of mauve, ICI in Britain announces the first fiber-reactive dye (Procion range) that forms a chemical bond with fabric.

Diversification in the Dye Industry

1899: The dye manufacturer Bayer in Germany introduces Aspirin, a coal tar product.

1909: Paul Ehrlich, whose biomedical research is based on synthetic dyes, discovers the first successful chemotherapeutic agent that attacks sites of infection within the body. It is an arsenic analog of an azo dye, manufactured by Hoechst as Salvarsan.

1909: Fritz Haber at Karlsruhe demonstrates to representatives from BASF his apparatus for the fixation of atmospheric nitrogen as ammonia.

1913: The Haber-Bosch process is inaugurated by BASF. It relies on high pressures, elevated temperatures, novel catalysts, and recovery of unreacted hydrogen and nitrogen, and becomes the basis of many important industrial process in the 20th century.

1935: Research into a red azo dye enables Bayer to introduce Prontosil, a chemotherapeutic agent active against cocci bacteria. This is the first sulphonamide drug.

Appendix II

These are a collection of e-mails between myself and Travis, Morris and Homburg. The e-mails are subjected chronologically to each author. Greetings and personal content have been removed. Only small amendments have been made in correcting grammatical errors.

Ernst Homburg,

Date: 27 Mar 2007

In 1984, when I wrote a Dutch paper on the synthetic dyestuffs industry myself, the general argument in the debate (Beer, Haber, Hohenberg, Borscheid) was that German chemical education was better than British chemical education & that there just more chemists in Germany. I then concluded that this statement could not be upheld in general, but that the crucial differences were in organic chemistry. Later I found out that even that conclusion might be too general, but that the differences in aromatic chemistry indeed were striking between Germany and Britain. Peter Murmann has included that view into his work. This indirectly answers your question on inorganic chemistry. Probably organic chemistry was weaker in Britain than in Germany and there was a relative bias towards inorganic chemistry. This can be substantiated by Lippmann's time tables, and by Frankland's witnesses for a government commission in 1871. But I consider the difference with respect to aromatic chemistry more crucial. There were a few important organic chemists in Britain: Williamson, Hofmann, Odling, Schorlemmer and this should not be forgotten.

It is difficult to compare English and German chemical teaching. There is no good comparative study. For Britain the best work are a number of papers by J.F. (Jim) Donnelly, and the older book by Bud and Roberts.

You are allowed to use our graphs/figures, with reference. For your convenience I attach the last Word version of our paper.

Peter Morris,

Date: 19 Mar 2007

Without going into detail (which would require a conversation rather than an e-mail), it seems to me that there are three big issues here:

1. Were there English manufacturers of intermediates and if so why did they fail to capture the market for intermediates (as opposed to dyes)?

2. Did the English manufacturers ever consider doing so?

3. Was their failure linked to the nature of chemical education in England?

I agree that England was a first-rate site for raw materials and equipment.

I understood England was an important source of intermediates (esp. phenol).

I suspect much of the reason for the failure of the English industry was the lack of innovation in the coal tar industry. Ludwig Mond when he was developing the ammonia-soda process had a lot of trouble getting coal-tar ammonia and had a lot of trouble with his deliveries. I was going to write a paper about this but never got round to it. Certainly the relative lack of organic chemists in England was a factor (as it was in the closure of Perkin & Sons) but I do not think it was crucial.

Peter Morris,

Date: 19 Mar 2007

However, as I understand it you propose that the English education system was geared towards inorganic rather than organic chemistry. This is an interesting thesis which needs to be completely unpacked.

First, what period are we talking about? It seems to be that it has to be the 1830s-1860s before the organic chemical industry took off.

What firms are we talking about? There were many small firms and relatively few large ones.

Where there many (any?) academically trained chemists in the English industry at this time?

If so, where were they trained? This is a difficult one as many industrial chemists took one or two courses rather than a full degree. It would be interesting to know if they took inorganic rather than organic courses.

Was their training biased towards inorganic chemistry? (I will discuss this briefly below).

Did the existing English firms have any influence on chemical education?

In brief I would point out that organic chemistry hardly existed when the English inorganic industry was at its peak. Clearly inorganic rather than organic chemistry was the prerequisite for the industry. To me this seems a matter of timing and a bandwagon effect. Because the English industry arose in the 1820s and 1830s when inorganic chemistry (both in academic and industrial terms) mattered, the emphasis was on inorganic chemistry. This produced a bandwagon effect and institutional inertia which prevented the English industry responding to the opportunity of synthetic dyes.

However, I doubt if the bias of English chemical education was responsible. First, academic training was of fairly minor importance for industrial chemists in this period and they would have picked courses that met their needs (i.e. analytical and inorganic ones), i.e. the bias came from the consumers of education rather than the producers (the professors). The overwhelming emphasis of English chemical education throughout the 19th century was analytical chemistry which is more inorganic rather than organic. In any event, most of the knowledge at the time was tacit knowledge learnt on the job rather than in college.

The issue of the influence of chemical manufacturers on education is an important one and has already been touched upon on the literature. It is not an area I am strong on but the demand of manufacturers would have been for analytical chemistry rather than inorganic chemistry because of most of the work of the works chemists would have been analytical (and indeed was still largely the case when I worked briefly in a pharmaceutical company in the mid-1970s).

Anthony Travis,

Date: 25 Sep 2007

Social origins: Generally middle-class men in both Germany and Britain, e.g. in Britain, Perkin (father was a builder), Nicholson, and the immigrants Ludvig Mond and Levinstein (both from middle class German homes). Not necessarily from family businesses into textiles or chemicals. Also sons of owners of private British chemical firms: Dale, Holliday, etc.

The main difference between Germany and Britain was, for the latter, less of a "culture" of doing and applying science, particularly in its application. British were used to bulk processing of textiles, coal, iron, etc.; highly dependent on manufacturing machines; and had ample resources in the colonies and at home, so McCloskey is correct. What they did was logical in the circumstances [economically rational].

Murmann and Homburg are also correct, even though their argument pertaining to the number of chemist is self evident. The best example of that is Perkin, almost alone until he sold out in 1873, by which time Caro, Graebe and Liebermann were collaborating, as was Caro with Baeyer. After Hofmann left London in 1865, there was nothing like this type of input in the UK, nor could there be until the late 1860s, even in Germany. The level of organic chemical science was not adequate to resolve many outstanding questions. I do not think that had Hofmann remained in London it would have mattered.

Murmann and Homburg are correct to give examples of capacities of reactors, but maybe the time period is too long to be totally relevant to your argument based I presume on an earlier period. What was important was the fact that British manufacturing technology until 1870 was better than German technology. See for example the fact that BASF copied Perkin's alizarin manufacturing process (and failed at first). The way of doing things in bulk helped Perkin and others a lot, but only until the Germans focused on the "science," from around 1867-68.

Anthony Travis,

Date: 20 Sep 2000

Here is a draft of a paper I gave in Boston a few weeks ago. Note the part about Raphael Meldola. Do you have the Heinrich Caro biography? That includes Meldola's investigations into the sources of dyes used in the UK, but in 1885-1886. I doubt that before the 1870s there exists any information regarding industrial output, except whatever is in the accounts of international exhibitions. In other words, relative quantitative outputs are perhaps impossible to establish; only the overtaking of Germany as seen through scientific and technological developments, and in particular the 1877 patent law, can provide a guide to the changeover. Maybe there is material in the archives of the German firms, but that would involve a lot of research. In any case from what I have seen I doubt that you will find much prior to the period of changeover.

----- Original Message -----

I cannot stop dwelling over the 'geographical shift of the centre of gravity' as you put it. I find it intriguing. I do not dispute the fact that, as you wrote it; "The West End of London was the place to be for any aspiring chemist with an interest in aniline and its reactions". What I am more uncertain about is the actual output of synthetic dyes in Britain, and to what extent one can speak of a industrial overtaking from a to b. If one were to speak of novelty and technological transfer the story would be different, but that is not easily quantifiable.

Anthony Travis,

Date: 18 Sep 2007

The attached may be of use to you. Regarding market share, if we consider the English market, the largest market in Europe, then during the first half of the 1860s there were imports from France, though sometime the origins were hidden in order to avoid patent infringement. French imports were less after the collapse of La Fuchsine. Then the German imports grew, particularly from 1870 with the import of alizarin, also masked, in this case imported as natural madder dye. This was to avoid infringing the Perkin/BASF patents of June 1869 and agreements over those patents.

As for British manufacturers, there was Perkin from around 1858, whose business declined in the early 1860s until the manufacture of synthetic alizarin was stated in 1869.

Simpson, Maule & Nicholson, of London, held the monopoly for a few years on the aniline red (magenta) and its blue and violet derivatives.

Levinstein started in Salford in 1864, then moved to nearby Manchester in 1865, and benefited from the removal of the SM&N monopoly.

Holliday, again suffered from the SM&N monopoly, at least until 1865.

These were the main firms, producing "aniline dyes", except for Perkin that started alizarin manufacture in 1869. Some later got into azo dyes, generally from the late 1870s [Travis is mainly referring to L.I. Levinstein & Co. and Read Holliday & Sons.].

So these British firms shared the market, though sharing is hardly the correct word, since they were in competition, and SM&N held a monopoly until 1865. With loss of that monopoly the industry was splintered. Perkin discusses production and imports of synthetic alizarin. In theory he monopolized the British trade during 1869-1873.

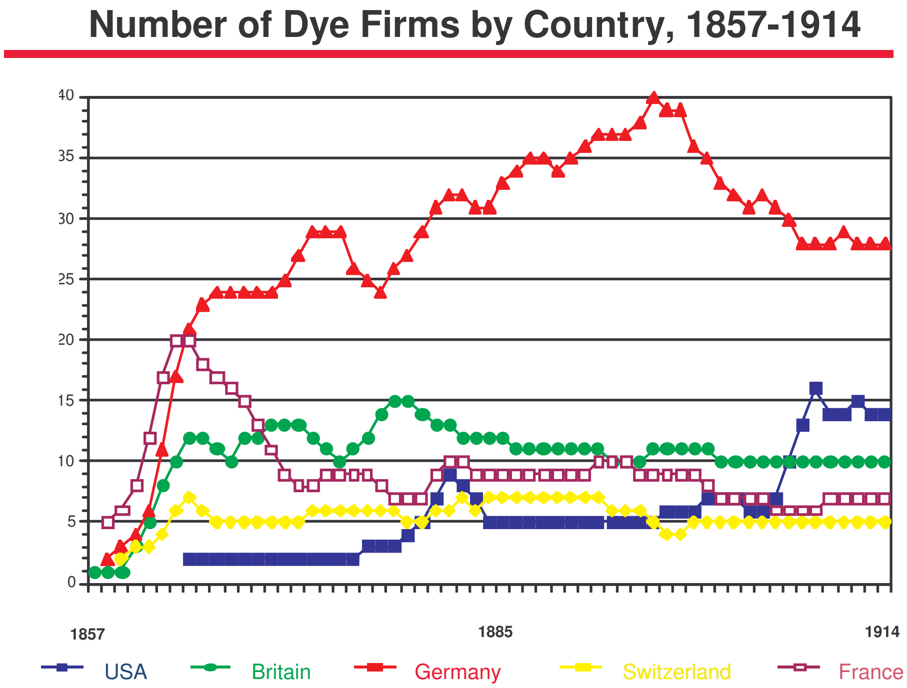
Nothing about quantities I am afraid, but I hope that the above helps a little for the early period.

----- Original Message -----

I find your thesis very convincing. But, there is one thing, as there always is. Again, the company database of Homburg & Murmann imply that the 'dominance' of British dye industry in the early years must have been held by very small number of companies, and if so how large is the market share relative to the consume ability of the textile industry? Do you have any data on the market share for British companies in the 1856-1870 period? It would be very interesting to get comparative figures.

<u>Appendix III</u>

Fig. 3.[360]



[360] Murmann and Homburg 2001: 188. There is a problem with the caption in the figure; German share of global firm population is shown by red squares and red triangles.

Table 2: Alizarin Producers Among Existing Firms and Entrants (1868-1876)[361]

Year	*Number of Entrants*	*% Alizarin Producers*	*Number of Existing Firms*	*% Alizarin Producers*
1868	1	0.0	52	0.0
1869	0	0.0	53	3.8
1870	7	28.6	48	8.3
1871	10	20.0	52	11.6
1872	4	75.0	54	14.8
1873	13	46.2	56	26.8
1874	3	33.3	57	33.3
1875	3	66.6	54	29.9
1876	6	50.0	55	29.1

[361] Murmann and Homburg 2001: 183.