EMERGENCE OF RESEARCH AND INNOVATION ACTIVITIES IN THE CHEMICAL INDUSTRY AT THE BEGINNING OF THE TWENTIETH CENTURY: THE CASE OF IG FARBEN AND DU PONT

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF SOCIAL SCIENCES

OF

MIDDLE EAST TECHNICAL UNIVERSITY

BY

MUHSİN DOĞAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR

THE DEGREE OF DOCTOR OF PHILOSOPHY

IN

THE DEPARTMENT OF SCIENCE AND TECHNOLOGY POLICY STUDIES

APRIL 2018

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

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April 2018, 243 pages

In the 19th Century, after constant investments by governments and private sector to Chemical industry, Germany and the USA rised in terms of technological leadership, technological infrastructure and human capital for a long period. In these countries, there had been their own unique National Systems of Innovation. Thanks to this process, two giant chemical firms – IG Farben in Germany and DuPont in the US have come to existence.

Each of these firms had successful innovation paths throughout their history. Their innovation performance in synthetic chemicals clearly demonstrates the vital importance of a sound, solid National Innovation System. However, coming to the 1940s, it is striking to see how these two giant technology firms entered into the service of political/bureaucratic authorities and how science and technology were affected by these circumstances. Therefore, the dissertation argues that two cases are different in three main aspects: research design of companies (centralized

vs. decentralized decision making), policy differences (applied vs. fundamental research), and driving forces of research (market-driven vs. science-driven research).

The principal purpose of the dissertation is to clarify these points. The first aim is to understand and then describe similarities and differences via analyzing innovation and learning process in IG Farben and DuPont between 1925 and 1945. The second aim is to explain the patterns of innovation and learning for innovation and technology studies with the help of comparative historical case study. Therefore, the dissertation predominantly focuses on pre-war and war periods to shed light on the effects of authoritive figures on chemical sector during the war period. Innovation activities of both firms during the war period will be examined in detail with the assistance of archival data and historical documents.

Keywords: History of innovation; emergence of chemistry; innovation systems; chemical industry; World War II.

ÖZ

YİRMİNCİ YÜZYIL BAŞLARINDA KİMYA ENDÜSTRİSİNDE ARAŞTIRMA VE YENİLİK FAALİYETLERİNİN ORTAYA ÇIKIŞI: IG FARBEN VE DU PONT VAKA İNCELEMESİ

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Nisan 2018, 243 sayfa

19. Yüzyılda, hükümetlerin ve özel sektörün yardımıyla, Kimya sektörüne yapılan sürekli yatırımların etkisinde Almanya ve ABD, teknolojik liderlik, teknolojik altyapı ve insan sermayesi açısından uzun bir süre boyunca bu sektörde liderlik konumuna sahip olmuştur. Bu ülkelerin kendine özgü Ulusal Yenilik Sistemleri sayesinde, iki dev kimya firması ortaya çıkmıştır - Almanya'da IG Farben ve ABD'de DuPont.

Her iki firma, tarih boyunca başarılı bir inovasyon örüntüsüne sahiptiler. Bu firmaların sentetik kimyasallardaki inovasyon performansları, sağlam bir Ulusal İnovasyon Sistemine sahip olmanın önemini açıkça göstermektedir. Ancak 1940'lı yıllara gelindiğinde, bu iki dev teknoloji firmasının nasıl siyasal / bürokratik otoritelerin hizmetine girdiklerini ve bilim ve teknolojinin bu durumdan nasıl etkilendiği görmek çarpıcıdır. Bu nedenle, bu doktora tezi, bu iki firmanın üç temel açıdan farklı olduğunu öne sürmektedir. Bunlar: şirketlerin araştırma tasarımları (merkezi ve merkezi olmayan karar verme), politika farklılıkları (uygulamalı ve/veya

temel araştırmalara yönelik seçimleri) ve araştırmalarının odağı (pazar odaklı veya bilim odaklı).

Tezin ana amacı, bu iki vakada temel farklılıkları ve benzerilikleri açıklığa kavuşturmaktır. Buradan hareketle ilk olarak, 1925 ve 1945 yılları arasında IG Farben ve DuPont firmalarındaki inovasyon ve öğrenme sürecini analiz ederek benzerlikleri ve farklılıkları anlamak ve tanımlamak amaçlanmıştır. İkinci olarak ise, tarihsel karşılaştırmalı vaka incelemesi yöntemiyle firmaların inovasyon ve öğrenme örüntülerini açıklamak amaçlanmıştır. Bu nedenle, bu çalışma ağırlıklı olarak savaş dönemi boyunca kimya sektörü üzerinde söz sahibi olmuş yetkililerin etkilerine ışık tutmak için savaş öncesi ve savaş dönemine odaklanmaktadır. Savaş döneminde firmaların inovasyon faaliyetleri, arşiv verilerinin ve tarihsel belgelerin yardımıyla ayrıntılı olarak incelenecektir.

Anahtar kelimeler: İnovasyon tarihi; kimyanın ortaya çıkışı; inovasyon sistemleri; kimya endüstrisi; İknci Dünya Savaşı.

To Servet,
my lovely cat

&

to the stars

that I haven't explored yet...

ACKNOWLEDGEMENTS

When I first read Carl Sagan's book, *Cosmos: A Personal Voyage*, I was mesmerized by the scientific advancements. I have always tried to keep my curiosity about the universe alive. This dissertation is a product of that book basically. It was a very challenging and complicated process. However, Sagan's lines are the best part of the writing process of the dissertation. In this part, I have to mention and show my appreciation to some people who helped, directed and inspired me during the dissertation process.

First and foremost, I would like to thank my advisor Assoc. Prof. Dr. İbrahim Semih AKÇOMAK for his supervision and support. He has always supported me and my ideas during the process. Moreover, his motivation and discipline (I call it Dutch discipline) inspires me to make new things. In addition, I would like to thank for his valuable supports, contributions and guidance during my six years as a research assistant at METU, as well. This dissertation would not come out without his supervision. I would like to express my gratitude for his accessibility, enthusiasm, and encouragement all the time.

I would like to express my gratitude to the committee members, Prof. Dr. Erkan ERDİL, Assoc. Prof. Dr. Seven AĞIR, Assist. Prof. Dr. Derya FINDIK, and Assist. Prof. Dr., Erkan GÜRPINAR for their time, support, understanding and insightful comments and contributions to improve my dissertation.

In this paragraph, I would like to express myself in Turkish for my family. Annem, Nezahat, babam Cemal Kasım, teyzem Nezaket, abim Ozan, kuzenim Damla ve kardeşim Doğancan DOĞAN'a onlardan çaldığım zamanlarda bana anlayış gösterdikleri için teşekkür ederim. Ayrıca Pazar günleri aile yemeklerine katılamayıp bu tez ile uğraştığım sürede beni her yönden anlayışla karşıladıkları için onlara müteşekkir olduğumu berlitmek istiyorum. Babannem ve anneannemin, onları ziyaret edemediğim zamanlarda bu tez ile uğraştığımı bilmelerini isterim. Ne yazık ki bu satırları anneannem ve dedeme okuyamayacağım ama beni anladıklarından şüphem yok. Benim bu aşamaya gelmemdeki emekleriniz için çok ama çok teşekkür ederim.

If the process of writing a dissertation is like climbing the mount Everest, one needs to make many camps, face with obstacles, and overcome challenges in order to reach the summit. Without a team, it would be very hard. I am lucky because my office mates have always given the necessary encouragement, psychological support and power to climb up my own Everest. Thanks to them, I could reach the summit. The TEKPOL team, Maryat COŞKUN, Cansu DURUKAN and Gülsevim EVSEL. They have also become my climbing team during the process. I am happy to know you guys. I am appreciated. Moreover, I should mention, from TEKPOL team, Dr. Arsev Umur AYDINOĞLU. His positive attitude and valuable comments shed light on my way. I am gratitude for it

I would like to thank Ezgi ÇELİK for her patience and tolerance during the studying, examining, and writing process of the dissertation. She has witnessed the whole process from the beginning to the end. Moreover, she made many corrections in the dissertation. Whole text was read by her in detail. Maybe, she hasn't known that her advices and support were very vital to me for improving my work. Therefore, I would like to present my deepest appreciation to her. Your endless patience made the process possible to me.

I am thankful to a person who is more than a friend. Büşra AKÇABOZAN KAYABOL, you have been the closest person to me especially during the writing process. On the other hand, your guidance about climbing, cycling and camping has always inspired me to achieve the impossible. Lastly, your positive attitude towards human relations has been crucial for me to understand other people in my social and professional life. I am appreciated with your friendship. I hope that we will get in touch until our 80s.

I would like to mention staff at METU library, BAP, Technoart (Murat Akkaya) and TEKPOL for their financial and physical supports. Many thanks to their support, I could realize this dissertation.

Moreover, I wish to express my thanks to my precious friends who made this process easier and more enjoyable than it was. I would like to express my deepest gratitude to Ozan and Şeyma PİROL (and their children Doğu and Tibet who are the source of positive energy for me), Ceyda Mine POLAT. I want to say thank you guys for being my friend during the process. I would like to thank my dearest friends Mine MUYAN YILIK (yenge) and Mehmet Ali YILIK and Yiğit KAYABOL (enişte), who is the owner of Kayaball Beer. Your presence has been essential for writing this dissertation. I owe a special thank to Gökçen AYDIN for making proof reading of

Chapter 1-2 of this dissertation. Thanks to her corrections, this dissertation has become more consistent in terms of language. In difficult times, many persons gave their attention and time to help me stay calm and protecting me to go into a mental depression. Those were Pınar ÇAĞ, Yankı SÜSEN, Melis TUNALI, Candaş ERDİŞ, Yelda ERDEN TOPAL, Ecem Gizem HÜNER, Merve ÇOLAK, Feride ASLAN, Aykut Mert YAKUT, Ünal TÖNGÜR, Gökten DOĞANGÜN and Sine TUÇ. I am grateful for your supports and efforts for me.

I would like to express my deepest gratitude to Selçuk DURGUT for his priceless help in designing of the final print of the dissertation

I would like to mention several people whom I have never met in person but I am always inspired from their being. Their endless passion, curiosity and understanding of universe and nature also make me a passionate person about the universe and its future. This work is deeply affected by their activities, philosophies and thoughts of Reinhold MESSNER, Alex HONNOLD, Carl SAGAN, Karl POPPER and Friedrich von HAYEK. There are many people who made this dissertation possible by touching my life. I am thankful for all of you.

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CHAPTER 1

INTRODUCTION

"The desire to put mankind into the saddle is the mainspring of most economic theory"

Alfred Marshall - 1999

"Economic theory is related to the practical activities of economizing men in much the same way that chemistry is related to the operations of the practical chemist. Although reference to freedom of the human will may well be legitimate as an objection to the complete predictability of economic activity, it can never have force as a denial of the conformity to definite laws of phenomena that condition the outcome of the economic activity of men and are entirely independent of the human will."

Carl Menger - 1871

"Most of the fundamental errors currently committed in economic analysis are due to a lack of historical experience more often than to any other shortcoming of the economist's equipment."

Joseph A Schumpeter - 1954

"This essentially subjective character of all economic theory, which it has developed much more clearly than most other branches social science but which I believe it has common with all social sciences in narrower sense, is best shown by a closer consideration of one of its simplest theorems, eg., the "law of rent."

Friedrich von Hayek - 1955

When *Homo Sapiens* began to cooperate and collaborate with others, our primitive material world theoretically began to shape our modern world (Harari 2015). The question of how humanity-controlled material world is the central notion that has shaped modern economics. In the *Wealth of Nations* in 1776, Adam Smith revealed his passion to understand systematically the non-mechanical actions of the material world. How society works and why individuals act to produce wealth were the main themes of his book. Just before Adam Smith, Richard Cantillon had a distinctive approach to understand the economic activity of the material world. In his famous book, –*Essai*- (*Essay on the Nature of Trade in General, 1775*), Cantillon proposed groundbreaking ideas on the importance of entrepreneurship. According

to him, entrepreneurs act and survive in a system characterized by uncertainty. In that time, the central point was that individual relations and institutions determine industrial relations. Both Cantillon's *entrepreneurship* and Smith's *spontaneous order* are leverages to understand the nature of wealth at the macro level and industrial relations at the micro level. These two books shaped one of the central questions of economics: "*Why some countries are rich and the others not*?"

The problem was analysed in different disciplines of social sciences like history, political science, anthropology, and economics. In answering this question, historians attempt to examine the determinants of economic change in different countries. An economic historian, Mokyr, for instance proposes that "*the difference between rich nations and poor nations is not, as Ernest Hemingway said, that the rich have more money than the poor, but that rich nations produce more goods and services. One reason they can do so is because their technology is better; that is, their ability to control and manipulate nature and people for productive ends is superior*" (Mokyr, 1990: 9). Like Mokyr, other historians have tried to examine the *divergence* between countries -and even continents- providing historical data (Clark, 2007; Jones, 2003; Landes & Rogers D Spotswood Collection, 1998; Pomeranz, 2000). In a similar manner, Paul Kennedy studied the political and imperial roots of change in the context of economics. His analysis spotlights the era between 1500 and 2000 to investigate the very same question mentioned above (Kennedy 1987). The economic change between regions and countries was also analysed by environmental determinists like Jared Diamond. Diamond proposed "*another one, popular with inhabitants of northern Europe, invokes the supposed stimulatory effects of their homeland's cold climate and the inhibitory effects of hot, humid, tropical climates on human creativity and energy. Perhaps the seasonally variable climate at high latitudes poses more diverse challenges than does a seasonally constant tropical climate. Perhaps cold climates require one to be more technologically inventive to survive because one must build a warm home and make warm clothing, whereas one can survive in the tropics with simpler housing and no clothing*" (Diamond, 1997: 47). The question of economic change has been a central research topic for the last 250 years since its first introduction by Smith. The much more down to earth form that tries to answer why some countries rich while others are poor necessitates a much deeper look that dwells upon the mechanisms. While the macro perspective presents various evidence on the usual suspects i.e., human capital, physical capital, geography, culture etc. it still lacks a sufficient understanding on the actual mechanism. Thus, while we know quite a lot regarding why some countries are rich (i.e., identifying indicators) the question of how (i.e., identifying mechanisms) is still a fertile soil.

I will use *evolutionary* and *institutional* perspectives in this dissertation to dwell upon the "how and why" questions. The first perspective uses the term *evolution* that comes from biology to understand the puzzle of change. The main idea is to explore and comprehend the nature of change using biological concepts like *variety*, *adaptation*, *source of variety*, and *selection.* Evolutionary theorists additionally think that economic development and growth of firms are shaped by industrial relations and innovative activities of firms (Basalla 1988; Dosi 1984a; Nelson and Winter 1982; Schumpeter 1934). Nelson and Winter (1982) widely used these concepts to understand the predictable patterns of firms, which they call *routines*. Originally, Schumpeter tries to understand *interdependencies*, *competition*, *structural change*, and *resource constraints* with the help of mainstream economics' tools (Schumpeter 1934). In this perspective, the main aim is to use organizational and institutional structures in analysing industrial relations benefitting widely from evolutiontionary aspects. The latter perspective I will benefit hinges on the concept of "institutions". All societies have formal institutions that are constructed by government and informal ones emerged by actions of society. The formal institutions are closely related to organizations (Ministry of Science and Technology, universities, etc.). It can be implemented and constructed by authorities, governments, and states. The latter covers a broad meaning. Hayek's institutions widely emerged from unintended consequences of human action (Hayek 2012b). In addition to Hayekian view, Douglas North defines institutions as "rules of the game" and also organizations as "player in the game" (North 1990). Emerged systems or orders might be affected by organizations; however, institutions evolve during time with the help of complex social systems. For instance, there are economic institutions like competition or patent laws that affect the performance of the individual firms thus the whole economy. As Acemoglu puts it: "*Economic institutions shape economic incentives: the incentives to become educated, to save and invest, to innovate and adopt new technologies, and so on. It is the political process that determines what economic institutions people live under, and it is the political institutions that determine how this process works*" (Acemoglu & Robinson, nd, p. 140). According to this view, there is a strong relationship between political and economic institutions, and economic performance. Moreover, institutions are vital to understand how economic change occurs. As we have seen above, mainstream economics is not sufficient to answer the famous question on why some countries are rich but others are poor. As suggested the mainstream theory was useful to identify the indicators that affect economic change but a multi-perspective approach is needed to identify the actual mechanisms. Thus, evolutionary and institutional perspectives illuminate the main

structure of this thesis that looks at the sources of economic differences in a much more micro perspective.

Why do evolution and institutions matter? On the one hand, institutions can affect productivity and innovation by changing the rules of the game and the incentive mechanism. This can be viewed as a direct effect of institutions on industrial dynamics. On the other hand, institutions can affect economic growth and development indirectly through its role on industrial dynamics. For a deeper understanding of the exact mechanisms and their roles, evolutionary perspective is useful. The thesis initially focuses on the differentiation of economic and political change in two cases. The historical cases will help to comprehend the innovative and economic achievements of the two cases.

Germany and USA are selected to understand some important questions in the literature. Those might be grouped in research and innovation activities of chemical sector. The countries are selected according to some criteria as mentioned in Methodology Chapter. In addition, some questions like: The question about difference across countries may be framed by focusing on specific industries. For instance, how did Germans establish first R&D Laboratories in their state? Or how did USA make innovations for chemical sector thanks to DuPont? Answers for those questions are not easy; however, they can be explained by comparing countries and firms in several aspects. Chemistry sector is classified as a science based sector or generic sector. Importance of those sectors can be founded by understanding the foundation of the sector. Furthermore, definition of sector covers many actors like universities, research institutes, firms, NGOs, and governments. This means that each individual unit should be analysed or at least included in the analysis. In the cases of Germany and USA, by only looking at two giant firms –IG Farben and DuPont- one can get sufficient information about the sector. They are giant firms, which have big organizational structures, employ many chemists, and have sophisticated research capabilities in their homeland etc. Therefore, by using the evolutionary and institutional perspective, the foremost purpose of this chapter is to analyse the cases of IG Farben and DuPont specifically focusing on their innovative activities. Understanding the nature of economic change in these micro units may help us to comprehend the dynamics of industrial change better. Therefore, this chapter has an excessive role that grasps the evolution of change in IG Farben and DuPont during 1925-45.

In this dissertation, chemical sector was chosen due to the fact that it is general-

purpose technology that spreads its knowledge and inventions over all industrial sectors in the market[1]. According to Delorme, innovative activities are intense in chemistry corporations[2]. Moreover, chemistry can be seen as the main promoter in industrial production due to its side effects and externalities on the economy. I will focus on the period and I intentionally chose to eliminate divergent conditions and to standardize circumstances for two countries. As known, the two countries, Germany and the US, entered the War as great powers. Hence, two giant chemical companies were selected to examine what were the differences and similarities in innovation and learning activities.

There are three important points in this thesis in terms of innovation studies literature. The first is size of the firms affected their market strategies. They needed to join international competition for gaining advantage. Nowadays, this situation has been called as Global Value Chain. In this case, IG Farben and DuPont had benefited from those "value" chains deceptively. The second point is related to evolutionary aspects of the cases. For those companies, evolutionary factors such as variety, dynamism etc. can be observed as a Schumpeterian concept. According to this concept, IG Farben and Du Pont conducted their business in adopting other business areas via merging in order to make variety of products. These concepts are examined with the help of profitability of firms while doing business in the market. The last point is type of conducting research activities in both company. This means that both companies and countries had highly benefited from innovation ecosystems or environment that founded promoting innovation in terms of "system approach" to innovation. Innovation activities were examined accordance with Nelson and Rosenberg (1993) and also Freeman and Soete's (1997) ideas. Under the guidance of the literature, this chapter will try to analyse and answer several questions what about the differences/similarities regarding the foundations of innovation between IG Farben and DuPont are? Were there differences in terms of the role of learning? How did external factors such as war, political conditions, economic system, and economic policies interact with the learning process and innovation process?

1.1 Motivation of the dissertation

The main motivation of writing this dissertation is to clarify main factors that affect the innovation and R&D performance of two companies in two different continents.

1 Freeman & Soete, 1997

2 Delorme, 1962

In the current literature, research emphasize emerging of chemical industries and their economic situations (Aftalion 1991; Haber 1971; Homburg, Travis, and Schröter 1998; Reader 1970). At this point, how science heritage, background of countries, economic relations, and structure of firms affect the innovation and R&D inside the companies is a good starting point. In this way, one can at least understand the scope in which sectors emerge and firms flourish. Then within this context, two big and successful companies are selected to make a comparison with respect to their innovation activities. This is vital to understand how firms evolve and adapt to achieve success in different context. In this dissertation, the cases of DuPont and IG Farben reflect how successful "research stories" can be realized in various paths of successful innovative activity.

Scope of the dissertation is limited with the date which covers the foundation of IG Farben, 1925 and end of the World War II, 1945. Within this scope, factors that affect the research and innovation in the cases are explained in both macro and micro view. First of all, institutional and evolutional change is traced through macro historical view. Hence, heritage and paths of two countries is examined in detailed. Afterwards, in the micro analysis unit, in our case; firms, is examined in detail to understand how mechanisms, routines and sense of research emerged and evolved. The data which comes from archives and secondary sources are meticulously examined to give a deeper understanding of differences in organization and organizing research activities.

1.2 Research Question of the Dissertation

By examining and comparing innovative factors, one can understand the natural process of innovation in IG Farben and Du Pont and see why the performance of companies was different. In doing so, we can understand that emergence of new knowledge (production of knowledge), knowledge transfer mechanisms, and organizational attitude towards research are important factors to comprehend the process of innovation. In the literature, the performance differences are examined to understand the process by explaining learning effects and gaining new information mechanisms (Ghoshal 1987; Hitt et al. 1996). By comparing and contrasting the cases in detail one can understand the specific mechanisms that caused differences in performance. *First of all, the question is designed to answer "how" question of the cases, afterward "why" question will be asked as research question of the thesis.* The research question of the dissertation therefore is:

How and why did research and innovation activities differ in two different context and companies between 1925 and 1945?

The question will be analysed by understanding the historical background of the countries and examining firm-level innovation experiences of the companies. This leads to two important sub-questions that are essential to answer the main research question of the thesis: *How did historical background of the countries affect research environment at the firm-level?* and *Could firm specific policies promote unique performance?* Those questions will be analysed via studying historical data in Chapters 3 and 4. Moreover, main findings will be developed in Chapter 5 and 6 in order to make deeper analyses for understanding the different context properly. In the literature, there has been no significant work on these research questions in terms of science and technology studies. However, there are similar works using different perspectives. For example, differences in innovation performance has been examined at the levels of firm, sector and country using tangible data like R&D expenditures (C. Freeman and Soete 1997; Malerba 2004; Murmann and Homburg 2014; Nelson and Rosenberg 1993; Pavitt 1984), or institutional differences that cause different development stories for countries (Acemoğlu and Robinson, n.d.; Chang, Grabel, and Wade 2014; Rapley 2016). This dissertation will examine firm level differences in detail in the context of different countries. The macro evolutions of countries are important factors that are binding the micro evolutions of firms. Specifically, the question will be tested by comparing research and output relationship inside the companies, indicating differences and similarities and its historical roots.

1.3 Novelty of the Dissertation

Current scientific works mainly focus on industrial economics and organizational theory. Attentive works of Haber (1958, 1971) and Reader (1970) show how technical developments and advancements created industries in USA, Britain and Germany. Emergence of chemical industries are discussed by such research in detail to understand historical consequences of the chemical technologies. More historical work on chemical industry literature is made by Lindner (2008), Homburg (1983, 1992; 1998; 2014), Murmann (2003; 2014). Those works specifically examine research and development process of the firms and new knowledge creation process inside them. Moreover, IG Farben case is examined by historians in the dimension of World War II. Hayes (1987), Jeffrey (2010), and Borkin (1979) have prominent research about war crimes, chemicals that used by military and technologies that specifically designed for the War. On the other hand, management and organizational theory literature are interested in DuPont and IG Farben case intensely. The prominent

work of Chandler (1977, 1990; 1971; 2003) provides detailed information on corporate strategy that affects research and innovation. Moreover, Chandler's work shows that there are different patterns that were followed by companies for each country. Hounshell and Smith's (1988; 1985) research gives details about DuPont's corporate strategy on research and organization. Those noticeable works are valuable sources to understand how structures and mechanisms cause change inside the firm. Science and Technology Studies (STS) as well are interested in such industrial formation. Especially, work of Nelson and Rosenberg (1993), Mowery (1999), and Freeman and Soete (1997) pay great attention on formation of chemical industries to understand how innovation and growth occur. However, as Freeman and Louça's book puts it more case study and more retro perspective work is needed for STS studies to clarify theoretical assumptions about innovation (C. Freeman and Louçã 2001). Hence, this dissertation is motivated by a gap which is between history, management and STI literature. DuPont and IG Farben cases are comparatively investigated in terms of STI studies using historical data and cliometric tools.

There are three novelties in this dissertation. The first one is the topic of the dissertation, which is assessed as an unworked topic in terms of comparative historical case study. IG Farben and Du Pont have been investigated in many fields like organizational theory, industrial economics etc. However, comparative historical case studies are rare in STS studies, which make them valuable. As Freeman puts it, "comparative studies" in STS literature is new but much-needed for development of the literature (C. Freeman and Soete 1997, chap. 1). The second novelty is the novelty of data. Much of the data used in this dissertation come from archives and libraries. The fieldwork of collecting firm specific data, classification and data cleaning was a daunting task. In the literature, there are important archives (see Methodology Chapter) that contain valuable sources for examining chemical industries. For example, Haber (1971), Reader (1970) and Murrman's (2003) works have contained archival data. However, their scope was different. The difficulty of obtaining comparative historical data forced us to use novel ways and methods. For instance, collected data is used to show relationship between parameters in visual way. The third novelty is related to the methodological tool. Network approach is not widely used in historical case studies. The main aim of using this tool is to make better visualization that shows relationships between actors. Moreover, the tool was helpful in proving some theoretical assumptions. For example, in theory the government relations of Du Pont were known because production data supported the assumption. However, government's demand from Du Pont and Du Pont's response to this demand via

developing innovative products were observed in production and users network. Mapping of these relationships is a novelty of this thesis.

1.4 Objective and Main Argument of the Dissertation

Simply the question is how and why research and innovation activities differed in two different context and companies between 1925 – 1945. In the literature, there are many works that are dealing with it. However, there is not a single study was observed in the reviewed innovation studies literature which contains the comparison of cases. As a result of this, hypothetically innovation process is accepted as a positive process that creates more economic growth and prosperity. Moreover, current approaches define those process as evolutionary and chaotic. Sometimes it can be called as a process that cannot known completely. Furthermore, neo-classical economic theories cannot address the source of technological change and innovation phenomena. This problem statements are discussed from the beginning of the twentieth century. The main tendency is to clarify the process through using case studies and detailed information in both qualitative and quantitative. Hence, the research question of the dissertation can be explained by the same way mentioned below. The aim is to overcome the addressed problem statements via scientific methods. Consequently, the cases can be examined in detail and new information can be found to use in other fields. The dissertation argues that two cases are different in three main aspects: research design of companies (centralized vs. decentralized decision making), policy differences (applied vs. fundamental research), and market-driven vs. science-driven research. These differences can be explained by interaction of some factors.

To sum, the main target of the dissertation is to clarify the points mentioned above. The first aim is understanding and then describe similiarities and differences via analysing innovation and learning process in IG Farben and DuPont between 1925 and 1945. The second aim is to explain and patterns of innovation and learning for science and innovation studies with the help of comparative case study. To achieve my objectives, I will use historical and theoretical analyses with the help of related the literature. In addition to this approach, making a historical innovation analysis can provide a picture about the mechanism, and this framework helps us to understand today's innovation policies and its mechanism.

The main argument of the dissertation is therefore, to understand whether or not different country contexts can or cannot lead to successful innovation

performance via investing basic science and finding proper conducting mechanism in terms of management. At the firm level, this argument supported by specific titles from the literature: analysis of emerging new technologies (Basalla 1988; Dosi 1984b; Landes 2003; Mokyr 1990), management of innovation (Burns and Stalker 1994; Alfred D. Chandler 1977, 1990; Mathews 2013; Porter 2011), policy design implementation (Edquist 2001; C. Freeman 1987).

1.5 Research Design

This research benefitted from primary and secondary historical sources. Research design contains archive research, library research and simply secondary data available in the literature. According to the agenda, first of all, German archives and libraries were visited to collect primary data. Initially, preliminary research about the data is conducted using web tools of the archives and science search engines. As result of the preliminary research, data sources and their places were mapped. Afterwards, in order to reach more related data, opinions of the specialists who have PhD from Germany or who hold PhD degrees on similar topics are taken regarding the archival work. In the field work several archives are visited in Germany and related information is gathered by photocopying and photographing primary documents. Obtaining data for the case of USA and DuPont was a bit different in the sense that DuPont still exists and its archives are held at one place in Delaware. As a result of this, mapping data sources was quite easier compared to Germany. Firstly, sources and their titles are determined on the web. Afterwards, expert opinions are taken to determine the availability and accessability of the data. The advantage of working with historical data of DuPont is that most of the archives are digitized.

Once the data is collected, two firms are compared on the basis of differences and similarities in their approach to innovation. Descriptive statistics and network analysis are used to analyse the data which are explained in details in Chapter 2.

1.6 Outline of the thesis

The dissertation is designed as seven chapters: method, country comparison and firm comparison; and two chapters that look at organization and research in a much more detailed way. The outline of the thesis is summarized below.

The second chapter of the dissertation explains the method used. This chapter contains information about the tools used to investigate the main question of

the thesis. Historical data sources and their specificities such as data availability, method of accessing the data and details of the archive work is provided. Also, the method of the thesis and rationale for selecting this method are given in details. This thesis uses mixed method that blends historical data analysis with network tools to compare and contrast countries, sectors and firms and to investigate the actual mechanisms that create economic differences between cases.

The third chapter contains macro comparisons to examine the sources of the economic development in USA and Germany. This chapter creates a base for further discussion at the sector and firm level. Such an introductory discussion at the country level is much needed since questions like, why and how Germans are pioneers in science or how Americans established a market for chemical sector have to be discussed in a context where the reader has at least some idea on the context and environment where two giants of the chemical sector, IG and DuPont, flourished. In this chapter, macro historical information is provided to understand the early history of the origins of innovation. Accordingly, the aim is to build a comparative base that hinges on the context-specific elements that are important in the evolution of chemical sectors in two countries and more specifically in the evolution of two firms. A summary table is provided at the end of the chapter to pinpoint and summarize the main points of country comparison. The main argument of the chapter is that, early roots of scientific and institutional background are persistent to promote innovation in the long run. We learn from this chapter that different economic development stories that stem from economic shortages and progressive science[3] can affect innovation performance.

The fourth chapter is specifically related to firm profile analysis. This micro chapter contains profile of firms, establishments, size, organization structures, research capacities, and relationships with market and authorities. This detailed information is supported with original data and relationship mapping by using network analysis tools. Sketching the main similarities and differences among the two firms is the main motivation of this chapter. While the chapter provides a brief comparison between firms it still possesses rich novel data and information that needs to be further analysed. At the end of this chapter two important factors -research and

3 According to Fritz Stern's work, Germany had a competitive science history. It means that pioneering about basic science both at national and international level was an important issue for politicians and policies since the era of Germania. We can learn this fact from the institutions, universities and education policies during German history (Stern 2006, chap. 1). This is also observed in USA history. Example of Flexner's report and establishing important universities for providing science can be explanatory to understand sense of science (Flexner 2017; Friedman 2004).

organization- are determined which is further analysed in the following chapters. For continuity, this chapter is also concluded with a comparison table that highlights the main elements of change in the case of IG Farben and DuPont. The main motivation of this chapter is to further investigate the explanations provided in the literature: investing R&D structure, the effect of promoting mechanisms, competition view and the value chain perspective on innovation. As we learn from the chapter, the internal and external factors affect the strategies and decisions of the companies. For example, Germany had been exposed to external factors, especially after 1939, that shaped its research policies. As a result of this, under the pressure of military, synthetic research had been developed. In the USA, no significant pressure from authorities in that sense was observed. However, the main external factor was competitive pressures from the European chemical firms. Main internal factors that affected innovation performance of companies can be summarized as establishing different management of innovation (research design) and promoting different paths in organizational and marketing innovations.

The fifth chapter of the dissertation is designed to answer the following question: Did organization structure of the firms matter in terms of innovation strategy and performance? Specific and novel data is analysed using network tools to answer this question in detail. Moreover, business strategies of the two firms in the sense of research and management types are assessed. In the literature, management of the organization may foster innovation via encouraging internal (flexible systems, promotion mechanisms, creating goals for further research) and external factors (market demand, product differentiation, and proper agreements among rivals) (Tidd and Bessant 2016). The results indicate that Du Pont and IG Farben had their own unique mechanisms in fostering innovation. They had adapted to their context-specific conditions successfully and designed the firm accordingly to benefit from such context-specific conditions.

The sixth chapter provides another specific analysis on research tendency and performance. How did each firm conduct research? How much did they spend for research? How did they manage learning activities? How did they promote accumulation of scientific knowledge? Chapter five analyses these questions deeply. The main argument of this chapter is shaped with the help of the main findings from Chapter 3 and 4. The basic finding is that output of research and research and development activities in general affected the innovation performance in positive way (Fagerberg, Mowery, and Nelson 2005, pt. 4). The findings can be grouped into three differences: research design of companies (centralized vs. decentralized

decision making), policy differences (applied vs. fundamental research), and market-driven vs. science-driven research. Differences in these three subjects by and large explain the different paths that firms follow.

Finally, the last chapter provides a conclusion. In this last chapter, all previous chapters are summarized to highlight the main findings of the thesis. Then these main findings are linked to current discussions for providing brief policy implications.

CHAPTER 2

METHODOLOGY

2.1 Starting Point and the Sources

Historical case study is an established working method in social sciences (George and Bennett 2005). Case studies have been successful in addressing economic phenomena in social sciences such as searching sources of wealth, examining poverty, and pursuing better life conditions. Fundamental contributions stem from employing historical case studies especially ones that use specific quantitative data.

In this thesis, two cases were examined and described in details in a specific time period. The main purpose of this effort is to understand and interpret the cases by using a deliberate network analysis tool. The tool has been used in all fields of sciences since the middle of the 1900s varying from basic sciences such as biology, geology, chemistry, and physics to social and humanity sciences such as economics, history, and sociology. For instance, in field of economics, graph tools have been used to visualize about 20 million trade and country statistics. The main aim of the Atlas Project is to measure the *amount of productive knowledge* for each country through using network mapping (Hausmann and Hidalgo 2013). In sociology, social networks helps to understand the relationship between social connectivity and social patterns (Hua Wang and Wellman 2010; Lee and Kim 2010). In the field of biology, oscillators (neuron, muscle movements etc.) are modelled with regards to dynamical biological systems in order to understand biological structure (Friesen and Block 1984; Winfree 2001). In the field of medicine, epidemic modelling has been used to predict the pattern of diffusion of viruses. In Africa, the recent outbreak of Ebola virus is predicted by complicated modelling in network mapping (Siettos et al. 2015; Yang et al. 2015).

In this thesis, comparative historical case study method has been chosen. The major reason for this selection is the rareness of comparative historical cases in innovation literature. Mostly, in the field of history, the method chiefly is preferred. Specifically, innovation process is rarely researched with this method. Therefore, two giant chemical companies are selected to understand the history of the innovation process. However, many obstacles are faced during the research. Working with archival data is independently a very constraining job because of the cost of research and availability of data. As a result of this, more flexible tools like network are preferred to improve the quality of the thesis. During the collection of data, several important data types are intentionally selected. Some quantitative data (trade statistics, profit statistics) are precisely researched from archives. Other materials like oral history, biographies, audio, and map archives are scanned additionally. These types of data are vital to make a consistent thesis in many aspects because missing data and other data-related problems can sometimes be controlled and triangulated with multi source information. All in all, information and data from various sources can complement each other to increase the robustness of the study.

In sum, this thesis presents a comparative historical analysis to understand the innovation process by conducting archival research and using case study and social networks tools. This chapter of the thesis provides detailed information about these tools and also discusses the scope and limitations of the data. Moreover, the data sources, though rich are also characterized by several limitations; but at the same time, they present various opportunities for the research that are further examined in the chapter. The final part of this chapter is related to software tools, which are used in the process of analysis.

2.2 Meaning of Comparative Historical Research Methodology

Comparative historical research or historical case study is a method that is used in social sciences in order to understand some theories, historical events, and historical occurrences. This methodology can use the qualitative and quantitative data to explain the factors (Neuman 2014, 42). The main aim of the comparative case studies is to explain several knowledge and information mechanisms (oral, quantitative data, memories, records etc.). Some qualitative and quantitative methodologies can be summarized below:

- The qualitative information that covers the certain times and periods obtained from the sources like interviews, surveys

- Country or society based quantitative data
- Specifically collected data from individuals or firms
- The data from the historical records that was published in newspapers, magazines, brochures, letters, memories, advertisements, meeting records, private archives of general managers, board decisions etc.
- Interpreting some data written by historians
- Oral histories
- Specific collection of something (government, society, and firms etc.) or somebody (manager, War victim etc.)
- Some data about a topic that is impossible to study (for example, Himmler's childhood life) (Abbott 1990; Gerring 2011).

Those are the points to understand why we use this type of methodology. Moreover, this type of methodology stems from case study methodology in social science. According to the methodology, data is generally based on qualitative evidence like ethnography, participant observations, field research etc. in order to investigate some topic or explain some theories or phenomena. In the literature, the role of case study has been broadly discussed in terms of validity to explain theory (Royce and Straits 2009; Bryman 2016). In social sciences, due to the chaotic structure of the "sciences", the theories cannot be explained precisely with natural sciences like Physics. For instance, Einstein's general theory of relativity claims that the speed of light should be constant in space-time (Einstein 2017). In 1915, the theory was proofed by mathematical tools; moreover, today's technology measures the speed of light precisely. This example was given to understand methodological difference between social and natural sciences. On the other hand, social science has several obstacles to explain something. First is related to demarcation of social sciences. As Karl Popper argued, the social sciences cannot be understood as a systematic mechanism. Moreover, theories in natural sciences can be explained and proved with the help of scientific tools such as mathematics. Afterwards the explanations can be validated or falsified by observations and data obtained from nature in order to make constant theory like Einstein's theory (Popper 2002). However, in social sciences, because of the demarcations like social class, culture etc. it is hard to say something precisely. Second is the chaotic structure of the social sciences, which means the units (firms, individuals etc.) have some features making chaotic structures. It can be explained in two aspects. Human actions have two features: adaptation and variety. Because of these two aspects, clarity and predictability of social phenomena is not an easy task to do. Due to those obstacles, social sciences

have developed their own methodologies such as the case study methodology. The case study methodology aims to understand patterns, mechanisms and processes in historical period or now. In addition, there is a differentiation within the methodology itself. Historical case studies and comparative historical case studies are the prior examples to those different methodologies they are heavily used to develop an "answer" for the research questions. Historical case studies aim at a certain time or period in order to explain a theory, phenomena, or historical events. This methodology aims to comprehend a social or economic event or theory via collecting data from qualitative or quantitative sources (Miller 1986). If one or more case is added to the historical analysis, then it is called comparative historical case. There are several advantages of using this type of methodology. For example, more robust explanation for a theory can be made with the comparison of firms, individuals, countries, and societies etc. Moreover, it enables to make synthesis by looking at differences and similarities between cases. process of case study and some examples between case, historical case and comparative historical case studies are provided below in order to clarify the methodologies mentioned in this chapter.

Before the explanations, case or historical case studies have a little bit different process than comparative case studies. Comparison makes to show synthesis of the cases in the one hand. On the other hand, as a result of the synthesis, it helps to develop some patterns in historical events. For example, World War II is a proper case to understand factors that cause the war. If the comparative analysis of two big wars in the world is made, some new patterns can emerge between the two wars about commencement of war. In order to emphasize the process differences between these methodologies, historical comparison method's process is summarized below.

The Process of the Historical Comparison Method

Main Aim	Process
Determining for research topic and question	Making relevant research topic and question
Data Collection	Locating data sources: archives, libraries, private libraries, governmental databases, literatures, visual libraries etc.
Data Evaluation	Finding data for evaluating the question. According to data, three steps should be examined: (a) whether information or data is suitable with the question. (b) any missing part in the data? (c) Do you need more data for accuracy of evidence?
Analysing Data	With the help of some tools or methods data can be analysed
Re-evaluate Data	Synthesising comparison cases with the differences and similarities to answer the question
Dissemination	Writing dissertation via using findings

Source: (Neuman 2014).

There are many works using different types of case study methodology. It is clarified in the table provided below. Table shows section topics and methodologies. For instance, works of Landes, Rosenberg and Nelson are great examples for historical comparison in case study. In summary, their methodology was set to explain industrial and economic differences across countries.

On the other hand, as seen below, historical case study is the most preferable type of methodology. The main reason is reliability and availability of data. Comparative historical case study is not an easy method because of the difficulty of comparing two or more factors with historical data So, historical case study that contains one factor or parameter might be more preferable. Moreover, there are several ethical concerns that can be issued in case studies. Those are summarized as

1. Validity of evidence data used
2. Confidentiality of people who are issued in data
3. Cultural differences

Those should be considered while doing research in case studies. In this dissertation, Comparative Historical case study methodology is used. This methodology has some disadvantages and advantages in terms of conducting data. Those are explained in detail in the next headline.

Case Study	Historical Case Study	Comparative Historical Case Study
(Benedict 2006; Rutherford 2017; Finlayson 2010; Schwartz 1998; Rees 2005; Bining 1933; Flechtner 1959; Moran 2005; Gianesini and Blair 2016; Rothbard 2006; Wilkie, Ferree, and Ratcliff 1998; Morrison, Pietrobelli, and Rabellotti 2008; Diamond 1997; Myers 2004; Madathil and Benshoff 2008; Schutt 2001; Tattersall 2013; Braun 1990; Alfred D. Chandler 1977)	(Rutherford 2017; Delorme 1962; Bird 1999; Erikson 2014; S. F. Cohen 1974; Gelderblom 2013; Beer 1958; Porter 2011; Poulsen et al. 2017; Johnson 2000a; Tammen 1978; Cho and Mun 2013; Abelshauser et al. 2008; S. R. Epstein and Prak 2008; Wilkinson 1984; Sullivan 2006; Iversen 2008; Hughes 1983; Hounshell and Smith 1988; Rossfeld 2008; Yu and Shih 2014; Haber 1971; Homburg, Travis, and Schröter 1998; Homburg 1992; Kershaw 2012; Wilkins 2004; Reich 1985; Gordon 2017; Kennedy 1987; G. R. Taylor 1951; Cloodt, Hagedoorn, and Roijakkers 2006; Balderston 1989; Wolff n.d.; Acemoğlu and Robinson, n.d.; Fisk 2009) (Rutherford 2017; Delorme 1962; Bird 1999; Erikson 2014; S. F. Cohen 1974; Gelderblom 2013; Beer 1958; Porter 2011; Poulsen et al. 2017; Johnson 2000a; Tammen 1978; Cho and Mun 2013; Abelshauser et al. 2008; S. R. Epstein and Prak 2008; Wilkinson 1984; Sullivan 2006; Iversen 2008; Hughes 1983; Hounshell and Smith 1988; Rossfeld 2008; Yu and Shih 2014; Haber 1971; Homburg, Travis, and Schröter 1998; Homburg 1992; Kershaw 2012; Wilkins 2004; Reich 1985; Gordon 2017; Kennedy 1987; G. R. Taylor 1951; Cloodt, Hagedoorn, and Roijakkers 2006; Balderston 1989; Wolff n.d.; Acemoğlu and Robinson, n.d.; Fisk 2009)(Delorme 1962; Bird 1999; Erikson 2014; S. F. Cohen 1974; Gelderblom 2013; Beer 1958; Porter 2011; Poulsen et al. 2017; Johnson 2000a; Tammen 1978; Cho and Mun 2013; Abelshauser et al. 2008; S. R. Epstein and Prak 2008; Wilkinson 1984; Iversen 2008; Sullivan 2006; Hughes 1983; Nelson and Rosenberg 1993; Hounshell and Smith 1988; Rossfeld 2008; Yu and Shih 2014; Haber 1971; Homburg, Travis, and Schröter 1998; Homburg 1992; Kershaw 2012; Wilkins 2004; Reich 1985; Gordon 2017; Kennedy 1987; G. R. Taylor 1951; Landes 2003; Balderston 1989; Acemoğlu and Robinson, n.d.; Fisk 2009; Wolff n.d.)	(Nelson and Winter 1982; Landes 1998; Kirzner 2015; Blau 1964; Casson 2012; Nelson and Rosenberg 1993; Alfred D. Chandler and Salsbury 1971; Chang, Grabel, and Wade 2014; Alfred D. Chandler 1990; Mowery and Nelson 1999; Alfred Dupont Chandler 2003; Resetar 2000; Pomeranz 2000; Landau and Rosenberg 1986; Landes 1966, 2003; Alfred D. Chandler 1977)

2.3 Data Sources

Certainly, it is not easy to set a framework for research in economic history. Data and sources could be scarce. In this thesis, there was no particular ready to use dataset. In order to solve the data problem, two main steps have been followed. The first is researching in online databases and identifying and examining the primary and secondary data sources. The second is archival research. All those steps have been done to find empirical and historical data to constitute the main framework of the thesis. In this chapter, detailed information of those steps is provided to explain the method of the research.

2.3.1 Online Databases and Published Works

Choosing and researching online databases are particularly vital processes. The research question of the thesis should be supported by empirical and historical data which is available online. In doing so, some selected databases have been searched according to the scope of the thesis. As a first step the related keywords were searched in the database of Web of Science and JSTOR. The sources give favourable opportunities which ease research while examining of the subjects. *Web of Science* also includes books, articles, and reviews. Its algorithm, which is based on citation ranking and connections that is related with another database, makes it a constant and reliable tool for research. In addition to this, another database, *JSTOR*, has also been scanned for more resources. It is a kind of digital library and it has many academic journals and book reviews. *JSTOR* is preferred because of its journal subscriptions. Selection of two databases is done under the pressure of big data problems. *Web of Science* is a beneficial tool. However, its huge database generally serves for basic and applied sciences. Moreover, its algorithm can cause omission of some valuable information. In order to overcome the problem, the second database and also printed material and its references are used for crosscheck. For printed materials like books *Worldcat* database is used. It is the largest network of libraries, which offers title and author searching which makes a detailed research possible. Moreover, secondary data sources for IG Farben are found thanks to this network database in German libraries. Table 1 is a summary for the first step of the research. It is important to note that these databases are not only used for obtaining scientific information on the subject matter but also used for collecting various data on the cases of IG Farben and Du Pont.

Table 1 The First Step of the Research: Searching and Tracing Secondary Data

Database	Scope	Reasons for Selection	Links
Web of Science	256 disciplines and nearly 90 million records[1]	Enormous, reliable source Coverage of the all journal and article databases	apps.webofknowledge.com
JSTOR	50 disciplines and more than 1,941 journals[2]	Specific journals in economic history and economic policy etc.	www.jstor.org
Worldcat	72,000 Libraries in more than 170 countries[3]	Used especially for the research on Germany. Detailed research over libraries. PhD Thesis Catalogues	www.worldcat.org

Summary of the table gives an insight about how research is done according to these criteria. By the way, all these selected resources are used to support foreground of the thesis. Moreover, two types of search titles are selected to illuminate the cases. The first one is early economic history of the countries and the second one is economics of chemistry. In the first step, articles and books dated from 1850s are provided. Chemistry is also scanned in those databases starting from the 1900s.

On the other hand, the books, which include primary and secondary data are examined according to related titles. While doing this, several prominent works and its references are benefited from. Especially, for the IG Farben case, valuable works of Haber (1971), Murmann (2003), TerMeer (1953) and Lindner (2008); for research activities of IG Farben, Homburg (1992), Beer, and Hayes (1987) are a guide for this research. Moreover, for Du Pont, worthwhile and stimulating works of Alfred Chandler is a starting point for scanning databases. Furthermore, Hounshell & Smith's (1988) astute data work and detailed references provide more information on DuPont's economic history.

2.4 Archival Research

Archival research, especially during the war times (1925 – 1945), is mostly a challenging task. The main difficulty of the research is the catalogue system of the

information. In order to clarify the archive works in the thesis, two main topics are considered separately as Germany and USA. In the light of the previous research explained above, several archival databases are determined. In order to narrow down the scope, a preliminary study is conducted before actually visiting the archives. This preliminary research is done in two ways: contacting archives and searching private catalogues of the firms online, if it is available. Selected archives are shown below in Table 2 in details.

Table 2 The Second Step: Archival Data and Places of the Archives

Firms	Dates	Activities	Sources
DuPont	1802 - 2015[4]	Chemical Engineering, Material Sciences, Agriculture, Food, Textile	Digital and printed catalogues of Hagley Museum and Library, Delaware Firm's private Archives, Wilmington
IG Farben	1925 - 1945	Dye, Chemical Process and Organic Chemistry, Pharmacy	Staatsbibliothek zu Berlin, Berlin Bibliothek der Humboldt-Universität, Berlin Library of Goethe University, Frankfurt BundesArchiv (1925 - 1939), Koblenz BundesArchiv (1939 - 1945), Berlin The Fritz Bauer Institute (Wollheim Memorial) Archives, Frankfurt
BASF	1865 - 1925	Organic, Inorganic chemicals, Dye, Soda	Firm Private Archives (Unternehmenarchiv, Ludwigshafen)

Table 2 The Second Step: Archival Data and Places of the Archives (continued)

Bayer	1863 - 1925	Pharmaceuticals, chemicals	Firm Private Archives (Bayer Werkarchiv, Leverkusen)
AGFA	1867 - 1925	Imagining systems	Firm Private Archives (Cologne)

All those archives and libraries present detailed information about IG Farben and DuPont from 1925 to 1945. At this point, there is an important obstacle that should not be forgotten. After the defeat of Germany in 1945 IG Farben dissolved. Therefore, especially, 1939 – 1945 dataset is not reliable. The next subsection provides more information about the IG Farben data. So as to make clear explanations, data section is divided into subsections: Germany and USA. Each subsection explains how data is collected and what steps are taken while acquiring data.

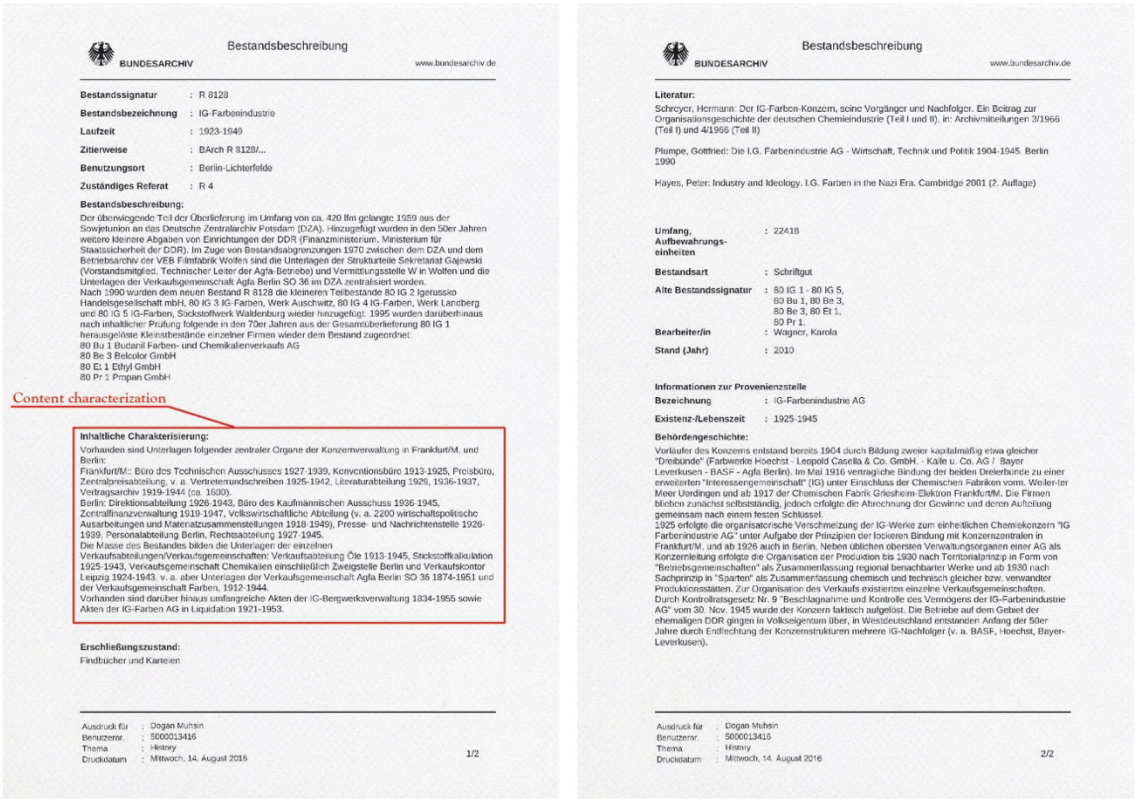
2.5 Germany

In Germany, archival data of IG Farben is traced with the assistance of *Invenio* catalogue system. Afterward, with the tools of the catalogue system, detailed information about sources (places, conditions, limitations etc.) is collected. At this point, Federal Archives of Germany (*Bundesarchiv*) provides more information about the sources. This type of source is called *Bestandsbeschreibung* (stock information), in German. The stock information card provides answers for the following questions: which type of information is stored? where can you find it?, who is the responsible person? etc. For clarifying the issue, a sample page of *Invenio* is provided in Figure 1 below. Moreover, a part of the stock information named *Inhaltliche Charakterisierung* (*Content Character*) specifies detailed and valuable information about the firm. Specifically, some other sources and related stocks are indicated in the part of the form. While doing the research, several stocks related to the case are found through the information provided by the form. *BundersArchiv* is separated into six parts:

1. Holy Roman Empire and German Confederation including Provisional Central Power (1495 – 1866)
2. North German Confederation and Empire (1867/1871 – 1945)
3. Federal Republic of Germany with Western Allied occupation zones (1945)
4. German Democratic Republic with Soviet zone of occupation (1945 – 1990)

5. Estates and collections
6. Film and film accompanying material

Figure 1: Sample Stock Form of BundesArchiv



Bestandsbeschreibung

BUNDESARCHIV www.bundesarchiv.de

Bestandssignatur : R 8128
Bestandsbezeichnung : IG-Farbenindustrie
Laufzeit : 1923-1949
Zitierweise : BArch R 8128/...
Benutzungsort : Berlin-Lichterfelde
Zuständiges Referat : R 4

Bestandsbeschreibung:
Der überwiegende Teil der Überlieferung im Umfang von ca. 420 lfm gelangte 1959 aus der Sowjetunion an das Deutsche Zentralarchiv Potsdam (DZA). Hinzugefügt wurden in den 50er Jahren weitere kleinere Abgaben von Einrichtungen der DDR (Finanzministerium, Ministerium für Staatssicherheit der DDR). Im Zuge von Bestandsabgrenzungen 1970 zwischen dem DZA und dem Betriebsarchiv der VEB Filmfabrik Wolfen sind die Unterlagen der Strukturteile Sekretariat Gajewski (Vorstandsmitglied, Technischer Leiter der Agfa-Betriebe) und Vermittlungsstelle W in Wolfen und die Unterlagen der Verkaufsgemeinschaft Agfa Berlin SO 36 im DZA zentralisiert worden.
Nach 1990 wurden dem neuen Bestand R 8128 die kleineren Teilbestände 80 IG 2 Igerussko Handelsgesellschaft mbH, 80 IG 3 IG-Farben, Werk Auschwitz, 80 IG 4 IG-Farben, Werk Landberg und 80 IG 5 IG-Farben, Stickstoffwerk Waldenburg wieder hinzugefügt. 1995 wurden darüberhinaus nach inhaltlicher Prüfung folgende in den 70er Jahren aus der Gesamtüberlieferung 80 IG 1 herausgelöste Kleinstbestände einzelner Firmen wieder dem Bestand zugeordnet:
80 Bu 1 Butanil Farben- und Chemikalienverkaufs AG
80 Be 3 Belcolor GmbH
80 Et 1 Ethyl GmbH
80 Pr 1 Propan GmbH

Content characterization

Inhaltliche Charakterisierung:
Vorhanden sind Unterlagen folgender zentraler Organe der Konzernverwaltung in Frankfurt/M. und Berlin:
Frankfurt/M.: Büro des Technischen Ausschusses 1927-1939, Konventionsbüro 1913-1925, Preisbüro, Zentralpreisabteilung, v. a. Vertreterrundschreiben 1925-1942, Literaturabteilung 1929, 1936-1937, Vertragsarchiv 1919-1944 (ca. 1600).
Berlin: Direktionsabteilung 1926-1943, Büro des Kaufmännischen Ausschuss 1936-1945, Zentralfinanzverwaltung 1919-1947, Volkswirtschaftliche Abteilung (v. a. 2200 wirtschaftspolitische Ausarbeitungen und Materialzusammenstellungen 1918-1949), Presse- und Nachrichtenstelle 1926-1939, Personalabteilung Berlin, Rechtsabteilung 1927-1945.
Die Masse des Bestandes bilden die Unterlagen der einzelnen
Verkaufsabteilungen/Verkaufsgemeinschaften: Verkaufsabteilung Öle 1913-1945, Stickstoffkalkulation 1925-1943, Verkaufsgemeinschaft Chemikalien einschließlich Zweigstelle Berlin und Verkaufskontor Leipzig 1924-1943, v. a. aber Unterlagen der Verkaufsgemeinschaft Agfa Berlin SO 36 1874-1951 und der Verkaufsgemeinschaft Farben, 1912-1944.
Vorhanden sind darüber hinaus umfangreiche Akten der IG-Bergwerksverwaltung 1834-1955 sowie Akten der IG-Farben AG in Liquidation 1921-1953.

Erschließungszustand:
Findbücher und Karteien

Ausdruck für : Dogan Muhsin
Benutzernr. : 5000013416
Thema : History
Druckdatum : Mittwoch, 14. August 2016
1/2

Bestandsbeschreibung

BUNDESARCHIV www.bundesarchiv.de

Literatur:
Schreyer, Hermann: Der IG-Farben-Konzern, seine Vorgänger und Nachfolger. Ein Beitrag zur Organisationsgeschichte der deutschen Chemieindustrie (Teil I und II). in: Archivmitteilungen 3/1966 (Teil I) und 4/1966 (Teil II)

Plumpe, Gottfried: Die I.G. Farbenindustrie AG - Wirtschaft, Technik und Politik 1904-1945. Berlin 1990

Hayes, Peter: Industry and Ideology. I.G. Farben in the Nazi Era. Cambridge 2001 (2. Auflage)

Umfang, Aufbewahrungseinheiten : 22418
Bestandsart : Schriftgut
Alte Bestandssignatur : 80 IG 1 - 80 IG 5, 80 Bu 1, 80 Be 3, 80 Be 3, 80 Et 1, 80 Pr 1,
Bearbeiter/in : Wagner, Karola
Stand (Jahr) : 2010

Informationen zur Provenienzstelle
Bezeichnung : IG-Farbenindustrie AG
Existenz-/Lebenszeit : 1925-1945

Behördengeschichte:
Vorläufer des Konzerns entstand bereits 1904 durch Bildung zweier kapitalmäßig etwa gleicher "Dreibünde" (Farbwerke Hoechst - Leopold Casella & Co. GmbH, - Kalle u. Co. AG / Bayer Leverkusen - BASF - Agfa Berlin). Im Mai 1916 vertragliche Bindung der beiden Dreierbünde zu einer erweiterten "Interessengemeinschaft" (IG) unter Einschluss der Chemischen Fabriken vorm. Weiler-ter Meer Uerdingen und ab 1917 der Chemischen Fabrik Griesheim-Elektron Frankfurt/M. Die Firmen blieben zunächst selbstständig, jedoch erfolgte die Abrechnung der Gewinne und deren Aufteilung gemeinsam nach einem festen Schlüssel.
1925 erfolgte die organisatorische Verschmelzung der IG-Werke zum einheitlichen Chemiekonzern "IG Farbenindustrie AG" unter Aufgabe der Prinzipien der lockeren Bindung mit Konzernzentralen in Frankfurt/M. und ab 1926 auch in Berlin. Neben üblichen obersten Verwaltungsorganen einer AG als Konzernleitung erfolgte die Organisation der Produktion bis 1930 nach Territorialprinzip in Form von "Betriebsgemeinschaften" als Zusammenfassung regional benachbarter Werke und ab 1930 nach Sachprinzip in "Sparten" als Zusammenfassung chemisch und technisch gleicher bzw. verwandter Produktionsstätten. Zur Organisation des Verkaufs existierten einzelne Verkaufsgemeinschaften.
Durch Kontrollratsgesetz Nr. 9 "Beschlagnahme und Kontrolle des Vermögens der IG-Farbenindustrie AG" vom 30. Nov. 1945 wurde der Konzern faktisch aufgelöst. Die Betriebe auf dem Gebiet der ehemaligen DDR gingen in Volkseigentum über, in Westdeutschland entstanden Anfang der 50er Jahre durch Entflechtung der Konzernstrukturen mehrere IG-Nachfolger (v. a. BASF, Hoechst, Bayer-Leverkusen).

Ausdruck für : Dogan Muhsin
Benutzernr. : 5000013416
Thema : History
Druckdatum : Mittwoch, 14. August 2016
2/2

Source: BundesArchiv in Berlin

According to this division, the data searching process mainly focuses on "*North German Confederation and Empire (1867/1871 – 1945)*" stocks. In this stock there is a part named as "*Organizations, associations and business enterprises*". This part delivers information about IG Farben's history. Based on the archival catalogue, following classification is done in order to refine the search:

- R 8128 IG Farbenindustrie AG - Mine Management
- R 8128 IG Farbenindustrie AG - Sale Community Photo or Agfa Berlin
- R 8128 IG Farbenindustrie AG - Contract archive
- R 8128 IG Farbenindustrie AG - National and Economic Policy Departments
- R 8128 IG Farbenindustrie AG in Liquidation (1952 – 2013)

- R 8128 IG Farbenindustrie AG - Auschwitz
- R 8128 IG Farbenindustrie AG - Nitrogen Production Calculation
- R 8128 IG Farbenindustrie AG - Central Accounting
- R 8128 IG Farbenindustrie AG - Directorate Department
- R 8128 IG Farbenindustrie AG - Sale Community oils
- R 8128 IG Farbenindustrie AG - Sales Community
- R 8128 IG Farbenindustrie AG - Headquarters of the Group Management Frankfurt

However, all those classification titles include thousands of entries several of which have not been completed cataloguing. A very beneficial source in this classification can be found in the Berlin archives located at Lichterfelde, Berlin is "*Monthly statements of all accounts of the IG Farben AG 1929 – 1939*". On the other hand, all records have complex connections with other records. For example, statistical units of Germany have some useful information about the firm. Nevertheless, those records are not kept in the same catalogue. In order to solve the problem of this complexity, an archive specialist can refine your data search in accordance with the related keywords. In this case, following topics are selected to improve the search: *Legal Conditions* (competition and trade law statistics, numbers of labour and engineers, numbers of workers, numbers of agreements), *Technological Development* (R&D numbers, patent numbers, cooperation numbers), *Industrial Structure* (suppliers' numbers, size of firms, numbers of firms in the chemical sector), *Market Structure* (trade numbers, product numbers and names), *War and Ideology* (invention numbers, patent numbers). According to this preliminary information, archive specialists provided the specific stocks shown below:

- R 43 Reich chancellery,
- R 3101 Reich Ministry of Labour,
- R 3 Reich Ministry of Armament and War Production,
- R 2 Ministry of Finance,
- R 3001 Ministry of Justice,
- R 8 VIII Reich Office for Chemistry.

All those stocks have many different types of information such as name of plants, workers, social security numbers, trade number etc. Moreover, all data are

embedded in the text. For example, account statistics can be found both in financial committee reports and trade statistics. In order to overcome those problems, the selections are scanned and photographed. During archive research, the important points are always written to a notebook to be used after work. The main questions like "what is the important point?", "what does the data cover?", "what are the current conditions of the research: completed, not completed etc.?", "what are the next steps in the research?" and "what is learned during scanning the documents: important dates, persons or key points" are beneficial for the next steps of research. After those archive experiences, data cleaning and classifying processes have been completed in Turkey.

In the case of Germany, there are several important problems, which are faced while finding the data. The first point is the language of the data. Some material is in old German language and it is difficult to find the meaning of certain words in current ordinary German Dictionaries. The second one is the requirement of an appointment for working with data, which may take two to three weeks. The third one is the mismatch in the key figures of the firm. The period of 1925 – 1945 is long enough to contain many important economic extremities like the Great Depression, hyperinflation, economic recovery etc. These facts should not be forgotten while conversion of Reich Marks. In order to solve this problem, the thesis uses the treasured work of Bidwell.

2.6 USA

In the thesis, major data sources for DuPont are determined through preliminary research by contacting with the company officials in Turkey and the USA. In this case, DuPont is an active corporation and its archives require permission for individual use because of privacy concerns. On the other hand, other data like DuPont family, technical committee members' biographies are available on web. Hagley Museum's archive and online catalogue is useful to reach more information about the firm.

2.7 Tools

The thesis is primarily based on comparative historical case study methodology. According to this methodology, data could be collected from the sources such as archives, secondary sources (prominent historical books and authors), oral records (oral history of related members of the case), and recollections (autobiographies, memoirs or diaries), historical records (regularly collected data like tax registrations,

border entry and exit registrations) (Schutt 2001, 387). All collected data are analysed to understand the factors that led different innovation paths for two firms. Therefore, some tools that based on quantitative data are used with intention of making consistent research. Moreover, the main aim of quantitative tools is to improve the understanding of the cases. While doing this, the primer data is collected and selected according to the topics of comparison. Afterward, the data is examined to understand the cause of relationships, events, policies or concepts. According to Schutt, this type of research is heavily used in sociological works to understand the reason about differences between cases or identify historical or sociological events, causes and reasons (Schutt 2001). Actually, the original idea stems from the works of Weber's comparative historical research (Weber 1958) and Durkheim's labour comparison (Durkheim 1964). The methodology has also been used by economic historians like Kenneth Pomeranz (*The Great Divergence*, 2000), Regina Grafe and Oscar Gelderblom (*The Rise and Fall of the Merchant Guilds*, (Gelderblom and Grafe 2010), and Gregory Clark (*Farewell to Alms*, (Clark 2007). The mentioned works above have used the comparative methodology with the help of some tools like statistical measurement programme or applied econometrics. In innovation economics literature, comparative methodology is practiced to recognize the industrial differences between countries, which stem from science and technology policies. The research of Freeman and Soete (C. Freeman and Soete 1997) is a good example of this track. They used comparative firm and country data to clarify industrial divergence between countries. Moreover, Mowery and Nelson (1999) also examined how firms adapted the technology and used it for their ability to gain competence in the global market. Porter (2011) likewise analysed that comparative competitive advantage of nine countries (he intentionally uses this measurement type to refer to famous Ricardo's comparative advantage theory) are vital to compare countries' economic structure and policies. Finally, Chandler's work is an historical comparison between firms that organizationally differ from the others. Chandler (1990) improves his vital organizational difference ideas thanks to deep comparative analyses of firms.

In the light of these facts two cases are compared in terms of the selected titles below:

- *Legal Conditions* (evolution of Patent, Competition and Trade law. Effects of those factors to legal conditions.)
- *Labour* (Numbers of labour and engineers)
- *Technological Development* (R&D activities and its evolution during the time)

- *Industrial Structure* (vertical or horizontal relations, communication of the other suppliers, how learning emerges.)
- *Market Structure* (How market emerge, institutional facts, evolution of institutions, trade relations.)

The above data are used to improve the understanding of the cases. Moreover, while collecting the data, the main concern is to get explanatory data like numbers of dye makers, numbers of white-collar workers etc. This data collection method is intentionally chosen because the thesis uses network analysing tools to compare IG Farben and Dupont where data is available. The network analysis in this thesis is conducted by Graphcommons' software. The reasons of selecting this software are detailed in the next subsection. Moreover, importance of the network theory deserves to be examined in detail as a priory step.

2.8 Importance of the Graphical Data

The network theory dates back to the problem of *Seven Bridges of Königsberg* by Leonhard Euler in 1736 (Estrada and Knight 2015, 5–6). The solution for the problem introduced the new graph-based models and theories in Mathematics. Developments in science and technology, in parallel with this data, processors, storages, and communications (especially internet) promote new type of graph theory. In the modern meaning, the network theory is introduced in 1920s with Wellman's work on network relationship between school children (Wellman 1926). Furthermore, Strogatz (2001) showed that complex data could be used for indicating interaction of the systems, peoples and science activities. In addition, Strogatz added that amount of the data (big data) is good in interpreting the diversity in science (Strogatz 2001, 275). The graph based modelling was heavily used in many fields of science: biology (Kuramoto 1984), genetics (Kauffman 1969), mathematics (game theory) (Nowak and May 1992). These examples constitute dynamic or self-organizing systems.

The terms "complex" and "complicated" are controversial issues in that sense. Not all self-organizing system can be classified as complex and not even more complicated structures like measurement of internet apps using networks are classified as a complex system. In that sense, there is no consensus on the definition of complexity. In order to clarify and give a straightforward example on this issue, Friedrich von Hayek's definition could be worthwhile to understand complicated and complex relationship. According to Hayek, complex structures like society, exchange economy, or systems which occurred as a result of unintended human actions

should have two main characteristics to be identified as a complex structure (Hayek 1945a). The first is interactions between agents (individuals, institutions) and other entities (structures, corporations etc.) (Hayek 2012b, 73; Oguz 2000). The second is adaptation, which means that individuals can adapt to new conditions or new situations faced during the action. This definition could further be explained with a good example from chess. When a person is playing chess, he or she should play according to the rules of the game. For example, pawn's move is defined a priori. It cannot move backwards and only moves in a single square. If adaptation is subjected in chess, then pawn should have acted like King or Knight when faced with a situation. Because of these features, chess is a complicated game. On the other hand, another game or systematic action type like football is complex since in the game, a defence player can act like a striker according to circumstances. Those examples could be useful to understand the differences between "complex" and "complicated" structures in a society. According to Hayek, complex is unpredictable and partially knowable events as a result of human actions (Hayek 1945a, 1960, 1964). On the other hand, complex network defines only complicated relationship in a society, which sometimes can be an advantageous tool to analyse economy and society. For instance, MIT Media Lab has launched a project in 2010 to show the complexity in the world trade with graphs. It is entitled as The Observatory of Economic Complexity. The project aims to show complex (complicated) relationship with around 20 million data . In a network, that type of visualization can help us to present major and minor relationships (Çetinkaya 2014, 69; Steen 2010, 17–50). In this thesis, complicated and complex relationships among firms both in USA and Germany (within the relationships of the selected firms) are presented with the network analyses. In this way, empirical evidence is provided for some obvious facts such as the role of government in the development of certain chemical industries and not so obvious facts such as the role of university tradition in top management of the selected firms.

In the light of this theoretical and practical information, using graph theory or network theory has several advantages:

1. Visualization: historical, political or economic relationships could be presented in a graph that provides clear and general view.
2. Data: if it is available, network structures can work with big data.
3. Implementation: contrary to other statistical tools, network enables all field of sciences (biology, geology, economics, politics, medicine) to

analyse data. Many application areas can use the tool.

4. Relationship: all type of relationship (asymmetric, directed, linear) can be observed. For example, in this thesis, IG Farben's business relationship (cartel structure as a result of resource scarcity in Germany) gives a representation to understand Nazi's economic program.

These advantages make network analysis an important tool in historical research. Moreover, it is possible to find some patterns through tracing network edges and its interrelations among nodes. For example, history of DuPont showed that the corporation had close relationship with the government. The relationship also provides interactions between products and users who use those products. (See Chapter 4). Thus, one can for instance speculate on why a product line was introduced. Another advantage of the analysis is presenting the big picture in one frame. If data is available like internet users' place data, then network mapping can show more clusters and cliques. The next subsection will assess those types of networks and some important technical details.

2.9 Network Types, Measures and Metrics

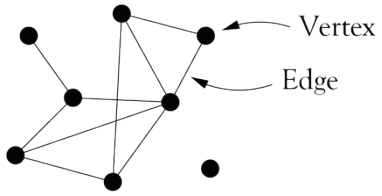


Figure 2: Simple Network

The basic definition of a network is described as a relationship between nodes (vertex) and edges. Nodes are connection points like society (person), biology (microbes), business (products), and genetics (genes). Moreover, edges are defined as degree and type of relationship. For instance, *competition* as an edge line can represent directed or undirected relationships between two automobile corporations (two different nodes). Figure 2 illustrates this type of simple network (Newman, Barabási, and Watts 2006). There are many network types in theory. Additionally, measures and metrics of network analyses have been developed thanks to advancement in computing abilities and modern tools (internet, mobile phones etc.). There are many metrics such as closeness, betweenness and degree centrality etc. which are used to measure a network's relationship degree. Some metrics could be used for a special

aim. For example, in a social network analysis, main emphasis of the network heavily focuses on bridges (betweenness centrality) in which a key node connects separate clusters to each other. In order to be clear on the issue, network types and metrics – algorithms are summarized in Table 3 below.

Table 3: Classification on network types and algorithms

Network Types	Bipartite, Complete, Directed, Undirected, Hyper, Multi, Random, Weighted, Social, Computer Networks
Measures, Metrics and Algorithms	Centrality, Degree, Betweenness, Closeness, PageRank, Motif, Clustering, Degree distribution, Assortative, Distance, Modularity, Efficiency
Features	Clique, Component, Cut, Cycle, Data structure, Edge, Loop, Neighbourhood, Path, Vertex (nodes), Matrix

Source: Compiled from works of Çetinkaya, 2014; Estrada & Knight, 2015; Steen, 2010; Strogatz, 2001.

This section provides a brief summary of the network analysis, specifically graph theory. There are many algorithms and features. Other network types especially random (probability distributions) and complex networks (small-world networks) have more dynamic and evolving systems. For example, small-world network is used to solve communication problems in a social network. Milgram's argument is to solve complication in communication within social relationships. This is also popularly known as the six degree of separation. It is a way to propose that a person in the world is only six steps away from the others within a dynamic system (Travers and Milgram 1969). Scale-free network (closely complex network) is mainly used to analyse the data that comes from the World Wide Web. Internet users, computer and medical viruses are analysed and examined with the assistance of those type of networks (Strogatz 2001, 271). Non-linearity is the main differentiation among network types. Dynamic systems might be modelled with those network types. In this sense, it is important to calculate the probability of the next move of nodes (vertex) (Strogatz 2001, 268). Moreover, to provide detailed examples, Figure 3 shows information including graphical differences between simplistic (regular) and more complicated (random) network relationships.

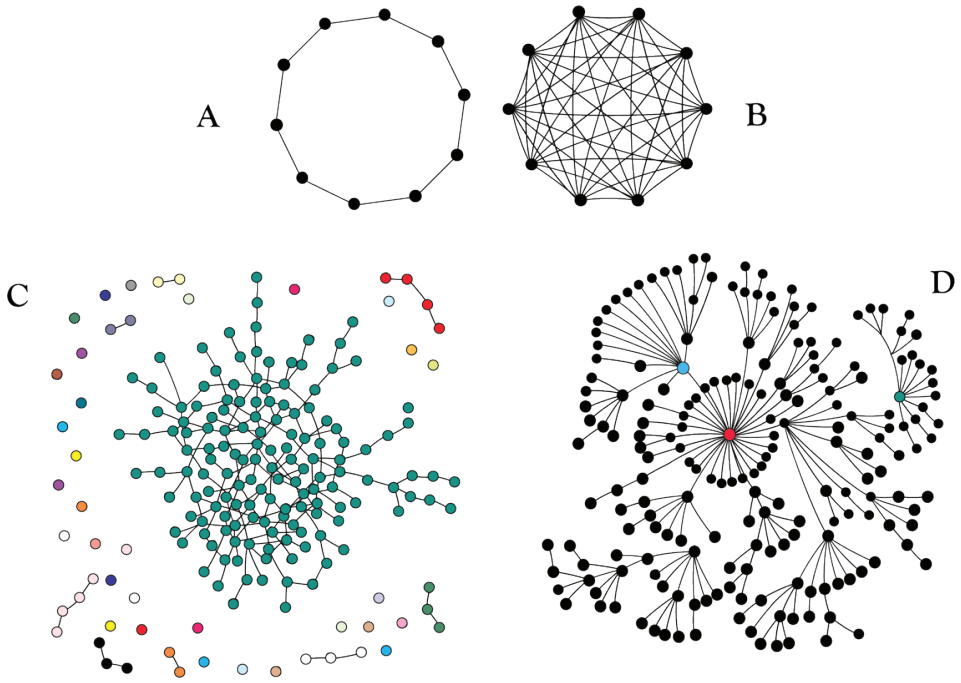


Figure 3: Random and Regular Network Illustrations
Source: Redesigned from Strogatz, 2001, p. 271.

According to the illustration, **A** represents that all 10 nodes circularly connected to each other. Regular and basic network structure is given in **A**. **B** illustrates a case where all nodes and all non-neighbour nodes are fully connected to each other. **C** is a random type of network. In the middle of the network there is a cluster and other random nodes are not connected to the cluster. This is a probabilistic graph to measure nodes (n) and edges (m) in a way to join nodes in pairs with the shortest possible way. Randomly, pairing nodes are clustering if m> n/2 (in Strogatz example n=200, m=193 above) (Strogatz 2001, 271). Finally, **D** is a classic example of a scale-free network. According to the network illustration, all nodes are connected to each other with edges; however, some nodes are highly connected to other nodes. In reality, thinking on internet users, or e-mail users, some network nodes (in this example, the e-mail owner) have more connections than the others. These connection numbers are indicated with colours in the figure. (According to the figure, Red nodes have k=33 links, Blue k=12 links, and green has only 11 links.) Those

scale-free networks are coined by Barabási et al. to define power relationship between nodes (Barabási, Albert, and Jeong 1999). Furthermore, the case of DuPont shows scale-free network features in terms of connections and nodes Determination of a network type is not an effortless process. There are several softwares in order to identify network feature (scale-free or random). In this thesis, PNet software is used to identify graph's features (*Exponential Random Graph Models* or *Scale-free Models*) ("PNet Software" 2017).

In this thesis, undirected multigraph type of network is used for explaining product and relationships for each corporation: IG Farben and DuPont. Some features and algorithms should be defined for better understanding of the quantitative method of this thesis. Betweenness centrality is used in the network analyses to understand important bridge nodes between clusters. The term firstly used by Freeman (L. C. Freeman 1977). In addition, Newmann et al. state that betweenness centrality measures "*the extent to which a vertex lies on paths between other vertices*" (Newman, Barabási, and Watts 2006, 185). For instance, merging companies have more connections (production, consumption etc.) between other firms. This means that network of companies makes a hierarchical connection among other companies. As a result of this, more connections give an insight about the power of relationship. For example, IG Farben have more power on other sharing companies because of its connections (See Chapter 4). This analysis is conducted to measure the strong relationships between firms thanks to betweenness centrality algorithm. Moreover, number of connections (called as *degree* feature of a network) is represented to reveal the core of some nodes like government expenditure types. In the thesis, *closeness* metric, which measures the quick access to all nodes is used to divulge some important nodes. It statistically measures "*the mean distance from a vertex to other vertices*" (Newman, Barabási, and Watts 2006, 181). For example, in IG Farben's merger network shows that BASF and Bayer had more "closeness" than other firms because of the distance between the main node, IG Farben (see Chapter 4). Finally, some features of networks like clique and clusters are showed in the network data. For example, DuPont's products are mainly clustered by conducting edges: *used by*. Classification of the clusters are made via products groups like explosives, chemicals etc. Naturally, there have been product clusters; however, detailed analyses show when adding some variables like "using" or "producing" to the networks, the relationships become meaningful in terms of understanding why and how questions. In this example, explosives were demanded by the government, which means that DuPont carried out its production line according to government demand conditions. Before the World War I, explosives demand of the USA was

relatively high. Some sources said that "$250 million" net profit made by the Du Pont during the War from just one product line.

Features, metrics, and algorithms can be complicated and short definitions provided above may not be sufficient to grasp the basic idea behind using network analysis. Therefore, Figure 3 illustrates basic metrics and algorithms on a sample network, which might be useful to understand complicated definitions provided above.

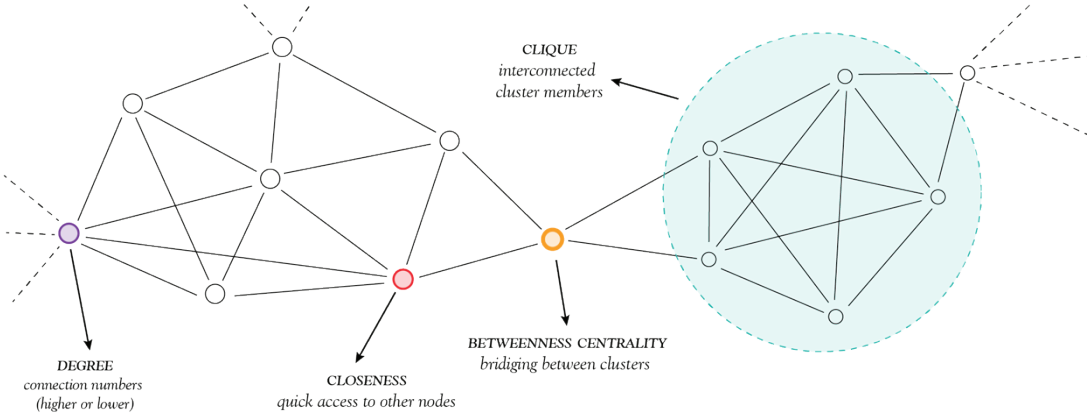


Figure 4: Metrics, Algorithms, and Features of a Sample Network

2.10 Using Software

For network analyses, there are many useful softwares on the market. The selection of the software is made in accordance with suitability for type of network analysis. For dynamic structures like peoples, animals, and microbes, some visualization programs like *Pajek*, *Graph-tool, Gephi* can be appropriate to generate the data. On the other hand, some graph based programs like *Graphcommons*, and *Semoss* are very subtle to constitute precise graphics. Technical or economic, there can be many reasons for the selection process while working with the network data.

In this thesis, *Graphcommons* software is intentionally selected for measuring the network structure. There are several reasons for this selection:

1. The software's mathematical algorithm: In *Graphcommons*, software is based on Force-directed graph drawing algorithm (*Force Atlas 2*) (Jacomy M et al. 2014). The algorithm is based on working of Tutte. His work enables to draw Polyhedral graphs under some assumptions (Tutte 1963). This type of algorithm has many advantages. First of all, drawing

aesthetic graphs is possible with this algorithm. Secondly, interrelations and connections can easily be seen. Thirdly, as a result of flexibility of the software, good quality of results (clusters, cliques and degrees) might be possible with small size of data. Fourthly, this algorithm has a cognitive advantage, which means that some physical objects can be traced and predicted, and examined easily compared to other softwares. Finally, Force Atlas 2 provides simplicity feature while drawing and organizing the network (Jacomy M et al. 2014).

2. The software is an open source programme. Open source program is specifically selected since some features can be developed while using the software. Also, this type of software has low cost solutions for research activities.
3. The software is user-friendly and simplistic.
4. After the analysis, exporting options and visualization opportunities are very generous in the software. Therefore, editing the graphs after the analysis can be easy.

The main purpose of using the software is to make clear network mapping in order to see the patterns, business relationships and importance of nodes in the context. As it is known, networks may not be an exact solution for understanding the relationships. On the other hand, tools of statistics and mathematical modelling might indicate more about the relationships. However, modelling in dynamic system in the network provides insightful correlation between variables. It is the simplest way to explain the relations among many variables. In addition to this, network modelling and analysis support researchers to use big or comprehensive data. Besides, it helps to examine not only big or detailed data but also small and non-time series data. It is a reliable tool in that sense. In historical research, finding data about the cases can be very hard. Sometimes data series are not suitable for more common statistical techniques. In such cases network graphs and mapping algorithms can give valuable viewpoint during the research. It does not mean that this type of research tool can reveal all historical relationships. However, in Hayekian terms, complex structures and some social science issues can be supported with this analysing method.

CHAPTER 3

THEORETICAL AND HISTORICAL BACKGROUND

3.1 Germany and United States of America: History matters

3.1.1 Germany: Brief History

In his book, Fritz Stern, a prominent historian, mentions about Germany as "*I have spent my professional life trying to answer: why and how did the universal human potential for evil become an actuality in Germany?*" (Stern, 2006, p 42). Germany has a very extraordinary place with respect to its political and economic history. It is a country where distinctive economic industrialization accompanies two great wars. Its stories have been written in both hell and heaven. On the one hand, Germany is a country which has a mesmerizing product base established on a well-organized industry that provides a significant number of innovative products and processes to the world; greatest music composers that perform art to touch our emotions deeply; influential scientists that change the world in basic and applied natural sciences and even social sciences. On the other hand, it is a country which committed the largest war crime being responsible for the genocide of the Jewish and other races. Moreover, at that time, there is the highest number of military expenditure (Kennedy 1987) also science (Cornwell 2004) that promotes military innovation. All those developments conducted at the expense of nearly 70 million people (Dear and Foot 2001).

In this chapter, brief historical information will be presented about four periods: Early Germany (from Roman Empire to 1500), early modern period (1500 – 1800), industrialization period (1800 – 1914) and the War period (1914 – 1945).

3.1.2 Early Period (from Roman Empire to 1500)

Nearly 30 000 years ago, Neanderthals a subspecies of archaic human were our rivals in biological evolution. Their strength and muscles improve Sapien's genes, which makes us the fittest of all (Tattersall 2013). Neanderthals, was first discovered in 1865

in an area which we call Germany today[4] (Pääbo 2014). From that time to Roman Empire many advances and changes occurred in the area. During the reign of the Holy Roman Empire, Germany area or territory was called as *Regnum Teutonicum* in Latin. The area enclosed the northern side of the Empire and Romans called the Germanic people as Barbarians[5] (Fulbrook 1990). Early Germanic people were engaged in agriculture and animal husbandry from beginning of the first century to the eleventh century. In the early period of the Holy Roman Empire, Alchemy was used for transforming the resources such as iron, silver and gold, which was found in the border of the Empire (Levere 2001). In Germania, alchemy was limited and produced in small scale in the beginning of the first century. Tacitus (c AD 56 –117) described the country as a land of forest and plentiful fruitful territory. According to Tacitus' writing, natural resources mentioned above were scarce (Tacitus 1900).

From Roman Empire times to 1500, the economic life characterized small-scale production systems and agricultural production (Abel 1980). There was no significant industry at that time (Mokyr 2003b). In the beginning of the fifteenth century production of steel in Solingen, Hessen and manufacturing of linen in Nuremberg was advanced (S. R. Epstein and Prak 2008). The productions were regulated by the Guilds (S. R. Epstein and Prak 2008; Mokyr 2003b). Guilds connected small market production from the hinterlands to the Baltic area through free trade and with the help of the Hanseatic League[6] (Mokyr, 2003a, p 405). Hanseatic trade connected German merchants to the northern part of the continent -Poland, Russia, Sweden and the Netherlands and to major trading cities such as United Kingdom, Netherlands (Gelderblom 2013).

3.1.3 Early Modern Period (1500-1800)

At the beginning of the sixteenth century, German economy was based on rural production. %75 percent of the labor force engaged in agricultural production. Moreover, urban strategic sectors such as textiles and steel shaped the economic development of Germany (Mokyr, 2003a, p 406). There were two great events that affected the decline of population numbers and led to economic stagnation. The first one was Black Death (1350), an epidemic disease killing millions in Germany (Ziegler 1969). The second one was Thirty Years' War (1618 – 1648) in which population declined from 17 million to 10 million as shown table 1. In 1600s, Germany had

4 Also, Germany named a valley as *Neanderthal*.

5 The Barbarian word was not used as a primitive people by Romans *Barbarians* were used for a word that means *foreigners* (Fulbrook 1990, 9).

6 *Hanseatic league* was established by guilds in Lubeck, middle low of Germany in 1358 (Day 1922).

18593 million dollars of GDP (measured as PPP in 2007 million dollars.) and between 1500s - 1600s the growth rate of the GDP was about %0.14 annually (Avakov 2010). Although the population numbers were influenced by the two incidents above, urban manufacturing flourished through specialization that was shaped by the *putting-out system*[7] (Williamson 1985). The system enabled entrepreneurs to develop their business and *manufacturing regions (Gewerbelandschafen)* emerged thanks to flexible production system. (Williamson 1985). Moreover, Verlag system created opportunity to make a business in cheap and efficient way. Afterward, the regions were connected with international trade through specialization of some products such as textile (Mokyr 2003b). On the other hand, Chemistry was limitedly implemented in some industries that used it as a practically. Furthermore, this practical use of chemistry occurred in several ways like: heating for pottery, forging for metal and metallurgy. The use of chemistry (at that time not called as a chemistry) had begun to develop its own way.

Table 4: Population size of Germany, 1500–1800

	Total population *Kaiserreich*, after 1740 excl. Alsace-Lorraine
1500	9.2
1550	12.9
1600	16.2
1650	10.0
1700	14.1
	excl. Alsace-Lorraine
1750	17.4
1770	18.6
1780	19.5
1790	20.5
1800	21.6

Source: (Pfister and Fertig 2010).

3.1.4 Age of Industrialization (1815-1914)

Germany's map once again changed after the French Wars. The War affected the productive regions of Germany. As a result of this, Region of Rhine river and Saxony Germany began to develop its trade linkages. Incidentally, mercantilist trade system that was called *Cameralism* became widespread after the French war in Germany. At the beginning of the 1800s, restoration and reform process began, at the same

7 In German *Verlagsystem* means that work is contracted by a merchant-entrepreneur to subcontractors who complete the work in their home or other facilities (Landes 1966; Williamson 1985).

time, Germany's coal, textile and iron production rose rapidly. Reforms which were called *Stein-Hardenberg* or *Prussian Reform* changed political and economic institutions (relatively free trade, patent regulations), education (As result of leadership of Humboldt German education system was divided into *Volksschule* (people's schools), Gymnasiums and universities) and industry (supressing Guilds and promoting competition). Stein and Hardenberg reforms started to liberalize German economy. The reformists were seriously influenced from Adam Smith and Classical Liberal ideas. In the first instance, rural production and property rights changed for the benefit of the peasant. Land lord's monopoly declined and labor was liberalized, it meant that each individual should not have to registration in a guild. Guilds lost their authority on entrepreneurs. Contrary to early system, entrance to the Guilds depended on the consent of the individuals.

By 1840, extensive expanding in the railway system was a fundamental step for the economy. Railways ownership was depended on private capital and private property in Germany which was important in the development of the railroads in Germany (Mokyr & Grant, H Roger, 2003, pp 332–336). Moreover, Germany produced its own rails and roads in the country. Its iron and coal output was carried with the railroad. Industrial development of the country largely relied on transporting of raw material to almost anywhere in the country. As Frederic List puts it, there are many effects of establishing railroads for the development of a nation (List 1966).

In 1870, Germany unified. Financial opportunities expanded which created additional funds for investment in heavy industry such as coal, steel and machinery. Especially increase in the long-term credit opportunities helped heavy industry to flourish (Mokyr 2003b, 5:412). The expansion of industry was accompanied by the expansion of science and scientific works. Scientific works was especially high in Chemistry and Physics. Important firms in the chemical sector were established in this century. Bayer was founded on August 1, 1863, Barmen, Germany and BASF on April 6, 1865 in Mannheim. Bayer was the biggest pharmaceutical company of the time. Some important pharmaceutical products such as *Aspirin*, *Heroin*, *Phenobarbital*[8] were invented by the company. BASF had been a forerunner – especially in terms of costs- in the production of Sodium carbonate (soda). *Leblanc process*[9] was used to produce soda until 1880 (Abelshauser et al. 2008). BASF's

8 Commonly used for sleep aid in the beginning of 1900s.

9 It was an industrial process to produce soda ash, hydrochloric acid efficiently. It was invented by Nicolas Leblanc in 1791 (Reader 1970).

innovative *Solvay Process*[10] was one of the most efficient way of production of sodium carbonate which led to changes in the production process of chemicals.

At the end of the nineteenth century two significant events changed the path of German industrial development. The first one was the end of the imperial reign in the world and the accompanying trend in rising nationalism which caused many of extreme events in the first half of the next century (Eric John Hobsbawm 1962). The second was expanding production and means of production with the help of the industrial revolution (Hobsbawm, 1997, pp 207–223).

3.1.5 War Time (1913-1945)

Germany's destiny was shaped between two wars. The consequences of the First World War were the main motivator for the second one. Politically, Germany is a unique case because it was defeated two times both in World War I (as known as the Great War) and World War II and the country had to pay high reparation according to Article 231 of the Treaty of Versailles for World War II and Potsdam Conference for World War II. However, Germany successfully manage to turn this to its advantage by scientifically and economically benefiting from the wars. Especially during the World War II, Nazis used basic and applied science –though in the most fierce way- for becoming the successor of the War. Many inventions and military innovations occurred in that time. There were two turning points during and after the World War I that needs to be explained further. The first is the *inflation problem* and it relation to *reparation funds*. The second is the changing *political structure* and *rising totalitarianism.*

The first point could be viewed as a negative effect of the war. It is a fact that uncontrolled monetizing paper money causes a higher level of inflation (Mises 1983). Between 1914 and 1918, Germany had a dilemma between financing war and creating revenue. The problem can easily be observed in the expenditures of Germany. Between 1914-18, the country had 194,301 million marks of expenditure and 32,372 million marks of revenue (Balderston 1989). In addition to this, the war ended with the defeat of Germany and according to *Article 231 of the Treaty of Versailles* Germany had to pay 50 million gold as reparation (Bell 1986; Hay 2002). High level of public debt and extreme reparations of the war caused a period of hyperinflation in 1921-1923. The hyperinflation changed two things. Firstly, it destroyed income, savings, and economic life. Secondly, the hyperinflation made it

10 It was developed after *Leblanc Process* by Ernest Solvay during the 1860s (Reader 1970). It has been used in the modern production of Soda.

easier to spread fascist ideas on the continent (Hobsbawm, 1994a, p 90).

The second point was the rising totalitarianism. After World War I, an insignificant soldier, who was Adolf Hitler, had an idea that was about changing Germany's economic destiny and taking back Germany's power. The idea stemmed from aggressive foreign policy that was called *Lebensraum* which was living space for Agrarianism (W. D. Smith and Mazal Holocaust Collection 1986; Weinberg 1980). Moreover, after the global crisis (aka Great Depression), inflation and unemployment rates were very high in Germany. These factors caused Hitler the came to power in 1933 (E. J. Hobsbawm 1994; Kershaw 1999) and he took 17 million votes (Kolb, 2005, p 224). Totalitarianism diffused to Europe unrestrainedly and Spain and Italy copied totalitarian ideas from the German experience (Linz 2000). Rising totalitarianism promoted economic growth through destructing private ownership and other economic institutions. When Hitler came to the power, he insisted on protecting and providing private ownership. However, in Nazi Germany, private organizations must obey Nazi's interests. As Linz said that authoritarian or totalitarian regimes concentrated the power in centre. This means all economic and political institutions and pluralism both social and economic system was constrained by authority. Moreover, private property, in literally term (Linz 2000). On the other hand, Hitler's economic program dropped unemployment numbers drastically from 6 million to 77,500 in 1939 and raised economic growth during the World War II (McNab 2009).

Hitler manipulated basic science and technology to become absolute omnipotent power (Cornwell 2004). Prominent scientists like Max Planck, Fritz Haber, Werner Heisenberg worked for and promoted Hitler's science (Cornwell, 2004, p 462). Thanks to slave labour and formation of cartels like IG Farben military innovations in developing aircrafts, advances in chemistry, emerging material sciences and electronics flourished (Murray and Millett 1996, 112).

End of the war, in 1945, Germany was defeated again and lost its economic power. Allied Powers played significant role in designing the collapse of capital markets, transportation and communication networks, heavy industries and nearly all economic institutions (Kershaw, 2012, pp 134–135).

3.2 USA: Brief History

In his book, *Decisive Moments in History* Stefan Zweig quote: "*Upon his initial return from the discovered America, Columbus displays an infinite number of curiosities and precious*

things during his triumphant march through the crowded streets of Seville and Barcelona: red-skinned human beings of a previously unknown race, animals that have never been seen before, the colourful, screeching parrots, the ponderous tapirs, then remarkable plants and fruits that will soon find their borne in Europe: Indian corn, tobacco, and the coconut." (Zweig 1999, 7). Columbus discovered a new continent, which he was not aware and brought a lot of precious materials and plants to Europe as well as codified experience of the journey. Voyage of Columbus was one of those *decisive moments* for the world because America has great significance in terms of economic history and technological development on the world. In this part of the chapter, three main periods in chronological orders, colonial period, industrialization period and finally war period, will be analysed to comprehend the brief history of the United States of America.

3.2.6 Colonial Period 1600s – 1774s

When Columbus discovered America at the end of the fifteenth century, he was unaware that he marked a great beginning for the whole world both economically and politically. When first voyager went to the "new" continent, there were indigenous people who had indigenous economy, society and community life. The natives' population was small in comparison to Europe. Peter C. Mancall's work proposed that before 1400s, population of the north side of America contained 12 – 26 million indigenous people (Mokyr, 2003b, p 158). During the seventeenth century, resources were manipulated by the western people emigrated from England, an occasion which is referred as colonization. American resources were abundant for establishing the very first economic relations. Agrarian products like tobacco and sugar were planted in newly established farm houses (Brogan 2001). Until the Civil War (1865), slavery was used to support agricultural production and trade (J. H. Franklin 1967). Some production methods were imported from the West in order to produce agricultural products which were mostly unfamiliar like sweet potato, corn or maize, pumpkins, tomato and strawberries in an efficient way. Westerner used fertilizers and fertilization systems for on the land of indigenous peoples (Bining & Cochran, 1964, p 55). Manufacturing in the early 1700s to 1760s developed as well accompanying the expanding agricultural production. Primer manufacturing areas were lumbering industries, shipbuilding, fur trade, iron, pottery fisheries, flour milling industries, and shop and home industries which were hat making, dried fruit, and dressmaking. Manufacturing was affected by the decisions of the regulatory authorities who were aiming to encourage the industry (Bining and Cochran 1964). *The Iron Act of 1750*[11] was a good example to such regulation, which aimed a production system under state control. Some products'

11 The act was aimed to restrict British Colonial's production (Bining 1933).

trade was limited during the Mercantilist policies. Trade was another mechanism that was used to provide raw materials and surplus products by the colonists. Larger ships were built for carrying products to Great Britain and other parts of Europe (Bining and Cochran 1964, 117). Furthermore, America used trade network to reach both colonials products. For instance, New England[12] sent tobacco for getting fish. This networks linked each areas that were comparatively at different development stage and (Bining & Cochran, 1964, p 103).

3.2.7 Industrialization Period

In her famous fiction, *Atlas Shrugged*, Ayn Rand imagined that the railway system was the real superior power behind the American economic development. Moreover, she proposed an ideal world in which networks of railway provided the cheapest and a safe transportation *from ocean to ocean*[13] as a result of mechanical and metrological innovations in railway system. Although Rand's supposition was a fiction, transportation systems and networks had great importance in the development of the American economy during the industrialization in 1800s (Brogan, 2001; G R Taylor, 1951). Steam locomotive was invented by the British; however, efficient applications of the rail system were developed by the North Americans (Brogan, 2001, p 378). The first mover in the railway system was the Baltimore & Ohio railway in 1830. Moreover, along the railroads, telegraph lines were established for communicating with long distances in the continent. Railroads, steamboats and telegraphs helped to promote industrial development. Thanks to these advances, American entrepreneurs penetrated in to new markets which were far from the centre and customers who settled out of cities but they wanted to buy service and products (Brogan, 2001, p 379). Table 2 shows the great expansion of the railway and canal systems, which enabled the industry to carry goods along the country.

Building new railroads and routes created new jobs; for instance, a single corporation in building railroads had 36,000 employees. Additionally, establishing new coal mines and steel plants needed to employ extra workers. As a result of this, there emerged new industrial situation: new business lines demanded new labour and suppliers to take advantage in a market (Brogan, 2001, p 381). Competitive trade system, capital accumulation and financial system are among the pillars that characterized industrialization period of America beside transportation and communication networks.

12 It consists of six American states: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

13 This is motto of the company in the book (Rand 1957).

Table 5: Expansion of Canals and Railroads

Year	Canal Mileage	Railroad Mileage
1820	150	0
1830	1277	73
1840	3326	3328
1850	3698	8879
1860	4000+	30,636

Source: (G. R Taylor, 1951).

Trade system had developed starting from the colonial times. There was a massive network of trade routes and shipping shores in all over the country. Trade was connecting two continents to obtain raw materials and agricultural products. However, rapid growth during 1774s – 1860s in industrial production made the country a unique producer in mining industries, agriculture, machinery and oil products. In antebellum period, GDP rose rapidly thanks to mechanization in agriculture and industry that enabled further expansion of production. Table 3 demonstrates the selected statistics on demography and economics in 1774-1860 (before the Civil War). Numbers remark that population and GDP were positively affected from economic growth. As seen on table, there were three important points that provide economic growth. First, diminishing agricultural share of the labour force leaded to transformation in economic structure which was largely industrialization. Second, as a result of rapid mechanization in industry, industrial output was gradually increased. Third, productivity was supported by increasing in population. Moreover, migrations from other continents and slave labour (until the end of the 1800s) joined the labour force to support production. In sum, all those factors caused and provided economic growth during nineteenth century.

Table 6: Selected Economic Statistics for the United States, 1774-1860

Gross Domestic Product		Population	GDP Per	Labor	Output Per	Labor Force	Agricultural
Year	(Million $)	(Thousands)	Capita ($S)	Force (Thousands)	Worker ($S)	Participation Rate	Share of The Labor Force
(dollar values expressed in prices of 1840)							
1774	145	2,419	60	844	172	0.35	0.76
1790	**NA**	3,929	**NA**	1,279	**NA**	0.33	**NA**
1800	348	5,297	66	1,712	203	0.32	0.74
1810	500	7,224	69	2,337	214	0.32	0.72
1820	689	9,618	72	3,150	219	0.33	0.71
1830	1,017	12,901	79	4,272	238	0.33	0.70
1840	1,553	17,120	91	5,778	269	0.34	0.67
1850	2,318	23,261	100	8,192	283	0.35	0.60
1860	3,905	31,513	**124**	11,290	346	0.36	0.56
Average annualized rates of growth							
1774-1800	3.4	3.1	0.4	2.8	0.6	-0.3	-0.1
1800-1860	4.1	3.0	1.1	3.2	0.9	0.2	-0.5
1774-1860	4.0	3.1	0.9	3.1	0.8	0.0	-0.4

Source: Adopted from (Mokyr, 2003b, p 164).

Rapid increase in industrial production and creation of new mechanized industries (building new factories, employing workers, creating new routes and roads, and establishing unique manufactures) also helped capital formation and increased savings (Brogan, 2001, p 381). Funding enabled innovation in basic economics tools. For instance, America developed a banking system promoting business relation through creating stocks, bonds and commercial papers. This attempt was designed for nationwide capital accumulation (Mokyr, 2003b, p 166). Capital expansion led early industrialists to make investment on newly emerging sectors. Raising banking system stirred up a trouble which is role of government in this accumulation process. According to Rothbard, abandoning of free market ideas and the rising *mercantilist attitudes of Britain* affected domestic producers positively in short-term; on the other hand, in the long run, central role of banking system was gradually affected negatively daily economic life. (Rothbard, 1983, p 139).

Furthermore, Rapid industrialization created new generic sectors like chemistry. Beginning of the 1900s was decisive in establishing new industries which depended on chemical and material sectors (Freeman, 2013, p 97). In America, the first chemical company –Du Pont- where the first dynamite and nylon had been produced was founded in 1902. By its inventions, DuPont, not only fostered daily

use consumer products such as woman tights, raincoats and but also stimulated military innovation such as raw materials for parachutes, powder bags and tires (Kinnane 2002). Furthermore, dynamite was used to provide coal mines and farming. Farming with dynamite was new and weird technique. It was promoted by Du Pont. Main use areas were: clearing land of stumps, trees and boulders; breaking up Hard-Pan, Shale; plowing; digging ditches, post holes, reservoirs; road-making; excavating cellars; regenerating old, worn-out farms (Du Pont 1910, 4–11). Main aim of the dynamite was save labour cost.

3.2.8 War Period

Despite the German war experience, USA won World War Iand its super power in military was confirmed (Ferro, 2002, p 128). Rapid industrialization in the late 19th century and emerging new sectors such as communication, chemistry and machinery supported America's mission in the Great War. Moreover, the Great War stimulated military innovations including machinery and materials production. Industrial leadership of America emerged in sectors that were influenced by *Taylorism*[14] - a production process that aim to increase productivity. For instance, scientific management principles of production in the steel industry boosted steel production (Freeman, 2013, p 73). In 1913, total production of steel was 313 million of tons, meanwhile, Germany was producing 193 million tons. At the end of the Great War, in 1918, American political, economic and industrial dominance in the world started (Hobsbawm, 1994a, pp 21–54).

There were two significant events in wartime history of America. Rising production and industrialization period during war and collapse of financial system known as Great Depression emerged from monetary and credit policies of the FED (Rothbard 1963)[15]. Easy credit booming and uncontrolled money supply was the primary causes of the depression (Robbins 1934). The depression had economy-wide affects. It caused unemployment and reduced production thus led to a massive decline in trading activity. Table 4 summarizes unemployment numbers of the USA between the beginning of the depression and the beginning of the war where one can see that just a year after the great depression unemployment doubled. There were both mainstream and heterodox remedies to help economy to recover. Mainstream view,

14 Frederick Taylor, in his notable book: *Principles of Scientific Management*, summarized that increasing economic efficiency and labour productivity can be possible with implementing principles of basic science to applied science through analysing of the production process deeply (F W Taylor, 1967).

15 By the way, many economists do not agree with that.

mostly Keynesian, proposed that expanding government expenditures and size was key to recover from the recession (Keynes 2015). Heterodox (or the Austrian) view based its arguments on two observations regarding the great depression of USA. The first was that government expenditure would eventually cause an over-heated economy. Second was related with the main position of the FED and the banking system that expanded money supply in an uncontrolled and irresponsible manner which they refer as the primary reason of the depression (Hayek 1966; Robbins 1934; Rothbard 1963, 1983). After the depression, in 1933, Roosevelt proposed a "new deal" which was a *social liberal* measurement for getting rid of economic collapse until 1937 recession. At the end of the second recession, USA faced new economic and political challenges.

Table 7: Unemployment numbers between 1929-1933 (in thousands)

Countries	1929	1930	1931	1932	1933
Canada	12	23	32	77	80
Czechoslovakia	50	88	340	634	878
France	9	14	72	347	356
Germany	2,484	3,041	4,744	6,034	5,599
Italy	309	413	735	1,085	1,111
Japan		352	397	474	
Sweden	44	42	73	99	121
Switzerland	9	21	61	103	113
United Kingdom	1,204	1,694	2,666	2,66	2,821
United States	-	2,964	6,403	10,477	13,359

Source: (Robbins 1934, 213)

Hemingway describes the war in his book *Farewell to Arms* as dramatic and cadmean victory (it can be expressed as "*to win a battle but lose the war*"). His fiction was written for the Great War experience. However, second war was not so much different. In 1941, USA declared war against the axis power (Weinberg 1995). There were three main achievements of the war. The first one was the economic recovery of the USA. Despite its viciousness the war was a remedy for depression much because of the reason that public expenditures, especially military spending, soared. Through the multiplier effect this created excess income and caused nominal GDP to increase by %12 on average annually as can be seen from Table 8.

Table 8: Federal Spending and Military Spending during World War II (dollar values in billions of constant 1940 dollars)

Year	Nominal GDP		Federal Spending			Defense Spending		
	total $	% increase	total $	% increase	% of GDP	total $	% increase	% of GDP
1940	101.4		9.47		9.34%	1.66		1.64%
1941	120.67	19.00%	13.00	37.28%	10.77%	6.13	269.28%	5.08%
1942	139.06	15.24%	30.18	132.15%	21.70%	22.05	259.71%	15.86%
1943	136.44	-1.88%	63.57	110.64%	46.59%	43.98	99.46%	32.23%
1944	174.84	28.14%	72.62	14.24%	41.54%	62.95	43.13%	36.00%
1945	173.52	-0.75%	72.11	-0.70%	41.56%	64.53	2.51%	37.19%

Source: (Tassava 2008).

Secondly, thanks to increasing military expenditures, USA started to promote basic science in thought of that it would spur military innovations. These attempts years later would give USA the leadership in science and technology. However, this was by and large the by-product of increased military expenditures. Considering the race between Germany and USA in developing the atomic bomb, this was an important moment in history. Germany and USA were competing in developing the atomic bomb, but it was the USA that gave priority to this case. *Manhattan Project* was the primer research and development project to stimulate producing of the atomic bomb (Rhodes 1986). Table 6 presents the estimated cost of the project. As can be seen in the table 6, total expenditure of the project was very high comparing to other war expenditure. Besides, USA adopting new technologies from western Europe. This was occurred in two ways: welcoming scientists who were blamed as Jews and people who were qualified technician but fleeing from war (Ball 2014, 66; Cornwell 2004, 93).

Table 9: Manhattan Project costs in 1945

Site	Cost (1945 USD)	Cost (2016 USD)	% of total
Oak Ridge	$1.19 billion	$15.6 billion	62.9%
Hanford	$390 million	$5.13 billion	20.6%
Special operating materials	$103 million	$1.36 billion	5.5%
Los Alamos	$74.1 million	$973 million	3.9%
Research and development	$69.7 million	$916 million	3.7%
Government overhead	$37.3 million	$490 million	2.0%
Heavy water plants	$26.8 million	$352 million	1.4%
Total	**$1.89 billion**	**$24.8 billion**	

Source: (Schwartz 1998).

Thirdly, in 1945, USA was the super power. Moreover, under leadership of USA,

new world order started to establish with the help of institutions which were founded under United nations instead of ineffective *League of Nations* in 1945 (E. J. Hobsbawm 1994). Europe was collapsed and looked for new "union" ideas to recovery their economic and political position. Japan was defeated and reel GDP declined nearly half (Maddison, Organisation for Economic Co-operation and Development, & Development Centre, 2003). USA faced new era of two pole era (Kennedy 1987).

3.3 Comparing Germany and USA

This part of the chapter ended with a comparison table for two countries. The comparison covers between 1500s and 1900s. The main and vital events in history will be expressed shortly according to economic change, political change, law and regulation, religion, events which are unintended occurrences and technological advances. Major changes present in Table 7. In the table, there are seven major topics that aim to compare each country. First is Economic conditions and changes. This topic is composed to show the major economic changes like policy implementation or great changing in economic sense according to works of Bell, 1986; Bining & Cochran, 1964; Brogan, 2001; Fulbrook, 1990; H. W. Smith, 2011; Weinberg, 1995. Second is mainly related to political variations. For instance, transition from empire to state democracy is typically important milestone for performance of each country (E. J. Hobsbawm 1994). Third is laws and regulations. This is very vital case to understand some economic rushing and policy changing after making rules and regulations. At this point, in the table, this topic is provided by important works of Gunderson, 1976; E. J. Hobsbawm, 1994b; Eric John Hobsbawm, 1962; Holborn, 1959; Mokyr, 2003c. Fourth and fifth topics are indented for information to know about dominant religion and event. Sixth topic concerns on major breakthroughs in science and technology. The topic provided information not only major technological changing but also products that caused fundamental changing in history. At the present, the topic supported with works of Landes, 2003; Mokyr, 1990; White, 1962. Final topic is linked to basic science or physical science like physics, chemistry, astronomy and earth sciences. The aim of the topic is to show several notable persons and developments during the time.

Table 10: Comparison of two Countries in Brief

Germany					
	1500s	**1600s**	**1700s**	**1800s**	**1900s**
Economic Conditions and Changes	Agriculture Small-Scale Manufacturing (iron etc.)	Putting-out systems Manufacturing regions Mercantilism (Cameralism)	Strong guilds Internalization and Trade Controlled market		End of Guilds Heavy Industrialization Closed market system
Political Change	Establishing Barbarian Germany	Imperial age	Weimar Republic and confederation		Third Reich and Fascism
Law and Regulations	Hansetic Trade	Stein-Hardenberg Prussian Reforms Constitutional system		Private Property	Treaty of Versailles Reparations European Union
Religion	Protestant Reformation	Protestant Christianity and Minority Jewish	Protestant Christianity and Minority Jewish		Protestant Christianity
Events	Black Death (declining population) Patent System		In Thirty Years' War Industrial Revolution Alsace-Lorraine		World War I World War II
Notable Technological Advance	Printing Machine	Machinery	Transportation, Rail and Canal ways R&D system		Chemistry process and synthetic revolution Aviation, Atomic Bomb, Electronics

Table 10: Comparison of two Countries in Brief (continued)

Science	Astronomy: German astronomer *Johannes Kepler* formulated his laws regarding planetary motion *Johannes Werner*: Mathematician	Anthropology: *Magnus Hundt*	*Carl Schmidt*: Biochemistry *Justus von Liebig*: Founding of organic chemistry	Founding of Industrial Chemistry *Max Delbrück*: Agricultural Chemistry	Chemistry: *Adolf von Baeyer* was a German chemist who synthesized *indigo* Physics: *Max Born* leaded development of quantum mechanics *Wernher von Braun* Aerospace and rocket technologies *Heisenberg* and *Max Planck*: Theoretical Physics *Albert Einstein*: Relativity

Table 10: Comparison of two Countries in Brief (continued)

USA					
	1500s	**1600s**	**1700s**	**1800s**	**1900s**
Economic Conditions and Changes	Agriculture Trade networks for Exploitation	Free trade and controlled market	Efficient agriculture Heavy Industry	Transportation and telegram lines Taylorism	Rapid Industrialization New deal
Political Change	Colonial system		Federation	American Revolution	Democracy
Law and Regulations	Private property		Indian Removal Act First Party System	Constitutional system End of Slavery	New Super Power: regulating trade, finance and global economy
Religion	Mesoamerican	Catholic Christianity	Christianity	Christianity	Christianity
Events	Immigration from Europa British colonization			Civil War	Great Depression and recession
Notable Technological Advance	Agricultural tools		Engines Electricity	Electronics Petroleum Mechanics	Chemistry, Material science State science Radar, Atomic bomb, Aviation and electronics: computers

Table 10: Comparison of two Countries in Brief (continued)

Science	-	-	-	*Robert Adrain*: Mathematics *George Chapman Caldwell*: Agricultural Chemistry Science Immigration: *Alexander Graham Bell* (electronics), *Joseph Priestley* (Chemistry), *Nikola Tesla* (electronics)	*Patsy O'Connell Sherman*: Products that made by chemicals *Enrico Fermi*: Nuclear Reactor *Albert Einstein*: Relativity *Robert Oppenheimer:* Atomic Bomb *Wernher von Braun* Aerospace and rocket technologies Computer Science Biological Science Applied Science

3.4 Economics of Chemistry

Story of chemistry is as old as the first humans who desired to satisfy their curiosity about the nature (life) and social order (wealth). Mystical beliefs of people led the emergence of *Alchemy* that mainly aimed searching for the Elixir of Life[16] and the Philosopher's Stone[17] (Greenberg 2007; Levere 2001; Moran 2005). Paulo Coelho, in his *Alchemist*, tells a story that passes in a mystical world where an Andalusian shepherd boy travelling from Spain to Egypt searching for a treasure with the assistance of Alchemy and alchemists, instead discover himself as the real treasure (Coelho 1996). After all, neither alchemy nor philosopher's stone can create new forms in modern scientific terms. But those efforts initiated the evolution process

16 *Elixir of Life* or *Elixir of Immortality* is liquid for using sometimes to be young sometimes to be immortal in Chinese and Indian alchemy (Atkins 2015; Levere 2001; Moran 2005).

17 *Philosopher's stone* is a substance that convert material into precious metal like gold and silver (Atkins 2015; Levere 2001; Moran 2005).

from alchemy to modern chemistry. Before modern chemistry, there were three type of chemistry: *practical chemistry* that is used in areas including mining, weaponry, jewellery making, pottery and purification of metals (primitive metallurgy); *mystical chemistry* that aimed at discovering the endless life and eternity and transforming metals like from silver to gold (alchemy); and *medicinal chemistry* that used herbs and plants for healing (Greenberg 2007).

Predominantly, early period of chemistry was conducted in the Arabian and Chinese lands where many discoveries were made such as the gunpowder, using solvent on furnaces and controlling of heat to apply metals (Levere 2001, 5). Western chemistry was a late-comer. The westerners started to use chemistry and chemicals mostly after the Arabs. According to Joel Mokyr, chemistry and chemicals were not invented in Europe; however, its applications[18] were widely use in the continent (Mokyr 1990). Chemicals such as alcohol, acids, mercury and dyes were used in production; nevertheless, alchemy and chemistry were not developed in Europe until the renaissance of the twelfth century[19] (Freely 2009, 2012). Mokyr summarize this situation of Europe as: "*It was progress without science, chemicals without chemistry, but it worked*." (Mokyr 1990, 55).

The major contribution on scientific revolution was Galileo's criticism on *geocentric* and *Tychonic* universe system (Heilbron 2010). After all, starting with Galileo's writings and the Renaissance, scientific revolution and modern science had been on the rise in Europe. On the other hand science was declining in the Arab world where the initial stimuli created by Islam in the 10th and 11th centuries was a major deterrent of development of science after twelfth century[20] (Hourani 2013, 46; Lipsey, Carlaw, and Bekar 2005, 268–69; Saliba 2007, 234). The process of transition from alchemy to chemistry was mainly leaded by the Europeans. Robert Boyle (1627 - 1691) was the first person who made experimental research in chemistry[21]. Likewise, Boyle and Newton served for the good of determining of scientific principles in modern terms. It was the epicentre moment in history of

18 There was example about *gunpowder*. Although, Chinese discovered the gunpowder around sixth century, firearms which worked with gunpowder were invented and used for gaining dominance in Europe around thirteenth century (Mokyr 1990; White 1962).

19 The period was many changes in science and philosophy. At that period Islamic science declined and Western science raised.

20 Until twelfth Century, in science, there were many revolutionary developments. Today, we used scientific methods like *Alchemy*, *Algebra* which stems from Arabic and Islamic roots. In the prefix *Al* is definitive article in Arab language.

21 His master work is *The Sceptical Chymist* in which matter consists of atoms in motion and every phenomenon stems from those motion. (Boyle 1900).

science; hence, it was proofed that multiplying matter which means adding more and more matter particle in atomic scale was possible. Newton, in his *Principia*, wrote that "*everybody can be transformed into a body of any other kind and successively take on all the intermediate degrees of qualities*." (quoted from Newton: Levere 2001, 12). The research on transmutation and multiplication was carried until the 1700s under the name of Alchemy and Chemistry.

After these developments which marked the modern scientific thinking a new era in chemistry and chemical production started in the mid 18th century. With the help of the ground-breaking discoveries, scientific fields such as Astronomy and Physics constituted methodological dominance on science in the 18th century when chemistry was losing its significance thanks to a controversial philosophical debate on what can be called the "proper" science (Levere 2001). According to Immanuel Kant, chemistry is a systematic art rather than a *proper science* due to the fact that chemistry is empirical; however, do not include *a priori* knowledge that explained consciousness of its necessity (Kant 2004, 44). Furthermore, Michael Faraday argued that "*Chemistry is necessarily an experimental science: its conclusions are drawn from data, and its principles supported by evidence from facts.*" (Faraday 1974). Chemistry won back its importance in the second half of the19th century in relationship with other fields such as economics and thanks to a wide network of benefiters such as the universities, research groups, chemical societies, science societies and the industry that used chemistry to promote science and scientific activities. The two-way link between chemistry and economic prosperity was probably affected by the process of development of the chemistry (Levere 2001, 122). In this process, the chemistry as science slowly evolved in to a major economic asset: the chemical sector. Several factors played role in this transition from chemistry as science to chemistry as economic power such as the industrial revolution, expansion of population and increased funding for scientific activities. Such factors will be analysed in next part of the section.

Funding for science

One of the first examples of *funding for science* was Justus Freiherr von Liebig (1803 – 1873), a German chemist. Von Liebig founded organic and agricultural chemistry and applied in industrial scale. Moreover, he pioneered teaching in research laboratories[22]. His work and scientific efforts were crucial in establishing industrial

22 Research laboratories have a vital role in the industrial development of chemistry. Liebig founded his first laboratory in Giessen in 1842. He worked on the chemical process in specific areas. His efforts paved the way of university and industry linkages especially in Germany. Moreover, his model leaded universities in the USA and Britain (Brock 1997).

and research linkages in Germany and England in 1800s (Levere 2001, 133). In short, Von Liebig has two important contributions, which are economizing chemical materials and establishing research laboratories. The possibility of producing synthetic dye from coal-tar enabled the industry to produce chemicals in large scale. First commercial synthetic dye was developed and produced in England (Murmann 2003). Correspondingly, the story of commercial dye[23] was written by Sir William Henry Perkin, inventor - entrepreneur (1838 –1907), who discovered *mauve* (aniline dye) accidentally in 1857 (Murmann 2003). Perkin synthesized aniline purple from chemicals derived from coal tar (Garfield 2001). The discovery of aniline purple was a revolutionary step in chemistry. After all, Perkin's accidental discovery led development of industrial synthetic dyes (Murmann 2003, 24). Before the synthetic revolution, natural dyes or colorants was derived from plants and minerals; but afterwards, Perkin used chemicals that were widely available in the market and with the help of process innovations he was able to produce purple aniline in the cheapest way. Thanks to those scientific efforts, Germany pioneered industrialization of chemicals. Table 8 shows that Germany was a leader in the production of dye; moreover, the country had positive trade balance in the global chemical market.

Table 12: World Dye Production in 1913 (estimated)

	Production in tons	Consumption in tons
Germany	135,000	20,000
Switzerland	10,000	3,000
France	7,000	9,000
United Kingdom	5,000	23,000
United States	3,000	26,000
Other producers	2,000	
China		28,000
India		8,000
Italy		7,000
Russia		7,000
Japan		5,500

23 Commercial dye refers to *the first synthetic organic chemical dye* or *industrial aniline*. It is derived from coal tar (benzene plus toluene). Benzene plus toluene was proceeding with nitration. As a result of the process, the matter was reduced to aniline. The last process was oxidation. After oxidation, mauve - aniline purple etc. was obtained. In this process, the most crucial step is obtaining coal tar. Coal tar is a mineral (of fossilized carbon) and Germany has significant coal reserves and coal market.

Table 12: World Dye Production in 1913 (estimated) (continued)

Canada		1,200
Mexico		600
Australia		500
Africa		1,000
Others		22,200
TOTAL	162,000	162,000

Source: (Reader 1970, Volume 1: The Forerunners, 1870-1926:257–58).

The very roots of benefiting from systematic Research and Development (R&D) and science-driven industry were two German firms; Bayer and BASF in the end of the 1800s. This marked the beginning of a new industrial period where research laboratories promote science and researchers collaborate with industry. Homburg's work on German dye industry shows that there were two crucial points in the genesis of research laboratories in Germany. First one is the formation of German patent system in 1877 . The second one is the acceleration of discoveries in chemistry as a result of the rising numbers of academic chemists (Homburg 1992, 110). On the other hand, in the beginning of the 1900s when competition in new industrial sectors (electricity, chemistry etc.) was fierce, American firms such as GE and Bell had founded research laboratories with the help of American patent law (Reich 1985). In addition, DuPont established the first research laboratory in 1903 at Delaware to foster the development of chemical industry (Kinnane 2002). Patent system (or the intellectual property rights) was the oldest institution to induce innovation and industrial research (Granstrand 1999). Positive correlation between research and patents was observed in the dyestuff industry during the end of the 1800s. Figure 1 shows that German dyestuff patents were higher than Britain and US. The foundation of German research laboratories (especially BASF and Hoechst) between 1870 and 1900, the patent law and the managerial system affected the production in dyestuff industry in great extent.

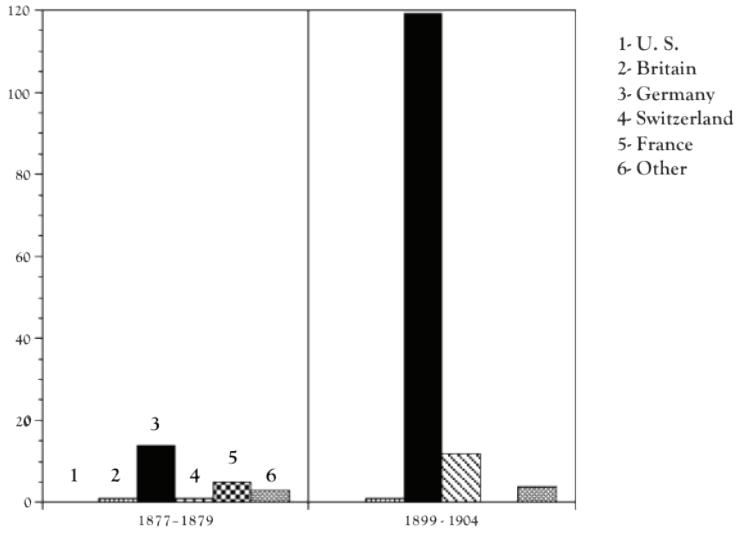


Figure 5: Number of Dye Patents in Germany, 1874 - 1904
Source: (Murmann 2003, 39).

Industry and research collaboration is even more important in an *innovation system approach*[24]. According to this view, innovation emerges with continuous interaction –both through collaboration and cooperation - of private (firms, entrepreneurs, private research institutes) and public actors (government, law and universities) in the boundary of a system (Edquist 2001; Fagerberg, Mowery, and Nelson 2005, 192; C. Freeman and Soete 1997, 271; Nelson and Rosenberg 1993), (B.-Å. Lundvall 1985, 29). In addition to system approach, Pavitt in 1984 proposed that chemistry is a science-based sector because development and innovation in the chemical industry was promoted and fostered by basic science (chemistry, biology, physics) and research activities (both academic and private) (Pavitt 1984, 362). His categorization was vital to comprehend the relationship between industry and science. In short, the genesis of the research laboratory and emerging collaboration between industry and science triggered the development of the chemical industry. Science was a suitable tool to foster innovation in chemistry. As Pavitt said, science-based firms were relatively R&D intensive, innovative and produce patent intense goods (Pavitt 1984, 366). This created a new production type for the market. Moreover, science-based firms offer specific solutions (for example substitution of fuel or rubber in different size and durability) and produce in large amounts as a result of economies of scale.

24 System of innovation concept was introduced by Lundvall's work *Product Innovation and User-Producer Interaction, Industrial Development* in 1985.

3.5 Expansion of Population and Industrial Revolution

In 1850, Britain has a significant economic size compared to US and Germany. The main reason for this economic development was advancement in machinery as a result of *Industrial Revolution*. Rise in population accompanied economic development (Table 9). As a result of expanding population, Britain's demand relatively rose (Landes 2003, 54). Cotton manufacturing and industrialization in the textile industry brought several changes for the chemical industry in Britain. First of all, expansion in textile industry increase demand from the chemical industry because the textile producers preferred to use synthetic dye instead of natural dye (Johnson 2000a). The second one was that changing living conditions due to new industrial setting (coal mining, textile, rising steam engine etc.) and the expansion of cities (fashion, new diseases, urbanization problems etc.) required new intermediates such as dye, soda, oil, synthetic, drugs etc. which were mostly supplied by the chemical industry. Lastly, between the two war, Britain took advantage of using chemistry for feeding an expanding industry that created innovations for further industrial growth (Johnson 2000a, 171).

Table 13: Population and GDP Levels 1860-1939

	Population (in Thousands)			GDP per capita (1990 Int. GK$)		
	Britain	Germany	United States	Britain	Germany	United States
1860	28,840	36,840	31,513	2,830	1,639	2,241
1914	46,049	67,790	99,118	4,927	3,059	4,799
1925	45,059	63,166	115,832	5,144	3,532	6,282
1939	47,991	69,286	131,028	6,262	5,406	6,561

Source: (Maddison 1991, 232–35, 2003).

Germany and US had the same population advantage (i.e., size) as Britain. Comparing with the 1800s, Germany transformed its market in to a less regulated one. In an age of heavy regulation around the world, deregulation was an advantage to realize economic growth. In addition, deregulation caused free market conditions to promote which brought breaking-up guilds, technical advancements and industrial growth in sectors like chemistry, metallurgy and mechanics (Bernal 2010, The Scientific and Industrial Revolutions:506). Britain and Germany had different approaches in developing the chemical sector according to Schröter. For example, cooperation and competition observed as important processes in developing the sector (Homburg, Travis, and Schröter 1998, 49). In addition, Alfred Chandler also emphasized the role of cooperation between firms and individuals when chemistry

was emerging as a sector (Alfred D. Chandler 1990). Accordingly, in the end of 1800s, Germany had a greater performance in chemistry in terms of promoting innovation and research activities. This performance also stemmed from demand conditions in the country and proper "science" and a university system as a mechanism which made cooperation between firms and academics easier. German dye industry, both domestically and internationally, was positively affected by size, industrial development and a rewarding science and university system, Germany, in 1863, produced %65 of total world dyestuffs (Meyer-Thurow 1982, 362).

In brief, importance of chemical sector in an economy arguably is observed in different ways. In Germany case, dyestuff and chemical products like inorganic chemicals (dye, soda, aniline etc.) was widely produced due to economic reasons. In fact, economic value of chemicals was high as a result of discovering inorganic chemicals like synthetic, rubber and nylon. Demand conditions and new market opportunity pushed German firms to access new dyestuff market. According to Murmann and Homburg, as a result of evolutionary conditions, there were many firms which willing to enter dye market across country during the end of the nineteenth century (Murmann and Homburg 2014). In the global level, dyestuff market was dominated by German firms between end of the 1800s and beginning of the 1900s shown Figure 2. Other market players like France, Switzerland, and Britain had different economic pattern. France was a leader in production of automobile. Britain had a greater chemical producer and its firms, named ICI (Imperial Chemical Industries), produced high number of chemicals. Historically, Britain was major country in producing synthetic dye industry in the early stage of dyestuff market (Reader 1970). However, how did Germany firms extremely rise among other countries? The question can be answered in three facts. First is R&D and science basis. German firms had own chemist and R&D division in order to make new chemical processes and products. This organizational advantage was main factor in making new chemicals and process (Homburg 1992). Second is Patent Law of Germany. For German dye firms, firms were lobbying to parliament and changed the law according to their benefits. For dye-making process, firms took incentives to make R&D and they granted 15-year monopoly right in the market (Murmann and Homburg 2014, 199). Third was number of firms. There was enormously higher competition between German firms compared to France, Britain and importantly USA. Those are important points to comprehend emerging of German dominant dye market. On the other hand, chemical production in USA was not insignificant; however, USA was latecomer in entering the dye industry. Actually, USA had a vital role to make innovation in chemical industry.

There were small numbers of firms however they had private and public R&D systems. Furthermore, relatively, university and industry cooperation risen in the beginning of the twentieth century (Homburg 1992). However, in the USA, dye producer numbers were low as compared with other European countries. There were two important reasons for explain this. First is lacking of textile network. According to Homburg, contrary to European case, USA had not a chance to develop network with firms which demanding synthetic dyes across trade route (Homburg 1983). Second was that USA did not possess own chemical suppliers and chemical intermediates. This problem was solved through trading with European firms.

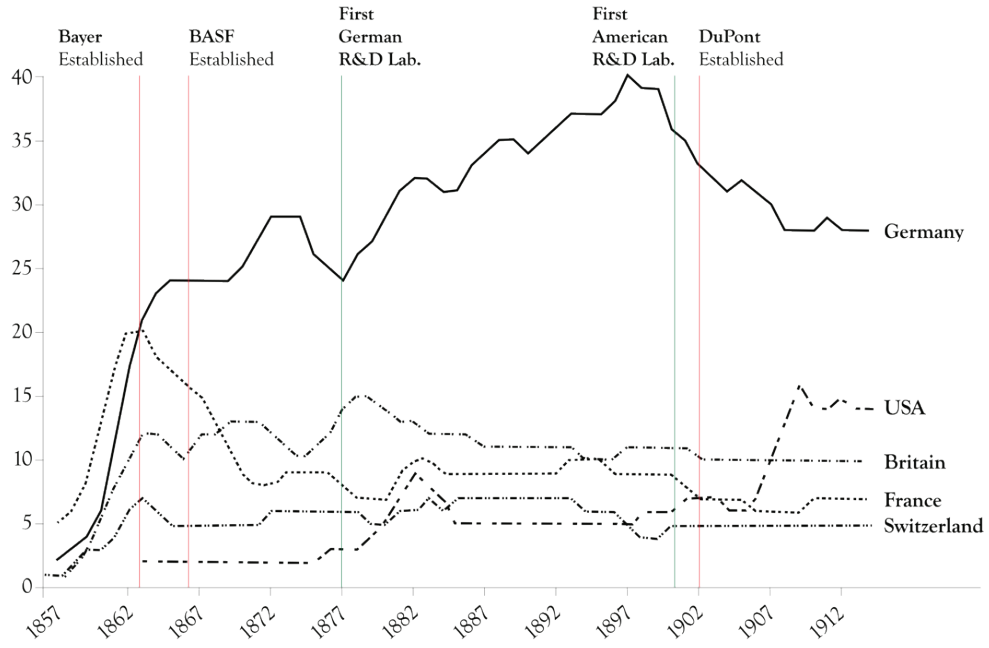


Figure 6: Number of Dye Firms
Source: Data from (Murmann and Homburg 2014, 191). Before consolidation of German firms (IG Farben) and DuPont's establishment date is added to Murmann & Homburg's data in order to enhance figure

Finally, in the global level, demand conditions, and utilization of economic values was prominent role in developing chemical sectors both USA and European firms. With the evolutionary perspective reasons that caused changing and variety between countries must be take account in order to understand economic relations. Furthermore, both each case, there are several important points economically.

First is firm variety and competition. End of the 1800s, European chemical market was more competitive than USA. Nevertheless, after World War I, producing different types of chemical products and innovative generic products was mainly coming from US continent. Second is difference in education and science systems. Germany has unique R&D systems which was directly work for the industry. On the other hand, USA had R&D system; however, organizational functionality was not as advanced as Germany's one.

This chapter aims to show the historical differences between Germany and USA. There are many causations in each case economically, politically, and historically. In this part of the thesis, historical and economic reasons is presented. Next chapter discusses firm level analyses to comprehend how did two chemical giants emerge? and which pattern did they use? Formation of IG Farben and Du Pont is issued in next chapter. The main concerning of the chapter is to understand several topics such as state relations, networks, organizational differences and science-industry relations.

CHAPTER 4

HISTORY OF THE FIRMS: IG FARBEN AND DUPONT

"Without coal and IG Farben, I can have no foreign policy."

Gustav Stresemann[25]

"The German nation is forced to live within a much too restricted space. Barred from owning the world's sources of raw materials, it is forced to produce the raw materials it needs for its national security out of its own deposits-from coal, salts, lime and other substances, as well as from air and water through chemical means."

Carl Krauch[26]

"More powerfully than any other industrial combine, IG Farben put its talents and capacities to service of the Nazi program of atmament, autharky, aggression and annihilation."

Stephan H. Lindner[27]

"DuPont people have transformed their company successfully for two centuries, making DuPont one of the most successful and sustained industrial enterprises in the world. Their story makes for exciting history, and this timeline tells how they did it."

DuPont[28]

4.1 IG Farben: Making a Chemical Giant

In economic literature, monopoly is defined by three main characteristics: making more profit, controlling market prices and barriers to entry (Bannock 2003, 262). IG Farben was founded on similar grounds to realize several goals such as reducing

25 Foreign Minister of Weimar Republic in Germany between 1923-1929.

26 He was the former executive in BASF until the establishment of IG Farben. Also, he was a member of NSDAP (National Socialist German Workers Party), and responsible for *Reich Office of Economic Development* (*Reichsamt für Wirtschaftsausbau*) in 1936 (Hentschel 1996, 162; Macrakis 1993, 102).

27 Professor and author of *Inside IG Farben: Hoechst During the Third Reich*.

28 DuPont's anonomous motto. It is quoted from the website: https://goo.gl/4KC6g1 (accessed date: 2016-11-22).

the production costs, diminishing operational and administrative costs, making high profit in the sector, and standing against suppression of competition from domestic and foreign markets (Lindner 2008). In addition, IG Farben's firms (BASF, Bayer, AGFA, Hoechst, Griesheim-Elektron, Weiler-ter Meer) aimed to manage scarce resources with the help of science of chemistry during the World War I. In the beginning of 1900s, IG Farben economically focused on subsiding scarce and expensive goods (such as organics: drugs, dyes, rubbers, fibers etc.). According to Reader and Murmann, in the beginning of 1900s Germany had a great role in the production of dye among other countries. Germany was a major producer and exporter at that time (Murmann 2003, 38; Reader 1970, Volume 1: The Forerunners, 1870-1926:258). Besides, there were two large competitors. The USA (DuPont) and Britain (ICI) were the primary rivals in terms of production of organic chemicals. The statistics of dye production also supported this picture (Reader 1970). Reader's detailed work showed that production of dye was 135,000 tons in Germany whereas consumption was only 20,000 tons. This gives a clue about Germany's production position in the market. On the other hand, USA's and Britain's (ICI was also a merger company which was founded in 1926) production efforts were considerable as well. Although, USA, Britain and France were main actors and innovators, which were responsible for many innovations in the synthetic dye sector from 1870 to 1900, Germany dominated the competition in the beginning of 1900s (Murmann 2003, 36–38). Figure 4 shows German foreign trade comparing 1900 and 1913. According to the data, German dyestuff industry and other chemical production exponentially increased between 1900 (represented in yellow) and 1913 (represented in blue). For instance, export of dyestuff was at the level of 5 million Sterling in 1900. In 1913, the numbers doubled to 11 million Sterling. Export of other chemical products rose as well.

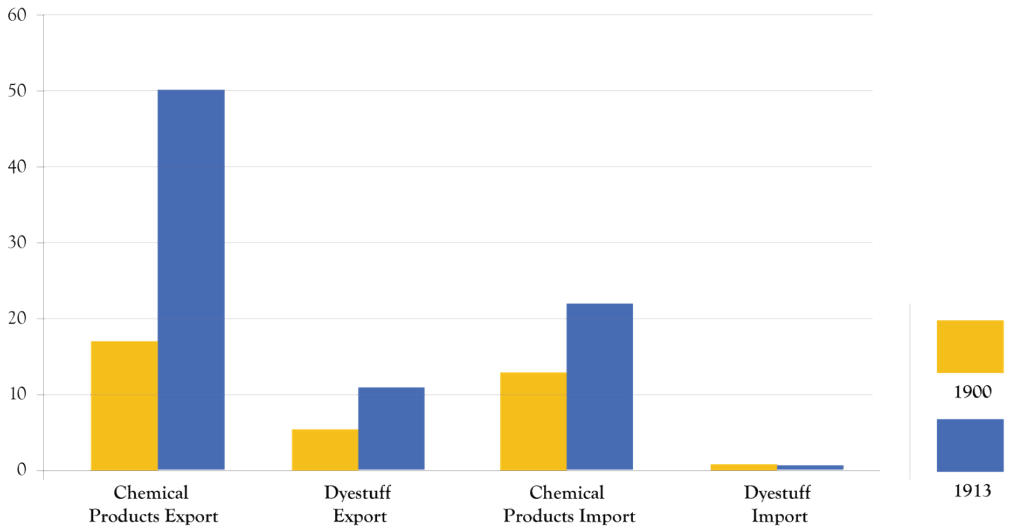


Figure 7: Exports and Imports of Chemical Products and Dyestuffs of Germany
Source: Data are composed from Haber (1971, p. 109).

In 1913, Germany had a net output of 120 million sterling and employed 120,000 people in the chemical and allied industries. Britain, which was the main rival in chemical sector, had 11.3 million sterling net output and employed 61,000 in 1912. On the other hand, USA had 840 million dollars (equal to 171 million sterling)[29] net output in all chemical sector including petroleum refining, ammunition and black powder. Excluding the goods of other chemicals, USA had 77 million sterling output and about 67,000 employees (Haber 1971, 108, 135, 174.; League of Nations Secretariat 1927). Both ICI and DuPont had the biggest market share in their domestic market. However, the highest demand from the rest of the world (East, China and India textile sectors) was generally met by IG Farben and its scientific talent. According to Chandler, British dyestuff corporations (especially before ICI) could compete with other firms in the world market thanks to the contributions of IG Farben's technical knowledge (*know-how*) (Alfred D. Chandler 1990, 360). New rivals in the chemical sector resulted in cooperation among firms. Therefore, new market opportunities were assimilated by the big companies like Du Pont and IG Farben.

Before the merger (before 1925), there was no stable condition in the chemical sector. Both the Great War and recession before the Great Depression affected the

29 Currency used as $4.90 = £1 according to Haber's work (Haber 1971, 174).

producers in terms of making new business and competing with rivals. As a result of the Great War, Germany had to pay war reparation according to the Treaty of Versailles. The Treaty proposed that *Allied Reparations Commission* set administered price for the chemical products produced in Germany. Hence, Germany, in other words IG Farben, paid reparations to France at an administered price. The products varied from organic chemicals (dye, fertilizers) to pharmaceuticals (drugs) (Alfred D. Chandler 1990, 564; Haber 1971, 249). The commission mainly focused on determining available resources of Germany and making payment possible in accordance with *Treaty of Versailles Article 233* (Hay 2002). This was a burden for the German economy which continued until Hitler's march to the parliament in 1933. In short, there were several reasons of the establishment of IG Farben which can be summarized under four main topics.

1. Unstable economic conditions after the Great War.
2. High and nearly impossible war obligations: financial oppression on chemical industries.
3. Rivals abroad and in home: Germany did not want to lose its market supply power in the world market.
4. Scarcity of national resources.

At this point, Carl Duisberg (Bayer's executive) had already underlined the necessity of stabilization for the chemical firms in Germany. In 1904, Duisberg called for all organic chemistry firms to create a monopoly in order to gain economic advantage (in other words to exploid economies of scale)[30]. Duisberg's call brought success to chemical firms in 1916. Big three (AGFA, BASF, Bayer) was founded as first IG known as single IG in the literature. Afterward, Duisberg proposed a new idea of union in order to avoid extra tax burden on the merger. This idea was accepted by all of the firms. At the merging stage, the biggest problem was the centralization of all activities and making new organization under one name. Stabilization came in 1924, and firms had the right to keep their individual names in internal activities and trademarks. Finally, IG Farben was established with its six constituents.

The name of IG Farben comes from *Interessen-Gemeinschaft Farbenindustrie AktienGesellschaft* (meaning community interest of dye-makers). It was officially founded in December 9, 1925 in Frankfurt, Germany. IG Farben was considered as a giant cartel because it was the largest non-governmental organization in Europe

30 Monopolistic market structure was common in Germany. For example, another important cartel was established by German Thyssen group (which consisted of Thyssen-Hütte AG, Krupp, and Hoesch-Werke AG) in order to form the national steel monopoly.

and the fourth in the world market between 1925-45 (Hayes 1987; Jeffreys 2010, 9; Lindner 2008). IG Farben consisted of six relatively big chemicals, pharmaceutical and dye-making companies. In 1925, *Bayer* (1863, pharmaceutical company), directed by Carl Duisberg, *BASF*[31] (1865, organic chemistry, dye-making) managed by Carl Bosch, *AGFA* (1867, medical and daily imagining systems), *Griesheim-Elektron* (1856, electrochemistry), *Weiler-ter Meer* (1877, textile dyes) and *Hoechst* (1862, dye-making) came together to form one company: IG Farben (Abelshauser et al. 2008; Aftalion 1991, 41, 103, 125; Heine 1990; F. S. Taylor 1957).

Clarifying the relationship between constituent firms and cartel partnership the discussion in this chapter benefits from network analysis. Purple nodes represent sectoral composition of the firms. IG Farben expanded to reduce within competition in Germany so to increase competitiveness of the overall chemical sector in order to exploid economies of scale thus power relations were one of the main elements of constituent firms. Therefore, in the analysis, use betweenness centrality to visualize power relations in terms of being central in the network (i.e., how important a node is in connecting to unconnected nodes). Turquoise nodes represent firms. This simple analysis show that, IG Farben's constituent firms come from different field of the chemical sector. Another key point, many relationships was determinant in founding of IG Farben.

Figure 5 summarizes how the establishment of IG Farben occurred using betweenness centrality among edges and nodes. In the figure, successors of the companies are also represented. In the figure, nodes are firms weighted by *firms' turnover size* and edges are defined as *merging* (*red lines)* into the IG Farben. Merging edges are weighted according to firms' *organizational sizes,* which reflect production amount and value added in the global market. 1 to 12 levels of weight are used for this purpose. Lastly, *become* (*yellow lines)* and *owned* (*brown lines)* edges point the situation of the firms after World War II. For example, Bayer founded in 1863 became part of the IG in 1925, relatively large size of the node reflects turnover and Bayer's acquisition variety. Bayer acquired Corn King Co., Pacific Plastic Co. and Ashe-Lockhart Inc. as can be seen from the brown lines in the figure. According to the figure, merging cluster shows that in the chemical sector, all merger companies benefited from scale and scope economies. On the other hand, the figure shows different types of main areas of firms (i.e., the purple nodes: organic, electrochemistry etc.). Thanks to interrelationship between firms, the cost of learning for seeking new technology,

31 Both Bosch and Fritz received Nobel Prize in Chemistry (respectively 1931 and 1918) and their invention which was *Bosch-Haber Process* was a notable progress in the production of ammonia in 1910.

resources and markets was reduced. In the next part of the thesis, interrelationship between other merger companies and investments that were made by IG Farben at home and abroad will be illustrated. In summary Figure 8 shows the evolution of firms, how IG Farben was formed and what it become after it dissolved at the end of the II World War. It was a huge organization carefully engineered to cover main areas of the chemical sector and at the same time that brings big players in the same area together.

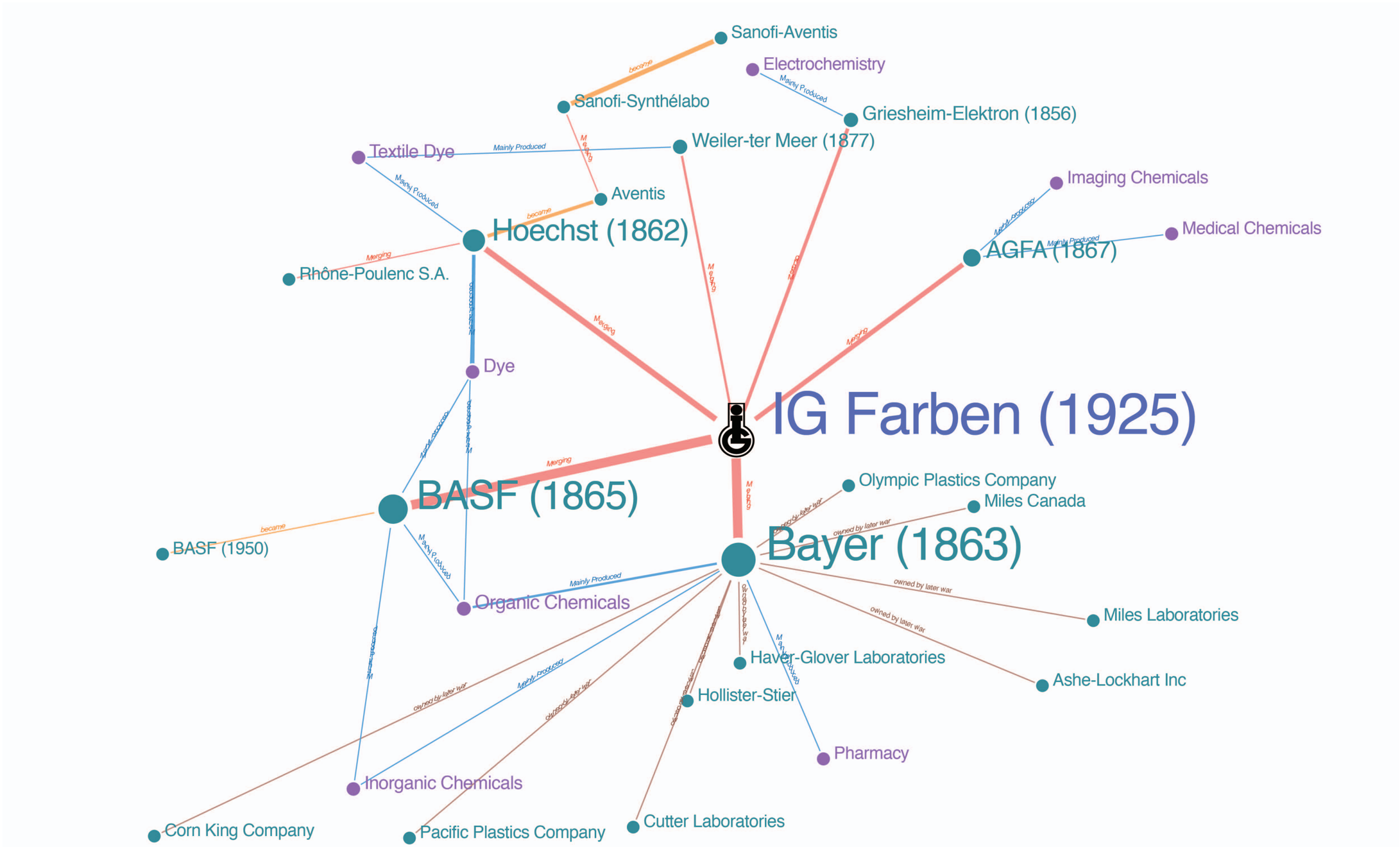


Figure 8: Foundation of IG Farben

Source: Data compiled from (Abelshauser et al. 2008; Alfred D. Chandler 1990; Haber 1971).
Notes: Represented Nodes: IG Farben in light purple; constituents (BASF, Bayer, AGFA etc.) in turquoise; main production areas (organic, inorganic chemistry) in deep purple Edges: "merging" in red; "mainly produced" (the firms' the main production lines) in blue; "owned by later the war" (if firms transformed at end of World War II) in brown; "became" (after dissolution of the firm) in yellow.

IG Farben was not only established for competing with other countries or getting over the economic recession, but it also was a giant organizational corporation which provided capital accumulation and technology transfer between merger firms. Haber stated that the shares of single IG were based on constituent firms' profit amounts. According to firm's profit numbers in 1906, BASF, Bayer, Hoechst had share of %24,82; Casella had %9,81; AGFA had %8,08; Grisheim Elektron had %6; Weiler-ter Meer had %1,65. The IG shares of individual firms reflect these numbers. There is the evidence that the cartel supplied capital and financial support among its members in order to diminish inequality (Haber 1971, 280–81). In addition to this, IG Farben exchanged licence, know-how and technological expertise. After the merger, nearly all firms continued their activities in their plants and buildings. However, the management was centralized, and all activities were controlled by the Central and Working Committees. Next part of this chapter will analyse the organizational aspects of IG Farben in detail. All central committees and structure of the organization are illustrated in the next part. The very details of the relation between organization and research are left to Chapter 5 and 6.

4.1.1 Teaching an old dog new trick: Organizational Structure of IG Farben

Germany had a long cartelisation story in its economic history. Cartels rose after the Great War as a result of instability in the economy and shortage of resources. Also, the main idea was economics of scale and its advantage on both home and abroad. According to Braun's comprehensive work on German economy, cartelisation gained importance in the late nineteenth century, in other words, at time of the Great Depression. Especially, sectors subject to scale economies like mining, steel, chemistry and iron had higher fixed costs, needed more specialized labour and had higher technological costs (R&D) which were the main reasons why firms tended to concentrate and form cartels (Braun 1990, 20–22). IG Farben was also established with more or less the same considerations. The first merger idea came from Duisberg. According to Duisberg, the most efficient way in the dye sector was specialization and producing in a way which was less costly than the rest of the world. IG Farben's first organizational strategy was outlined by Duisberg as well. Organization structure of IG Farben was unique compared to other rivals such as the ICI (British) cartel and DuPont (USA). There were several differences as regards to organization.

Firstly, IG Farben had a complicated relationship between internal and external economic activities. This means that merger firms followed their own economic activities, organizational routines, relationships and cooperation both in home and abroad. There were six main constituents in the beginning. Afterward, between

1926 and 1939, there were many partnerships and acquisitions. Figure 6 explains these complex relations of IG Farben between 1916 and 1945. All edges and nodes data come from different historical sources like seminal works, books and archival data. The size of the nodes reflects the betweenness centrality. The analysis shows that IG Farben was based on a complex organizational structure. It had 10 direct relationships and 24 indirect relationships, which shows that IG Farben was a great conglomeration that promoted, benefited and exploited variety of industries such as chemical, oil, electronics, and mechanics. This complex network enabled IG Farben to benefit from scale advantages and reduction of learning costs. For example, gasoline was produced synthetically by IG in 1927. Afterward, IG Farben acquired share of the Deutsche Gasoline which was an attempt to enter a new market as a major player. In addition, this new sector (gasoline) created new learning opportunities both organizationally and scientifically. As a result of this acquisition, IG Farben reduced marketing costs. IG Farben was not a corporate like others in USA and Britain. Its strategy was designed to reduce the costs and find efficient ways of production. Developing new organizational settings and marketing tools was just strategies to achieve cost reduction and efficiency gains in production. According to Chandler, Duisberg and Bosch agreed that constituent firms were capable of developing new products and inventions due to their old and long histories (Alfred D. Chandler 1990, 584). Each constituent firm brought its resources, network and work routines. In addition, Haber supported this idea from a different angle. Farben was founded on the grounds of reaching economic efficiency in large scale between 1925 and 1939. Firms which were at small scale had their own technical and scientific capabilities (Haber 1971, 285).

Secondly, IG Farben centralized its own internal firm's relations. There was an administrative council. It worked as general management of the firms in present day meaning. The head of the council may be called as the CEO of the firm - a position and its duties whom were carried out by Carl Duisberg. At this point one should keep in mind that, Duisberg was already experienced because of leading and organizing the 1904 and 1916 alliances (Alfred D. Chandler 1990, 564). His leading arguments were obviously supported by Hoechst and Bayer (Lindner 2008, 22–24). However, opposition in management of IG Farben came from Carl Bosch who was the chair at the Working Committee. Bosch and Duisberg did not agree about the firms' structure. Duisberg's ideas were more democratic than Bosch's. Duisberg believed an organization that constituents participate in full strength especially in strategic decision making and the business management positions better be filled by elections. Linder calls this "a sharp difference" between two leading chairmans

(Lindner 2008, 22). The discussion remained on the agenda until the establishment of the IG in 1925. Afterward, Bosch insisted on his more autocratic ideas about management of the firm. Bosch's position was autocratic in the sense that all stages of the management were designed under one-handed decision of the manager. This highly centralized decision making gave great power to Bosch. Most of the time he implemented his own decisions without the consent of other board members which was an important organizational management difference of IG Farben.

Bosch was a quick-minded person and his selection of company employees was done according to practical and pragmatic reasons. For example, in Bosch's idea, a famous and successful chemist was a reason to be selected to head of the research and development department. He could be thought as autocratic leader who prefer using more authoritarian way in organization rather than using more democratic ways (Alfred D. Chandler 1990, 567; Haber 1971, 284).

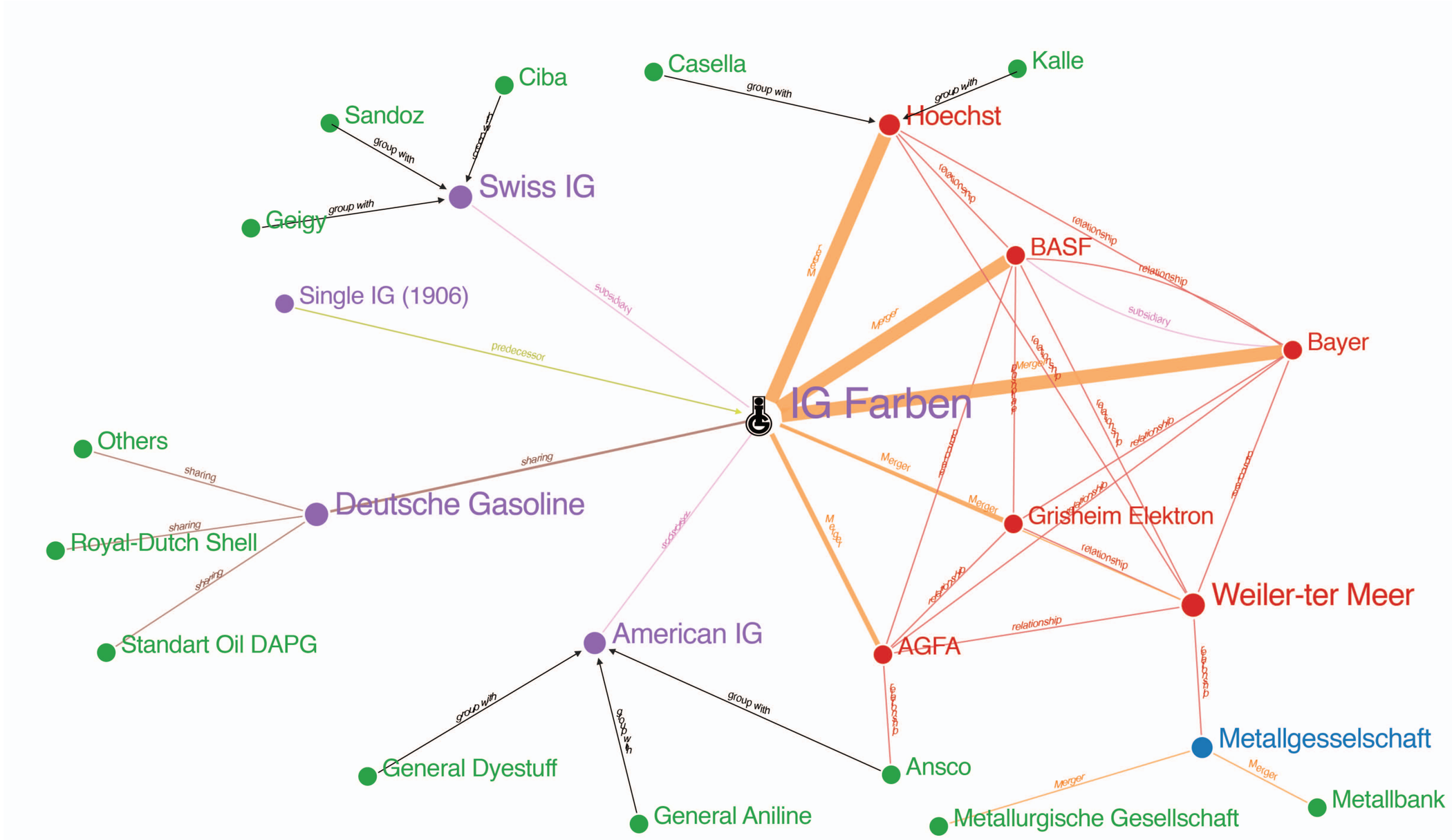


Figure 9: Business relationships of IG Farben

Source: Data compiled from (Abelshauser et al. 2008; Alfred D. Chandler 1990; Haber 1971; Hayes 1987; Jeffreys 2010; Lindner 2008; TerMeer 1953).
Notes: Represented Nodes: Purple: forms of IG Farben (meaning: Cartel's partnerships, and participations); Red represents constituent firms (Bayer, AGFA etc.); Green: other members or shareholder of the firm (Kalle and Casella were shareholder of Hoechst); Blue: different cartel which is related to IG Farben cartel. Edges: Red shows all "relationships"; Orange shows "merger" relations; Brown: shareholder of the related firms; Pink represents "subsidiary" firms to the main firm; Green shows before merging identity of firms. And light brown represents "group with" with other firms (like American IG is consisted of three other firms)

Farben, research and development activities was fundamentally conducted by the self-government in Sparte under the supervision of the headquarter in Frankfurt (Alfred D. Chandler 1990, 560).

These production and research systems were unique to IG Farben. Rivals in the chemical industry like ICI and DuPont had their own unique systems. These complex organizational systems and its benefits were also analysed by Chandler as a "comparative managerial system" which means that large enterprises and its complex organizational systems enable efficient production through learning. Managerial capabilities and unique organizational designs were important to handle advantages and disadvantages that accrue from scale and scope. As a result of this, capitalist corporates may tend to make their activities innovatively in large scale (Alfred D. Chandler 1990, 587). Chandler's idea finds its support in IG Farben of Germany. Figure 7 shows the complex structure of IG Farben's organization.

32 Heinrich Caro was a German chemist who was responsible for synthesizing alizarin dye at BASF research laboratory.

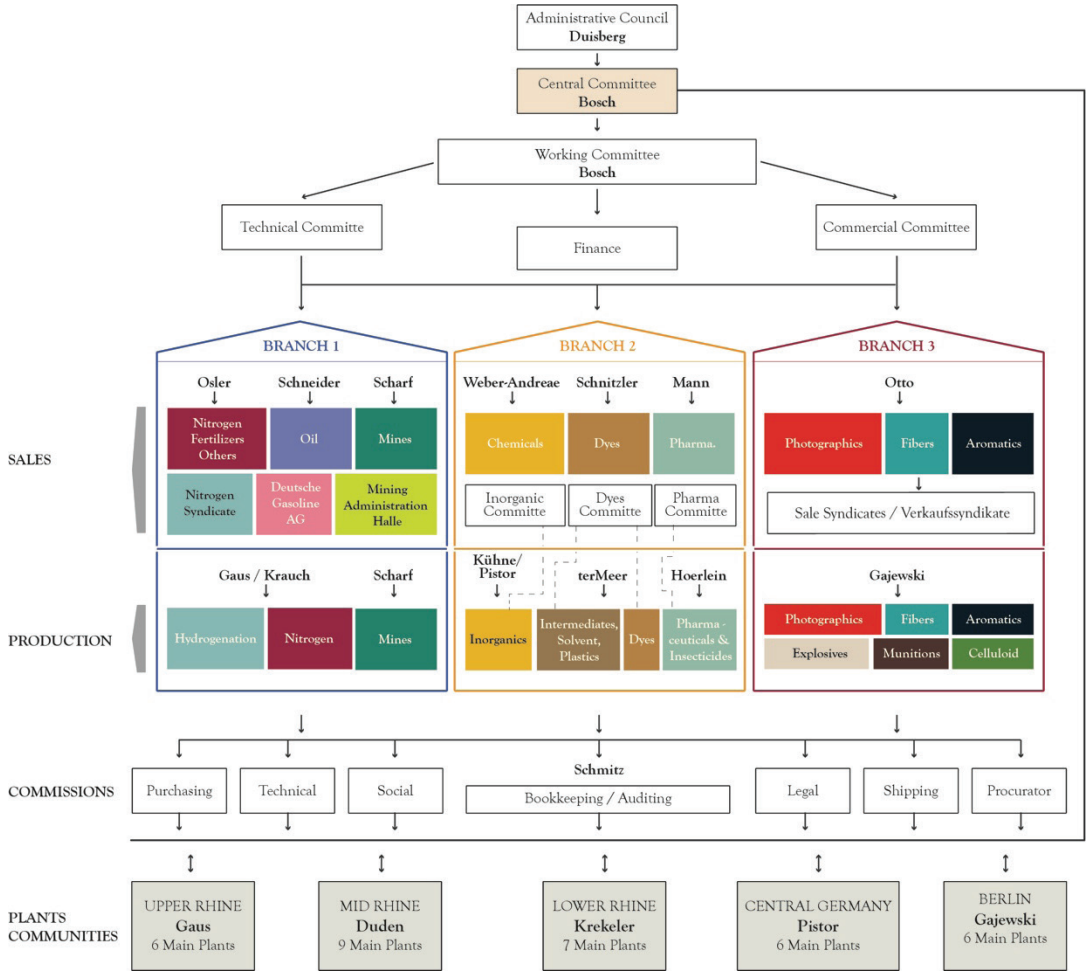


Figure 10: Complex Organizational Structure of IG Farben
Source: Redesigned and compiled from (Alfred D. Chandler 1990, 570; Hayes 1987, 388).

Notes: Manager names are indicated in bold.

This organization schema presents IG Farben's intra-business relations. In short, IG Farben was governed by a unique complex managerial system where divisions (especially research) were self-managed quasi-independent entities that report and act according to the general routines that are established by the centralized working committees.

4.1.2 Research activities of IG Farben and Hitler's Rising

There were sharp differences between Hindenburg's (1925 – 1933) and Hitler's (1933 – 1945) governmental service in terms of IG Farben's science, production,

and research efforts. When Hindenburg was defeated by Hitler in a democratic way in 1933, Farben's freedom was constrained by the authoritarian government. Before Hitler, IG Farben mainly focused strengthening its competitive position and international cooperation. When Hitler took the office he immediately called the IG Farben *Vorstand* (Governing board) to decide on the new economic agenda of Germany (Hayes 1987, 84). Initially, Nazis demanded money for developing and supporting its party agenda on the condition that IG Farben could carry out its routine activities (Hayes 1987, 86). This was the beginning of Nazis' intervention to the corporations like the IG. In 1939, Poland was occupied and World War II was ignited by Germans. The short process from the Nazi occupation to the start of the World War II slowly transformed IG Farben from a free self-governing giant cartel in to a state-controlled corporation.

IG Farben was a relatively free firm in terms of decision making between 1925-1929. After the crisis and rising fascism, the authoritarian government slowly transformed the firm. In such a short time IG occupied a central role in not only supplying resources to pursue war but also financing the war. For instance, Reich's needs was proposed to IG representatives in a series of secret meetings in 1940 (Jeffreys 2010, 274). Those meetings were arranged by the Economic Ministry and *Wehrmacht* commanders. The Nazis demanded synthetic fuel, gasoline, synthetic rubber and rayon during the war (Alfred D. Chandler 1990, 583; Cornwell 2004, 371) which were all provided by IG Farben's plants. For rayon and similar business lines, IG Farben made a joint venture contract with VSt (Alfred D. Chandler 1990). Figure 8 shows the chemical production index (all areas coal, oil, organic and inorganic etc.) between 1925 and 1929. Production was moderately constant (1925=100) in the stabilization and establishment era. Subsequently, in the following years, Germany's chemical sector production rose %7.9 annually on average while German economy grew %4 annually (Abelshauser et al. 2008, 212).

Figure 11: Chemical Production in Germany between 1925 and 1929

Source: (Abelshauser et al. 2008, 213).

There is no reliable data on the turnover and the German industrial production between 1939 and 1945. However, Haber stated that IG Farben, in 1926, had a turnover of 1027 million RM. In 1929, it was 1420 million RM (Haber 1971, 284). According to Chandler and ter Meer's works, in 1933, when Hitler came in to power turnover was 891 million RM. Just before the war, in 1939, Farben had 1939 million RM turnover (Alfred D. Chandler 1990, 581; TerMeer 1953, 116). IG Farben employed 84,000 persons in 1925. In 1928, this number was 114,000 persons. Furthermore, in the concentration camps at Auschwitz and Buna about 300,000 slave labour settled during the war and around 30,000 died in the camps in 1944 (Cornwell 2004, 373). Moreover, 10,000 people[33] were working under the Buna rubber factories based on Nazis' Four Year Plan (Rees 2005, 222). In short, IG Farben transformed its production line and slowly evolved from a free corporation that benefitted scale economies to achieve cost minimization to a giant cartel that not only served but also gained from the authoritarian power. World War II stimulated Farben's production by great extent. However, scientific activities and especially research was conducted according to Nazis' needs just opposite to the early times of the firm where research was by and large governed in a decentralized manner. Nazis' final

33 Famous Italian Writer Primo Levi also was forced to work in the Buna factory. Levi told his bad experience with chemistry laboratory in his book entitled as *If This Is a Man* as: "*The ravaged Buna lies under the first snows, silent and stiff like an enormous corpse; every day the sirens of the Fliegeralarm wail; the Russians are fifty miles away. The electric power station has stopped, the methanol rectification columns no longer exist, three of the four acetylene gasometers have been blown up.*" (Levi 1959, 161)

solution[34] and the Jewish policy afterwards were the turning points for the firm (Jeffreys 2010, 310). Afterall, the main aim of the Nazi plan was to excluded Jewish, political opponents and "others" by murdering them in systematic way.

In light of the historic business background, IG Farben can be assessed roughly in four major periods, which are; before the merger (1906 – 1925), founding and rising period (1925 – 1933), Nazi period (1933 – 1945), and liquidation period (1945 – 2012). The research activities of the firm were highly extensive in the first and second period for several reasons. The first reason was that constituent firms had research experience from the past. BASF was founded in 1865 and it had its own research laboratory inside the firm. Cooperation with the university was carried out by Caro himself (Abelshauser et al. 2008, 52–53). This relationship was defined as "symbiotic" since Caro and BASF sent researchers and employees to universities specifically for obtaining scientific knowledge from the university. As a result of this, BASF established its central laboratory in 1877 (*Hauptlaboratorium*)[35] in order to spur and use scientific knowledge for innovation activities (Homburg 1992, 100). In addition, because of Duisberg's initiative, Hoechst opened its own central laboratory in 1889. It has been already stated that IG Farben had no central laboratory (Haber 1971, 357). Premises of individual firms were maintained, for example, AGFA developed its photo and imagining research in Berlin and USA (*Ansco*), BASF had research operations in its main laboratory in Ludwigshafen (Abelshauser et al. 2008, 230).

34 The extermination of Jewish people was a Nazi plan. Eichmann was the key person responsible for the transportation of the Jewish people to the camps. Those camps also included IG Farben's plants such as *Buna-Werke*, *Birkaneu* and *Monowitz*. Farben agreed the transformation of the plants into concentration camps and financed them (Borkin 1979). Furthermore, Hannah Arendt, an observer and reporter at Adolf Eichmann's trial, reported that Eichmann had a responsibility of sending people to suitable camps. This process was done by him according to "*absorptive capacity*" (words of Arendt) of the persons. A giant like IG Farben used these people as resource in their business (Arendt 1994, 249). Towards the end of the War, strong business relationship changed and Himmler interestingly changed his mind. Besides the financial suppot of IG Farben and Krupp, Himmler demanded money and goods from the Jewish society. There was an interesting moment according to Arendt in Jerusalem trial. She quoted that "*In a discussion of Himmler's offer in 1944 to exchange a million Jews for ten thousand trucks, and his own role in this plan, Eichmann was asked: "Mr. Witness, in the negotiations with your superiors, did you express any pity for the Jews and did you say there was room to help them?" And he replied: "I am here under oath and must speak the truth. Not out of mercy did I launch this transaction"—which would have been fine, except that it was not Eichmann who "launched" it. But he then continued, quite truthfully: "My reasons I explained this morning," and they were as follows: Himmler had sent his own man to Budapest to deal with matters of Jewish emigration. (Which, incidentally, had become a flourishing business: for enormous amounts of money, Jews could buy their way out. Eichmann, however, did not mention this.)*" (Arendt 1994, 105).

35 This means that BASF did not have only one central laboratory. Many of the private and small laboratories were handled by BASF during that time. Moreover, work of Homburg et al. shows a systematic relationship of research and innovation inside BASF and Hoechst's activities.

Hoechst had process laboratory which conducted applied research and developed chemicals to make intermediates in 1934 (Lindner 2008, 274). The second reason was that German firms cared about research and management issues because of the competitiveness and high profit in the new emerged market. The country had a huge chemical industry and they were experienced in routine testing and analysing inside the laboratories (Haber 1971, 357). The situation created a successful path for German chemical industry had already benefited from systematically research generously. Similarly, DuPont was the first firm doing research too. At this point, the path was shaped by the German view of science and the chemical industry provided innovations for other industries like pharmacy, automotive, defence etc.

Table 14: Research Activities of IG Farben (RM million)

		1927	**1928**	**1929**	**1930**
Sparte I (*nitrogen, oil from coal, synthetic products*)	***Research***	106	92	82	56
	Sales	500	540	480	340
	Turnover	590	670	672	500
	Research %	21,2	17,04	17,08	16,47
Sparte II (*dyes, pharmaceuticals and general chemicals*)	***Research***	40	40	48	38
	Sales	686	760	792	700
	Turnover	1035	1116	1112	915
	Research %	5,83	5,26	6,06	5,43
Sparte III (*photo products, films, fibres and other imagining products*)	***Research***	8	8	8	6
	Sales	80	120	150	130
	Turnover	90	114	120	116
	Research %	10,00	6,67	5,33	4,62

Table 14: Research Activities of IG Farben (RM million) (continued)

Total	***Research***	154	140	138	100
	Sales	1266	1420	1422	1170
	Turnover	1715	1900	1904	1531
	Research %	12,16	9,86	9,70	8,55

Source: Compiled and redesigned from (Alfred D. Chandler 1990, 581; Haber 1971, 358; Tammen 1978, 50; TerMeer 1953, 116).

Notes: Research, sales and turnover figures have been rounded off. Some figures were in Sterling currency. Conversion of the currencies were calculated according to Bidwell, 1970, p. 22; Haber, 1971 (20 RM= 1 Sterling between 1927 – 1930). After conversion and compiling of the data, which was taken from the German archives, all data was cross checked with noticeable works in the literature on IG Farben.

Research expenditures of IG Farben are summarized in Table 11. According to the table, production divisions (in German *Sparte*) managed different level of productions. Sparte 1 was responsible for producing matters such as nitrogen, oil from coal, synthetic products. The division had the biggest expenditure amount among the others. In 1927, Research expenditure was 106 million RM and towards the global crisis it reduced to 82 million RM. In 1930, all divisions reduced expenditures due to the global crisis. Sparte 2 produced dyes, pharmaceuticals and general chemicals. In this level, responsibility of research was on the oldest chemical firms like BASF and Bayer. Their rich human capital with capable labour, well-equipped laboratories and technology patents and licences set up a research strong base where further research activities flourish. This division had the highest turnover numbers, which can be observed from Table 11. In 1927, %60 of total turnover was provided by Sparte 2. Sparte 3 had relatively lower research numbers. This sparte included photography products, films, fibres and other imagining products that were mainly produced by AGFA in Berlin. Average research expenditure was %17 of total sales for Sparte 1 between 1927 and 1930. For others, those numbers were under %10. In sum, IG Farben invested %10,07 of its turnover to research activities in the late 1920s. This number is huge by current standards. For instance, BASF invested 1.8 billion to R&D activities in 2016, which is only %3,2 of total sales. On the other hand, Bayer invested 4.6 billion to R&D activities, which is roughly %10 of its sales ("Bayer's Annual Report 2016" n.d., "BASF: Half-Year Financial Report 2017" n.d.). Du Pont spent about 1.6 billion to R&D, which is about %6,5 of total sales. Compared to these numbers driven mainly by the current knowledge economy investing about %12-13 to research in 1925 is very important.

When IG Farben and university relations are considered, strong relations of the firm with the university students and academic staff was observed. Chemical manufacturers like BASF and Bayer retained their research activities inside the factories (at Ludwigshafen) and support it from the outside utilizing links with the university. In a similar manner, IG Farben carried out its research and development activities within the factories with the support of academics (Abelshauser et al. 2008, 230). Working groups of IG Farben were responsible for conducting and managing such activities. According Abelshauser et al., at the end of 1925, 44 academics were employed as researchers and academic consultants in IG Farben. This number was 47 in the early 1930s (Abelshauser et al. 2008, 231). Ludwigshafen was the main centre of R&D for both IG Farben and BASF where ammonia was largely developed and produced. Oppau plant was an investment of BASF before the merger. It produced agricultural fertilizers and several intermediates for the industry. Moreover, there were several important laboratories in IG Farben the most important of which was the High Pressure Experimental laboratory. Its activities were conducted by Matthias Pier who was an industrial chemist working on the production of synthetic gas and methanol (Abelshauser et al. 2008, 232). Total workforce in Oppau was 14,631 in 1925. This number increased till the Great Depression.

On the other hand, the number of chemistry students could be a good example of the national attitude towards the chemistry sector. In Germany, between 1920 – 1929, there were about 31.500 chemistry students (Haber 1971). USA had about 18.900 students about the same time[36]. When size of the countries is taken in to consideration one can see the importance of chemistry in Germany. However, the importance of chemistry education may be helpful to understand national policy on industrial production. Germany had paid attention to education-science-industry relations from the beginning of 1800s to early 1900s. The establishment of BASF and Bayer was a proof for the national policy of industrialization. Chemistry required skilled persons who were willing to test, analyse, research, develop and eventually produce. This means that theoretical knowledge and practical knowhow formed the main impetus for the development of chemistry as science, which was also valid for industrial chemistry. Just to give an example regarding the importance of chemistry one can consider Nobel Prize in chemistry during the life of IG Farben. The Nobel Prize data shows that the total number of the prizes was seven for Germany between 1927 – 1944. For the same time period, the USA had only two Nobel Prizes in chemistry (Rajasekharan and Tiwari 2016).

36 By the way, the number did not include the years between 1922 – 1923.

4.1.3 End of IG Farben and Liquidation after World War II

Although, IG Farben was the biggest corporation in Europe and the pioneer for research and scientific activities, it had a corrupt reputation after Hitler. After Duisberg's leadership, Carl Bosch took the top management in 1935. Meanwhile, Hitler proposed a new economic plan for Germany. Afterward, in 1936, Four-year Plan for Germany was put into force by Hermann Goering. The justifications were simple: making a new German economy, which was self-sufficient and that promoted industrial, scientific and technological production for economic recovery and independency. Hitler justified his idea with words: "*I am establishing this today as the new Four-Year Program. In four years Germany, must be completely independent of foreign countries with regard to all materials that German talent, our chemistry and machine industry, as well as our mining industry can itself produce in some way.*" (Noakes and Pridham 1998).

The plan was conducted in several steps one of which was conducting research and development activities. Karl Krauch was made the responsible chemist and manager for the activities by Goering (unofficial name was *Office for the Expansion of IG Farben* in Germany: *Amt fur IG-Farben Ausbau*) (Hentschel 1996, 32). The second step was making an agreement with IG Farben on some important issues regarding resource management, input production and finance. Domestic fuel must be produced by the Germans with resources at limits in Germany. According to Krauch, this was possible by using raw materials. Production of aviation fuel was a vital step for both the aftermath of the war and the destiny of Hitler. Krauch via hydrogenation process made aviation fuel production possible. Testing of the fuel was done by Lufthansa (Borkin 1979, 57–58). Providing resources for Germany in support of preparation for the war was a turning point in the history of IG Farben. This tight relation between Nazi Germany and the firm was based on another agreement to make more fuel and rubber for Germany. Hitler demanded to increase IG Farben's capacity of plants to increase the production of fuel. In return, Nazis gave a guarantee to IG Farben to pay the cost of production. According to Borkin, this was a critical moment in political history, since Hitler was able to solve the problem of foreign dependency on oil. The production of synthetic fuel was an important element for the German defence in the World War II (Borkin 1979, 60). The same conditions were valid for the problem of dependency on rubber. Several concentration camps (Buna-Werke camps in Poland etc.) and slave labour (Jewish, political offenders, gypsies etc.) served to make rubber and develop a synthetic substitute for it (Harp 2016, 105). IG Farben relations with the Nazis are clearly observed in Table 12. From

1933 to 1939, net profits and support to Nazi party gradually increased. After the four-year plan of NSDAP, contribution from IG Farben and other enterprises (such as Krupp, steel trust etc.) also gave support for the policies and the accompanying strategies of the Nazis. Before the War broke, IG Farben was the main producer for and supporter of the National Socialist Party. Table 12 also shows that contribution to NSDAP was a profitable business for IG. The contributions as ratio to net profits rose from %4 to %6 in three years. But especially after 1936 the ratio falls to about %3-4 though contributions in absolute terms rise. It is remarkable to see that from 1935 onwards profits doubled in a year and tripled in about three years which is an indication of how profitable was working with the Nazis – a somewhat rational decision for a profit maximizing firm.

Table 15: Contributions of Net Profits of IG Farben (in '000 RM)

Year	Contributions to the NSDAP	Net Profits
1933	3 584	74 000
1934	4 020	68 000
1935	4 515	71 000
1936	4 960	140 000
1937	5 467	188 000
1938	8 156	191 000
1939	7 538	240 000

Source: (Noakes and Pridham 2000, State, Economy and Society 1933-1939:121)

Notes: "*Contributions to the NSDAP*" numbers are rounded up

Finally, at the end of the war, Germany was defeated by the Allied Powers. IG Farben's plants such as Buna-Werke, Monowitz, and Auschwitz were bombed by RAF (Royal Air Force) in 1944 to cut production exploiting slave labour and other war-related resources which were produced for supporting the War (Overy 2013, 583–84). When allied powers won the War, the end had started for IG Farben. In 1944, Farben's status was unclear. The Russians took control of some plants, however much of the assets of the firms remained in West Germany. After the war, three successors took their capital and started the new businesses. Those were BASF, Bayer and Hoechst.

IG Farben's activities were stopped and IG Farben trials started in 1947. Denazification of the firm resulted at Nuremberg. According to the indictment of the USA, Carl Krauch and twenty-two others[37] were on trial "*War Crimes and Crimes against*

37 **Hermann Schmitz**, **Georg von Schnitzler**, **Fritz Gajewski**, **Heinrich Hörlein** (*head of chemical research*), August von Knieriem, **Fritz ter Meer**, Christian Schneider, **Otto Ambros**, Max

Humanity and participated in a common plan or conspiracy to commit these Crimes- all as defined in Control Council Law No. 10. These crimes were said to include planning, preparation, initiation and waging wars of aggression all invasions of other countries... other crimes such as the production and supply of poison gas for experimental purposes on and the extermination of concentration camp inmates, the supply of Farben drugs for experiments on such inmates..." (United Nations War Crimes Commission 1947, 1–3). After indictments, 13 of defendants were found guilty and others were not. The maximum charge was given to Walter Duerrfeld who was a German engineer and plant manager of the Buna plant (Verg, Plumpe, and Schultheis 1988, 298). Finally, IG Farben was found guilty according to "*Those who knowingly participated in and approved the utilisation of slave labour within the Farben organisation should bear a serious responsibility as being connected with and taking a consenting part in war crimes and crimes against humanity, as recognised in Control Council Law No. 10*[38]." (United Nations War Crimes Commission 1947, 62).

After Nuremberg trials, IG Farben was defunct in 1952 and the successors started their activities. The six successors (AGFA, BASF, Bayer, Caselle, Kalle, and Hoechst) recovered, started new production activities in a short time and reached the 1939 chemical production levels at the end of 1949 (Jeffreys 2010, 403). Actually, General Eisenhower demanded to dissolve the firms immediately after the trials[39]. Because of the Cold War and German economic uncertainty, this was delayed. Liquidation of the Farben started in 1952 (*The New York Times* 1955) and was completed in 2013 after about 60 years. Liquidation process of IG Farben was obviously not easily completed. After the war, families of extermination victims claimed compensations for their lost. In 1999, the Farben's share was traded in Frankfurt (Andrews 1999). On the other hand, the real estates of the old company were another problem in the dissolution process. After compensation claims and a long period, the process of liquidation could be completed in 2013.

Brüggemann, Ernst Bürgin, Heinrich Bütefisch, Paul Häfliger, Max Ilgner, Friedrich Jähne, **Hans Kühne**, Carl Lautenschläger, Wilhelm Rudolf Mann, **Heinrich Osler**, Carl Wurster, Walter Duerrfeld, Heinrich Gattineau, Erich von der Heyde, Hans Kugler (*names in bold indicate manager positions in divisions or branches*).

38 "Control Council Law No. 10, Punishment of Persons Guilty of War Crimes, Crimes Against Peace and Against Humanity," 1945.

39 This was reflected in the press as "Allies Order I.G. Farben Dissolved; 'Sound' Units Will Run Separately; Farben Break-Up Ordered by Alles" (Raymond 1950)

4.2 DuPont: A Corporate driven by Systematically Science

The DuPont was founded 215 years ago as a gunpowder producer by Eleuthére Irénée (E. I.) Du Pont in Delaware, Wilmington (Kinnane 2002, 30). The broad history of the company include science, novelty, innovations and making chemicals that changed the world such as *Teflon*, *Tyvek*, *Nylon*, *Lycra*, *Nomex* etc. Such innovations enabled us to comprehend the link from science to innovation and even go beyond of what we think we could achieve. For instance, the first moon project was supported by DuPont's various innovative products (Kinnane 2002, 195). Chemistry sector has always presented good examples of how scientific knowledge can satisfy economic needs.

As mentioned in the previous chapter, American economic history was shaped by the virgin nature that provided valuable resources for the industries. Economic institutions and organizations evolved so to benefit and utilize such rich resources. New transportation needed to use flat land areas, telecommunication applied to all over the continent, and population demanded more consumer products. Firms which were technologically sufficient and that formed the right routines survived, but some others did not.

Initially, Du Pont was not only a company that promoted innovation and scientific activity, but also promoted industrial development, which was an unwritten government backed mission at the beginning of 1900s. Like Germany, USA was also a late-comer in terms of chemical industries (Landes 2003, 336). As a result of this, USA and Germany compete on the grounds of the most innovative period of our science and technology history with its unique organizations, institutions and ecosystem. Chemical industries are knowledge intensive and versatile ecosystems. It affects all production systems in an economy. According to Mokyr, with Chandler's words, after the first industrial revolution, production system changed in terms of scale. As a result of rapid improvements in communication opportunities and transport infrastructure, scope rather than scale economies gain grounds. (Alfred D. Chandler 1990; Mokyr 1990). In addition to this, Hughes said that rising network systems, railroads, electricity and chemical products were consequences of the improvements in technological production (Hughes 1983, 140). Chemicals made a lot of things possible. As a result of development in synthetic materials, it made the production easier. Economic problems like scarcity and mass production with resources, and material problems like durability and lightness were solved with advances in synthetics.

The story of Du Pont should best be understood in such an economic, political and scientific system within the reality of North American economic history. This part of the thesis focuses on how Du Pont emerged and served the economy. In order to answer this question, three main titles are planned. The first is the history of the establishment of Du Pont that covered about hundred years from 1800s to 1900s. The second one is production and innovation period between 1926 – 1945 so to match the IG Farben case. The last section briefly overviews the situation of the firm after the War.

4.2.4 Establishment of the firm

During the French Revolution, I. E. Du Pont's father dealt with his printing works. His name was Pierre Samuel du Pont de Nemours. Fate of the DuPont family was affected from the social network of Pierre Du Pont. Pierre was friends with the famous and notable chemist in his time, Antonie Lavoisier (Gould 1991). Lavoisier had numerous contributions to modern chemistry such as Law of conservation of mass, existence of oxygen[40], and naming chemical compounds[41] (Yount 1997, 14). Like the British Perkin, Lavoisier also was a pioneer in science of chemistry. Lavoisier assisted the family in two ways. The first was a deep scientific and practical knowledge about chemistry and the second was his gunpowder research and its influence on the family to enter gunpowder business. During the French Revolution, Lavoisier remained in France, he was found guilty and sent to guillotine[42].

I. E. Du Pont did not want to be a victim of the Revolution in his homeland. I.E. had experience in France in black powder business. Also, his family was noble and rich. Moving to the America was a start to make black powder business abroad. As a result of the American Civil War, the government was demanding more gunpowder, which ignited the establishment of Du Pont. As known from archival letters, Benjamin Franklin, Thomas Jefferson and Pierre Samuel du Pont de Nemours had a close business relationship around 1800 (B. Franklin 1772; Jefferson 1816). With

40 He was the first person who identified and named *oxygen* as an element.

41 In chemistry, two or more elements are groupped as a substance, for example, oxygen and carbon are elements. When elements are grouped as substance was merely called as compound. For instance, Carbon Dioxide was formulated as CO_2 and its compound consists of two oxygen molecule and one carbon molecule. This systematic naming was started and founded by Lavoisier.

42 There is an intresting story about Lavoisier's end. He was a noble researcher and chemist. He mainly focused on Black Powder research. During the Revolution, he was arrested and tax collectors put him to trial. He was found quilty and sentenced to death punishment. He asked for time to finish his scientific work. However, the reply was short and informative "*republic no need to scientists - La république n'a pas besoin de savants*" (Gould 1991, 354).

the help of this relationship, I. E. Du Pont bought gun powder machinery from the British and began to work for supplying powder to the America (Kinnane 2002, 17). In America, the family shaped its gunpowder mills in accordance with land ownership. The original first mills were founded in 1802 and other mills, which were Hagley and Upper Yard, were established around Wilmington until 1936. Main powder needed three main compounds: sulphur, saltpetre, and charcoal. Sulphur was provided from Italy. Saltpetre was a complicated product. Its trade was dominated by the British East India Company (Erikson 2014, 51–52).

Until I.E.'s grandson, whose name is Lammot, the production process of powder was mostly the same. Lammot (the son of Alfred Du Pont) took the office after retirement of his father in 1850 (Kinnane 2002, 27). Lammot was a researcher who studied chemistry at the University of Pennsylvania. In 1857, a new method which was used in blasting powder was patented. With this new method, Lammot diminished the demand of saltpetre source. As a result of this, a new mill was founded in Wapwallopen Creek, Pennsylvania (Alfred D. Chandler and Salsbury 1971, 6). Lammot's efforts were a new beginning for the company, because the family business had grown and needed to respond economic and organizational changes. Explosive business was rapidly expanding considering the time period where the demand was a major incentive. Moreover, in 1866, Alfred Nobel invented the first dynamite which was patented in 1967[43]. This invention was simple and secure to use because of its chemical compound. Nobel's invention was commercialized with the activities of Du Pont. The corporate, at Repauno Plant, produced and developed the product which was three times safer, convenient and effective than black powder (Kinnane 2002, 36). The commercial explosive was demanded by two important public institutions. The first was the government. It demanded dynamite to handle infrastructure works such as road, canal building, telephone and telegram construction, dim construction, mines etc. The second was US Navy. Military used the products for several reasons like breaking up icebergs for transferring ships, digging up battlefront etc. This surge of demand made dynamite and explosive works profitable. As known from Chandler's work, explosive industry was mainly dominated by Du Pont in America. In the first quarter of the nineteenth century, this status did not change thanks to mergers and acquisitions as further discussed in chapter 5 (Alfred D. Chandler 1990, 173).

From the beginning of the company, research activities were driven by internal

43 Although Alfred Nobel was the inventor and owner of patent of the product, it was licensed to Du Pont and other firms.

sources such as private research room and labs. Moreover, continuity of research activities mainly depended on apprenticeship among chemists. Contrary to German and Britain experience, Du Pont did not include systematic research places like research labs, specific test areas and buildings etc. in its residential area. Research activities, in the early period, were carried out by family members and their friends' networks. Until the beginning of 1900s, Du Pont did not use legal institutions such as patents, research engineers and technical control (Fisk 2009, 45). Knowledge, at that time, was controlled by family's managerial capacity. For instance, research on explosives provided much valuable knowledge about chemistry. Du Pont barely used knowledge systematically in its business in the early 1900s. In next part, the question of how systematic research activities changed product lines and research habits of the corporate is analysed.

4.2.5 Research and Innovation Period

When Du Pont turned 100 years old in 1902, explosives and its intermediates were the predominant production lines of the company. Modernization of the organizational system, diversification in product lines and decentralization of research activities mainly started in 1902 in the reign of the three cousins (T. Coleman, Pierre S. and Alfred I.) who frequently discussed to purchase the company. Alfred was the pioneer in that sense. He left Massachusetts Institute of Technology and worked for mills and black powder business. Coleman graduated from MIT mines engineering and Pierre also studied chemistry at MIT. They were eager to purchase the company and took the business. In 1902, they bought the company from their relatives for a price of $20 million (Kinnane 2002, 64). After the purchase, Du Pont decided to enhance its activities and benefit from scale economies. It was already a member of the Gun Powder Trade Association (GTA) and the family had the property of many powder firms and association holdings. According to Chandler and Hounshell and Smith's works, Du Pont merger period was a great opportunity to exploit market share and gain market power (Alfred D. Chandler 1990, 76–77; Alfred D. Chandler and Salsbury 1971, 83–85, 93–95; Hounshell and Smith 1988). Fewer competitors and diversified products were the two main motivations of the company.

At this point, Du Pont started to cluster scattered research activities into two different research laboratories, one focused on basic and the other on applied research. The Executive Committee decided to make a new research strategy. According to this strategy, company conducted two types of research activities: making new products and inventing new materials and processes. This step was

certainly "the important step" in establishing a scientific guideline for the company. In Wilmington, Experimental Station lab was established to conduct basic research activities to invent new materials and processes (Haber 1958, 143–45). The Lab produced many product innovations and inventions like: Pyroxylin (nitrocellulose), synthetic textile fibers, artificial leather, silk[44] etc. until the management of Fin Sparre in 1913. Between 1902 and 1907, 108 competitors were acquired by Du Pont. Exploiting the knowledge from the firms acquired and producing for market needs became routine strategies of the company, which Sparre's managerial success supported (see Chapter 6 for details). Between 1900 and 1945, there were many new chemical processes, materials, production methods and products. Nylon, plastics, synthetic dye, coating products, rayon were prominent new products of company (E.I. du Pont de Nemours & Company 1916). Thanks to diversification, Du Pont served many industries varied from automotive to agriculture. These complex production lines were promoted by the managerial strategy of the company which to a certain degree rests on mergers and acquisitions.

Figure 9 depicts the relations between products, which were produced between 1802 and 1916 and the areas in which the products were used. The main aim of the mapping was to clarify several points such as whether complex relations of the firm are structured; whether product lines had inter-relations among different industries and; what main product lines were. The mapping was run under *Force Atlas 2* graphic algorithm to simplify the analysis. In Chapter 2, detailed information about software algorithm is provided. The figure was designed from the data on 377 specific products (turquoise nodes), 37 users (red nodes), 13 production lines (purple nodes), and one producer (claret red nodes). Nodes are connected or inter-connected with each other with 377 *production edges* (blue edges) where each edge reflect production by department, 252 *used edges* (red edges) where each edge reflects whom the products that used by, and 17 *produced edges* (purple edges) where each edge reflect the main producer which in this case was Du Pont itself. The data is analysed using the same algorithm; however, nodes were weighted by different variables. While Products, Users, Production Types were weighted by degree centrality, Producer was weighted by betweenness centrality. The aim of using different weights was to show the big clusters. According to Figure 9, the firm had 13 main product lines (purple edges). Those lines show Du Pont's production clusters and their main users. In the organization chart plants and departments were designed to make efficient production. When we support the mapping with

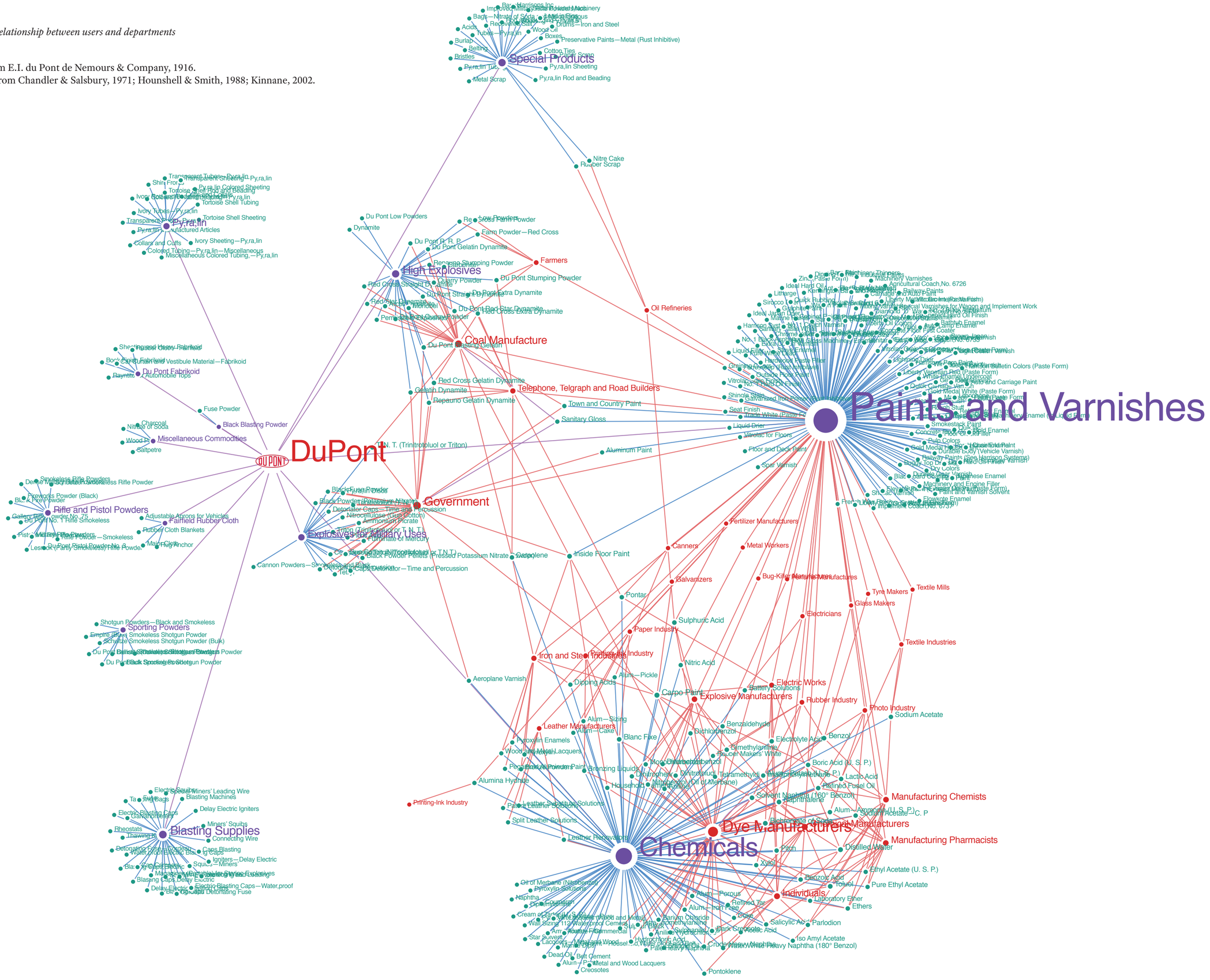
44 Artificial silk was patented by French. Because of this, in 1924, Du Pont decided to establish its artifical silk work as Rayon Company. This was generic name of chemical thing.

historical data on Du Pont, one can see that chemicals and dye works were the main production areas of the company. Especially, in the period of the three cousins (the beginning of the 1900s) research activities and investment focused on chemicals and dyes. There are four main reasons for such a concentration:

- Policies of economic development of the government after the Civil War were vital where infrastructure investments played major role. At this point, Du Pont rose as main producer and provider of various needs of the industry because of family's strong ties with the governing authority from Franklin to Jefferson.
- Industrial Revolution and its opportunities like the rising electricity, communication and chemistry sectors created demand. Du Pont invested in chemistry because of cyclical factors. Late-comer advantage in the chemical sector was high. USA and Germany, after Britain's first movement, rushed entering the sector. (C. Freeman and Soete 1997, 123–42).
- Conditions before and after World War I and the economic shortage created new opportunities for the firm. Demand for dye heavily increased during the War where dye making became a major theme of competition between rivals (Germany and Britain). Moreover, innovative products like nylon, synthetic etc. were used in World War I.
- Competition pressure from abroad forced Du Pont to behave strategically. Germany as a late-comer dominated the dye industry with its innovative techniques and products. This pressure resulted in cooperation between Du Pont and ICI (Britain).

Figure 12: Products relationship between users and departments

Data: Raw data from E.I. du Pont de Nemours & Company, 1916.
Verification of data from Chandler & Salsbury, 1971; Hounshell & Smith, 1988; Kinnane, 2002.



The results of this network analysis are further supported by a simple relational mapping analysis as can be seen in Table 13. According to the table, chemicals and dye products were main production lines for the firm. When Du Pont was established in the beginning of 1800s, it was a powder and dynamite producer. The variety in products came with opening to new competitive markets, which is further discussed in Chapter 3. Moreover, Table 13 also provided information about the users of the products. In order to clarify the network relationship, Figure 10 is provided below. In Figure 10, Dye and chemical relations could be clearly seen. Moreover, for the two products, primer demand came from Dye Manufacturers and Government. This was probably important to indicate the role of government in developing an enterprise's internal research and production activities.

Table 16: Top 5 Results from relation mapping analyse.

TOP 5 PRODUCTION TYPE	Connections	TOP 5 USERS	Connections
Paints and Varnishes	*163*	*Dye Manufacturers*	*47*
Chemicals	*98*	*Government*	*28*
Blasting Supplies	*29*	*Coal Manufacture*	*22*
Special Products	*27*	*Chemical Manufacturers*	*16*
High Explosives	*26*	*Individuals*	*15*
TOP 5 PRODUCTS	**Connections**	**TOP 5 NODES**	**Connections**
Carpo Paint	*8*	*Paints and Varnishes*	*163*
Distilled Water	*7*	*Chemicals*	*98*
Toluol	*6*	*Dye Manufacturers*	*47*
Bichromate of Soda	*6*	*Blasting Supplies*	*29*
Inside Floor Paint	*6*	*Government*	*28*

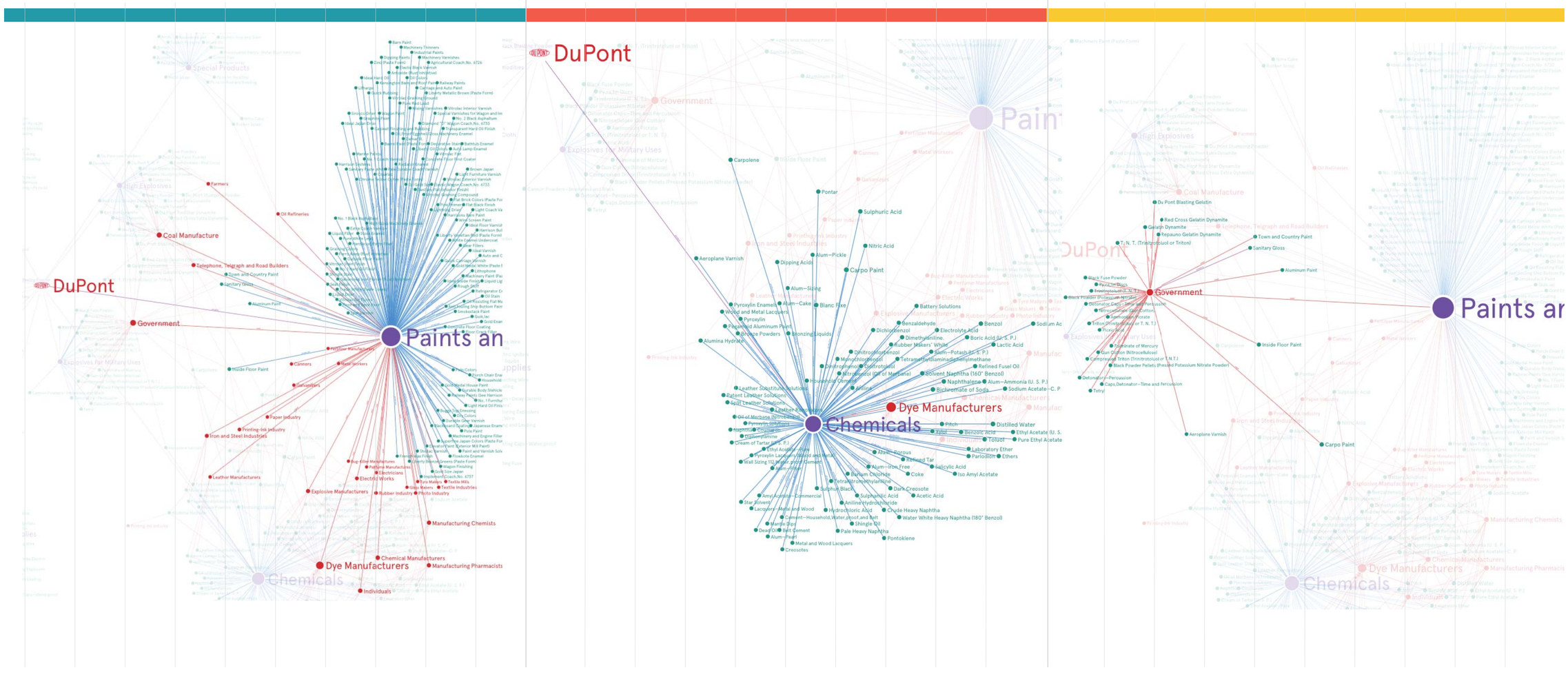
It should not be forgotten that indicated relations are not causal. Chemical products were intermediate goods for several industries; some users demanded directly (for example, dye manufacturers), others demanded indirectly (for instance, the government). This information could be useful while interpreting the data. For example, between two wars, Du Pont's business and research strategy were shaped by the mainly the government demand.

In sum, between 1902 – 1926, the strategy of the firm can be summarized under three main topics: involving in *mergers and acquisition* activities to reduce competition, conducting *research activities* for new materials, processes and products, and *marketing activities* for creating new market needs. Du Pont's innovation and research strategy fit into Freeman's *offensive innovation* taxonomy (C. Freeman and Soete 1997). According to this taxonomy, in order to gain market leadership, firms

introduce new products in competitive environment (C. Freeman and Soete 1997, 260). Du Pont performed well in diversification of products and investment in many research opportunities. Diversification strategy stemmed from the necessity of catching-up the forerunners through first imitating, but then innovating. Du Pont's rapid advancement in innovation and research activities in the dye and chemical sectors is an offensive strategy to increase competitiveness.

Figure 13: Dye and chemical sectors relationships detailed results

Data: Raw data from E.I. du Pont de Nemours & Company, 1916.
Verification of data from Chandler & Salsbury, 1971; Hounshell & Smith, 1988; Kinnane, 2002.



The three cousins also led a major organizational change in Du Pont that increased their hierarchical power in the firm. The new system was designed in two important parts: executive and finance. All production departments were connected to the president -the executive manager. Operating departments were connected well. On the other hand, financial committee was dominated by Pierre. All pricing and financial systems were revised. New investment and acquisition or merger decisions were examined by Pierre and presented to Coleman. Financial stability was under the control of the executive department where there was routine check on profitability.

The company had two important challenges in terms of organizational structure. The first was the investment of overseas and diversification. The second was vertical integration with other firms. Pierre made several agreements with overseas markets (Anglo-German, Chile, and France) (Alfred D. Chandler and Salsbury 1971, 169–72) the most important of which was signed with the Nobel Company in order to exchange licence, knowledge and patents. The company carried out business in explosives and chemicals. Its main research heavily focused on improving explosives through drying techniques, propellants in order to develop military shells, electrical system improvements and nitrates research to improve explosives. According to Salsbury and Chandler's work *"... (the company) certainly gained in technical and scientific knowledge by this exchange."* (Alfred D. Chandler and Salsbury 1971, 198).

Between 1902 and 1926, Du Pont followed a strong diversification strategy based on vertical integration - a process controlled by Pierre and Coleman. Pierre took control over the investment decisions where the profitability of the new enterprises was thoroughly calculated. For instance, in 1909, the Executive Committee decided to make a research investment on artificial leather. They closed down the Powder Plant at New Jersey and began to conduct experimental research on artificial leather[45]. Executive Committee decided that "*the Development Department shall have charge of study of any new business or products which is not embodied in the company's regular process of manufacture until the study is completed.*" (Alfred D. Chandler and Salsbury 1971, 249). The decision permitted the Development Department to continue studying on the material. In sum, the department found a new process (*solvent recovery process*) reducing the cost of the older version in manufacturing of artificial leathers (Alfred D. Chandler and Salsbury 1971, 250). In the market, there were no potential rivals for this process. As a result of the new improvements, Du Pont acquired Fabrikoid Company for a price of $1.2 million

45 By the way, Pierre was not satisfied regarding how the cost of the new enterprise was allocated.

in order to manufacture artificial silk and leather. This production was mainly demanded by the government for supplying the needs of the army which gained importance before the World War I (Kinnane 2002, 70).

Aggressive acquisition and economic activities were ordinary developments for the company. However, Pierre and other members of Executive Committee discussed such decisions thoroughly. Decision to penetrate in to new markets, investment opportunities and research decisions were made by the three cousins individually but approved collectively. This situation continued until the reorganization in 1911. With the new organization, the company centralized its internal organization activities. The sharp difference between two periods was the hierarchal change in the finance committee and executive committee. According to the new system, executive board was responsible for making decision and forming strategies. After that, other administrative parts of the company applied those decisions. Figure 11 presents the new structure of the company. According to Figure 11, executive council should be consisted of experienced members (Alfred D. Chandler and Salsbury 1971, 304). Other difference was separating routine and daily works from the major activities. Routine works were carried out with executive chief and treasurer of the company. Other major decisions (capital investments, establishment of plants) were made by the executive council.

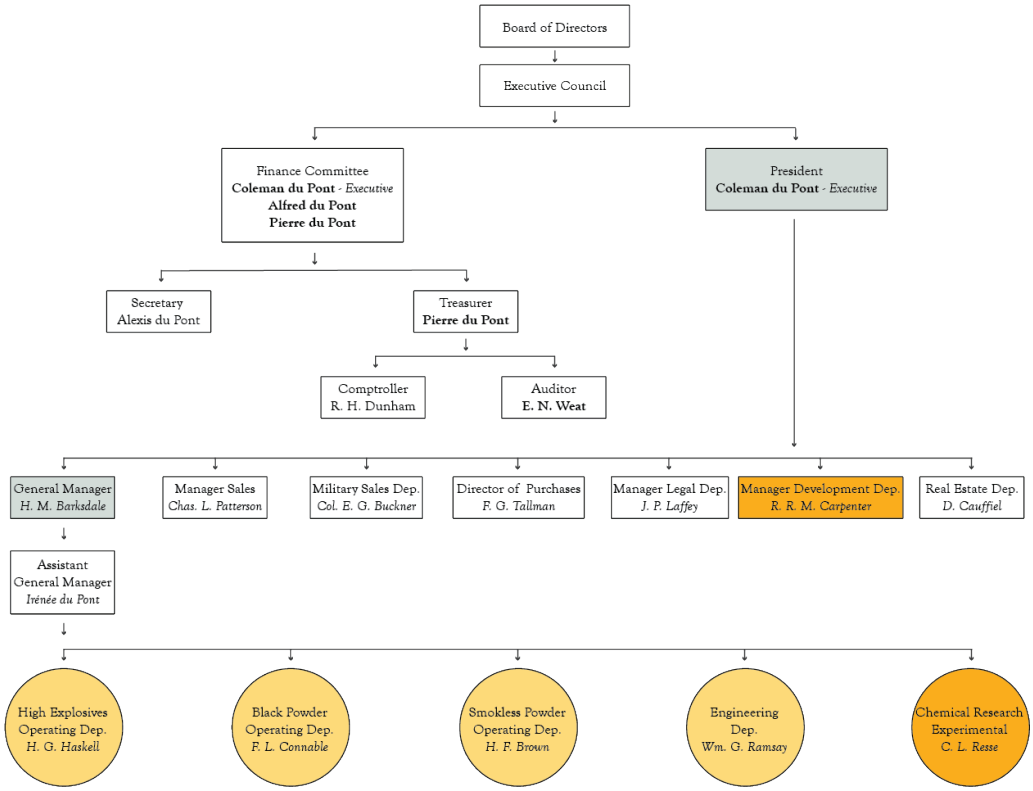


Figure 14: Organization schema of Du Pont after the change in 1911
Source: Redrawing from Chandler, 1990, p. 88; Chandler & Salsbury, 1971, p. 306 and 316.

The organizational change affected the committee system of the firm. The new committees were directly connected to the Executive Committee which composed of seven members: Coleman du Pont (Chairman), Pierre du Pont, Alfred du Pont, H. M. Barksdale, J. A. Haskell, A. J. Moxham and L. Patterson. The distinctive point in the new committee system was the renewed task distribution of the constituents. As a result of the new system, Development Committee was responsible for the R&D activities and moreover Executive Committee's demands were considered by the development committee. This new type of organization provide more flexibility for R&D activities in the company.

When net profit numbers considered, the new system could be deemed successful according to Table 14. Moreover, profits were slightly different from the previous years until World War I. The War economy was the main factor to stimulate research and net sales. In attempt to make consistent analysis, some important events, which possibly affect the sales and profit numbers are indicated in Table 18.

Table 17: Main economic indicators of Du Pont and Important Events (in millions)

	1904	1905	1906	1907	1908	1909	1910	1911
Gross Earnings	26.1	27.7	30.8	31.7	28.0	30.8	33.2	33.4
Net Profits	4.4	5.1	5.3	3.9	4.9	6.0	6.3	6.5
Percentage	*16,86*	*18,41*	*17,21*	*12,30*	*17,50*	*19,48*	*18,98*	*19,46*
Important Events	One Year before establishment of new Experimental Lab.	*Pyroxylin* and rushing to the new production line					Synthetic Textile Fibers and Artificial Leather	the new organization begins
	1912	**1913**	**1914**	**1915**	**1916**	**1917**	**1918**	**1919**
Gross Earnings	36.5	26.7	25.2	131.1	318.8	269.8	329.1	105.4
Net Profits	6.9	5.3	5.6	57.8	82.1	49.3	43.1	17.7
Percentage	*18,90*	*19,85*	*22,22*	*44,09*	*25,75*	*18,27*	*13,10*	*16,79*
Important Events	Antitrust against Du Pont and Split into three: Atlas Powder Company and Hercules Powder Company		***Beginning of the World War I***	entering plastic industry	Du Pont bought GM motors	producing dyes	***World War I ended***	

Source: *Table data from* **Chandler & Salsbury, 1971, p. 609.** *Events data from* **Kinnane, 2002.**

Notes: All numbers are rounded. Purchasing of GM Motors made possible to sell plastics products, artificial leather (synthetic silk), and dyes (car dyes, varnishes etc.)

War economics was the main motivator (and the main reason of increased sales) in some production lines for the company. However, Du Pont was also interested in research activities mostly to gain competitive advantage in the sector. In the USA, beginning of 1900s was a turning point to stimulate scientific activities. This new industrial and scientific era was also supported by the institutions. Capital

flows thanks to globalization at the beginning of the century and a more science-oriented education changed in accordance with the industrial needs and national necessities. American system was different in terms of higher education and research opportunities. Research universities were constituted later than Europe. Additionally, the most famous universities like Johns Hopkins (1910), University of Michigan (1844), Chicago University (1906) founded their chemistry research laboratories and departments (Haber 1971, 64–67). One should not that, those universities were late-comers in terms of systematic research between industry and university. According to George Lunge, who was a German chemist, engineering and physics research opportunities of North America were better than Germans; however, chemical research amenities were not (quoted from Haber 1971, 64). When the numbers of chemical engineers were considered, only 536 people attended to chemical engineering courses in 1900 compared to 4,548 people attended to the same courses in 1918 (Haber 1971, 63). For the same years, 4,459 and 5,944 people attended to mechanical engineering courses and 2,555 and 5,683 people attended to electrical engineering courses, respectively. Moreover, the numbers of chemical students were 5,700 in 1920 and 4,900 in 1928. Though these numbers represent only chemical engineers but not chemistry students, when compared with Britain and Germany, it was rather low. Moreover, numbers slowly decreased toward the World War II. The reason for that could be the economic instability for engineers and scientists during the Great Depression.

It should not be forgotten that 1900s were marvellous times for science and scientific activities. According to *Scientific American Magazine's* study from November 1921 (when the magazine was launched) to October 2010, *engineering* (included material, transportation) was mentioned 249 times, while chemistry was mentioned just 30 times most of which were between 1921 and 1950 – a period that more or less covers the two world wars and the period of investigation of this thesis. Moreover, another important subject, *military innovation* was only mentioned 47 times during the war times. The rest of the cover stories were shared by *biological Science* (233), *astronomy* (93), *physics* (116), and *others* (277) (Fischetti and Chrisriansen 2014). This shows that practical information and applied science was more in demand than pure scientific knowledge. Engineering and complementary basic science (chemistry, physics) was broadly mentioned as a result of the necessities of the nation. After all, *Scientific American* was the most important science magazine in the USA. Its cover story, even a little, reflects the scientific vision of the country. When compared with Germany, the USA had a different research ecosystem. It was less controlled but much supported by the government. Moreover, the research culture was privately

promoted by the universities and publishers in the USA. Hence, the advantage of science-culture promoted economic prospects. This means that different science objectives and routines simultaneously affected industries. After all, in that sense, science and industry relationship always had been close and mutual since the thirteenth century in Middle East and Europe (Lipsey, Carlaw, and Bekar 2005). Moreover, system approach was some new theoretical explanations on science and industry relationship. The US case was a proof that scientific background was vital to make industrial potentials possible.

On the other hand, other organizations promoted science by establishing renowned organizations and supporting basic science financially. For instance, the Carnegie Foundation gave about $22 million for pure scientific research activities between 1902 and 1911 (Haber 1971, 67). Between 1880 and 1905, US chemical industry grew with the help of the systematic supports. In 1880, the value of products in the chemical industry was $38,6 million; in 1905 this number tripled to about $92 million (Haber 1958, 143).

In 1925, the main rival of Du Pont in Europe, IG Farben was already established to benefit from economic scale and to serve as a new powerful chemical engine for the German economy. 1926 ICI and The Nobel Group merged. These developments in Europe stimulated other rivals to evaluate their position before the World War II. Du Pont signed an agreement with ICI for scientific collaboration and economic cooperation in 1929. According to the agreement, two firms agreed to share licence, patent and technology (Kinnane 2002, 101). This new relationship paved the way for further opportunities. Du Pont began to learn from other chemical firms and expanded its product lines. Explosives and dye were not the focal production lines anymore. In 1929, the Rayon Technical Division Acetate Research Laboratories was established. Neoprene also was invented and produced in 1930. Under economic conditions of the Great Depression, Du Pont lost 30 percent of its net income. 30 000 employees were affected by the Depression (Kinnane 2002, 122). However, the inventions and innovations were still stimulated by the government and consumers. Pre-war period resulted in many innovations, acquisitions, and cooperation activities for Du Pont. For instance, in 1929, the company purchased Roessler & Hasslacher Chemical Company. Also, Du Pont produced special products for use of dye manufacturers like Krebs Pigment & Chemical Company (Kinnane 2002).

In 1939, Du Pont's monopoly was established further by the invention of Nylon[46].

46 Today, women stockings and many consumer products are made from Nylon.

Nylon could be used in all industrial areas like textile, military, consumer products etc. It was invented during research on polymer in Experimental Research Centre of Du Pont. Because of its versatile nature and huge market potential Nylon was produced commercially in many new Du Pont plants. Afterward, the war economy further stimulated the demand for Nylon. For instance, 38 million miles of nylon was produced for the government to be used in parachute yarn (Colby 2014, 316). Furthermore, Cordura[47], which was a kind of synthetic fiber, was produced and introduced to the market. This product was relatively important for military use. Backpacks of soldiers, jackets and hand gloves were produced with this strong and durable material. This product was mainly used in World War II for truck tires. Gerard Colby's work states that in 1941, new nylon plants exclusively produced Rayon and Cordura for military vehicles. The amount of the production was about 168 million pounds (Colby 2014).

1939 was a decisive moment in the history of both Du Pont and the USA. The war just began in Europe and the USA was shortly involved in World War II in 1941 as a result of being attacked on Pearl Harbor by Japan (Stone 2012, 73–74). At that time, Du Pont decided to change corporate vision in accordance with the economic (e.g, rising war economy after the depression) and political (e.g., government necessities) state. In the light of this new vision, Du Pont started a new era with a new motto "*Better Things for Better Livings*" at New York World's fair in 1939 (Kinnane 2002, 127). There were several differences when compared with the earlier times:

- Change in the main motivation of the firm towards "science-based" activities (Kinnane 2002).
- According to necessities of the new era, decreasing production of explosives and increasing new production lines like Rayon, Nylon, Orion, synthetic fibres etc.
- Sensitive research on atomic bomb and its market created by the military needs.
- Change in marketing strategy. The more the consumer demands (in size and variety), the more Du Pont produce with the help of establishment of new campaigns, new fairs, radio programs (*Cavalcade of America*), and exhibitions (Bird 1999).
- Market expansion in order to enable the new products to all the markets in North America.

47 *Cordura*, nowadays is used in various areas that demand use of special fabrics for mountaineering. Additionally, the most important brands use this fabric licence in their production.

Du Pont was a scientific research leader between two world wars. It always used its capacity to make an innovative product. In 1942, Du Pont also supported the Manhattan Project and the making of the atomic bomb with its licences and patents. Some sources accused the corporate for making much profit by killing people (Colby 2014). Others said that Du Pont symbolically got $1 payment from the government for giving patent and licences which emerged after the project (Kinnane 2002, 147). After all, Du Pont engineers had a great role in making the bomb. Manhattan Project was not only a government project to make a bomb, but also a "massive scientific work" with the word of Hans Bette (Rhodes 1986, 443). There were many scientific opportunities in the fields of chemistry, materials, engineering, and physics.

Between 1926 and 1945, Du Pont performed well in terms of economic and scientific activities. At the beginning of 1900s, they started to dominate the chemical sector and produced many products for a variety of use. When started as a business solely producing powder they were limited in scope and scale. However, World War I and World War II stimulated their business. Also, organizational innovation and various mergers and acquisitions affected the corporate's story in great deal. After all in this period, with the words of Chris Freeman the corporate was highly innovative in terms of products, processes and services (C. Freeman and Soete 1997).

4.3 Aftermath: The End of the War and the New World

Du Pont's most important decision was to continue research activities intensely. By 1950s, the corporate invested $50 million for the establishment of new research laboratories and plants (Hounshell and Smith 1988, 350). The corporate started to conduct research on Polymer and the most important persons in that field joined the corporate during the process. Many new products were licenced after the war like Zytel, Kevlar[48], Delrin and Tyvek (Kinnane 2002) all of which were results of the science-based vision of the corporation. In 1952, the corporation purchased a plant and entered the European market. Du Pont established an organic chemical plant in order to produce synthetic rubber and artificial silk. As a result of this move, the corporation gained technological advantage abroad.

Today, Du Pont has $25.1 billion net revenue and $1.9 billion net income ("DuPont's Net Income 2011-2015 | Statistic" n.d.). Moreover, it is the third largest chemical company after Dow and Exxon Mobile Chemical companies ("Largest U.S. Chemical

48 Developed in Du Pont's research laboratories in 1965 it was mainly used for body armor of civil servants and many other related products.

Companies Based on Revenue | Statistic" n.d.). The corporation is operational in various industries such as agriculture, automotive, building & construction, electronics, energy, food & beverage, health care & medical, mining, packaging & printing, and plastics thanks to about 530 innovative products ("Production Lines of Du Pont" 2016). Du Pont mainly uses its capability to develop new market opportunities with the help of Innovation Centres around the World. Specific solutions and technical necessities are the vital part of the new Du Pont business. Giving an example would clarify this new business style. Du Pont established an innovation centre in Turkey serving to firms' specific problems. Arçelik (white goods manufacturer) demanded a solution from Du Pont for the problem of excessive heat of the coffee pot in the new product named *Telve*[49]. The pot's coating needed a new material that reduces heat. Innovation Centre contacted with the client and sent the problem to the research centre in the USA in order to solve the problem in a less costly scientific way. The problem was solved with the help of using a new type of coating for the product, which gave durability and safety for the Arcelik's product. In return, Arcelik has paid licence fee to Du Pont. This type of making business by providing solutions is integrated into Du Pont organization. Du Pont serves to over 90 countries with its 10,000 scientists and engineers and codified knowledge stock of 23,000 patents ("Du Pont: 2013 Annual Review" 2013).

In 2015 Du Pont and Dow Chemicals (the biggest chemical producer in the USA) decided to merge. And the new *DowDupont* company is worth about $130 billion and employs about 116,000 persons[50] (Picker and Merced 2015).

Finally, a comparison table between IG Farben and Du Pont is provided below to summarize the discussion in the thesis. Table 15 is designed with broad titles of comparison such as: type, capital structure, organizational types etc. that helps us to take a closer look inside the company structures and economic facts. In the next chapter of the thesis, those selected domains will be analysed in detail. Hence, the thesis' main question, which is how innovation activities differ in different settings, will be examined under those titles.

49 A kind of Turkish coffee machine

50 53,000 from Du Pont, 63,000 from Dow Chemical (2014).

Table 18: A Comparison between IG Farben and Du Pont

	IG Farben	**Du Pont**
Foundation	1925, Frankfurt	1802, Wilmington
Ownership Structure	Joint Stock Company (*Aktiengesellschaft*)	Family Business (*first years in its activity)* Public Company
Workforce	~ 97,500 (*Workers 74,600 – Staff 22,900)*[1]	About 83,000
Capital Structure	Merger	**Conglomerate** (*especially after World War I*)
Organization[2]	Centralized (*from beginning to the end*) *Some key person:* Bosch and Duisberg	Decentralized (*from 1902 to the end*) *Some key person:* Alfred, Coleman and Pierre
Specialization[3]	Dye, Chemical Process and Organic Chemistry, Pharmacy	Chemical Engineering, Material Sciences, Agriculture, Food, Textile
Plants	9 main plants including research facilities	10 main plants including research facilities
Patents and Innovations[4]	Innovation (1925-1945) **%44** Total Plastic Material Patents (1931-1945) **%20** Important Innovations (1870 -1945) **%45**	Innovation (1925-1945) **%11** Total Plastic Material Patents (1931-1945) **%8** Important Innovations (1870 -1945) **%10**

Table 18: A Comparison between IG Farben and Du Pont (continued)

Marketing	Poster, ads and exhibitions used in pharmacy (Bayer), Dye and Soda (BASF) Photo (AGFA) Not other intermediate goods	heavily used for sales in agriculture, communication, textile, automobile etc. fair, exhibition, TV ads. Exploiting New American communication concepts "better life, better things."
Government Relations **(who controlled?)**	**Before Hitler:** Regular relations: products were supplied to domestic and public demand **After Hitler:** Intensive demand from the Reich. Production and research for the Reich	From the beginning, always close relationship (privileges, exceptions and considerable demand)
War Effect	**WWI**: Higher reparation burden Excessive demand for some products (gas, synthetic stuffs) **Interwar Period**: Under reparations Government tax and export support to the firm **WWII**: Excessive and aggressive demand for the Reich war project Expanding plants accordance with Hitler's desire War economy and necessities Role in Holocaust Vitamins, pills etc. for military use	**WWI**: Demand for specific products (see Figure 9) War needs and innovation period **Interwar Period**: Research activities Highly cost-cutting projects **WWII**: New products and new process for new necessities (tires, parachutes, gear armours etc.) To be the winner of the war supporting Manhattan Project with all departments

Table 18: A Comparison between IG Farben and Du Pont (continued)

Firm Strategy[5]	Offensive Innovator	Offensive Innovator
Firm's Categories[6]	Science-Based Scale Intensive Highly Vertical	Science-Based Scale Intensive / Production Intensive Highly Vertical

Notes: **(1)** Numbers are 1 January 1930 (Haber 1971, 380). Staff indicated scientific and commercial people.

(2) Those names are selected according to their outstanding organizational talents.

(3) Based on the work of (Alfred D. Chandler and Salsbury 1971; C. Freeman and Soete 1997; Hounshell and Smith 1988; Kinnane 2002; Lindner 2008)

(4) (Delorme 1962; C. Freeman and Soete 1997). Numbers of *Innovations* are 36. Numbers of *Total Plastic Material Patents* are 4,341 and Numbers of *Important Innovations* are 20

(5) based on Freeman's explanations (C. Freeman and Soete 1997, 307).

(6) based on Pavitt's methodology (Pavitt 1984, 354).

According to the comparison table, two companies diversified in four main topics:

- external factors (Hitler and government intervention),
- science heritage (education system or national system),
- organizational attitude (as a result of managerial and cultural differences)
- sense of research (more industrial research and more cooperation between industry and university).

To summarize these factors briefly, first of all, external factors were vital in shaping two companies. For example, Nazi's synthetic fuel demand forced IG to concentrate all research activities on this specific topic. Sense of research was affected by the authorities in the case of Germany, which means that there was no "economically free" environment especially after the 1930s. On the other hand, Du Pont had always

a close relationship with the government. As a result of this in some cases research policy of the company was determined by the US government. For example, during World War II, Du Pont established plutonium production plant (Hounshell and Smith 1988, 332). Second, science heritage was a distinctive difference between IG Farben and Du Pont. Detailed explanations are given in Chapter 3. According to the explanations, IG Farben had benefited from German science and university system in great extent. For example, invention of the new materials, molecules and synthesis processes were already common developments in Germany from the beginning of eighteenth century. In the USA, education system and science were supported by institutions that were market oriented as well as the government. Therefore, although German science was heavily based on pure and fundamental characteristic, American science was based more on the applied elements (for instance development of chemical engineering versus chemistry departments) to promote economic development. Third, the organizational structures of the firms were naturally different from each other. German side was more controlled and more centralized. On the other hand, American side promoted more flexible research and management system. Finally, research sense was affected by each other. German side mainly supported pure or basic research. Labs and research centres served to realize innovation in the field so to say in a more linear fashion from theoretical to applied science. Du Pont used the same path until 1921. Afterward, they focused on "pure" research; however, market driven production and research was what made Du Pont different from IG Farben.

The first issue mentioned above is rather out of the scope of this thesis. Despite the importance of political issues in shaping the firms and the sector, the literature is enormous. In the text, there are frequent elaborations on the link between politics, war and the two firms but a detailed discussion is specifically avoided. Therefore, this thesis is focused on the remaining three elements: science, research and organization. There are two chapters that focus on research (Chapter 6) and organization (Chapter 5) respectively and the issue of scientific heritage interlinks both research and organization because it constructs a base where both research and organizational change can flourish.

CHAPTER 5

ORGANIZATIONAL INNOVATION AND MANAGERIAL ACTIVITIES IN TWO CORPORATIONS

"...The Du Pont Company completed the administrative organization of its merger in as many months as it took the United States Rubber Company years. In 1903 three du Pont cousins consolidated their small enterprise with many other small, single-unit family firms. They then completely reorganized the American explosives industry and, installed an organizational structure that incorporated "the best practice" of the day. The highly rational managers at Du Pont continued to perfect these techniques, so that by 1910 that company was employing nearly all the basic methods that are currently used in managing big business."

Alfred Chandler[51]

"One of the most important reasons for forming the IG was to attain what is now known in business circles as synergy. The whole was supposed to be greater than the sum of its parts. It was supposed to achieve economies of scale in mass production, that is, to expand the manufacturing facilities to the optimum size so as to allow for higher output at lower unit costs. This approach was, however, less important in the chemical industry of that day than for other industries, such as steel. ...Better communication and cooperation among the component divisions (generally the former firms that made up the concern) would allow the IG to innovate technologically and to compete more effective Lyon world and domestic markets."

Raymond G. Stokes[52]

5.1 Organizational Innovations and Fate of the Corporations

In economics, theory of firms traced back the literature of 1700s. Adam Smith (1981), Richard Cantillon (2006) and Karl Marx (1991) gave many notable works in order to explain firms and economic relationships. Classical economics tried to find an explanation about why and how the economy emerged and continued. They perceived "firm" as a producer, competitor and risk-taker. Afterward, Neo-classical theory, made deeper explanations about the firm. They saw the firm as organizational entity that acts for the sake of profit and makes industrial transformation in the setting of an economy. In parallel with this idea competition as an integral part of firm theory was developed to comprehend how and why

51 (Alfred D. Chandler 1977, 417).

52 (Stokes 2008, 215–16).

firms were able to make economic difference (making growth in different way) (Buchholz 1989).

By 1930, Schumpeter proposed his idea about methodology of economics and general economic theory. According to him, economic development (and growth) had some characteristics such as continuity of economy (i.e., cycles) and seeking of new things by actors such as organizations and individuals (Schumpeter 1934). Explaining of firm and other economic actors lead to the emergence of a new literature on science and technology. Both Classical and Neo-classical theory tended to ignore technology and particularly innovation as a source of growth as mentioned previously. However, especially Schumpeter's inspiring works on innovation affected research to flourish in the direction of technology, innovation at the firm level. The idea has been supported by the works that investigates the nature of innovation. Firm and economy relationship and managerial side of innovation caused many new ideas to emerge. According to these, an economy surrounded by many actors that affected the process of new things. Firm based theories were based on the explanation of firm activity in terms of managerial (power hierarchies, controlling) (Tannenbaum 1962), organizational (integration types, structure) (Lawrence and Lorsch 1967; Wolfe 1994), and sectoral (competitive advantage etc.) (Cantwell 2005; Porter 2011) aspects. Those approaches have aimed to understand the innovation performance of the firms. Furthermore, studies show that business strategy of organizations lead to better economic and innovative performance (Teece 1981). Additionally, Burns and Stalker's work shows that technological performance of firms is affected by environmental conditions like relations, technology and industrial structure. The work was based on binary logic; as a result of this, organizations was divided into two main structure type: organic (evolutionary perspective) and mechanistic (neo-classical perspective) (Burns and Stalker 1994). A key aspect of Burns and Stalker's work was to show importance of learning, knowledge and managerial environment. As in organizational terms, the work of Burns and Stalker has been quoted as "contingency theory". Investigation of organization was a continuing concern within the theory of innovation. For instance, Mintzberg's work concerned to constitute structural architypes (such as simple, machine bureaucracy, professional bureaucracy, divisionalized form and adhocracy) in order to understand innovative potential of firms and organizations (Mintzberg 1979; Lam 2005, 120). Importance of Mintzberg's work was that it helped to understand complex structures' inside. It means that organizations act under uncertain and mostly unforeseen environment. There is not "one-way or one-solution" to be successful. This approach is very much close to the

evolutionary view that leads us to a better understanding of firm organization. To illustrate according to Mintzberg's work Du Pont's organization might be referred as *machine bureaucracy* before 1903, but after that firm had *professional* and *divisionalized structure*; on the other hand, IG Farben's organization, when thought about innovative performance, might be defined as *divisionalized form*.

Moreover, the theory concerning organizational side of firms shows how firms tend to be innovative in the economic context. Contingency theory was developed with other significant contributions related to firms' capacity and yielding ability. This means that outside environment changed the structure and organization of firms which stemmed from Chandlerian view (Alfred D. Chandler 1990). According to Chandler, firms adopt outside conditions such as new markets, competencies, and new products etc. in the economy since they do not to lose its competitive and innovative capacity (Lam 2005, 121). The idea is also supported by the works of Lazonick and West (1998), which claimed that innovativeness was affected by strategy and structure of the firm - a notion called as "innovative enterprise". Selection of firms was vital in those two theories (contingency and Chandlerian) because diversification, structure, strategy and marketing were intensely determined by the performance of the firm. This type of organizational theory was called as multidivisional or M-form (Teece 1980).

Finally, organizational theories touched the important issues mentioned above. As known, theory of knowledge has been depended on philosophical roots. Definition of knowledge, epistemological foundations, and its importance in economic life was discussed in many ways. According to the debates, knowledge gained importance in two economic areas: creating new knowledge, (in terms of personal side) and organizational learning. Research on learning and epistemological root of knowledge developed some organizational theories to understand effects of learning on performance and innovation. First of all, learning has been grouped into two sides: individualistic and collective. Individualistic learning required formal structures (production space), routines (work, education), and procedures (rules, management) (Simon 1991, 125). On the other hand, Walsh and Ungson proposed that accumulation of knowledge creates collective learning (Walsh and Ungson 1991). The biggest part of this type of knowledge stemmed from *trial-error* experience. At this point, interaction and collaboration gained vitality. There are four reasons that explain why firms collaborate with each other. First one is asymmetry of power that means power of an organization over another one. Second is reciprocity that reflects *give-take* relations of cooperation and collaboration of

organizations. Organizations prefer reciprocal exchange instead of exercise power. Third is efficiency of output in the firms. Fourth is stability of an adaptive response to environmental uncertainties. This last one might be explained in terms of *dynamic capabilities* of firms. According to the dynamic capabilities theory, firms adopt the environment in which it is possible to make innovation.

To sum up, organizational theory focused on three significant strands: organizational cognition and learning (Brown and Duguid 1991; Simon 1991) ; knowledge creation (Nonaka and Takeuchi 1995); change and adoption (Penrose 2009; Lazonick and West 1998; Porter 2011). All of these are important to understand innovative performance of a firm. As such this chapter will assess these three factors for DuPont and IG Farben. After all, while analysing the cases, some measurements will be used according to data availability. This means that, in order to make consistent work, the cases will be compared under three dimensions of organizations: managerial structure (centralized or decentralized), learning (collective or individual), and knowledge creation (inside the firm or outside the firm). Due to data problems, the analysis will be limited to the 1925 – 1945 period. For early developments, a synopsis will be provided for each cases at the beginning of the subtitles. This chapter will further enhance our understanding regarding how each corporation developed its business and what roots of innovation are there inside the organizations. Chapter 4 has summarized various factors regarding the success of innovation in two firms and Chapter 6 looked at R&D in detail. This chapter will look specifically at organizational differences.

5.2 IG Farben: Complicated Structure and More Innovative Organization

According to Freeman and Soete, chemical sector is shaped by big corporations (C. Freeman and Soete 1997, chap. 4) which mainly emerged in Germany and USA. There were many reasons why it occurred in those countries. These factors have already been explained in details in Chapter 3 . In this part, three dimensions of organizational theory mentioned above will be discussed for the IG Farben case.

IG Farben had a more concentrated and complicated structure in chemistry sector. Before the merging each constituent corporation was relatively big. At that time, BASF was the largest company in organic chemicals and dye products (Abelshauser et al. 2008, 15). This point was important to take the advantage of scale inside the industry. Scale advantage made more profitable business for companies (see Chapter 4). This simple fact was the main reason of establishing IG Farben in 1925 as a giant organization/firm. After the foundation, IG faced new

struggles. Management of plants and research activities were more complicated than previous. Although the management of the IG Farben was controlled from the headquarter in Frankfurt, the plants which were located in rest of the Germany were by and large managed by the old structures of the companies. Moreover, companies used past experiences to serve the common aim. In the literature, IG Farben's organizational structure was commonly discussed. According to Chandler, German corporations tend to grow as a result of taking the advantage of being the first-mover and organization structure that caused more diversification in chemical sector (Alfred D. Chandler 1990, 175–76). Chandler also describes IG Farben as a "combination" which is a clue about the organization structure of IG Farben. There are many reasons how such a huge corporation could handle management. Centralization problem and the management of learning activities were always controversial issues for the company.

5.3 Managerial Structure

IG Farben's headquarter was located in Frankfurt where business operations were handled. The headquarter was responsible from several things:

1. Organizing financial works
2. Handling patent works
3. Making production programmes for each division
4. Commercial and advertising
5. Making purchases and investments (Waller 1928, 14).

Those activities were handled centrally. Other activities like research and product development were carried by regional divisions. This means that Farben's structure was centralized when we look at main tasks to handle the company, but the actual decision making for research and product development was decentralized (*regionale dezentralisierte Zentralisation*) (Haber 1971, 338). Divisions' management was connected to a committee where most activities were centrally planned. Divisions act accordingly to this plan but were made responsible for decision making on various tasks related to production. To illustrate, Bayer's activities in Leverkusen were controlled by the headquarter; however, inside research programmes and innovative activities were organized by the head of the region. In 1925, IG Farben had three main branches (Sparte)[53] and 37 production plants (36 of

53 *Sparte 1*: mining and agricultural products. *Sparte 2*: the production of organic and inorganic chemicals and pharmaceuticals. *Sparte 3*: photographic products (for medical and daily use), explosives (for military).

them were active) around Germany (Marsch 1994). Those plants were monitored and coordinated by a technical committee. Each Sparte had a manager who was responsible to the headquarter of the company. At the beginning of the foundation, the position of chairman was occupied by Duisberg who reported about research and development activities of each Sparte. Central intervention did not have direct effect on the research programme of the regional groups (Sparte). For example, the lower Rhine group (Leverkusen Bayer etc.) had own internal research programme and labs etc. (see Chapter 6). Each Sparte had its own management structure and responsibilities for some duties shown below which means that regional divisions were highly decentralized. Each Sparte was responsible for the administration of what to produce was centrally planned but the decision of how to produce was mainly left to regional divisions.

1. Raw materials
2. Production
3. Coordination
4. Research
5. Development activities
6. Marketing plans

Those responsibilities were controlled by committees which are strictly concerned by some issues such as finance, research, personnel etc. that were related to company's economic success. Moreover, there were four committees (Central, Technical, Working and Commercial) to assess the work of branches. The main duty of those was making policy in accordance with IG Farben's business strategy. The committees continued their activities until the Nazi period. Generally, activities of committees provided and established a common aim for the company. According to Haber's work, qualitative and quantitative data was not clear to assess the efficiency of the committees (Haber 1971, 340). Unlike Du Pont, IG Farben's management structure was dominated by some powerful groups. Inside the company, bureaucratic structure was issued sometimes while making decision. Research groups were not always free to make it. In this way, IG Farben's organizational structure could be called as controlled and systematic in nearly all stages of the process. Responsibilities and hierarchical structure of the organization is given below in Figure 1. The key observation is that research and production was monitored, planned and determined from the top. However, innovation might emerge from the bottom or top. Zyklon and Dye were proper examples as Zyklon was imposed by the top management (during the World War

II, in order to gain military advantage upon enemies); on the other hand, many innovations in dyestuff were successfully conducted during research routines of the divisions and were carried to the top management afterwards. After all, the top management intervened in some stage. Figure 1 clarifies mentioned intervention in "mostly free" title. Other working routines and general matters were determined by the headquarter.

Finally, there were three distinctive features of IG's managerial structure: responsibilities, importance of top management, and bureaucracy. Originally, responsibilities were distributed hierarchical and the headquarter of the company was the main position were important decisions such as new investments, new plants etc. were made. On the other hand, each divisions or branch were responsible to a committee. In that sense, small groups (for example: the middle rhine: Hoechst) could ask for a new plant; however, for a new process the branch manager was the responsible person. Responsibilities' limit and scope were determined by the top management. Haber and Lindner supported the idea that the management of IG Farben was a challenging task in terms of carrying business in order to achieve. The ideas of board members were vital in doing so (Lindner 2008; Haber 1971). Members were selected according to their experience and success. Many members were scientists or had scientific roots. The scientific resources of the company in terms of human capital were provided by the recruitment policy and science network of Germany. Carrying business in such a big scale was of course difficult. Farben's most distinctive managerial policy was controlling and monitoring of all these processes and production. Especially, Duisberg's management style was more concerned type as he'd intervene in organizing people, plants and production. For Bayer, before the merger, had been applied the same rigid rules. Rigid rules create its own bureaucracy. All decision about the future was made by committees and the board. This created a complicated structure: centralization of all activities directly affected innovation process. The important thing in this structure was learning and sharing knowledge. This created a unique way for the company next title will explain this in detail.

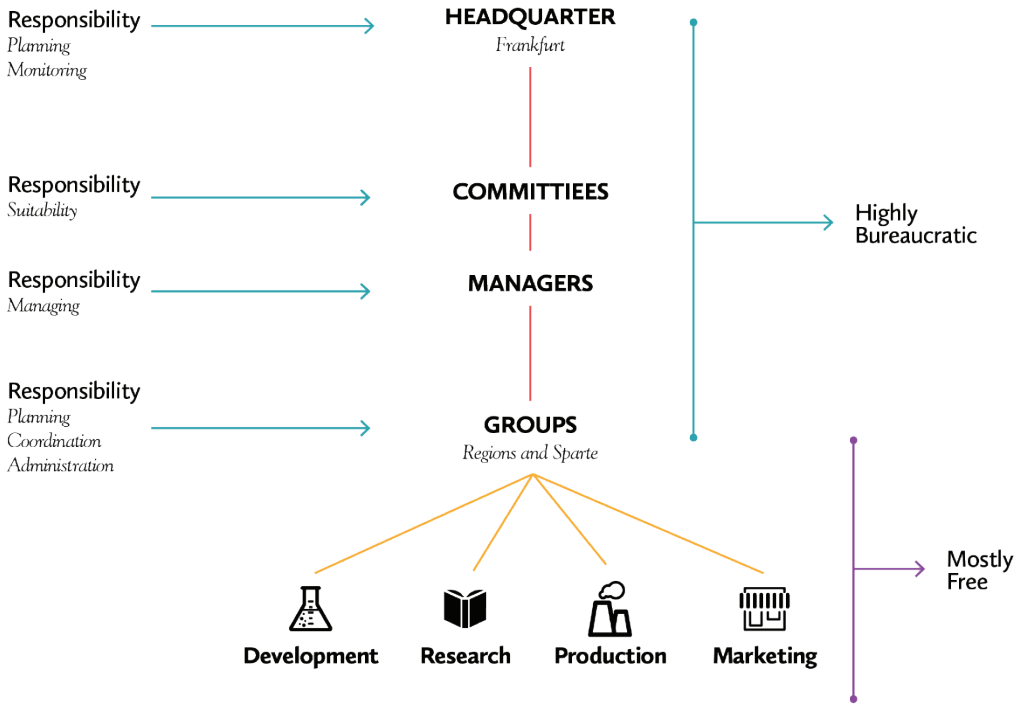


Figure 15: Organization Responsibilities and Structure

5.4 Learning and Knowledge Creation

IG Farben had a strong and prominent scientific tradition. Inside this structure, there were many research labs, in-company training, library etc. In 1880s, the first systemic, large scale and sustainable research was started by chemical companies such as Bayer, BASF etc. (Haber 1971, 352). This type of research was defining a new boundary for the chemical companies because before the research and development activities was done outside of the firm by the individual scientists or peoples (Marie and Pierre Curie's research lab (Giroud 1986)). With the emergence of the idea of "industrial research", the systematic research was carried by the professionals inside the firm. This caused two important achievements. First was that making those activities under the same roof promoted proximity between knowledge sources. This means research teams and production processes were connected to each other via the organizational structure[54]. Second was that systematic research encourages creating rules (lab rules), routines (quality of production, branding) and standardization. These two mechanisms were the main factors of learning inside the firm.

For the IG Farben case, learning activities happened through two important channels: firm's internal and external activities. Internal activities might be summarized as

54 Similarly, proximity was issued for Du Pont after 1903.

education and inner learning routines that affected the learning. According to current studies, economics of knowledge and learning has been explained in terms of R&D and innovation activities of a region, system or firm (Nelson and Rosenberg 1993; Malerba 2004; Mowery and Nelson 1999). Firms use the knowledge to build competence and conduct innovation in order to gain competitiveness (B.-Ake Lundvall 2004). While doing so, entities benefit from some mechanisms that help to emerge certain types of tacit and codified knowledge which can be acquired by doing or experiencing. "Learning by doing" is a good way to obtain knowledge (Lamoreaux, Raff, and Temin 2007, 145). This mechanism is vital for a firm to maintain scientific-based production. IG Farben developed learning mechanisms such as close relationship with other institutions and organizations (university-industry relationship etc.). In order to maintain such a system, IG Farben had been heavily involved in industry-academy relationship and had its own recruitment policies. In parallel with this idea, the German government, as an external factor, had always supported science to spread across the whole economy. In 1920, the government systematically promoted and financed chemistry institutes: *Kaiser Wilhelm Gesellschaft*, *Handbuch der Organischen Chemie*, and *the Helmholtz Gesellschaft für physikalisch technische Forschung*. Those are financed with 5 million RM in 1925 and 8 million RM in 1928 (Haber 1971, 368). Government's intentional support created a scientific environment that was easily accessed by industrial entities. Many entrepreneur scientists such as Carl Bosch and Fritz Haber had been involved in those institutes to disseminate knowledge and create a scientific base that fed the chemical companies until the war. Those scientific environments provided two significant opportunities for the industry. First was creating scientific knowledge that could be obtained by companies. Second was scientific networks that could easily be accessible as means of obtaining human capital. It was clear that IG Farben benefited from the knowledge and networks. Between 1919 and 1933, under the leadership of Fritz Haber, more than 600 academic papers that was related to chemistry was published at the Institute of Physical Chemistry (Haber 1971, 368). Haber had a great influence on IG Farben's research. The knowledge generation had always been promoted by company's resources. In brief, IG Farben, in order to obtain these opportunities, made many activities such as arranging conferences, promoting academic publishing, recruiting more qualified staff, and promoting chemistry students at the universities.

Another opportunity was networks. The importance of network effect has been discussed in the literature intensely. There have been many works on explaining the relationship between organizational learning and innovation (Tsai 2001). Moreover,

power of network (transferring knowledge) has been observed in transferring of knowledge between institutions and business (Huber 1991). As a result of network relationships, IG Farben had access to scientific knowledge thanks to its closeness to the university network. It was hard to find proper data on interaction between the universities and IG Farben. On the other hand, the key persons who occupied important positions in the company had great network effect in terms of transferring their academic knowledge from the university to the firm. In order to measure this effect, the relationship between university graduates and people who worked in important positions has been measured via network tools. According to the measurement, three variables were examined to understand of relationships between the nodes via using betweenness metric. Results are given below in Figure 2. According to the network graph, betweenness centrality is high at Berlin University and Leipzig. Berlin was pioneer education place for basic science. Many notable persons were educated there like Werhner Braun, Gustav Ludwig Hertz and Ernst Ruska etc. Carl Bosch and Fritz Haber were related with each other as they were from the same university. Graduate education in such institutions creates personal networks as well as knowledge. Gaining this type of knowledge is necessary for an organization. In the theory, organizational learning and accumulation of knowledge can be promoted in many ways. In the IG Farben case, closeness to the knowledge sources and proper organizational settings were the vital source of successful R&D and innovation activities. Hence, organizational settings enabled acquiring knowledge properly. At this point, current studies prove that firms' ability of using knowledge and their R&D performance are positively correlated which is referred as absorptive capacity of a firm (W. M. Cohen and Levinthal 1990). Network relations create more knowledge as a result of intense interaction. However, if IG Farben had not possess such an organization that had a system providing proper environment to use the knowledge, then it would not have been a successful innovator in the chemical sector.

IG Farben, specifically, had an organization, which promoted scientific activities. This organization can be viewed as humus for scientific activities to emerge not only from the top management but also from the lower divisions that were involved in actual production. Research activities were not only better handled but the knowledge that is produced from such activities was able to diffuse inside the company thanks to the organizational structure. In brief, IG Farben's success depended on a set of factors on the junction of research activities and organization.

1. Absorptive capacity of the company
2. Closeness to scientific environment as a result of recruitment policy

3. Mechanisms that extract personal knowledge[55]: key persons charged key positions for example Fritz Haber were the responsible of the committee that dealt with the research activities.
4. Centralization of the important decisions: investments etc.
5. Decentralized research issues for each division
6. Making an environment in order to obtain experience and learn. Labs of the company were proper places for such type of learning that arise from trial-error.

55 By the way, the personal knowledge term was coined by Michael Polanyi. According to Polanyi, this type of knowledge was not extracted fully. Some portion of the knowledge was not codified. Experience and interaction (talking, doing something) was the only way to obtain the knowledge (Polanyi 1998).

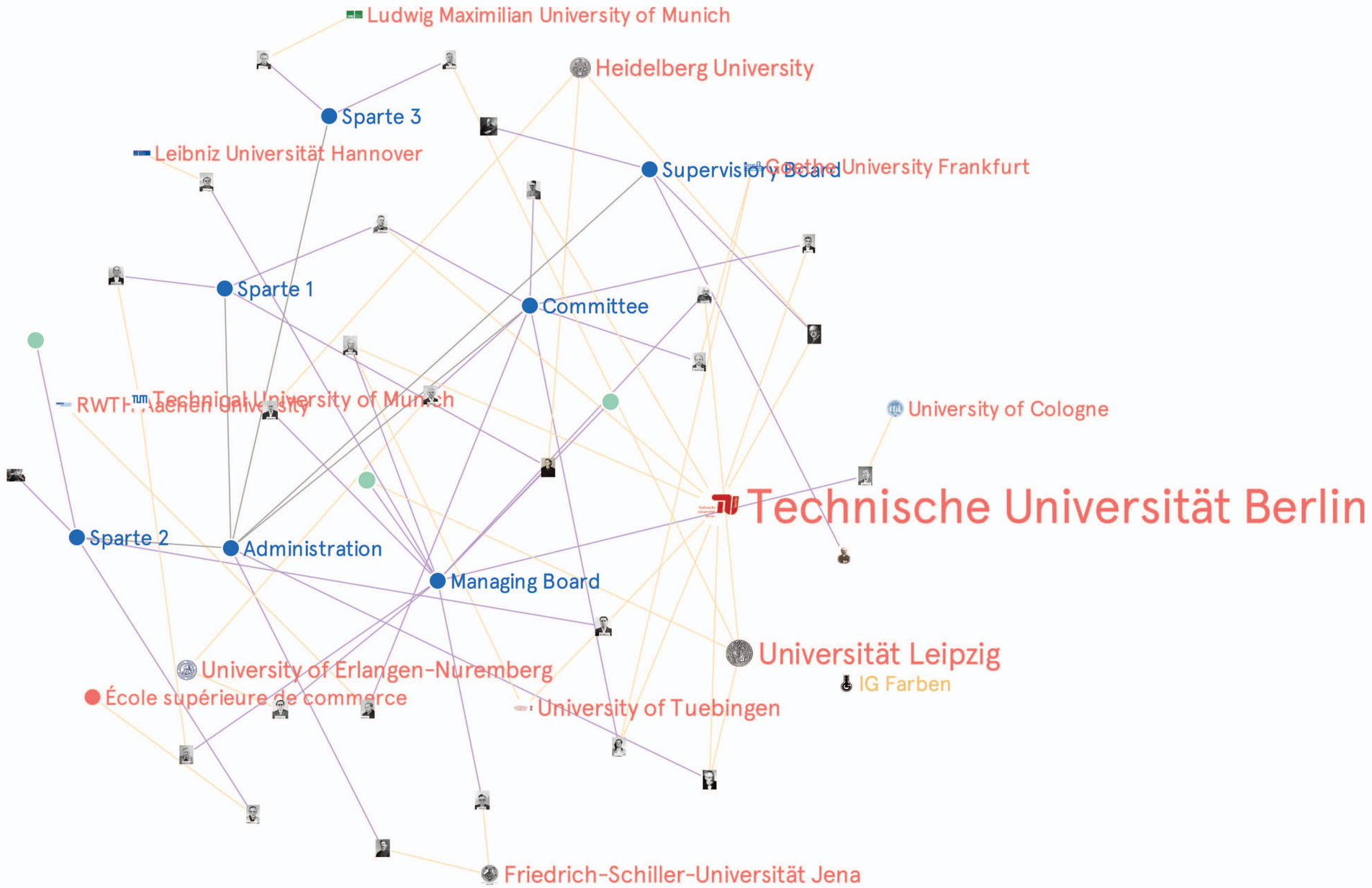


Figure 16: Key Persons and University Linkages: IG Farben

Notes: Purple edges: people who work under the related division. Yellow edges: graduation from the related university. Grey edges: represent Sub-departments. Key Executives: Otto Ambros (1901–1990), Carl Bosch (1874–1940), Ernst Bürgin (1885–1966), Heinrich Bütefisch (1894–1969), Hans Deichmann (1907–2004), Walther Dürrfeld (1899–1967), Carl Duisberg (1861–1935), Max Faust (1891–1980), Friedrich (Fritz) Gajewski (1885–1965)Heinrich Gattineau (1905–1985), Fritz Haber (1868–1934), Paul Friedrich Häfliger (1886–1950), Erich von der Heyde (1900–unknown), Philipp Heinrich Hörlein (1882–1954), Max Ilgner (1899–1966), Friedrich Jähne (1879–1965), August von Knieriem (1887–1978), Carl Krauch (1887–1968), Hans Kühne (1880–1969), Hans Kugler (1900–1968), Carl-Ludwig Lautenschläger (1888–1962), Wilhelm Rudolf Mann (1894–1992), Fritz (Friedrich Hermann) ter Meer (1884–1967), Heinrich Oster (1878–1954), Hermann Schmitz (1881–1960), Christian Schneider (1887–1972), Georg von Schnitzler (1884–1962), Arthur von Weinberg (1860–1943), Carl von Weinberg (1861–1943), Carl Wurster (1900–1974)

Selected nodes and their analysis are given below in Table 1. The table shows that administration clusters have more PhD than others. This means that IG Farben's top positions were occupied by people who had PhD degrees in Chemistry. Therefore, we can say that science-based business was intensely connected to scientific institutions not only from the skilled scientific workers but also from the top management. Knowledge creation and learning in IG Farben greatly affected from this type of relationship.

Table 19: Selected Nodes from the network of the Figure

TOP 5 ORGANIZATIONS	Connections	CLUSTERS	Connections
Technische Universität Berlin	*8*	*Cluster of Administration*	*12*
Universität Leipzig	*4*	*Cluster of Technische Universität Berlin*	*12*
Heidelberg University	*3*	*Cluster of Managing Board*	*9*
Goethe University Frankfurt	*2*	*Cluster of Sparte 1*	*5*
University of Erlangen-Nuremberg	*2*	*Cluster of Sparte 2*	*5*

Finally, IG Farben was a unique organization in terms of carrying R&D and scientific activities in such a big scale. In doing so, IG Farben benefited several organizational advantages. Centralization and de-centralization issues were already mentioned above in details. However, at this point, it should not be forgotten that IG Farben's scale was a disadvantage in some way while coming up with specific solutions for the domestic market. On the other hand, there were advantages of organizing such a big scale of business. Especially, before the Nazi period, IG Farben's investments and research interests were mostly affected by the scale advantage. Hierarchical and bureaucratic structure of the management was influential in doing business. The size of the IG Farben was huge; as a result of this, the important decisions were made by the administrative council and committees. The managerial board was called as "*Council of the Gods*". This means that managerial board had a great voice on the company's activities. IG Farben, unlike Du Pont, was a first-mover in chemistry. Thus, IG Farben had benefited both from economics of scale and scope (Alfred D. Chandler 1990, 175). Company's organizational structure evolved thanks to diversification which stemmed from being first-mover.

IG Farben had always carried the burden of "being the biggest in the sector", thanks to making more research and development activities. The structure was described by ter Meer as: "*a very skilful structure of technical, commercial and administrative*

committees which worked smoothly together or on their own and which dealt expertly with the countless problems of the concern or presented them for a final decision by the board." (Haber 1971, 338). This description is an indication of how a giant could be managed efficiently.

5.5 Du Pont: Science and Market Driven Corporate Strategy

American companies were latecomers in terms of the chemical market. At the beginning of 1913, Germany produced % 85 of world production of chemicals while USA managed a mere % 2 (Reader 1970, Volume 1: The Forerunners, 1870-1926:258). However, after World War I, Du Pont had gained importance in terms of chemical products. Although Germany dominated the market, rivals of German companies like British and American firms tended to grow during the twentieth century. Du Pont was a family company that carried old dynamite and powder business in 1802. Previously, Du Pont only made research and development activities on powder and dynamite (for economic rationales see Chapter 6). Beginning of the new era with three Du Pont cousins in 1903 changed company's organizational structure. First of all, renovation of 1903 was a revolutionary movement for the company. Three important developments occurred after that date:

1. Diversification
2. Decentralization
3. Market driven business strategy

At the beginning of the twentieth century, Du Pont made a decision about product line and process. Dye business was dominated by the Germans. And its patent and licences were not copied easily. Developments in the dyestuff market and licencing issues forced Du Pont for a new quest. Therefore, central research policy and the organization were rebuilt in 1921 for a remedy to diversify product line and gain competence in the world market (Hounshell and Smith 1988, 125). Diversification process had started in 1921 under the leadership of Charles Stine and continued until the War years. Diversification decision accompanied new business strategy. According to this strategy, Du Pont made a key business move in order to gain knowledge and abilities. The new product lines were supported and sometimes mainly created by acquisitions and mergers.

Du Pont, in the process of diversification had done many acquisitions and mergers. For example, vital breakup occurred in agreement with General Motors. According to the agreement, Du Pont obtained a share of the company, which paved the

way for benefitting from the GM research activities. GM experience opened new production areas like finishes, polish, and varnish. At that time, there were no clear-cut protection systems of car body and cockpit for the car makers. A quote from the head of Cadillac illustrates the importance of this kind new products bluntly: *"... bad engine or other mechanical fault in a car which would do less damage, from an advertising standpoint, than poor paint..."* (Hounshell and Smith 1988, 142). Such concerns and the GM experience forced Du Pont into new chemical product lines. After re-organization of the chemical department, cellulose and paint department was founded around 1920s in order to make more research on the sector. Acquisition and merger was a corporate strategy for Du Pont. Figure 3 presents the main acquisitions and mergers of the company from 1910 to 1933. The blue dots refer to companies acquired and merged with the date of the event in parentheses. The red dots reflect product lines.

According to Figure 3, it is obvious that there is close relation between Du Pont's departments and its main acquisitions. For example, nitrocellulose business was not easy to tap in. Therefore, around 1910, Du Pont decided to obtain Fabrikoid Company for entering the new business line. Thanks to research in this line, Du Pont was able to process Nylon and its derivatives. Du Pont's strategy was based on economic rationales such as more profit, gaining competence and innovation. It was a question why Du Pont carried out its business with major acquisition operations. There were two main reasons for that. First of all, during the diversification phase, the company faced new challenges in terms of knowledge and capabilities. Handling knowledge in chemical sector was not an easy work due to the fact that many novelties stemmed from intense and complicated research and development activities. In order to tap in these inventive and innovative processes, the company acquired other companies mainly to acquire their sector specific knowledge (dyestuff, Freon etc.). The main aim of this business strategy (or innovation strategy) was to reach other firms' network, knowledge, experience, and physical opportunities. The second reason was that organizational learning was issued while adding a new firm to the company. For instance, In late 1919, Du Pont entered rayon business with French rayon company (Comptoie des Textiles Artificiels) (Hounshell and Smith 1988, 162). Doing business with French was a good opportunity to learn artificial silk and its derivatives. As a result of this, Du Pont established its Rayon R&D department and entered textile business with innovative products.

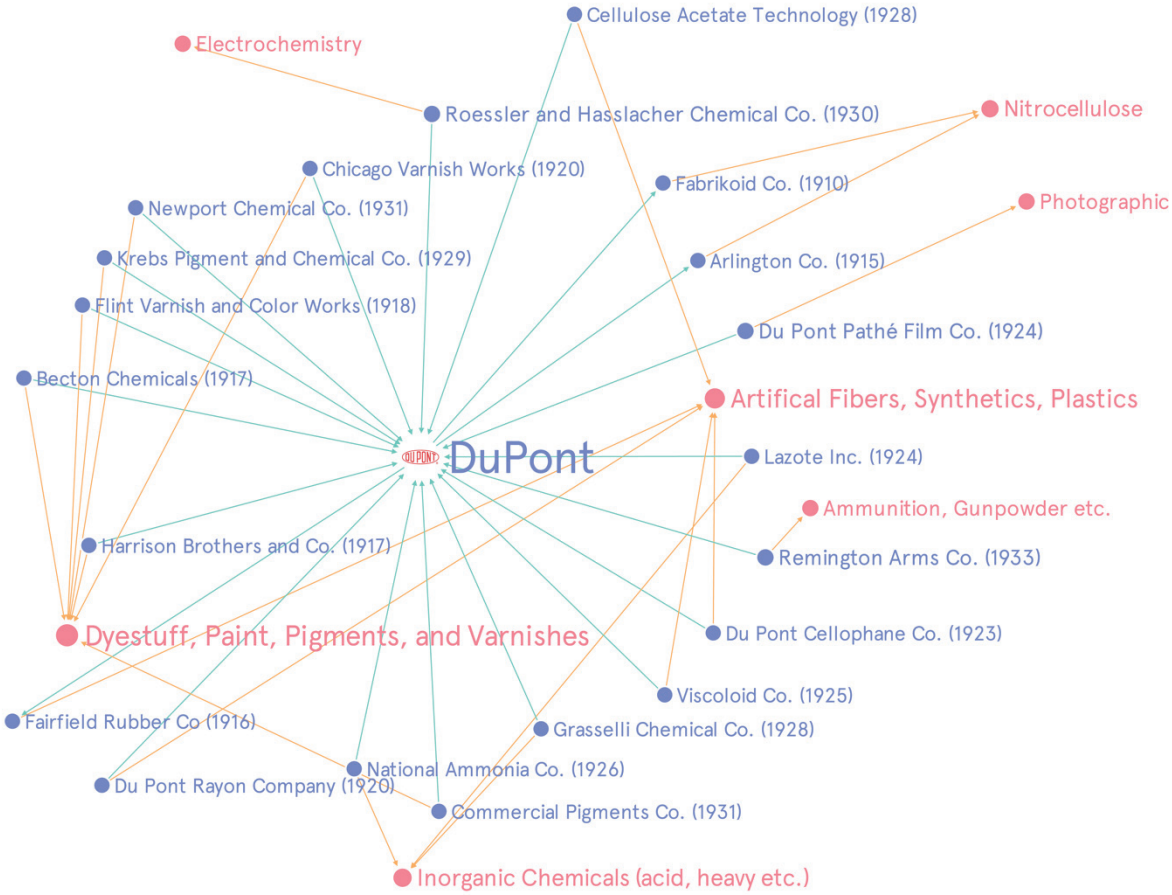


Figure 17: Evolution History of Acquisitions in Du Pont Company 1910 -33 Source: data compiled from (Hounshell and Smith 1988, 608–610).

Du Pont's corporate strategy was slightly different from IG Farben in terms of organizational attitude towards new challenges and importance of market needs. At this point, it should be mentioned that Du Pont was a market driven corporate in some way; on the other hand, as the examples of Cellophane, Nylon, and Teflon show Du Pont actually created its own market demand through dominating the market with innovative products. So as to explain organizational factors which

affected the corporate strategy, managerial structure, knowledge creation and learning will be analysed below.

5.5.1 Managerial Structure

Du Pont was established in 1802. The initial aim of the company was making dynamite and powder business in America. It started as family-business when French origin family had a hegemony in non-organize firms (not a structural company or firm, It emphasized family-business mostly) until 1903, nearly 100 years (Alfred D. Chandler and Salsbury 1971). Until 1903, business was based on research on dynamite and the organization structure was centralized. At that point, the management was by and large non-professional. Chandler proposed that American managerial capitalism was shaped at the early twentieth century. After that industrial structure was dominated by professional managers and more complicated organizational structures emerged (Alfred D. Chandler 1990, 174).

There were two breaking points in the evolution of the managerial structure of the company: the era of three cousins (1903) and Charles Stine's new research programme (1926). Three cousins period was characterized by:

1. More centralized structure
2. Decentralized research
3. Diversification of product lines
4. Professional management structure

All of these changes were important turning points in the history of the company. According to more centralized structure, old family business was replaced with more administrative and controlled management. Chandler and Salsbury described this as "*modern, centrally administrated corporation with its own operating sales, and auxiliary departments…"* (Alfred D. Chandler and Salsbury 1971, 118). Making a new managerial structure was not easy work for the three cousins. At the beginning, T. Coleman du Pont leaded the company as President. Other cousins, Pierre was in the Finance works; Alfred was head of powder and dynamite business. They made important decisions about the organizational structure of the company. Management was carried out with the President and the Executive and Finance Committees. Those committees strictly monitored the activities of

the industrial department[56] and auxiliary department[57]. The departments and sub-firms were directly connected to management of executives. Unlike IG Farben, this management type was mostly flexible. Centralization was always an issue in the company. Therefore, effective management was always mentioned among executives. By 1921, the central management scheme was more-professional and centralized as can be seen in Figure 18 below.

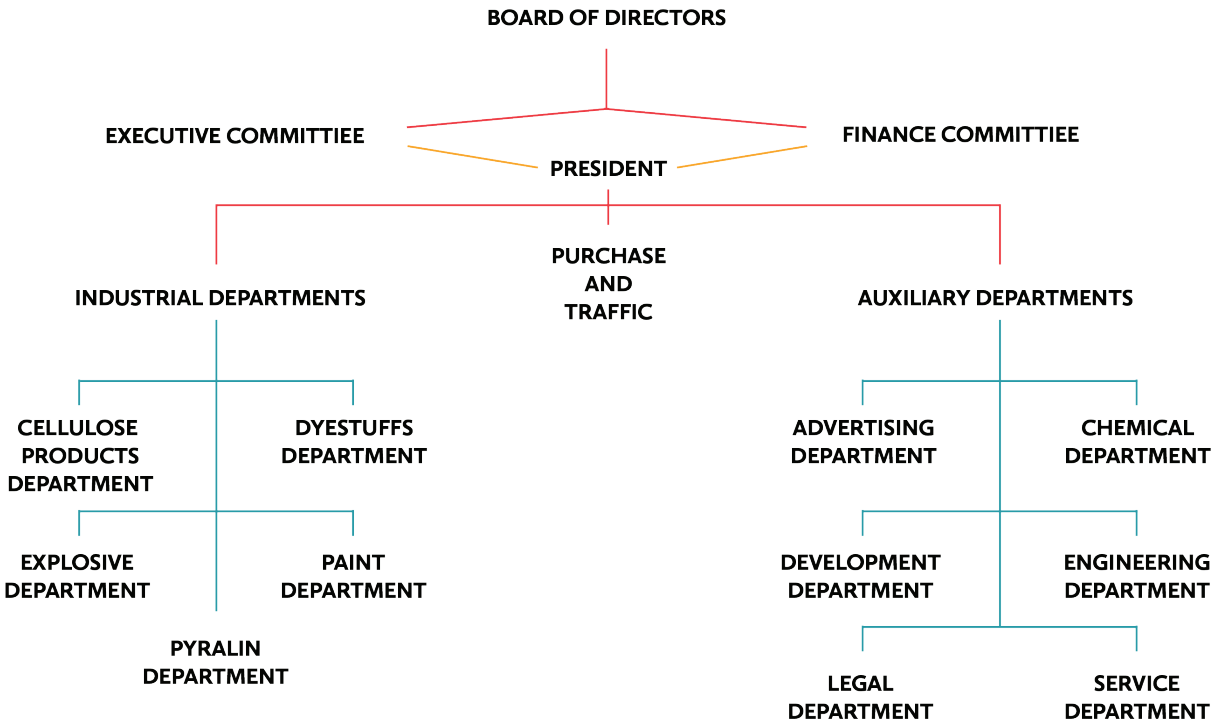


Figure 18: Organization Scheme of Du Pont
Source: data compiled and redesigned from (Hounshell and Smith 1988, 15).

According to Figure 18, professional administration was prominent to carry business. In addition, responsibilities of the president were controlled by the board of directors just as in the case of IG Farben. However, know-how was not disseminated around the company. Apart from research departments and specific knowledge hubs, management structure dealt with managerial problems

56 By 1931, the department contained R&H Chemical Company, Rayon and Cellophane Companies, Viscoloid Co, Graselli Chemical Co., Krebs Pigment and Chemical Co., DuPont-Pathé Film Man. Co., Ammonia Department, Dyestuffs Department, Explosive Department, Fabrics and Finishes Department, Smokeless Powder Department (Alfred D. Chandler 1990, 186–87).

57 By 1931, the department contained Advertising Department, Chemical Department, Development Department, Engineering Department, Foreign Relations Department, Legal Department, and Service Department. (Alfred D. Chandler 1990, 186–87).

like competence, marketing, investment, government relations etc. At this point Du Pont's new managerial system was an integration into American managerial capitalism, mentioned by Chandler (1990). Moreover, decision-making process on systematic product development involved two steps: the president and the executive committee. This means that activity of Du Pont was centralized in managerial meaning. Also, all divisions were monitored and controlled by the headquarter. The effect of headquarter was high from 1903 to end of the World War I. Managerial structure of the company was complicated. At this structure, knowledge and learning was challenging but attractive activities.

5.5.2 Learning and Knowledge Creation

Especially, after Stine, organizationally decentralized research programme was the main source of knowledge creation and learning. By 1921, the main aim of the research programme was dominated by science and "pure scientific work". According to this fundamental research programme, all knowledge sources will be redesigned to reach scientific success, which was desired by the company. Stine's importance could be understood in reorganizing the research divisions in accordance with the de-centralization of managerial task. Moreover, the new way of organization enabled more research and development activities rather than useful and profitable products. These changes was not taken well by the headquarter; however, Stine, in his memorandum, proposed that this type of research organization helped to solve practical issues besides fundamental or pure research (Hounshell and Smith 1988, 224). The plan was simple that all knowledge hubs (individual labs, division research centres, people etc.) were connected to each other through common platforms. In Du Pont, individual research team (Like Carother's polymer team) carried its activities individually in private manner where results of the research were not shared with other research divisions. Only the head of research (Stine) were informed about the progress. On the other hand, non-private of each division research was completely open to all company. Reports, publications, articles, and patent ideas were shared to all researchers in the Du Pont Company (Hermes 1996; Hounshell and Smith 1988). Intrafirm learning did not face serious obstacles during the company history. Du Pont strategy was divided into two important goals: market formation and learning science from others.

Market formation means that the company focused to create market for its new products such as Nylon, Kevlar and Teflon. Demand for those products was not natural; the company successfully made it. As a result of pure research and sometimes

incidentally, new products were invented. At the beginning, fashion and textile industries did not know how to use such inventions. Du Pont also provided this type of information and knowledge to the industry. There were two ways of doing this: magazines and training for using areas. Du Pont Magazine was established firstly in 1913 in order to disseminate products information, user information, and innovations (Kinnane 2002). As a result of this publication, Du Pont's brand name and the practical uses of the products can be understood by the masses. Second important issue was training and instruction books. Du Pont supported those materials and activities so as to gain more market share and sell its new products. For example, after developments in dynamite technology, the Company widen its use to new areas such as agriculture. This step was vital to understand the idea behind corporate's advertising strategy. When Du Pont introduced the new products to agrarian people they published an instruction book which contained how and which dynamites should be used in order to make agricultural land development. (Du Pont 1910). Moreover, in cellophane case Du Pont sent technical people to tell how and why to use the product (Hounshell and Smith 1988, 169). These clever marketing strategies encouraged people to make material based innovation as well. Du Pont's advertising was not only focused on industrialists but also on the public. During the great depression era, economy needed to recover and increasing demand was thought of a good remedy via advertising and product diversification. Du Pont's products which were Cellophane, Nylon, Cordura, Teflon were the main actors in this story. Afterward, those products leaded to many market innovations like: Teflon skillets, tires, food packaging etc. Also, they created new sectors such as packaging design, sensitive transportation etc. all of which were issued thanks to learning (inside and outside) and knowledge networks.

Inside the company, like IG Farben, education background of key persons was important. Science-based business deserved intense skilful attention, which came from the university; however, the company also supported proper recruitments policy. Wallace Carothers, for instance, was hired in the period of Stine and Bolton. Carothers graduated from Harvard University. At that time, Bolton recognized him in the Harvard network as a passionate and smart person. He was hired and he established a team for polymer research in Du Pont. As a result of this, he invented the Nylon (Hermes 1996, 75–135). Du Pont's recruitment policy followed nearly the same path with IG Farben. Accordingly, two companies used the similar recruitment policy which is based on close network relationship and reputation of institutions. Harvard, MIT and Johns Hopkins had decisive role in the history of the IG Farben. In their work, Hounshell and Smith proposed that, there was a

"Hopkins Mafia" in the key positions of the company (Hounshell and Smith 1988, 287 especially under management of the Stine). The key persons who worked in the management and research departments were analysed between 1925 and 1935, which produced Figure 5. The blue dots refer to departments of the company, the red dots refer to universities and finally the green dots refer to people.

The main purpose of this analysis is to show whether there are university cliques (clusters) between the key persons in the company. This is vital to understand recruitment policy and university-firm relationships. If there was a close relationship between division and university's capability (for example Harvard has been prominent in Polymer science), then this may indicate a two-way knowledge transfer either from the university to the firm or from the firm to the university. Under the light of this assumption, Figure 5 explains the relationships among people and institutions. First impression from the figure is that the main clusters were Massachusetts Institute of Technology, Harvard, and Johns Hopkins Universities. The key persons came from those networks. According to the clustering analysis Harvard had 13, MIT had 12, Johns Hopkins had 10 connections (see Table 2). This indicates that people who graduated from these universities brought local and theoretical knowledge of the institutions that they graduated from. When they start working in the company, they naturally brought their personal, tacit, codified knowledge as well as their social and professional networks.

Another important point that emerges from the network is that chemical department was the biggest knowledge hub among others. It was a fact that chemical department had an intense research and development programme and budget (for the numbers please see Chapter 6). In this network, there was an outside connection from Germany. In IG Farben case, it is not a simple connection from the outside. This could be explained as a bridge between outside and inside of the work. In this example, there were three important connections between Germany and USA. Charles Resse graduated from Heidelberg University; Elmer Bolton graduated from the Kaiser Wilhelm Institute; Fin Sparre was from the University of Dresden. Those institutions were noticeable in terms of organic and inorganic chemistry.

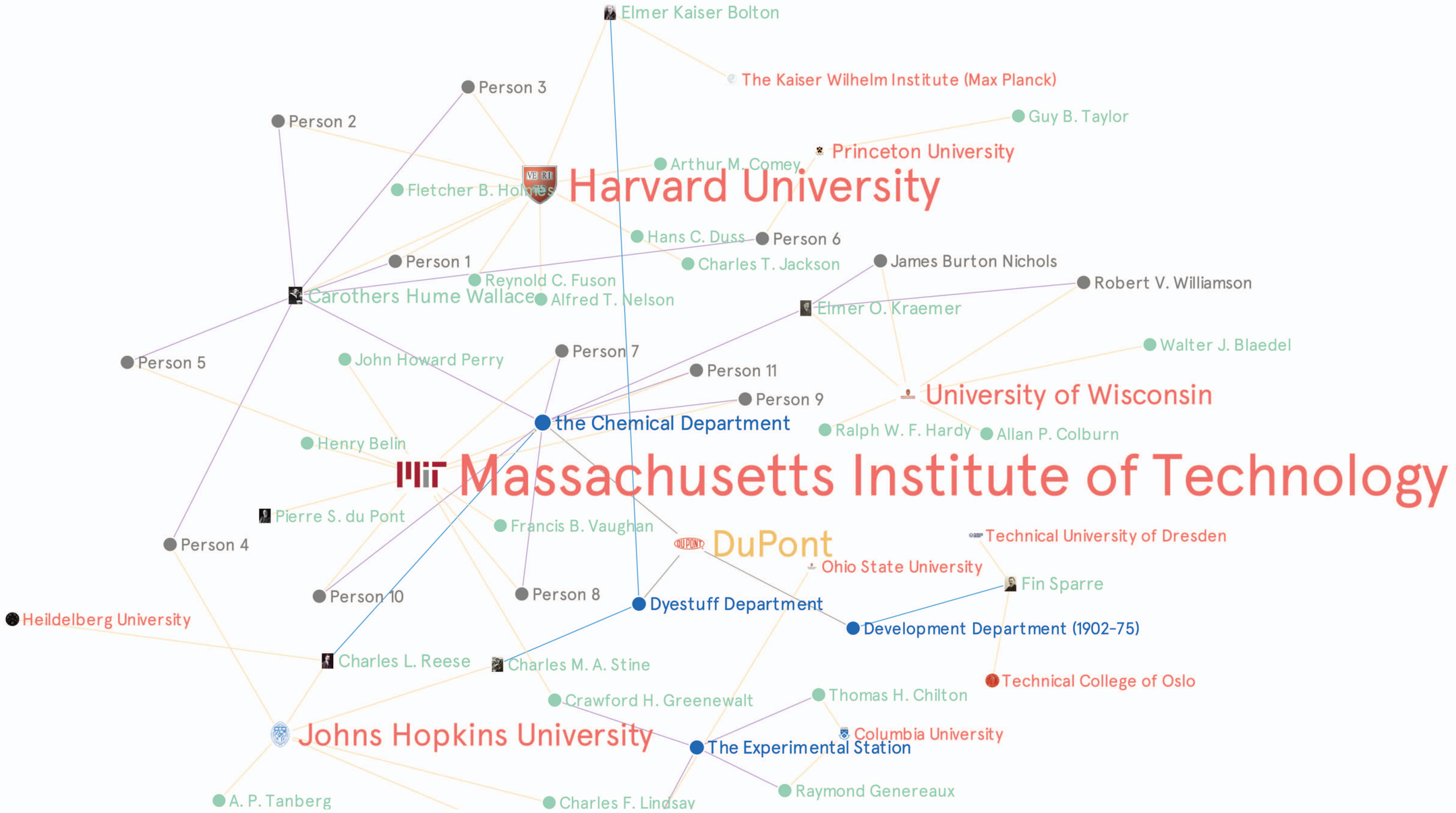


Figure 19: Key Persons and University Linkages: Du Pont

Notes: Purple edges: working under the related division Yellow edges: graduation from the related university Grey edges: representing Sub-departments. Key Executives: Raymond Genereaux, Thomas H. Chilton, Crawford H. Greenewalt, Walter J. Blaedel, Allan P. Colburn, Ralph W. F. Hardy, Charles E. Arnold, Francis B. Vaughan, John Howard Perry, Reynold C. Fuson, Charles L. Reese, Carothers Hume Wallace, Fletcher B. Holmes, Elmer Kaiser Bolton, Henry Belin, Fin Sparre, Pierre S. du Pont, Charles M. A. Stine, Elmer O. Kraemer, Guy B. Taylor, Hamilton Bradshaw, A. P. Tanberg, Charles F. Lindsay, Charles T. Jackson, Arthur M. Comey, Alfred T. Nelson, Hans C. Duss

Table 20: Selected Nodes from the network of the Figure

TOP 5 ORGANIZTION	Connections	CLUSTERS	Connections
Harvard University	*11*	*Cluster of Harvard University*	*13*
Massachusetts Institute of Technology	*11*	*Cluster of Massachusetts Institute of Technology*	*12*
Johns Hopkins University	*6*	*Cluster of Johns Hopkins University*	*10*
University of Wisconsin	*6*	*Cluster of The Experimental Station*	*7*
Columbia University	*2*	*Cluster of University of Wisconsin*	*7*

Those outside connections, before the World War II, turned the close relationship between IG Farben and also ICI. Germany was an important science and knowledge hub in terms of chemistry. As a result of this, Du Pont's key persons benefited from the knowledge eagerly. Final word, the main implications of this analyse is to clarify the relationship between institutions and people. Thanks to those institutions, Du Pont achieved innovations in many product and production line.

To sum up, Du Pont started as a family business. But after two important breaking points (1903 and 1921) the company had followed a new line of organizational structure and research and development framework. This new line brought professional administration in the organization structure and systematic research activities that were both science-pushed and demand-pulled. In this chapter from the analysis of DuPont's organization and its relation with the organization of research activities following points can be made:

1. Du Pont's management structure was more centralized compared to IG Farben.
2. Research and development activities were mostly free organized in a decentralized structure.
3. Network of the key persons in the firm is a proof that universities are indispensable source for science-based firms.
4. Business strategy of the company was not only market-driven but was also market forming.
5. Finally, Du Pont's communication strategy between departments was coordinated by the president and the executive committees.

5.6 Summary

Especially, after the foundation of IG Farben around 1925, global chemical market tended to grow and many other chemical firms joined the market. IG Farben and Du Pont though rather different from each other were two successful big firms in the market. Predecessor firms of the IG Farben had already started to do systemic chemical research at the middle of nineteenth century. Thus, so to say, IG Farben sat on the shoulder of giants. Du Pont, however, established as a family business with a rather narrow scope evolved to play major role in the chemical sector starting from the 1900s. Considering the major acquisition and merger operation of Du Pont in the 1920s, it won't be wrong to say that the two companies had more or less started the business around 1920s (to be exact IG Farben in 1925 and Du Pont in 1921). From this date, the research and development activities were a major driver of the chemical industry. Science was always the supportive force in stimulating economic growth. At this point, two companies followed their own paths. In this chapter, the role of organizational learning and structure was analysed. Comparison between two cases may be helpful to summarize this chapter. Main findings of this chapter are as follows:

1. Significance of central management in such a scale was recognized by both companies.
2. Research activities were not directly intervened by the presidential office in Du Pont; on the other hand, research activities were directly determined by executives in IG Farben.
3. IG Farben relied on scientific management. Rules, routines and standards were very important. Du Pont had a more flexible production system.
4. Recruitment policies more or less were the same for the two companies.
5. University networks were important not only as a source of knowledge and human capital but also as a source of social capital of the people in the top positions.
6. Both in IG Farben and Du Pont managers were well educated and most had PhD degrees.
7. IG Farben created a new entrepreneurship form: scientist-entrepreneurs like Carl Bosch is a good example to this.
8. Du Pont knew that American market system needed to expand itself. Understanding the importance of new products was a major breakthrough for the firm.

9. Finally, learning opportunities inside and outside were recognized in both companies. Moreover, those opportunities were institutionalized for obtaining even more benefit from them.

Finally, those findings are provided to summary of this chapter. On the other hand, some issues need to be addressed for further explanations about the cases. In this dissertation, data that comes from different sources is analysed in some variety ways. Descriptive statistics and analysing of secondary data are the common way that is used to explain the question of the dissertation. Second way is network anaylsis. The rationales for using the network anaylsis are described and explained in the methodology chapter of the dissertation. In this paragraph, I will make further explanation about network anaylsis and the relationship of this chapter. Firstly, there are three important points while selection of the anaylsis. First is about limitation of mathematical numbers. Sometimes, works are related to numbers to explain something in descriptive way. For example, GDP or population numbers are used to understand the difference between the selected countries in one hand. However, detailed analysis and answers come from further research on it. In some case, generally social science, the numbers are not sufficient to explain process, change or spontenaous order etc. Because of this reason, visualization might be a proper tool to explain something. Furthermore, in this chapter, I use some historical data and put them together to understand linear relationship between parameters. For example, graduation information of the people shows us there is a close network relationship in formation of research teams. The slightly different case can be observed Du Pont case. I mean that the information about the graduation can not be explained in numbers. Morover, the numbers can not say something about graduation and research teams' relationship. Second important point is bridges. Bridge or gates in network anaylsis are commonly used to understand relationship between nodes. At this point, the links and bridges in some case can be very important part of the anaylsis. There is no indication with number in any social theory to explain why and how information flows occur through those bridge and gates. Last point is about visualisation of the data. Visulisation can not be understood by all of scientific fields frequently. However, new trend, especially in natural science, is visualisation data to make better understanding. For example, the relationsip between ebola epidemic and country can be showed with the help of network anaylsis of big data. Another example, the cooperation between Neanderthal and Homo Sapiens through history can be showed with the same methodological tool. There is no historical record in numbers for this case. Similarly, in this dissertation those networks are used to comprehend some relations. Networks of the manager and research teams are the proper example for this.

Advantages of the network tools are summurized above. In this paragraph will focus on what important points are indicated by this anaylsis. There are several important and essential things; however, three points are need to explain in this line of the paragraph. Those are:

1. Governmental relationships
2. Key persons
3. Close networks

According to data that mentioned in this and previous chapters, governmental relations betweem corporations create vital differences between Du Pont and IG Farben. In Du Pont case, the demand side effect of government creates some new research areas for Du Pont in explosives and powder business. According to visual data, it can be clearly observed the close product and user relationship. Other case draws different graphs in product and users until the war. Those give us an insight and information about the cases. Which and how differences and similarities affect the research agenda of the corporation can be understand with this way. Other important point is key persons and its effects on the process of recruitment for research and management departments. In this title, the main findings say that the more or less the companies used the same path to select persons for the departments. According to data, networks shows close structures of the networks as cliques and clusters. The mapping of the network is very useful to understand the action of cases. Final point is related to the close networks mentioned upper line. Close network means each node closely linked to others. Closeness is measured by weight of line. According to this information, close networks have two vital features: more information sharing between nodes and emerging new ideas thanks to more interaction. The cases have relatively close network clusters in recruitment and graduation parameters. Therefore, each close network makes more creative idea and research thanks to link other individual networks. For Du Pont, Johns Hopkins network contains more linked people (hiring or recruitment). Informal relations, because of those network, can be enable tacit and experienced knowledge between research groups or teams. Similarly, for IG Farben, the network in Berlin Technical University had vital role to benefit from those network opportunities.

This chapter thank to network analysis and descriptive statistics examined two cases to understand managerial and organizational differences to touch research habits, routines and changings. Next chapter will be analysed those routines for each case separately.

CHAPTER 6

EFFECTS OF RESEARCH AND INNOVATION ACTIVITIES

"Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited national resources, and will assure means of defence against aggression. But to achieve these objectives - to secure a high level of employment, to maintain a position of world leadership - the flow of new scientific knowledge must be both continuous and substantial."

Vannevar Bush[58]

(After visiting Bayer's research facility) «The foregoing is but a very imperfect account of this marvellous works research laboratory. A more typical and concrete illustration of the appreciation of the value of science by German manufacturers, however, could not possibly be found. but yet it is only one of many that might be brought forward. Personally, I can. only say, that while lamenting the criminal short-sightedness of my countrymen, I am lost in admiration of the enterprise displayed by their foreign competitors: it cannot be denied that they deserve to succeed!»

Henry Edward Armstrong[59]

6.1 Why Innovation and R&D Matters?

As many works have proved, invention and innovation activities are considered as important economic phenomena (Hall and Rosenberg 2011). Occasionally, technical advances (steam engine, telephone) happen thanks to those incremental or radical changes, but being considered as an innovation or not requires more questioning. The two concepts have ordinarily close relationship and sometimes they are confused, although there is an explicit difference between them. As Joel Mokyr said, invention and innovation relationship must be distinguished in order to answer three questions: why and how technical changes occur? How technical creativity happens? Do those changes create a determined pattern in terms of the economy? (Mokyr 1990, 11).

58 1890 – 1974, Head of the *Office of Scientific Research and Development* during the war. (Bush 1945, 10)

59 1848 – 1937, English chemist and fellow of the Royal Society.

At this point, the differences between innovation and invention and their importance will be provided. Moreover, foundations of those activities and their relationship with research and development (in general meaning), and science (in specific meaning) will be mentioned.

In simple meaning, innovation is a process, which covers all economic human activities. The "process" idea was also supported by Joseph Schumpeter in his well-known book entitled as *Business Cycles* (1939). According to Schumpeter, meaning of innovation has to include *making new things* inside the realm of economy (Schumpeter 1939, 80). This means that individuals or innovative people who are called as "entrepreneurs" by Schumpeter, act in accordance with economic benefits (i.e., the profit motive). Moreover, those who want to make difference in economic environment have to commit innovative activities for gaining economic advantage (Sweezy 1943, 93). The link between innovation and economic benefits was additionally mentioned by Mises: "*The driving force of the market, the element tending toward unceasing innovation and improvement, is provided by the restlessness of the promoter and his eagerness to make profits as large as possible*" (Mises 1963, 256). According to him, nature of the market is shaped by human action of entrepreneurs who are making new things to reach new profit opportunities. As known from Schumpeter's work, innovation is a dynamic process, which results from the capitalist economy where entrepreneurs seek entrepreneurial profit (Schumpeter 1934). As a result of those actions, the new ideas are put into practice and entrepreneurs establish their businesses. In broad perspective, those actions are repetitive in an economy (Schumpeter 1934, 17). Naturally, the repetitions, somehow and sometimes results in discovery of "new combinations". Finding new things and putting them into practice (at this point practice refers to economic use) are the first features of innovation. The second feature is to be introduced to the market for economic gains (Schumpeter 1934, 45). In so far, as provided above, the features of innovation are sufficient to distinguish *innovation* from *invention*. Hence, the basic and noticeable difference between them is its *application* in market. Innovation could be established in the market and have to be demanded or developed through the market.

On the other hand, *invention* or *inventive activities* are not required to be market assets that would make money. Jan Fagerberg (2005) illustrate this difference by giving example on *time lag* between invention and innovation. Sometimes, complementary factors (added technical improvements from other sectors etc.) and vital inputs (demand etc.) are not suitable to produce an *invented thing* in commercial scale

(Fagerberg, Mowery, and Nelson 2005, 4). For example, Leonardo da Vinci (1452 – 1519) sketched many drawings on flying machines and made prototypes of them. The effort could be evaluated as inventing some new things. However, because of the "proper" technical conditions, commercialization of flying was delayed until the 1900s. Moreover, Kline and Rosenberg (1986) state that "*The fact is that most important innovations go through rather drastic changes over their lifetimes—changes that may, and often do, totally transform their economic significance. The subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form*." (Landau and Rosenberg 1986, 283). For instance, invention of steam engine was a technical improvement in the field of machine industry; however, economic effect of it was observed after the introduction of the technology as an internal production factor for the industry. Moreover, Adam Smith (1723 – 1790) in his famed book entitled *the Wealth of Nations*, emphasized the economic effects of invention and innovation in terms of labour productivity in England. He states that *"...the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many.*" "Invention of something" (in his case, it is the steam engine) caused productivity to rise. As a result of this, economic effect of an "invention" was observed in England as organizational change in the industry. Furthermore, this example shows that invention and its practical use provides some economic benefits like rising productivity during the Industrial Revolution in England.

So far, differences between invention and innovation are emphasized. In accordance with the consensus on the definition, the main differences of those activities could be grouped in three points: the first is that each invention could not be transformed into an innovation; the second is that while innovation requires an interaction between economic and social institutions, invention does not; the third, and most importantly, innovation needs an economic incentive mechanism like making more profit; on the other hand, invention does not. Non-economic incentives (with Mokyr's term intangible symbols) like rewarding Nobel Prize, medals etc. also matter for inventions (Mokyr 1990, 40). In order to clarify the differences between invention and innovation several examples are provided in Table 21 below.

Table 21: Some Examples on Invention and Innovation

Invention	Innovation
Typography, Printing Ink	Printing Machine
Synthetic	Gore-Tex waterproof jackets
Silicone, Electricity	Transistor
Cellophane	Food packaging
Nylon	Women Stockings
Wheel [1]	Car
Radar	Car's pedestrian radar

(1) Here is an important point: invention of wheel and its practical use could be considered as inventive activity. Moreover, using a car for transportation has many "incremental" innovation processes. Finally, commercial appearance of car is considered as an innovative activity.

Innovations could be classified according to types and characters. From Schumpeter's writing, Fagerberg (2005) summarized five types of innovation:

- New products (e.g., rubber tires).
- New methods or techniques of production (e.g., Haber–Bosch process in the making of ammonia).
- Making or discovering new sources of supply (e.g., Synthetic fuel contrary to fossil fuel).
- Finding new markets (e.g., Nylon and women socks market).
- Organizing business with new approach (e.g., DuPont's marketing strategy for selling its dynamite to farmers. See Chapter 5). (Fagerberg, Mowery, and Nelson 2005, 9–10).

The types of innovations can be observed broadly in the industry. For example, IG Farben could be classified as innovative in terms of creating new markets, products and methods. Similarly, DuPont could also be considered as an innovative organization. At this point, further explanations on innovative activity can be useful to answer the question on how and why innovation occurs. Not all new things are inventions. Sometimes, small but non-scientific technical improvements (for example organizing production differently) can cause technological change. Innovation that involves small but not novel changes can be characterized as *incremental* or *marginal* innovations. Otherwise, when "mostly" novel and significant things are introduced

to market, they are named as *radical* innovations (Fagerberg, Mowery, and Nelson 2005, 6; Hall and Rosenberg 2011, vol. 2, chap. 4). Demarcation between terms like radical or incremental is not determined clear-cut.

As known from empirical works, innovation process has a systemic nature (Freeman and Soete 1997; Hippel 1988; Nelson and Rosenberg 1993). According to this explanation, innovation requires some external sources like institutions (market, financial system etc.), organizations (public, private enterprise etc.) and incentives (public or private encouragement like tax incentives, profit opportunities etc.). In some cases the process is handled by the private or public sectors. For instance, IG Farben's rubber works were considered mostly a private initiative. Du Pont's dynamite innovations generally stemmed from public demand. Those activities, mostly, are carried out by entrepreneurs who are encouraged by economic incentives such as decreasing tax rates, public procurement etc. In addition, innovation is also stimulated by establishing right business mechanisms like finance of innovation. Thus, with the words of Van de Ven (2008, 149), innovation is a "collective achievement". Although economic institutions of a country can stimulate innovation performance, likewise, the social (Mokyr 2016) and scientific (Jacob 1988) experience of a country affect the innovation process. For example, "*Cultural Entrepreneurs*"[60], with Mokyr's term, are those who lead the cultural change in a society in economic and institutional terms. In addition, according Mokyr, Isaac Newton (1642 – 1726) was a social entrepreneur by revealing the rule of nature in a systematic manner (mathematics, physic, astronomy). Subsequently, Newton's approach changed many things in science and technology and influenced economic development in the eighteenth century (Mokyr 2016, 99). Changes in scientific perception have shaped today's scientific vision in every field of applied and basic science such as engineering, mathematics, and physics. Francis Bacon (1561 – 1626), like Newton, was a pioneer to establish scientific method and scientific principles (Mokyr 2016, 71–98). Today's economic and technological advances influenced and developed via those "innovative" impressions.

60 Entrepreneurship can be defined in various ways. For economic definition, Kirzner perceives the entrepreneur as a profit-seeker and aware of *alertness* which come from market. This kind of features of entrepreneur causes finding new things, discoveries and profit opportunities in the market. Moreover, Kirzner said that market process has many actors and entrepreneurs are important in economizing opportunities. Entrepreneurial profit approach is the key to understand how firms and individuals succeed in market conditions. Kirzner emphasizes this function as a result of intended and unintended consequences of the process (Kirzner 2015). The sociological definition, for example, Greif's moral entrepreneur definition tries to stress how some societies are affected by the persons who are important in affecting their followers with moral visions (Greif and Tadelis 2010).

Innovation, in terms of economic dimension, has been a complicated phenomenon. In the literature, the complication has been tried to be explained through measuring innovation in many ways such as the *Community Innovation Survey*, patent statistics, technological machinery inputs, research and development expenditures etc. (K. Smith 2005, 149). Measuring innovation enables to explain *how and why question* but the measurement problem has not been solved yet. Some features of innovation, social or philosophical as mentioned above, have not been assessed properly. Likewise, an invention or innovation process includes many variables and factors: social order can affect an innovation process (before Enlightenment, between 1685 and 1815 church has an authoritarian role on science and society in Europe (Dixon 2008, 14)), economic institutions can be important (competition has positive effect on innovation and invention process (Cantwell 2005)), cultural differences can be a leverage in innovative activities (knowledge and growth has been truly influenced by acceptance of cultures (Jacob 1988; Mokyr 2016)). In the light of these facts, it can be said that innovation is an evolutionary process, which is affected by various circumstances.

At this point, as it is known, innovative process, scientific improvements and research are closely linked to each other. Scientific research or pure science activities may also have positive effect on innovation activities. The research on this issue proves that funding basic science creates more innovation (Bush 1945; Crawford 1981). In addition to this, Flexner also supports the idea that science can be effectively promoted for the sake of science; as a result of this, many technical and technological improvements are accessible for the economy and society (Flexner 2017). It is a fact that Maxwell's equations led to industrial applications such as radar, electrical based devices etc. Moreover, if Robert Boyle (1627 – 1691) had not made research on the sake of "science" and had not composed *Boyle's Law*, then rubber tires could not be introduced to market. Or if Newton had not discovered the laws of optics and colour spectrum using calculus and reflecting telescope, humanity would never have met with Gore-tex synthetic textile fabrics (Tyson, Strauss, and Gott 2016, 35). The relationships cannot be separated from each other easily. Science can create technological development; likewise, technology can promote science. Furthermore, innovation sometimes requires scientific research, but sometimes not. However, as it is known from the works of Hayek, scientific knowledge has two distinctive characteristics: non-dispersed and cumulativeness (Hayek 1945b, 2012a, 189; Oguz 2000, 150). Non-dispersed means that knowledge czan acquire from systematic theories like *General Law of Gravity*. The important point in that sense is that scientific knowledge is available for all and general rules

of scientific knowledge could be explicit and centralised contrary to economic knowledge. Moreover, cumulativeness refers to a process. Knowledge might be developed and acquired with the help of *trial and error* actions of others' (Petsoulas 2013, 19). A scientist uses scientific knowledge, which has been composed earlier. For example, Newton's effort to make systematic works on calculus paved the way for developments in modern chemistry. Each known thing in a society emerges with the help of past *experiences* and *codified* (explicit) knowledge[61]. This fact proves that scientific developments and research, in the long-term shapes industrial products and processes and naturally and type of industrial relations.

Finally, the demarcation between science, novelty and innovation cannot be drawn easily. Causality relationship between them is a problem. Cumulative process of science provides innovation process with the help of R&D. The aforementioned topics show that innovation and technological progress are not meaningful without scientific achievement. In so far, the arguments explain the question on why and how innovation occurs. In order to avoid confusion in the process of knowledge creation the story of rubber ties is illustrated in Figure 1 as an example of the complicated relations between science, research, invention and innovation. The main aim of the figure is to show how each scientific improvement can be important on next scientific invention or technological innovation. If work on optics somehow had not started, Newton may not be successful in forming scientific rules. In a similar manner, demand on rubber forced private sector (Bayer) to foster scientific research in order to produce rubber synthetically.

61 Codification debate in the science and technology literature has an extensive coverage. With Michael Polanyi's vocabulary, knowledge has not always been created in explicit way. As a result of its nature, sometimes individuals have knowledge but they are not aware of how "knowing" happened. This type of knowledge is called as *Tacit Knowledge* (Polanyi 1983). Scientific knowledge can mostly be explicit like formulas, laws, systematic, calculations etc. Nevertheless, tacit dimension of knowledge cannot disappear in the knowledge creation process according to Polanyi. At the expense of giving a long citation, in order to clarify the importance of tacit knowledge in science his words are quoted (bolded emphasis is the author's): "*The popular conception of science teaches that science is a collection of observable facts, which anybody can verify for himself. We have seen that this is not true in the case of* ***expert knowledge****, as in diagnosing a disease. But it is not true either in the physical sciences. In the first place,* ***you cannot possibly get hold of the equipment for testing****, for example, a statement of astronomy or of chemistry. And supposing you could somehow get the use of an observatory or a chemical laboratory, you would probably damage their instruments beyond repair before you ever made an observation. And even if you should succeed in carrying out an observation to check upon a statement of science and you found a result which contradicted it, you would rightly assume that you had made a mistake.*" (Polanyi 1983, 63–64).

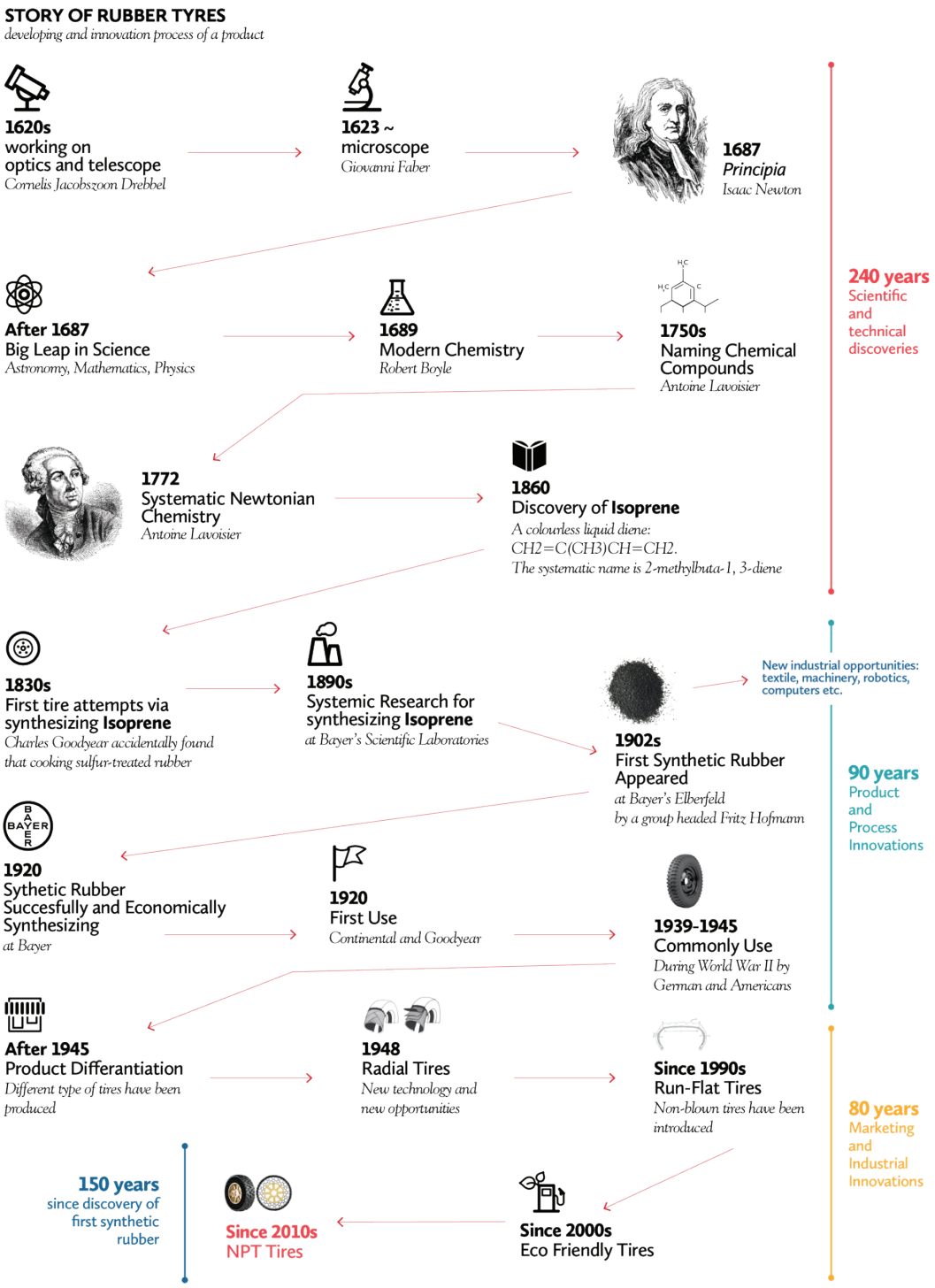


Figure 20: Story of a Product: Scientific Activity, Research, Invention, and Innovation Process

Source: *Telescope and microscope*: **(McClellan and Dorn 2015, 243, 288), Newton (Iliffe 2007; Nicholson 2016),** *Chemistry, Lavoisier, Isoprene* **(Atkins 2015; Daintith 2008; Talapatra and Talapatra 2015, 332; Yount 1997),** *Synthetic Rubber* **(Daintith and Martin 2005; Harp 2016; Obrecht et al. 2000),** *Bayer* **(Verg, Plumpe, and Schultheis 1988),** *Tires* **(French 1991).**

As seen from Figure 1, the process of innovation (rubber tyres) is divided into three main parts. The first part is scientific advances and novelty (revolutions). It took 240 years to transform the first scientific ideas in to modern chemistry. At this point, education system and dissemination of science have a key role to understand the process. In that period, different geographies had different science capacities; therefore, dissemination of knowledge was not easy in the field of science. The second part is related to research-intensive developing process. Private entrepreneurs bear the big responsibility to generate economically efficient products. Bayer, for instance, already had a private R&D laboratory at Elberfeld, Germany so as to realize industrial opportunities in the field of chemistry. In this very specific laboratory, Bayer had extensive research on tar, dye-manufacturing and rubber since 1860 (Armstrong 1893, 30). By 1902, Bayer opened *Artificial Rubber Laboratory*[62] and employed 11 chemists. At that time, totally 262 chemists (57 of them is research chemist) was employed at all laboratories of Bayer (Meyer-Thurow 1982, 371). The third part of Figure 1 is mostly associated with organizational and incremental innovations. It took 80 years to develop variety of products with different novelties. Considering the very long history, novelty of tire is truly affected by scientific and technical advances, which is very good example of Hayek's cumulativeness mentioned earlier. In summary, developing a product or inventing something takes long time (in this example it might be as much as 410 years) from pure scientific research to actual product.

6.2 Elements of Innovation

Innovation is treated as a complex issue in the literature. Features, specializations and factors that make innovation have profoundly been tried to be defined since the time of Schumpeter. Initial works on the issue can be considered as an attempt to reveal the nature of innovation and its institutional roots. Nelson and Winter (1982) tried to understand the change in economic relations. The main argument is that if economic development is observed there must be a driving force, which trigger those changes. Technology is one of the most important driving forces.[63] The understanding of economic growth and increased competitiveness are improved by innovation theories. Most of industrial case studies, like Freeman (1987; 1997), Dosi (1984b), Mowery and Nelson (1999), and Malerba (2004)

62 By 1902, Bayer had seven laboratories: Main, Pharmaceutical, Bacteriological, Inorganic, Alizarin, Photographic and Technical Products, Artificial Rubber Laboratories.

63 At this point, in mainstream economics after Marshall, technology is not a calculable variable contrary to Nelson and Winter's arguments. According to Marshall, technology is given (Rothbard 2006, 105).

reveal that competitiveness, economic growth and industrial relations have been positively correlated with innovation and technological change. Another important step in the literature is the emphasis on the difference between innovation and technological change and the "system" approach that is used to understand innovation. The approach premises that in a given boundary (like nation, sector or cluster) firms perform innovation and research activities in a tight nit of network that consists of economic, social, political, organizational and institutional actors. The determinants of a "system" have been developed by Nelson and Rosenberg (1993) and Freeman (2008). Elements of innovation have been examined at the nation, sector and firm level extensively. Some cases show that innovation process might not require a "system" in the short term; on the other hand, research activities, in the long run, need a well-defined set of investments, incentives, organizations and institutions. Moreover, those elements are inevitable for establishing a successful innovation system. Silicon Valley example can be explanatory for a successful system approach. If had no patent, education and market system, the Valley could not be a success story. For the particular case of the chemical industry, in the long run, the firm cases investigated in details below were supported through establishing strong and coherent systems like patent, education organizations and other incentive mechanisms.

In the case of chemical industry in Germany and USA there was a proper ground to understand the elements of "research and innovative activities". For each IG Farben and DuPont, the innovation ecosystems, which the firms are embedded in, were observably different. However, the difference in innovation ecosystem was also a result of success of the two giant companies. The next part of the chapter clarifies various issues like how research is conducted in each case and how innovation elements that act as a stimulus to economic efficiency are decisive for success.

6.3 IG Farben: Mecca of Chemistry

Even in the beginning of the 20th century, Germany had a significant science history that was benefited generously to develop the chemical sector. There was no doubt, until now, Germany, naturally IG Farben had a remarkable history in terms of developing science organizations (*Academy of Sciences Leopoldina*, 1652; *Prussian Academy of Sciences*, 1700) and scientific institutions (*Gymnasium*, *Technische Hochschulen*, *Humboldt* rules in higher education). Under this title, three issues will be considered in detail in order to understand the effects of research activities in the

company: *heritage from the past -science and research tradition until 1900s*, IG Farben's *industrial research before and after Hitler - intervention period*, and *the integration to the world again*.

6.3.1 Heritage from the Past: Science and Research Tradition until 1900s

As David Landes puts it, Germany has an extraordinary position among other competitors in the chemical industry which resulted in a monopoly in the beginning of nineteenth century (Landes 2003, 275–76). Also, Meyer-Thurow supported the idea of "great" Germany in chemistry. He argued that German dye manufacturers had a supremacy in both science-based industry and growth of the sector (Meyer-Thurow 1982, 363). The facts about German's dominance were based on the country's science and education history. Germany had a rooted science history; similar to Britain. *Academy of Sciences Leopoldina* was established in 1652. Its members were most influential and notable scientists like Max Born, Albert Einstein, Gustav Hertz, Carl Bosch, and Fritz Haber ("Die Leopoldina: Nationale Akademie Der Wissenschaften" 2017). Moreover, science background of the country as a result of the scientific accumulations delivered many scientific developments (radar, synthetic fuel and X-ray etc.) leading technology development and technological products in many aspects. According to Cornell, science inheritance was a significant aspect in understanding technology and scientific advance of Germany (Cornwell 2004). In parallel, Germany had great scientific knowledge in chemistry, especially organic chemistry. Dye manufacturers generously benefited from the knowledge of organic chemistry since the beginning of 1850s. According to Marsch, rapid growth of chemistry industry had started at Offenbach region in Germany. Hoechst, Bayer, Griesheim-Elektron, BASF, and Kalle was founded between 1850 and 1863 (Marsch 1994, 25). The founders of those firms were university educated chemists or hold PhD degree in chemistry. In addition to this, in order to benefit from scientific knowledge, firms conducted original research activities thanks to "scientist" workers. By 1863, BASF employed one chemist; Bayer had three. By 1912 BASF had 300[64] and Bayer had 320 chemists, respectively (Marsch 1994, 26). In 1928, IG Farben employed 642 chemists only in Central Laboratory at Ludwigshafen (Johnson 2000b, 43). There were about 1000 chemist in the entire IG Farben from the beginning of the company (Marsch 1994). In addition to this, science-based firms strongly implemented their own research programs. After its establishment Bayer set out its research laboratory to do research on organic chemistry in 1886[65]. Same

64 Total workers of BASF (included chemist) was about 6400 in 1900 (Homburg 1992, 105).

65 *Laboratorium der Azofabrik, Wissenschaftliches Hauptlaboratorium* (Homburg 1992).

path was observed in BASF, when Heinrich Caro founded the Main Laboratory in 1877[66] to carry out high quality research works. As a result, establishing a system of research caused each company to had its own infrastructure to transform its scientific and technological knowledge. Another IG Farben constituent firm, Hoechst, established its *Zentrallaboratorium* at Frankfurt in 1883 (Lindner 2008).

Organizational and institutional change in the dye industry resulted from two important events. The first was enactment of the German Patent Law (*Reichspatentgesetz*) (1877). The second was related with economic factors as a result of scientific advances and developments. German Patent Law in 1877 was changed especially for the chemical sector due to the fact that to produce material copying the products was not allowed anymore. Therefore, the process, procedures and techniques could be patented to the firm. Before the Patent Law, firms did their research activities outside of the firm. This type of institutional change induced by the patent system led the conversion of the sense of research (Homburg 1992, 104; Marsch 1994, 23; Meyer-Thurow 1982, 367). Changes had been initiated inside the firms as forming new research units to make fundamental and applied research. As mentioned above, BASF and Bayer and many other dye manufacturers set their laboratories inside the firm to found new products and processes. The second development was related to economic factors that affected production of dye manufacturers. Market of dye had been rapidly growing during the 1850s. Growth factors were mostly based on demand. More demand from textile industry and other fabricators who use organic chemical intermediates increased the production of dye manufacturers. To illustrate, by 1878, estimates showed that world production of dye was about 70 million RM; 44 million of it was produced by German firms. This number, in 1883, was 92 million of which 60 million was the share of Germany (Meyer-Thurow 1982, 365). Further research in chemistry promoted new processes that resulted in making and producing chemicals in an efficient way. This increased production and affected the numbers of workers positively. From 1860 to 1900, the biggest chemical producers grew at an exponential rate. Firm size in terms of employment could give an idea about the sector's importance and composition (See Figure 21).

66 It was initially founded as Caro's private laboratory and afterward it became *Hauptlaboratorium* for BASF company.

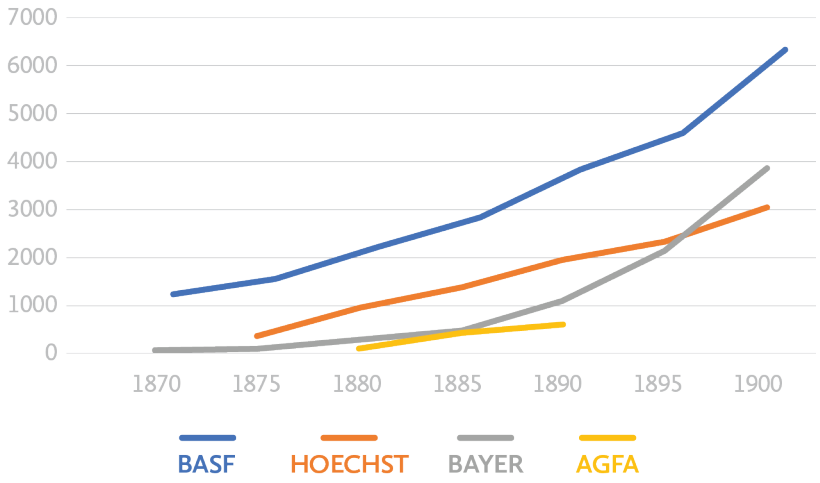


Figure 21: Number of Workers between 1870 and 1900
Source: Data from (Homburg 1992, 105)

Size and scale economies were the reason why German dye manufacturers produced more and rapidly during the1900s. Moreover, size promoted a new type of research sense and a new type of organizational challenge in order to handle works in an efficient way. As a result of this, companies had started to change its activities and organizations. The change could be understood as *establishment of research laboratories* inside the firm. There is no doubt that historians like Meyer-Thurow, Homburg and Marsch who are prominent researchers in the history of chemical sectors agreed that the dominance of Germany in the sector had started with the help of these changes. Meyer-Thurow called this change as "industrialization of invention", Homburg and Hounshell & Smith, similarly, argued that research laboratories were an "entity" inside the firm which significantly affected the production line of the company and corporate strategy (Homburg 1992; Hounshell and Smith 1988).

Rising research laboratories demanded more people who were trained and educated in chemistry. Bayer, just after opening its research laboratory, defined and changed the task composition of jobs. For example, Foreman's duty was defined again. They were replaced with university-trained chemists. Many chemists were employed in research laboratory during 1880 – 1900. By 1900, 134 chemists (this number was 11 in 1880) were employed to continue systematic and high-quality production (Meyer-Thurow 1982, 368). BASF, thanks to research on chemical processes made synthesis of Alizarin and Aniline (indigo dye pigment prepared from this). Those developments played vital role to expand German dye market. By 1912, BASF hired

300 chemists (in 10 000 total workers) (Marsch 1994, 30). With the expansion, rapid patenting and development process had just begun in Germany. By the way, similar paths for establishment of research laboratories were followed by other manufacturers such as Hoechst, terMeer, and AGFA. Comparing with the USA, DuPont, the diffusion of this new trend in the chemical sector – establishing research laboratories inside the firm- had an early kick-start in Germany. DuPont established its research laboratories by 1902 with a lag of about 25-30 years. By 1906, DuPont invested about 150 000 dollars on establishing R&D laboratories (Hounshell and Smith 1988, 14). In 1909, Bayer spent about 203 000 dollars[67].

With the rapid expansion of research laboratories, two fundamental issues had been raised. The first was management of the research activities. The second was continuing the "creative" science process. Management issue was a turning point for German firms (Homburg 1992). They wanted to carry out high quality and standard research in production thanks to management of the research process in their own way consisting of three basic elements:

1. Recruitments of research managers who also were chemists.
2. More active role for persons who work in laboratories.
3. Decentralizing activities.

Those are the factors mainly affected the management side of the "industrialization of inventions". The second fundamental activity was sustaining of the research process. German firms, BASF and Bayer developed incentive mechanisms to update scientific knowledge and elevate the interest of the chemists who worked in the laboratories. Bayer prepared regular scientific conferences for catching new ideas and scientific developments. Those conferences were the best place to share ideas and information among academicians and scientists (Meyer-Thurow 1982, 371). Besides, in Bayer, chemists benefited from financial incentives like royalties and distinctive annual salaries. To illustrate, a chemist, in Bayer, earned 20 000 RM annual salary and also 51 727 RM of royalties (Meyer-Thurow 1982, 374). Those were the important incentives to promote research activities among competitors in domestic and international markets. In addition to this, German chemical industry promoted and supported students to encourage joining the firms after graduation.

67 Calculation based on rates of exchange which are from Haber's work (1971). According to his work, currency is calculated as 1£ = 4.9$ and 1£ = 20 RM. Number of R&D expenditure was based on Thurow-Meyer's work (1982, 381 footnote: 37).

At this point, it should not be forgotten that many Nobel laureate scientists worked in IG Farben in both management and research. Fritz Haber and Carl Bosch were famous examples. Bosch, also served at managerial position in both IG Farben and BASF. Haber, too, supported many new inventions with his scientific talent (Chemical gas, and so importantly, nitrogen processes) from the beginning of the twentieth century (Charles 2009). Their Haber-Bosch process was a revolutionary development in industry and science. Practical benefit of the process, especially, was seen in agricultural fertilizers. The new process enabled to produce higher quantity of fertilizers in reasonable price. As a result of this, Haber-Bosch's process was called as a solution for "feeding the world" (Smil 2004). Haber was a Jewish scientist and friend of Albert Einstein from Berlin. Before Hitler, this friendship had made many developments in science. Hitler's attitude toward the Jews, in the beginning 1936, affected Haber's position in IG Farben and Germany. Haber did not want to leave the country and demanded to serve the Third Reich, a situation that was highly criticized by Einstein (Stern 2016, 59). Scientific achievements of Jewish scientist were no less than a Nobel award (Cornwell 2004, 127). But the destiny of Jewish scientists shared the same faith with other Jews who lived in Germany[68].

Until now, the factors that had key role to develop new products in the chemical sector are examined before the establishment of IG Farben. Therefore, BASF, Bayer, AGFA, and Hoechst, which are constituent firms of IG Farben were examined for understanding research activities in the early period of the IG Farben. After all, science heritage of Germany made German firms to adopt a "new" phase of industrialization. This means that knowledge accumulation clearly promoted an environment in which firms transformed their businesses into "science-based" enterprises. The changes enabled entrepreneurs to take first-mover advantage in the industry. When early period of IG Farben is compared with DuPont, it is obvious that domination of Germany was an evolutionary process in itself; not a coincidence. Next section shows how IG Farben continued its research activities and succeeded diversification of products until Hitler's coming into power in 1933.

68 Jewish and science effects show itself in the "science networks". Thanks to those networks IG Farben was successful in innovation. When number of patent statistics between 1925 and 1945 is analysed one can see that %20 of the total plastic patents in the World were obtained by IG Farben. Another statistic shows that IG Farben had %45 of "important innovations" between 1870 and 1945 (Delorme 1962; C. Freeman and Soete 1997).

6.3.2 IG Farben's Industrial Research Activities: Before and After Hitler

IG Farben (in German: *Interessen-Gemeinschaft Farbenindustrie AktienGesellschaft*) was formally founded in December 9, 1925 in Frankfurt, Germany. IG Farben composed of six pretty big companies[69] some of which are already mentioned above: Bayer (1863, pharmaceutical company), BASF (1865, organic chemistry, dye-making), AGFA (1867, medical and daily imagining systems), Griesheim-Elektron (1856, electrochemistry), Weiler-ter Meer (1877, textile dyes) and Hoechst (1862, dye-making). Between 1926 and 1936, IG Farben's research strategy continued in full strength. Antecedents firms' research routines and habits were not changed much in the merger process. The new merging company faced three major difficulties while the business grew.

The first is diversification of the product lines. IG Farben and its constituent firms were mainly specialized on organic chemistry: dye products such as indigo, alizarin etc. Therefore, as a result of the merger, the new firm contained more qualified men and more knowledge that could be exchanged among firms. Research, especially fundamental research, created new and diverse lines like inorganic chemistry, nylon, plastic etc. Hence, IG Farben increased the variety of products in its plants through sophistication of research activities. Production lines and names of the products, by 1929, are summarized in Figure 4 below. New lines and product diversification were supported by financial sources. In 1928, total research expenditure of new lines was 70.6 million RM. Parenthetically; total research expenditure was 134.9 million RM. After Hitler's intervention, in 1936, the numbers were 14.1 in new lines and 69.4 million RM in total research expenditures respectively (Marsch 1994, 54). Research costs by selected years are represented in Figure 3 below.

69 Six company and its major plants are **BASF**: *Ludwigshafen, Oppau, Merseburg, Niedersachswerfen*; **Bayer**: *Elberfeld, Leverkusen, Donnagen*; **Hoechst**: *Frankfurt am Main, Gersthofen, Biebrich*; **Agfa**: *Berlin-Treptow, Berlin, Bitterfeld*, **Griesheim-Elektron**: *Frankfurt am Main, Offenbach, Bitterfeld*; **Weiler-terMeer**: *Cologne, Müngersdorf, Nippes* (IG Farbenindustrie AG 1928).

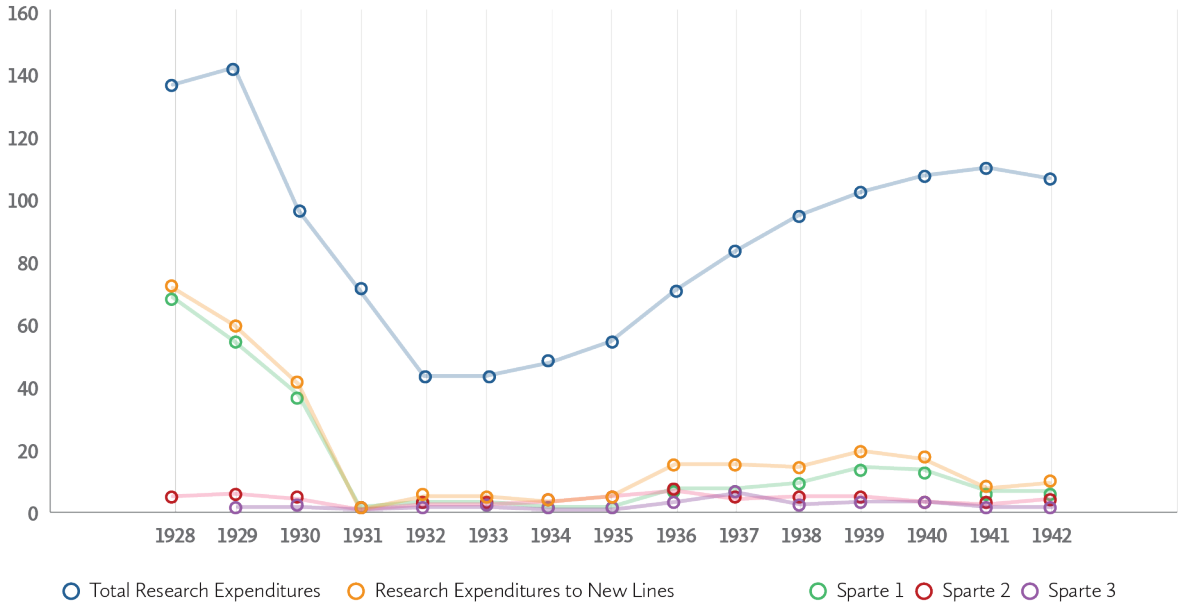


Figure 22: Research Costs by Selected Years in New Lines and Total (in Millions of RM)
Source: Data from (Marsch 1994, 54)

Each main laboratory conducted fundamental research in house due to the institutional settings of market. Profit opportunities pushed IG Farben's research laboratories to examine polymer. Synthesizing polyamide reached success in 1936 and new product was named as *Nylon 6* (Marsch 1994, 54). By the way, in DuPont, Wallace Carothers and its group succeeded synthesizing Nylon 66 in 1934 (Hounshell and Smith 1988, 183). Sparte II was specialized on rubber, plastic and important organic intermediates. Basic research and scientific investigations were conducted with the help of 4.8 million RM research budget. Comparing with Sparte I, this number was very low. By 1942, IG Farben sold 114.2 million RM plastics and spent only 0.2 million RM for its research. Specialization and accumulation of knowledge was positively correlated with scale economies. Sparte II and Sparte III benefited from this too. Main activities of Sparte III were making fundamental research on photographic products, artificial fibres an etc.

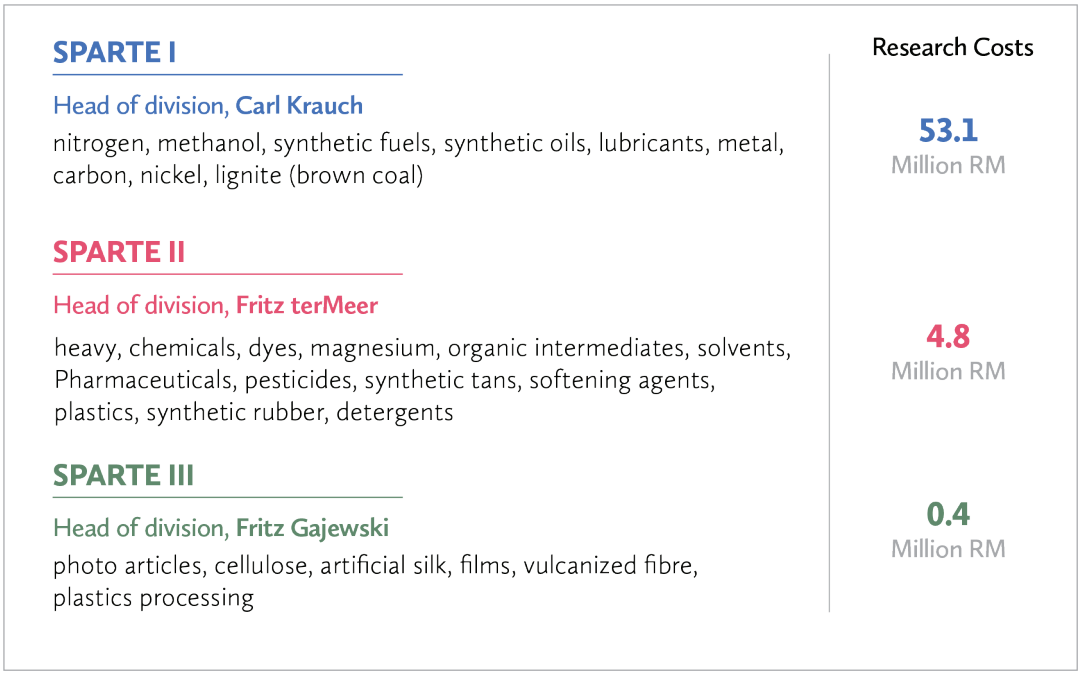


Figure 23: Production of Divisions and Research Costs of IG Farben in 1929
Source: Product data and numbers from (Marsch 1994, 37, 54)

The second difficulty was the decision of centralization vs. decentralization of research. The same problem was seen in DuPont chemical works. The difficulty stemmed as a natural result of the size of the company. Boundaries of IG Farben were quite big. When the merger company was established in 1925, it had 37 production plants across the country. 36 were actively operating for regular production (TerMeer 1953). The size of the company affected the research activities as well. Consequently, two important events drove the discussions on changing the organization structure. First, mainly advocated by Duisberg, rests on the idea that research should be centralized and controlled by a central committee or commission to reach efficiency and success. However, this idea was criticized, especially by terMeer. According to terMeer , who was the head of Sparte II, research perception of IG Farben needs to be reviewed, since the advantages of decentralized research were probably higher than centrally coordinated research activities. terMeer had started to change the research structure in 1929 and when completed in 1936, there were over 50 laboratories inside the company (Marsch 1994, 49). Second important event was the research decisions in plants. Planning was done by the scientific commission that convenes twice in a year. As a result of this planning mechanism, research was mainly conducted by individual plants. Knowledge, cooperation and technical support were discussed in the commission. This model

answers the purpose of making "new" things such as Azo dye, rubber, artificial silk, rayon etc. Finally, centralized research policy continued until Hitler's Four-Year Plan (See Chapter 4). Afterward, strict and inflexible controlling had started. By the way, each Sparte had its own organization structure. At this point, centralization or decentralization type of management was not meaningful so much. According to available data, Sparte 1 which was controlled by Krauch and Scharf was more diversified in terms of organizing sales and production. Sparte 2 had a complex structure. Inorganic chemical department was controlled and managed by Kühne and Pistor. Dyes department was managed by terMeer and Pharmaceuticals was managed by Hoerlein. Also in this Sparte, all departments were controlled by department-related committee such as Dyes committee, inorganics committee etc. At this point, Sparte 2 can be said to have de-centralized departments that had their own decision-making processes; however, the Sparte was strictly controlled by IG Farben management and scientific board. On the other hand, Sparte 3 had its own one-hand management sense. Photographic, Fibers, Explosives, Celluloid business and production was managed by Gajerski. It was responsible to make efficient production and R&D.

After all the main difficulty was conducting research under Nazi interventions. From the start of the company until Hitler's Four-Year Plan, IG Farben handled research activities under strict power of Nazi fascism. Total research expenditures were about 343 million dollars in 1928. Dye, process, hydrogenation, rubber works, inorganic chemicals were carried out by the organization. Farben's research policy was influenced by the competitors but the foreign policy of the country had little effect. Industrial growth of the country needs more intermediates and IG was there to satisfy the demand. Sales numbers showed that in 1926, IG's hydrogen sales was %42.4 of total sales (1078 million dollars). Dye sales was %33.3 (848 million dollars). Compositions of sales in 1926 – 1932 – 1936 and 1942 are represented in Figure 24 below. Dramatic change happened in the production of Dye. In 1942, total research expenditure was zero; however, production quantity was the same compared to the previous year. During World War II, IG Farben mainly focused on chemicals and synthetic gasoline. Moreover, in accordance with the Four-Year Plan, the Reich demanded war related research and products. BUNA rubber production, which was mostly conducted by slave workers is a good example to explain the war effect. Research activities steadily decreased during the war. Especially, toward to the end of the war, IG Farben almost totally cut down its research activities.

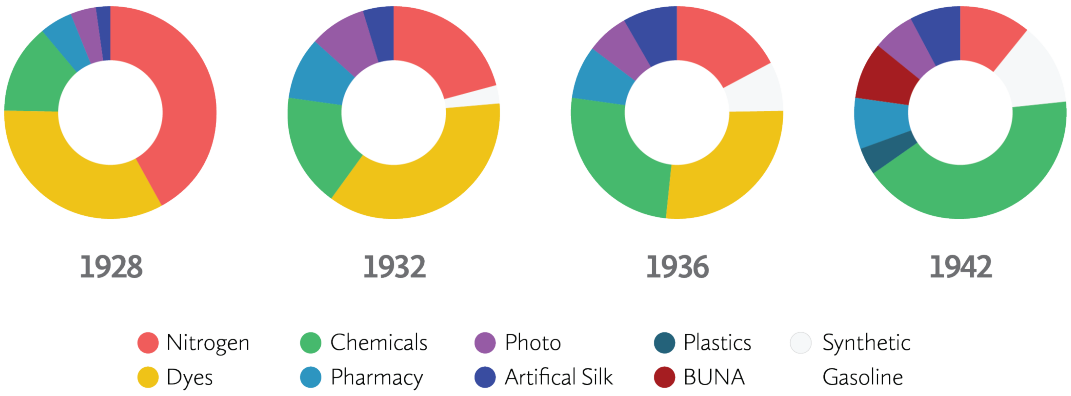


Figure 24: Composition of Sales in Selected Years (Percentage)
Source: Numbers from (Marsch 1994, 73)

Intervention of the Reich was also observed in cooperation with other competitors. DuPont always desired to benefit from German knowledge and know-how; moreover, DuPont wanted to licence IG Farben's styrene resins patent. In a similar manner, IG needed to get DuPont's mono vinylacetylene (MVA) patents to make butadiene which is required to make synthetic rubber (Hounshell and Smith 1988, 206). According to Hounshell and Smith, "despite political risk", three agreements were issued to make mutual information exchange in 1938 (1988, 207). However, those agreements were cancelled in May 15, 1941 (G. D. Taylor and Sudnik 1984, 139). Many other interventions were seen in the history of IG Farben. Unfortunately, some of them forced the company to commit war crime (see Chapter 2). Statistics, especially between 1941 and 1945 are not reliable for this very specific reason that IG had become a company that produced for and financed the war. As a result of the war, IG Farben renounced its economic and scientific activities at the expense of losing its reputation in the market.

In conclusion, IG Farben faced three major research difficulties between 1925 and 1945. Those are examined in detailed above to understand how the company conducted research. Some figures are intentionally used to understand the holistic view on innovative process. After all, although, IG Farben became obsolete in 1952, its legacy, research institutions and organizations have continued. Dissolution of IG Farben was not the end for the German chemical firms. BASF (1952), Bayer (1951), AGFA and Hoechst continued its activities under their old entities. At this point, past science experience and accumulated knowledge of IG Farben were transmitted to new firms. Moreover, Cold War experience of Germany showed that chemical companies occupied a place in the Western part of the Germany isolated from

the Eastern part. Consequently, adaptation of the chemical companies to the new world was not easy but integration to global market was chased by the German firms (Schwarz 2010, 136).

On the other hand, German chemical and dye firms had grown rapidly during the beginning of twentieth century. However, in the first quarter of the century, the economic conditions were not stable. Growth rates were low and sectors were not supported by external factors like education system, government supports etc. IG Farben benefited from German education system and knowledge that resided in both industry and university. Many innovations, inventions and technical developments were promoted by science-based companies. On the other hand, political conditions in Germany, competitiveness with Britain and American companies (tariff and barriers), hyperinflation – world economic depression in 1929, and two World War predominantly determined success and failure of the companies among other competitor countries (Lesch 2000, 9; Marsch 1994, 59). Activities of IG Farben, specifically in Buna plant, was investigated and concluded in Nuremberg, at the IG Farben Trials between 1947 and 1948 (Hayes 1987, 377).

6.4 DuPont: A Science Driven Company

It is clear that DuPont was established as an explosive producer company in 1802. The foundation of the company was not planned as a pure-chemical producer but as a prior dynamite producer (Kinnane 2002). Moreover, it was a family-business (for *more information about the history of company see* Chapter 2). Until the end of the nineteenth century, the company had carried its business in the line of old fashioned dynamite and black powder production. There is no doubt that many technical developments and inventions happened in the first phase of the company but the real transformation came in the second phase after 1900.

DuPont transformed its organization and research activities in the beginning of twentieth century. Transformation occurred as a result of two important events in the company. The first was a change in management when three cousins (Coleman, Pierre and Alfred) took important positions in the company. The second is the establishment of Eastern Laboratory (by Eastern Dynamite Laboratory subsidiary of DuPont) to conduct systematic invention process (Kinnane 2002). Haber describes the position of DuPont as "[DuPont] *... activities and success have often been described, and with added embellishments have become part of the folklore of American free enterprise. But the firm's development also had its less glamorous side and what is remarkable, perhaps even exceptional, in the routine of its policy is the consistency*

with which the long-term objectives pursued. These objectives were in the first place to lessen the dependence on the explosives…" (1971, 312). Similarly, transformation of the company is defined by Salsbury and Chandler as "[establishment of experimental station] *in the long run, the most significant thing it market the institutionalizing of technical research and development for the DuPont.*" (1971, 142). Moreover, Hounshell and Smith added that "*in the early 1900s, however, that promising future would seem all too distant as the cousins struggled to turn the enterprise into a more profitable, more controlled business.*" (1988, 16). The literature show that DuPont company had entered the new phase by consolidating its business activities and establishment of development (research) laboratories.

At that time, in the US, research was organized as individual initiatives – a period referred as "*era of heroic invention*". The main purpose of this definition was to underline how "*one man*" inventor could come up with a solution in accordance with economic needs and requirements (R. C. Epstein 1926, 238). On the other hand, systematic research was also supported by the companies widely at the beginning of twentieth century. Bell and General Electric laboratories are proper illustrations for the kind of controlled and deliberate organization of research activities (Reich 1985). At this point, DuPont's research activities are analysed in three subtitles in this chapter: Organizing research between 1902 and 1921; Reanimation of Research organization 1922 and 1939 and conducting research during the World War II.

6.4.3 Organizing Research Between 1902 – 1921

There were two important laboratories conducting research activities of the Company at the beginning of 1900s: The Eastern Lab and the Experimental Lab. The Eastern Laboratory was a subsidiary company of DuPont (Eastern Dynamite Company) and head of the Lab was Charles Lee Reese (1862-1940), a chemist who held a PhD from Heidelberg, Germany. The main purpose of the Laboratory was:

1. Examining new explosives,
2. Cooperation with other explosive industries,
3. Improving processes, techniques and products,
4. Training young chemists so to employ them in the company's laboratories as technical assistant in the future (Hounshell and Smith 1988, 19).

The laboratory employed 11 chemists in 1902. Those people worked on two important technical solutions for the industry: dynamite, which works at very low temperatures and an efficiency process which is extracting and excluding nitro-

glycerine from waste acids. The first one was named as "artic powder" which was one of the foremost inventions which was made under controlled research of the lab. The second was patented as a process by the Lab in 1905 (Reese 1905). Activities of the Eastern laboratory were mostly related to perfection of powder business. Therefore, standardization of chemicals and several improvements were made in the Laboratory. Main concerns were avoiding duplication of other labs and contents of research. Avoiding duplication created an efficient way to make research and provided more specialization and flexibility in terms of selecting research issues. Structure of organization and management of the Eastern Laboratory is thoroughly discussed in Chapter 4 of this dissertation.

Under management of Coleman, Executive Committee decided that new type of "experimental" laboratory was needed to expand product lines when possibly joining the new markets. By 1903, the General Experimental Laboratory was founded by the decision of the Executive Committee. Important purpose of the Experimental Lab was to develop new safe, usable and technological powders and its intermediates. In the beginning of the 1900s, DuPont's main customer was the government. Therefore, DuPont mainly developed powder and related products. According to this fact, Arthur J. Moxam (1854–1931), the head of Competition, Development and Experimental Works, approved designing joint research programmes with the Bethlehem Steel Company. The main expectation from this relationship was to improve quality of product in ballistic work (Hounshell and Smith 1988, 31–32). As Lab's report indicated the main role of the lab was:

5. Routine analysis of the chemicals,
6. Product improvements and development,
7. Developing method for cotton purification,
8. Inspecting and investigating of other competitors' powder (German and French types),
9. Manufacturing of colourless smoke powder (Ibid. 1988, 35).

The laboratories composed of seven research staffs. Four of them were educated chemist, one director (Francis I. du Pont) and the remaining two were "independent inventors". J. N. Wingett (Called as Wizard) had no academic "title"; however, among the others had the highest monthly salary (300 dollars in the price of 1903 also 65,000 dollars in cash for patent applications.) (Ibid. 1988, 37). Between 1904 and 1911, the two laboratories continued their activities encouraging applied science for production. The research potential of the labs was used to solve problems

in the production stage of powders. Before the War, the main demand for the products was still coming from the government. Hence, DuPont tried to solve several technical problems like the dynamites' freezing at low temperatures and the inefficient process while producing dynamites. As a result of research activities, DuPont found several valuable explosives such as trinitrotoluene (TNT) which was stemmed from previous German research on Lydol (Ibid. 1988, 52).

The Eastern Lab. served as a quick response place in mainstream business line: explosives, powders etc. On the other hand, the Experimental Station satisfied different demands from customers like special explosives etc. Both Labs conducted research while evolving the activities to the new line in which systematic research and development occurred. In so far, Figure 25 provides information about the company's expenditures and net earnings between 1906 and 1911 presented in nominal prices of related years. According to the figure, net earnings relatively decreased; however, R&D expenditures increased which shows how the R&D activities became central in DuPont. Within a decade in the 1900s the R&D expenditures as a ratio to net earnings increased about 3 folds from a band of 2-3% to a band of 8-9%.

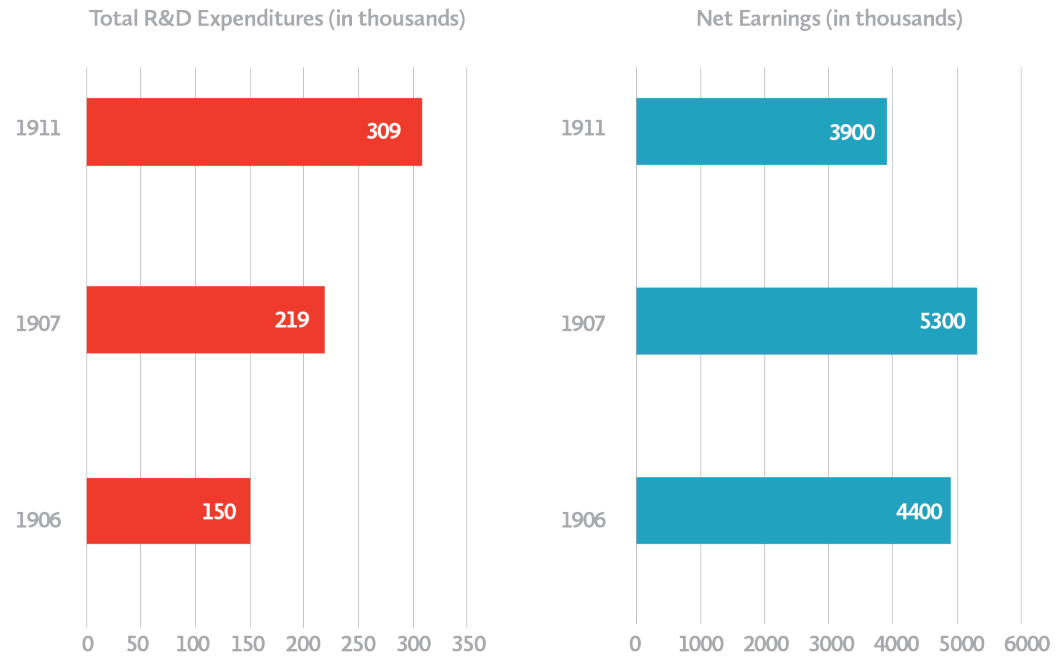


Figure 25: Research and Development Expenditures and Net Earnings (in thousands)

Source: Data from (Hounshell and Smith 1988, 12, 14)

After 1911, DuPont made a fateful decision about research organization and parallel to that, about products diversity. The decision was made by Pierre du Pont who changed the organization of research and development activities according to the Company's future needs. The change started with utilizing production process and plants' working to adapt new production areas like organic chemistry and dyes. Apart from explosive business DuPont planned to enter new markets with the development sense of "high-risk and high-reward" (Ibid. 1988, 66). Those areas were artificial silk, artificial leathers, dyes and its intermediates for end users. Two important events lead to this change. The first was the War effect. As a natural result of the War, trade relationship with Germany was negatively affected. Understandably, import activities were cut which provided new opportunities for the company. The second was the rising demand in customer products (shoes etc.) with the consequence of increasing demand in natural rubber. Especially this second reason led the company to enter artificial rubber business which resulted in the decision of the Executive Committee purchasing *Fabrikoid* for 1,2 million dollars (Ibid. 1988, 68). Following, largest celluloid producer of the Unites States, Arlington Company was also purchased by the Executive Committee for 8 million dollars to benefit from its knowledge and enter new markets besides producing nitrocellulose (Ibid. 1988, 72–73).

During the War, British and German position was an important determinant of the developments in the US' dye market. Especially, the blockage of Britain was a main obstacle for transportation of German exports to the market. It was one of the factors why DuPont became concerned about dye manufacturing. Reasons of this event are summarized below:

1. The US-German trade was cut by Britain Naval. No more dye import was possible.
2. Powder demand was rising in the US (dye and powder manufacturing depended on *diphenylamine*)
3. Other intermediates supplied by Germany to produce dye were not reachable (H. S. Freeman and Mock 2013, 477).

As a result of the blockage, DuPont needed to develop its own business in dye manufacturing at the national scale. After 1911, with its research experience, DuPont directed its attention on establishing new plants where intermediates for dye-making process and explosives produced. According to the Executive Committee's plan, economic shortage caused by the War and sterilizing the market

from competition was a chance to produce in more diverse areas which were organic chemicals (oils, paints, dyes, varnishes), acids, artificial silk and rubbers, celluloid etc. (Hounshell and Smith 1988, 77). DuPont continued this business until 1921. Moreover, three key facts were vital to understand the difficulties faced during the process of entering in to new business. The first fact was German science and experience in dye-making. Germany had entered the business in the middle of 1850s. Bayer's and BASF's efforts were the beginnings of gaining experience in both scientific and applied fields. They endlessly invented and developed new processes and products (example of Alizarin, Indigo and Azo dyes) (Birren and Riffe 1980). By 1920s, they had 900 types of dye (Verg, Plumpe, and Schultheis 1988). Moreover, Germans discovered the advantages of "research laboratories". As early as 1891, Henry E. Armstrong, chemist and member of the Royal Society, visited the research laboratory of Bayer in Elberfeld and he reported that 78 chemists worked in dye development. 56 of them had PhD degree (1893, 30). In summary, Germany had great knowledge and know-how about dye-making processes. The second fact was a persistent demand for German dyes in the US. DuPont already invested about 11 million dollars for research, development and workers in dye manufacturing business in 1919 (Hounshell and Smith 1988, 74). In addition to this, DuPont tried to duplicate German dyes in two ways: making more research and industrial theft. Between 1911 and 1921, DuPont made more research on developing dyes. Though its first products were far worse than the quality of Germans' dye DuPont still worked for becoming successful in the market. On the other hand, DuPont convinced people to involve in industrial theft. Bayer's old workers, a group of chemist who were Dr. Joseph Hachslander, Heinrich Jordan, Otto Runge, and Max Engelmann, agreed with DuPont to steal "valuable information for dye-making" on behalf of DuPont (DuPont rejected this accusation) (Colby 2014, 185). Those attempts showed that dye-making business was underestimated by DuPont's Executive Committee. Making a dye was more complicated work than they thought. The last fact was the status of the market aftermath of the war. Between two wars, Germany dominated the US' dye market again. Because of this, DuPont started to lobby against German dyes around 1920s. Furthermore, in 1922, the 29th president of the US, Warren Harding, signed a new tariff (known as the Fordney-McCumber Tariff) for regulating the market especially in terms of chemicals. As a result of the tariff, German products' prices increased (Berglund 1923, 21). When compared to other regulations on chemical trade, the Fordney-McCumber Tariff was fairly a heavy one. Table 2 summarized the tariffs on dye intermediates below:

Table 22: Comparison of the Tariffs in the USA

Products	Act of 1909	Act of 1913	Act of 1922
Coal-tar products (*intermediates*)	Free to 20 per cent	Free to 15 per cent	7c. per pound plus 55 per cent (*ad-valorem*)
Coal-tar products (*finished*)	Free to 40 per cent	Free to 40 per cent	7c. per pound plus 60 per cent (*ad-valorem*)

Source: (Berglund 1923, 22).

1911 – 1921 was an intensive period for the company in terms of new products line, organizational change and research activities. Major developments were seen in organic chemicals during this period. In addition to this, artificial rubber and silk were important steps for future plans of the company. Diversification happened in many fields inside the company. However, main determinants of the diversification strategy were economic (shortage and competition) and political (demand from the military). Chapter 4, shows the relationship of products and users in terms of diversifying products. After the reorganization in 1914, the company benefited from the research activities and always spent more money for dye research activities. On the other hand, trend of R&D expenditure was affected by other factors easily like management decisions, production policy etc. Summary of research expenditure that support the argument was shown in Figure 7 below. According to Figure 7, total R&D expenditure increased 775% from 1911 to 1919. This trend was exponential and continued till the end of World War I. After the War, R&D expenditure decreased about 50%. There were many explanations for the decline. The main reason is of course the economic conditions of the USA after World War I and before the economic crisis of the late 1920s.

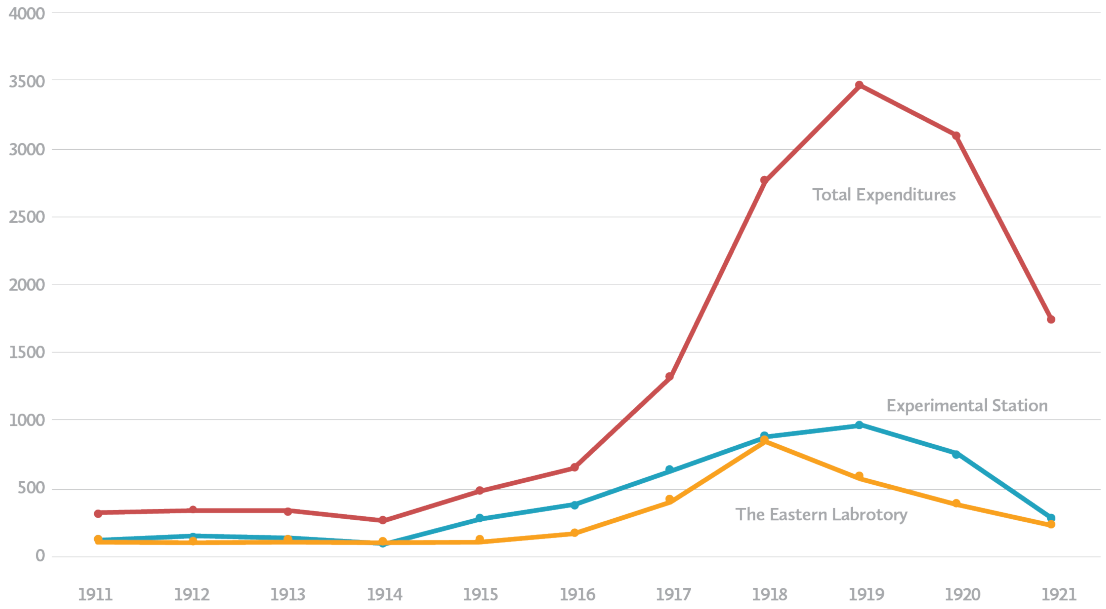


Figure 26: Research and Development Expenditures Selected Labs (in thousands) Source: Data from (Hounshell and Smith 1988, 62)

6.4.4 More Science and More Research: DuPont from 1922 to 1945

DuPont, after the diversification process, made significant decisions about the future of the company. Old business was not that important anymore. New business lines, namely organic chemistry, artificial silk and polymer workings promised new opportunities that enabled more innovation. The turning point, in this sense, was entering new industries with the help of research. In 1920s, DuPont went into a new lacquer and finishing products business. This attempt resulted in two important inventions: Duco and Dulux (Hounshell and Smith 1988, 144). At the beginning of the business, development process was done according to the needs of the automobile industry. GM motors and Cadillac needed a solution for the problem that was related to extreme temperature conditions. Cars' interior and paint of the body shell was negatively affected from extreme heat conditions. Duco finishes were developed to eliminate this problem. Cadillac's head quoted that "*... bad engine or other mechanical fault in a car which would do less damage, from advertising standpoint, that poor paint.*" (Ibid. 1988, 142). Problem oriented solution returned to DuPont by selling 14 million dollars of Duco in 1928 (Ibid. 1988, 143).

In 1931, Dyestuff Department changed its name as Organic Chemicals Department (Orchem), which was directed by Elmer K. Bolton. He graduated from Harvard as an organic chemist and had a distinguished career in organic chemistry. His mentor was Nobel Laureate, Richard Willstätter who worked on organic chemistry

and coloration of flowers in The Kaiser Wilhelm Institute (Johnson 2017). Orchem's expenditures for research are represented in Figure 27 below.

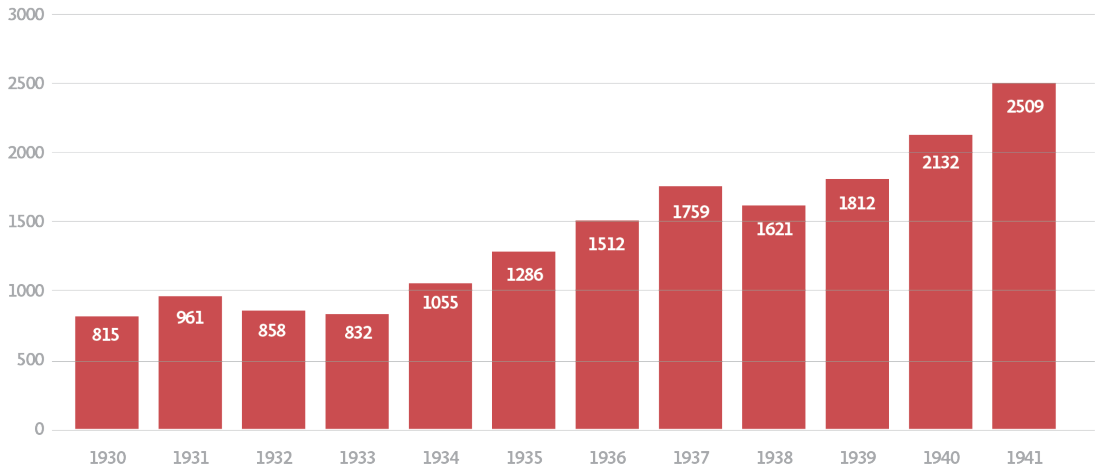


Figure 27: Organic Chemical Department Research Expenditures (in thousand dollars)
Source: Data from (Hounshell and Smith 1988, 289).

Research of Orchem showed exclusive privileges among other laboratories. After the Chemical Department (1,182,000 dollars), Orchem had the second largest budget in 1931. With the help of research opportunities and management of Bolton, Orchem fostered three important and profitable innovations: Tetraethyllead (TEL) (did not discover but found a new process), Freon and Fluorocarbon (did not discover but found a new process), and lastly Teflon (invented in 1938, patented in 1941 on behalf of Roy J. Plunkett[70]). Freon business was used in refrigerator maintenance and production and with the assistance of General Motors, it was also applied to automobile industry. TEL was commercialized for automobile industry too. Lastly, Teflon was patented in 1941 and the product was a "great discovery". There were two important facts about Teflon: it was a highly profitable product; it created new research areas such as polymer-based technologies in 1945 (Hounshell and Smith 1988, chap. 21 p. 477).

Orchem's successful inventions and developments were also duplicated by the Rayon Department. The department was established in 1936. Rayon fibre was based on French technological advances, early on, when DuPont made a joint venture agreement with French Rayon Company in 1920s (Casson 2012, 198). Therefore,

70 (Plunkett 1941).

DuPont had already been interested in artificial silk and fibres since the 1920s. As Fin Sparre said artificial silk business was a great opportunity to make more money in the future of DuPont (Hounshell and Smith 1988, 162). Rayon business grew continuously after the Post War conditions due to rising "fashion" in textile industry. New fashion trend rapidly rose in America around 1920s. The advertising of the "new clothes" supported this change thanks to obtaining more "glossy" silk (David 2015, 203–4). Glossy and cheaper clothes attracted more men and women who wanted to dress like "Victorian Style" in textile (Johnston 1924, 10). Johnston, in his article at *Du Pont Magazine*, added that Rayon consumption rose exponentially from 1912 to 1923. In 1923, nearly 40 million pounds were consumed (1924, 11). Moreover, the Department, as a result of artificial silk, continued to invest in research activities. Figure 9 shows the research expenditure history of the department.

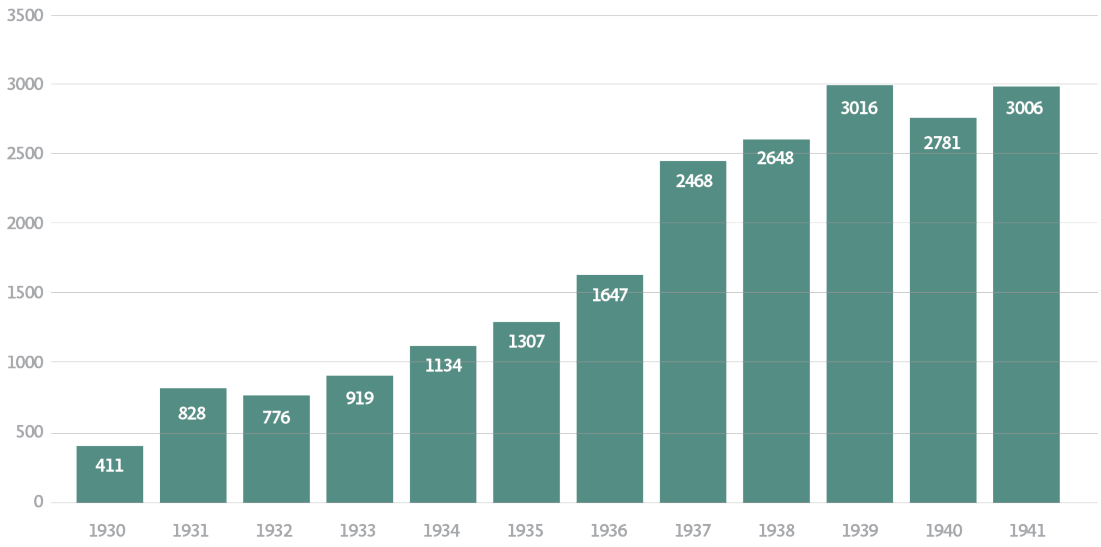


Figure 28: The Rayon Department Research Expenditures (in thousand dollars) Source: Data from (Hounshell and Smith 1988, 289).

Apart from artificial silk, The Rayon Department had two significant innovations in the 1930s, which gained very important market success. Also, they created new organizational systems and changed the sense of research of the company. This means that DuPont not only benefited from mere research experience but also research enabled new opportunities for further research and innovation.

The first distinguishing innovation was making Cordura (introduced in 1934),

which was widely consumed by producers and customers. There were numerous areas of use: textile (helmet, shoes, pants), automobile industry (tires), military (protection guards) etc. Consequently, DuPont developed new strategy for Cordura which involved making a tire that was based on Cordura yarn. Because of patent issues, Goodyear developed the yarn and its properties for making a tire (Hounshell and Smith 1988, 169). Consequently, DuPont sold 9 million pounds of yarn related to tire business. It is important to note that tire business evolved to replace natural rubber into new artificial one that is based on Cordura. During World War II, this business hastened by further research of DuPont. After all, the problem of the Cordura can be defined as a patenting problem. Moreover, DuPont patented it for protecting and gaining future reward. British patent system was not permitting a kind of action for DuPont; as a result of this, there were different rules in USA patent and Britain patent systems (Ibid. 1988, 168).

The last but not least Cellophane was an important innovation of its own. *Du Pont Magazine*'s, December 1924, issue introduced Cellophane as "*... it may be said that a well-groomed, attractive package "makes" the product it contains, at least so far as saleability is concerned. With packages, as with persons, a good appearance counts. Quality merchandise clothed in a distinctive Cellophane wrap looks the part."* (Johnston 1924, 10). Cellophane was a chemical product, which had similar properties with Cordura. Cellophane was patented and produced by Jacques Edwin Brandenberger in Switzerland (Brandenberger 1917). DuPont made an agreement to obtain know-how and reach to licence of Brandenberger under the control of Fin Sparre (Hounshell and Smith 1988, 171). This deal paved the way for a successful production strategy. In this story, there were two essential elements. Cellophane business was developed with advertising and with the cooperation of sales and development departments. Advertising had a vital role to sell more products. Especially, in the food industry, Cellophane was introduced as a remedy for qualiy loss due to poor packing. Thanks to Cellophane, the hygiene problem is by and large solved and moreover consumers can see what is in the package as cellophane wraps were transparent. At its advertising poster, DuPont highlighted this feature of Cellophane as "*Meat's at Its Best in Cellophane: Cleaner and Fresher*" (E.I. du Pont de Nemours & Company 1956). Other element was related to organizational change, which will be analysed in Chapter 5.

Cellophane strategy seemed successful when one compares investment and returns. Summary of total investments and returns are shown in Figure 10 and Figure 11 below. After the crisis DuPont invested 11,2 million dollars in 1930 in this business. This number exponentially increased until the war. Returns on investment for the

same year was 39,9 per cent. Returns on investments were high at the beginning but afterward it gradually decreased. Over the period of about 15 years average return on investment was 35,6 per cent which made Cellophane business very profitable in terms of the returns (Stocking and Mueller 1955, 62).

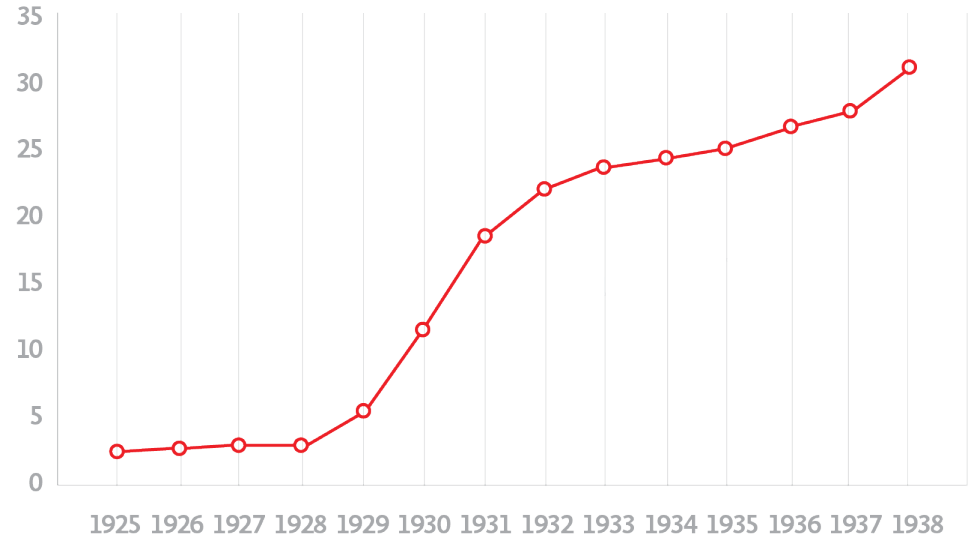


Figure 29: Total Investments on Cellophane (in million dollars)
Source: Data from (Stocking and Mueller 1955, 62).

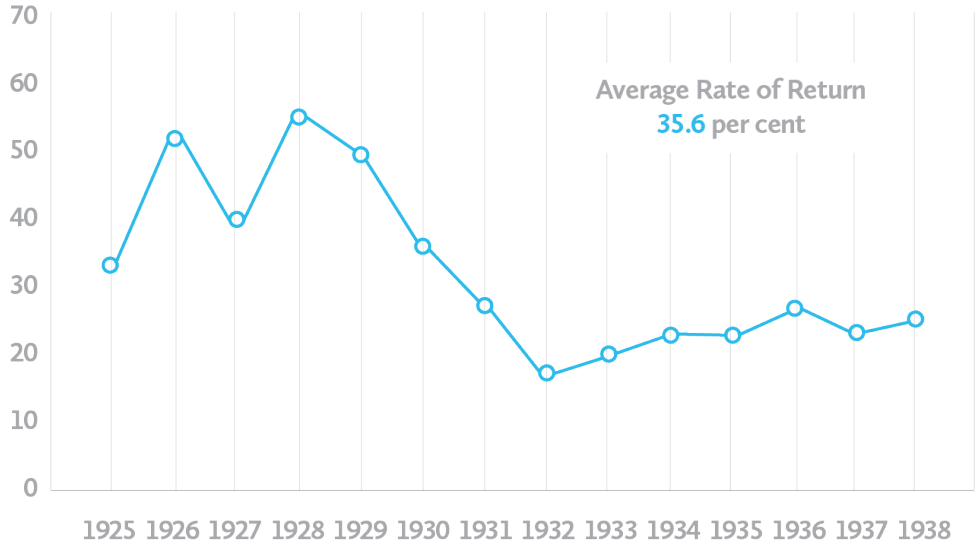


Figure 30: Returns on Cellophane Investment (per cent)
Source: Data from (Stocking and Mueller 1955, 62).

Rayon Department's success continued in 1950s. The major improvements and innovation stimulated military technologies (helmet, tire, adhesive, nylon) until the War. As mentioned before, in 1926, the Company faced new difficulties such as the debate on applied-fundamental research and new type of organization in research, which promised more applied science with educated people like engineers[71]. Although DuPont pioneered the emergence of a new type of chemistry labelled as "chemical engineering", the fundamental research debate continued until the end of the war. Charles Stine, Chemical Department Director, proposed four arguments for supporting fundamental research in the company:

1. Prestige in academy and industry was obtained by publishing
2. Interesting and unexpected findings provided by people
3. Scientific research and knowledge could be useful in knowledge exchange (IG Farben agreement example)
4. Pure science promoted applied and practical applications within the economy (Hounshell and Smith 1988, 223).

As a result of the debate, with slight differences, the Executive Committee continued investing in the research program of Stine. By the way, other difficulties of the Great Depression (1929) and World War II (1939 – 1945, the US entering the War in 1941) were also making doing business hard in the economy. After the Global Crisis in 1929, DuPont followed fundamental research policies in the Chemical Department[72]. As a result of the efforts two remarkable discoveries emerged: Nylon and Neoprene. These products were significant in terms of organization of research and cooperation with other competitors[73]. First of all, both of the products were developed in nine years and R&D costs were 4,3 and 2,5 million dollars respectively. Both of them had military and civilian uses. Nylon was used in textile (stockings, shoes, gloves, jackets) and many fields of everyday life (food, packaging etc.) (Hermes 1996). On the other hand, Neoprene was used in heavy duty works like tires, mechanical mechanisms etc. The development process of Nylon was carried

71 For the applied-fundamental science debate see (Hounshell and Smith 1988, chap. 12). Emerging "chemical engineering" as a profession within the American universities see (Ibid. 1988, chap. 14).

72 Research programme of DuPont was changed from the ideas of Stine (fundamental) to Bolton (applied) after the World War II (Hounshell and Smith 1988).

73 Cooperation with ICI was made to exchange patent and process especially in dyestuff business in 1929. During the agreement, DuPont discovered Nylon (1934) and Neoprene (1930); on the other hand, ICI discovered Polyethylene. Another agreement was made with IG Farben in specifically share licence and patents in 1938, despite "risk". They did not take long time and cancelled in 1941 (Ibid. 1988, 206).

with a team which was directed by a pure scientist: Wallace Carothers[74] (Hermes 1996). Carothers was a dedicated person and he wanted to make basic research. Nylon works resulted in success thanks to many works and studies on polymer chemistry (Hounshell and Smith 1988, 198).

Finally, DuPont's research programme had been changed many times to improve the company's profit and reputation. Between 1941 and 1961, sales and R&D expenditures have increased. Figure 12 shows this trend for each year. During and just after the war R&D expenditures as a share of total sales was about 3-4%. In 20 years, it doubled reaching to about 7-8%.

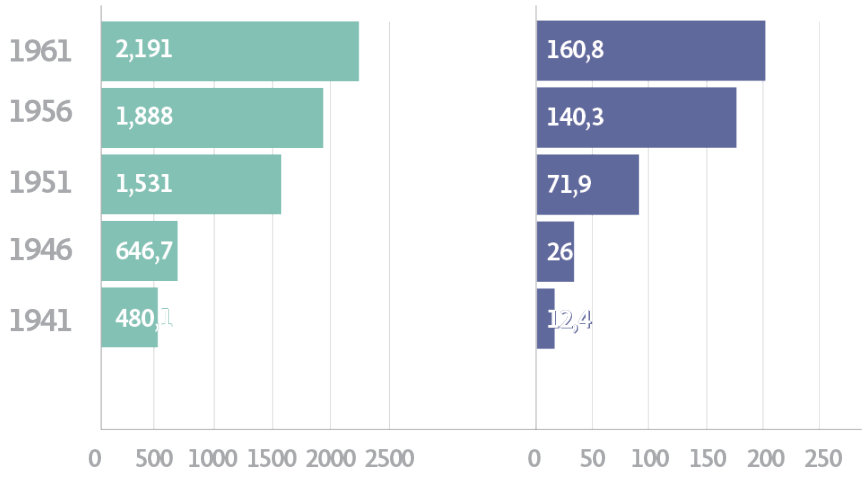


Figure 31: Sales and R&D Expenditure (million dollars)
Source: Data from (Hounshell and Smith 1988, 348).

DuPont's achievement in research could be summarized in three titles:

- DuPont was not only an intermediate or final product developer. It made science as a "corporate strategy" for gaining profit. Because of this, DuPont's customers were supported by providing technical assistance, development process, advertising and "how to use" the information. For example, Cellophane was promoted by DuPont's sales Department, which had huge impact on the sales of cellophane.
- The company had capacity and was capable to conduct research in any fields of chemistry. Therefore, investment decisions for new areas were strategic and carefully planned and executed.

74 He killed himself just after patent application for Nylon in a hotel room in 1937 (Ibid. 1988, 246).

- Cooperation especially with IG Farben and ICI was a great opportunity to gain scientific knowledge. As known, this was not easy in the history of company; on the other hand, valuable information gathered through cooperation opened up new economic opportunities (example of Cellophane).

As a last word, DuPont's research ability and culture was not the same with IG Farben. Especially in terms of basic science, at the beginning of twentieth century, DuPont required German experience in both theoretical and applied sense. DuPont handled the drawbacks in a successful way thanks to insistently following the science and technology path. In order to summarize and clarify some points, Table 3 below compares two companies in terms of research activities.

Table 23: Comparison of Research in two Companies

	IG Farben	**Du Pont**
Motivation	Science oriented and Economic shortage in resources	Market driven and science oriented
Intervention	After Hitler's Four-year plan, research was ch anged authorities	There was no significant intervention from
Collaboration	With universities and prominent science institutes	With universities through recruitment policies
Entrepreneurial types	Scientist entrepreneur	Classical "risk-taker" entrepreneur
Funding	Mostly fundamental research, also some applied research	Generally fundamental research but applied research became important

CHAPTER 7

CONCLUSION

7.1 Summary of the Dissertation

This part discusses the general results and findings of the dissertation. It contains three main subparts: summary of the chapters, the answers to the research questions and main policy implications of the dissertation. Moreover, in this final section research limitation will be discussed.

Chapter two defines the methodology of the thesis. The investigation of the research question of the dissertation is supported by primary and secondary data sources. Working with the archival data and its processing are challenging tasks. Therefore, in chapter 2, all steps are explained carefully. In this dissertation, the mixed method comparative analysis is chosen to interpret the data. Within the broad comparison, detailed data analysis involving network method is also used. After all, rareness of the archival data and scope of the work created some limitations.

Chapter 3 of the dissertation is a comparison chapter of two countries. The main aim of the chapter is to explain Germany's and the USA's economic story and highlight context-specific reasons behind their economic development success. Basically, the research question of the dissertation is based on the comparison of two firms in two different countries. Thus, it is important to know at least the main issues regarding the context that these firms had flourished and developed in. Looking at the economic history in brief is fruitful in this respect. The main factors that, by and large, determine economic conditions of the two countries is analysed under four titles:

1. Economic shortages in resources
2. Competition and variety of market
3. Science background
4. Demand conditions: market-driven research and demand-side of the researches

These four items stand out in the comparison of the economic history of Germany and the USA. In order to clarify these items further explanations will be provided. First of all, each country had a different economic development path. USA had own rich resources, which created an endless market for industrial production. But first, transportation and communication infrastructure were developed to support industrial production and market formation in various sectors. As a result of this, many fields emerged in the industry like chemistry, pharmacy, metal works, transportation, and mining etc. Thus, the USA's economic development was shaped by rich resources accompanied by solid infrastructure. On the other hand, Germany had been short of resources since the foundation of the Prussian Empire. As it is known, Germany entered two world wars because of economic issues, which created a further economic strain in Germany. Thus, many sectors like chemistry were established as an economic remedy to problems such as energy and food shortages. Secondly, European market was competitive. In the chemical sector the British, Swedish, French, and the Dutch had their own developed markets and scientific research traditions that science-based sectors like chemistry could built on. The USA's market emerged later than Europe. Hence, they were consumer of chemical products from the outside market at the beginning of the era. This is a latecomer advantage that causes a difference between countries. Thirdly, science traditions of the countries were different from each other. German science was well established and mainly promoted fundamental science in institutes and universities. "Science Mecca" metaphor had been used to show that German sense of science was shaped by the real meaning of science; as a result, the root of the chemistry and its derivations (chemical engineering, biochemistry) were already founded in this country. The USA had its own unique tradition. Strong education and science institutions were supported by the market structure. Therefore, USA created its unique science traditions. Main difference between the two countries was the science-industry relationships. In the USA, science was promoted by the industry in many aspects. Germany was not flexible in that sense, compared to USA. Science was a good guide for the development; however, it was not (or should not be) corrupted by the market itself. German firms (especially in chemistry), developed a new concept that can be called as the "scientist-entrepreneur". It was a little different from "capitalistic entrepreneurs". The main difference was that scientist-entrepreneurs took top management positions from the beginning till the end. Fourthly, market structures of the countries differed in terms of demand conditions. The USA market structure was mainly shaped by more production and more consumption perhaps because of the size of the country and the rapid

population growth. Consequently, marketing and incremental innovations played vital role both to satisfy demand and for demand to signal innovative activities. Du Pont's market strategy could be a good example of this. In Chapter 4, the network of users and products clearly show that Nylon, Teflon, and Cordura were introduced to market for both end-users and suppliers as industrial input. On the other hand, only a portion of Germany's production, like pharmacy and photo products, was for end-users; the main production line was shaped by the industry. As known from literature, Germany was a main producer in dye and mostly organic chemicals (Haber 1958). Its business line was different from Du Pont. The difference is important to understand innovation strategies of the firms. While IG Farben produced raw materials for mostly industry, Du Pont continued producing heavily end-user products. This difference created a different organizational and research structure in the companies as discussed in Chapters 5 and 6. For example, Du Pont's Nylon product was developed for finding a solution for nylon related materials like textile, packaging, and food etc. On the other hand, IG Farben was mainly engaged inorganic chemicals like synthetic fuel, acids, gases, and intermediates.

Chapter four compares IG Farben and Du Pont on the basis of our important topics: external factors (Hitler and government intervention), science heritage (education system or national system of science), organizational attitude (as a result of managerial and cultural differences), and research practices (more industrial research and more cooperation between industry and university). Firstly, external factors were vital in shaping two companies. For example, Nazi's synthetic fuel demand forced IG Farben to concentrate all research activities on this specific topic. Sense of research was affected by the authorities in the case of Germany, which means that there was no "economically free" environment especially after the 1930s. On the other hand, Du Pont had always a close relationship with the government. As a result of this, research policy of the company was affected by the US government. For example, dynamite and black powder research was conducted as a result of government demand. Secondly, as mentioned above, science heritage was a distinctive difference between IG Farben and Du Pont. IG Farben had benefited from German science and university system to a great extent. For example, invention of the new materials, molecules, and synthesis processes were already common developments in Germany from the beginning of eighteenth century. In the USA, education system and science were supported by institutions that were market oriented as well as the government. Therefore, although German science was heavily based on pure and fundamental characteristics, American science was based more on the applied elements (for instance development of chemical

engineering versus chemistry departments) to promote economic development. Third, the organizational structures of the firms were naturally different from each other. IG was more controlled by the government and had a more centralized organization. Instead, the USA endorsed more flexible research and management systems, which is reflected in firms that flourish in the USA like Du Pont. Finally, research sense was affected by each other (IG and Du Pont). German system mainly supported pure or basic research. Labs and research centers served to realize innovation in the field so to say in a more linear fashion going from theoretical to applied science. Du Pont focused on "pure and practical" research; however, the importance of market driven production and research was what made Du Pont different from IG Farben.

The fifth and sixth chapters are specific analyses chapters, which are designed to conduct research and support the findings that come from the investigation. The fifth chapter is related to the organizational issues. The main results of the analyses can be summarized as follows. Both companies benefited from the central management structure in certain times. In terms of management of research activities, IG Farben was directly connected to top management, while Du Pont was relatively free. IG Farben's management structure mainly fitted in the "scientific management" rules of Fayol. Du Pont was relatively free and flexible. Recruitment policies were the same for both companies. According to these policies, highly qualified, and highly educated persons were selected, trained and supported. Moreover, administrative level was also comprised of educated people whom were selected consciously and strategically to support the management. In addition, the founder of the IG Farben, Carl Bosch, created a new type of entrepreneurship: scientist-entrepreneur. DuPont's founders were not scientists; however, they were supported by many prominent scientists like Antonie Lavoisier. Chapter 6 and this last chapter analyse research policy differences between two companies in terms of establishing research centres and conducting research. According to the chapter, the main differences while conducting research were defined by the motivation of the companies. In the USA case, market structure and economic resources enabled make market driven scientific research. The Cellophane case is an example of market driven scientific research. As a result of the research, both the company and science benefited; the former in terms of profit and the latter in terms of creating new fundamental or applied scientific research areas. The German case, naturally, was different from the USA. Germans made pure and basic scientific research that produced remedies for economic shortages (fuel, dye, acid, etc.). In addition, German research did not focus on end-user products like (packaging products,

socks etc.). Their research was more on big economic problems like providing raw materials for dye industry and fertilizers for agricultural activities. Though these problems were real and concrete, their solutions involved a great deal of blue-sky research. Another important difference between the cases was the implications of the interventionism. German research was mostly overshadowed by Hitler's control over the company. The USA had a relatively free environment for science and research to develop. Last but not least, collaboration was important for both of the cases. The companies benefitted generously from the network of educated people and their scientific knowledge.

7.2 Main Findings and Answers to the Research Question

In this part, general conclusions and results of the dissertation are discussed. First of all, this dissertation is based on a simple research question: why did research and innovation activities differ in two different contexts and companies between 1925 and 1945? The main findings will be provided in three main topics.

First of all, the IG Farben case shows that acquisitions and mergers enabled to reach a variety of knowledge types like producer knowledge, capabilities etc. This type of a business strategy leads to a new type of corporation. In the literature, "global" companies have been discussed in terms of their engagement in knowledge flows and successful integration to other important economic actors or companies to gain efficiency in production. At this point, recent studies have been interested in the importance of (global) value chains (Grosse 2015; Morrison, Pietrobelli, and Rabellotti 2008; C. Pietrobelli and Saliola 2008; Carlo Pietrobelli 2008; Carlo Pietrobelli and Rabellotti 2011). In simple words, value chains can be defined as efficient bridges between firms, which bring economic benefits to all firms in the chain and to the rest through spillovers. Porter states that value chain is a process that benefited from all steps of products delivered to market. Basically, IG Farben case had a value chain relationship in terms of marketing. However, IG Farben also fitted the literature of global value chains. According to the theory, complex productions systems need new markets and consumers around the world to produce at scale to gain efficiency. Moreover, innovative performance and innovative strategies of local firms help to compete at the global level (Porter 2011). IG Farben's foundation aim was parallel with this argument. Global level competition promoted innovation in the chemical industry. IG Farben made a business strategy to obtain competitive advantage and benefited from global value chains. The complicated research management structure and innovative production, and also the existence

of an important rival from the USA supported this new type of strategy of forming a value chain. Thus, the forming of IG is a primitive strategy for creating a global value chain. As a result of this strategy, IG Farben benefited from global chemical clusters (USA, Britain etc.) in terms of knowledge, codified information exchange, and cooperation in product development process to recruit some experts who flew from Nazi authority. A similar approach was observed in the Du Pont case. The vast merger and acquisition activities and cooperation with the other giants (IG Farben, ICI) brought a new type of strategy that affected the development and innovation strategies of DuPont. The major difference is that, in the case of IG, the coordination was deliberately pushed by the government so to say that German government created the IG. However, the merger and acquisition decision of Du Pont was a pure business strategy.

Another significant finding is related to market creation. According to recent studies, capabilities, creativity, and knowledge have important roles for market creation at the firm level (Tollin and Carù 2008). Additionally, government has a greater role in creating a new competitive market according to Mazzucato (2011) in the sense that governments can take an active entrepreneurial role in actually creating the market. Biotechnology and advances in ICT rely heavily on government research; hence, government can create new markets, support them in their infancy and move to a regulator role when private initiatives take risk and invest. At this point, Du Pont case differed from IG Farben. While a significant portion of Du Pont research served to government demand in 1900s, government, also, did military research before the World War II. Many innovations that were developed in that time by both the US government independently and Du Pont privately, turned into consumer products. For example, Teflon and Cordura are used to make strong materials and textile products. The US government and Du Pont leaded this type of an entrepreneurship in a collaborative fashion. This means, Du Pont's research and government research in chemical industry was a kind of new market creation in terms of introducing radical innovations to the market. For instance, Cellophane case indicated how Du Pont created a new necessity for American retail sectors. A new type of packaging opened up a new type of marketing and business line.

Additionally, emergence of a new sector or sector formation phenomena can be seen in both cases. IG Farben and Du Pont create their domestic market at the beginning. They developed capabilities to do successful research. Companies affected market formation in two ways. First was through benefiting from clustering advantage. In the IG Farben case, this was obvious. For instance, Offenbach chemical cluster

served to firms' knowledge, expertise, and experienced knowledge. This economic experience is not very much different form todays Silicon Valley experience. After decades, in the USA, Silicon Valley was upraised with the assistance of proper economic conditions and economic capability of the country. As a result, new sectors like software, computer hardware, nano-tech production have flourished in the economy. Similar observations can be made in our cases. IG Farben and Du Pont had created sectors that affected cross-sectoral relationships. For instance, as a result of development in the chemical sector, a new product was found in the textile sector. Moreover, in the 1900s, emergence of the new chemical sector was supported by private and public initiatives; however, the emergence process was heavily dependent on "spontaneous human actions" and "evolutionary" dynamics. It was created by as a result of humans' actions unconsciously, like cluster of Silicon Valley. At this point, emergence or spontaneous actions can be understood in the level of interventionism history of the countries. For example, economic history of modern China indicates more interventionist economic development which ignores spontaneous system mostly; on the other hand, American system and its institutions have benefited from and have supported spontaneous market formation. German case is totally fragmentary. Until the Nazi Period, it was not wrong to say that extractive and interventionist character shaped the economy. However, before this specific period, German scientific and economic tradition have evolved from the oldest day to modern times in historically. After all, as Acemoglu and Robinson argue democratic history can lead to sustainable innovative economic development as a result of developing and carrying inclusive institutions (Acemoglu and Robinson 2012).

Specifically, I find two factors important in answering the research question of the dissertation, which are mainly related to research policies and organizational structures. In two cases, reasons of the main differences that affects innovation capacity of the companies can be explained under these factors. In literature review, we see that research agendas of the countries, more or less, have a similar path. It means that science-based development and gaining competitive advantage at the global level were desired both by the USA and Germany. The general theory of innovation asserts that research expenditure can promote innovation. However, both in IG Farben and Du Pont cases, research organization and firm organization, though differently, stand out as two important factors that determine innovation success. The simple and clear answer to the research question is; a *proper setup for conducting basic and applied research that is supported by a strong heritage and creating an organizational structure that promotes scientific activities and creates new*

opportunities for the market, could lead to successful but different innovation paths.

In summary, there are three important findings: role of the government, firm strategies in acting on global field, and sense of management. The first one can be observed in two ways: monopolized power on all activities of the companies and demand effects on research agendas. In IG Farben, government's role was transformed from a pro-active policy setup that involved mechanisms like tax incentives, education promotion, and procurement (coal and fuel research) in to a more centralized and autocratic setup in which decision-making process was dominated by the head of the power (the government) without any consent and freedom. IG Farben carried out its research and development activities according to economic necessities or economic shortages (agricultural necessities or energy problem). On the other hand, Du Pont's experience was different from the IG Farben in terms of non-strict and constructive character of the government, which resulted in pursuing a more flexible research programme. Following the evolutionary path of natural market actions was a distinctive factor in successful innovative activities of Du Pont. In the literature, Mazzucato argues that role of government can be pro-active to create a new sector or market. For example, in China, ICT and renewable energy sector has been established and advanced by mostly government initiatives. The argument could be useful to understand the early setting up of the chemical sector in Germany and USA.

The second finding is related to firm strategies. Interventionism shaped, somehow, the strategies of the companies. However, companies had their own global strategies in order to engage in the global market and gain a leadership position in the sector. This effort could be examined in both cases via analysing global partnership and export, import data. As a result of this, IG Farben started to integrate its business to global market earlier than Du Pont. In terms of the literature, this can be blunt first example of global value chains. To sum up, value chains have been used mostly by IG Farben and to a certain extent by Du Pont to acquire knowledge, expertise and competitive advantages.

The third finding that stands out is related to the management practices. As Chandler puts it, Du Pont and IG Farben had successful executive organizations in terms of realizing profitable business with the help of science and technology. The importance of managerial decisions showed itself in acquisition and joint venture policies inside the companies. IG Farben used acquisition as a corporate strategy in order to gain competence and enter new markets; for instance, by

establishing a joint venture with Dutch company, Shell, created an opportunity to enter "fossil fuel" business. In a similar manner, Du Pont's acquisition policy was vital in acquiring new knowledge and expertise to obtain competitive advantage. For example, in order to produce new fibers, films, Du Pont established the Rayon Department via acquiring French rayon company, Comptoir des Textiles Artificiels in 1919. This was a technology transfer from France to USA.

7.3 Main Implications of the Dissertation

This thesis shows the evolution of two chemical firms in two different settings. The path for success differs and is greatly affected by context specific factors which are already discussed in the main text and summarized in this chapter. Historical case studies are good sources to reveal specific mechanisms for success; as such they can serve as good learning tools. The findings of this thesis have several implications for today's policy-making process. It should not be forgotten that industrialization of chemical sector had started in the beginning of the nineteenth century. Germans and British were the first-movers in terms of establishing industrial production facilities in the chemical sector. This is important to understand the leadership of Germans, advantage of first-movers and advantages and disadvantages of late-comers in development economics. According to the theory, first-mover advantage causes radical innovations and enhances competitive position (Sarin 2010). Many emerging countries had not benefited from such an advantage. However, lessons from the historical cases can be drawn for countries that want to develop their chemical sectors and products. From the detailed investigation of the cases essential steps for establishing chemical sectors emerge as:

1. *Supporting basic science in education*: In both cases, countries and even firms had unique education systems. Such an effort improved the capability of the country and specifically the capabilities of the companies.
2. *Role of government should be proactive*: Each country should be assessed in their specific timeline to understand the role of government. Before the Nazi period, 1925 – 1933, IG Farben was relatively free to choose its research agenda and economic preferences like investing in new organic chemicals etc. In that period, German government promoted chemical research and chemistry education at the sector level. Offenbach region and Upper Rhine region raised as important chemical clusters as a result of this policies. The role of the state could be labelled as pro-active due to the fact that Germany, from the empire period, systematically promoted

basic science and industry relationship. During the Nazi period, more controlled and more monopolized interventions was observed, implying that main research decisions were made by the authority. On the other hand, Du Pont's relations with the government was on a different track. In this case, role of the government can be defined as proactive, but it was rather an enabler one. The USA, in the macro sense, supported industrial relations with science and set up a solid ecosystem for innovation. In such an environment, interventionist policies worked better. The government was not directly involved in affecting strategic decisions but rather played a pro-active enabler role, for instance, by creating and supporting education institutions. Thus, minor interventions (like reform in engineering education) could affect all the ecosystem. In addition, government procurement, especially demand from the military, was an important factor that affected strategy of Du Pont, which in turn affected its research agenda. This type of a mutual relationship could be seen as an intervention with benefits or an evolutionary process of natural interaction.

3. *Building capabilities*: In each case, companies adopt to changing environments introducing organizational, product and process innovations. Entering the dye production business is an example for Du Pont. Capabilities can adapt to a new environment that is created by the state itself. For instance, between 1925 and 1945, Germany create a new need. Synthetic fuel was requested by the military; therefore, IG Farben had to adapt its capabilities to the new changing demand environment. Du Pont's story touches many similar cases. For example, powder demand from the domestic market forced Du Pont to do more research and involve in innovative activities in the field. This simple decision created capabilities, that later Du Pont used to enter other product lines. Indirect intervention, such as procurements, can lead innovation capabilities to build, with the assistance of strong and inclusive institutions.
4. *Creating strong institutions*: Patent law, competition law and other unwritten rules and habits should serve to establish a good business environment that facilitates business growth. This type of an environment was observed in both countries. At this point, strong institutions mean that institutions of the country must be inclusive to foster innovation and technological change in a sustainable way. On the other hand, according to Acemoglu and Robinson, extractive institutions emerged as a result of

centralized power and strong authorities (Acemoglu and Robinson 2012). For example, China have benefited from those institutions while fostering economic growth. In our case, Nazi era used centralized and monopolized power to achieve economic growth. To sum up, strong institutions must be "inclusive" to enable sustainable innovation performance like in our case: Du Pont and IG Farben.

5. *Promoting local clustering and industrial agglomerations*: In the foundation of the sector, local level support was important in both cases. For example, Germany promoted Offenbach chemical clusters in order to produce economic necessities. A similar development was observed in Delaware powder cluster. In each case, local advantages of the chemical clusters were exploited via creating factories in the neighborhood, to benefit from learning and competition in the region. Therefore, once clusters emerge and start to pull production, talents and knowledge authorities can lead to make specific promotions to support clusters. In both cases, those regions were promoted by the government. For example, Offenbach region was exempt from general taxes until environmental problems emerged (Rhine river polluted by the chemical firms). In addition, Du Pont benefited local tax discounts and cuts (Colby 2014, 15).

7.4 State Policy Discussion

In this title, state policy differences and similarities are discussed to make a consistent analysis in conclusion chapter. Before doing this, it should not be forgotten that each country has a unique path in their history. For Germany case, until Hitler rule, there was a government that was involved in science policies actively. Afterwards, Hitler changed the whole story and made development plans to serve Germany's future interests. According to this process, Hitler initiated "compulsory" production for his war machines and determined a new way to make science. This way contained many obstacles in terms of science and technology policies. One important obstacle was that, science and technology agenda was entirely determined by Hitler government and all cooperation and collaborations with outside were restricted. On the other hand, the USA benefited from government-controlled science and technology, even economy policies. Tax advantages and public procurements, sector based scientific grants were tools to support science and technology inside. Table 25 provided below shows the differences and similarities between two countries.

Table 24: Comparison of State Science and Technology Policies

	Germany - IG Farben	**The USA - Du Pont**
Actors	Firms, Government, Universities, Foreign cooperations and Research Centers (Munich Science Ins. etc)	Firms, Government, Universities, NGOs, Individual Foreign cooperations and Research Centers
Support Types	Public procurement Tax incentive in clusters Scientific Grants Privileges for clusters *-After Hitler-* Direct procurement Contract (based on specific needs like gas)	Public procurement Tax incentive in firm-level Barriers in trade for Europe materials are related to science Scientific Grants and incentives Contracts (based on firm-level)
Collaboration	Foreign collaboration was cutted by Hitler Discrimination of Jewish scientists in research entities	Collaboration between industry and university are supported Foreign scientists are welcomed
Funding	Before Hitler, public and private funding After Hitler, only government supported projects	Private and public funding
Technological Grants	Practical technological solutions (electricity, dye etc.) are supported by government to gain economic advantages	

According to Table 25, five dimensions are discussed below to understand the differences and similarities. First of all, actors were the same for two countries' ecosystems. Firms and government or state were the primary player in science and technology policies. Distinctly, in the USA, individuals were supported for their individual projects by state. Second dimension is support types. Generally, in Germany, support types were the same with the USA until 1933. Public authorities were buyers for both two corporations. Tax incentives were slightly different than each other. In Germany, clusters, like Offenbach Dye and Chemistry clusters, benefited tax cut or incentives generously. This story was a little bit different in the USA. Firm-level incentives were common among firms. For example, Du Pont took tax cut or incentives from state for doing business in gunpowder and explosives. Also, some privileges for clusters were provided by federal managers in Germany (like some specific environment taxes). In the USA, science and technology was also supported by trade policies that involves barriers and tarrifs on raw materials for chemistry industry, etc. After Hitler, procurments and direct contracts changed. Hitler regime decided to support certain products that related to war interest. On the other hand, the USA provided some direct contracts on demand of dye, chemicals etc. in firm-level. Third important dimension is collaboration. In Germany, before Hitler, collaboration with foreign and domestic actors were supported by government, to enrich scientific and technological output. After Hitler, the rule of game was changed. Jewish population in the field of science and technology were excluded from universities, research centers and firms (finally from the country). Discrimination was resulted in differences in foreign science policies. Hitler did not allow any scientific collaboration with other Europeans and Americans. On the other hand, the USA highly benefited from industry and university collaboration, differently from Germany. Many universities found their fundings from industry. State was always eager to make the connection in terms of market and budget. For example, Johns Hopkins University organized some conferences to bring together scientists and businessmen. Moreover, in Du Pont, some PhDs and other scientific technicians were exempt from tax burden. In addition, foreign scientists (especially who flew from Germany) were welcomed and supported[75]. Fourth dimension is funding types. In Germany, normally, before Hitler science and scientific activities were supported by public and private (Kaiser Wilhelm Institute) authorities. After Hitler, this was changed according to demand of third Reich. On the other hand, in the USA, ordinary structure of funding was

75 There were no data how many scientists employed in Du Pont.

favored. According to this, government always gave a budget to their authorities so that firms and individuals could benefit from it. Private initiatives (like firms) can support the activities also. Finally, the common and similar dimension was about technological grants. Practical technological stuff and technologies that avail to industry by firms were supported in both countries. Thanks to these activities, government directly or indirectly gain advantages in foreign policies. Examples for those can be seen in the story of invention of Nylon (for the USA) and Dye (for Germany).

This part discussed the differences and similarities in terms of science and technology policies between the USA and Germany. There were important dissimilarities that came with Hitler period and moreover, slightly different policies were issued. The next title will explain limitations of the dissertation and further research opportunities.

7.5 Limitations & Further Research

Naturally, this dissertation has some limitations in terms of data and reaching archival sources. Archival work is a challenging task in its own right. In this dissertation, preliminary research is conducted with the desire to reach more data sources. As a result of this preliminary research, five archives and libraries were spotted to obtain data for German side of the research. Those archives contain valuable and varied data, which are explained in the methodology chapter in depth. Further archival work could enable to reach more specific data sets. For example, IG Farben was a merger company. As a natural result of this, constituent firms of IG Farben had their own archives like Bayer at Leverkusen, BASF at Ludwigshafen. Visiting all these archives is of course a daunting task, consumes time and effort and is also expensive. In this dissertation, archives are selected, so to say, purposefully to find information supporting the main argument which is related to different paths in breakthrough innovations in the chemical sector in different geographies. Thus, we were more interested with rare education, research and managerial data sets. However, there are more data sets (and archives) which need to be studied. Especially, the private corporate archives (like Bayer's) and its contents could be explored to do further research that would enrich the findings in this thesis.

On the other hand, data collection for the USA case was a relatively easy-going task compared to Germany. Du Pont's operations and business continues; the archive of the company is settled in one place at Delaware, USA; and Du Pont's archives have mostly been digitalized. Consequently, reaching sources are easier

than Germany. However, the archives and library of the Du Pont (located at Hagley Museum) should be visited to obtain more data. Though digital sources for Du Pont produced sufficient information and data for the thesis, ideally, the archival work in Germany should be accompanied by a similar archival work in USA.

Finally, this dissertation explains how IG Farben and Du Pont flourished in the chemical sector between 1925 and 1945 under different circumstances. Both were successful, both were innovative and both were the leading firm in their geographies. But their success comes from adaptation to context-specific factors. According to this main finding, new research agendas and opportunities might be issued from the perspective of Science and Technology Studies.

As a last word, the success of two countries was not a coincidence. They are good cases that show that science is an indispensable guide for understanding the universe and promoting economic development.

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APPENDICIES

A. KEYWORDS

Keywords shown below are used during web and database research for both IG Farben and Du Pont

E.I. du Pont de Nemours & Company.
Accidents, Prevention.
Blasting.
Business enterprises--History.
Business enterprises--Periodicals.
Chemical industry--Periodicals.
Chemicals--Catalogs.
Chemistry.
Chemistry--Technical history.
Chemistry, Technical--Periodical.
Clippings (Books, newspapers, etc.)
Commercial catalogs.
Corporation reports.
Corporations--Investor relations--United States.
Diagnostic laboratory tests.
Elastomers.
Employees' magazines, newsletters, etc.
Engineering--Materials.
Explosives.
Plastics.
Polyesters.
Polyethylene.
Polymers.
Research, Industrial.
Safety education.
Science--Research.
Scientists.
Solvents.
Synthetic products.
Textile fibers, Synthetic.
Thermoplastics.
Trade literature.

Trademarks.
Delaware--Industries.
Du Pont family.
Agricultural chemistry.
Chemistry, Organic.
Chemistry, Physical and theoretical.
Interessengemeinschaft Farbenindustrie Aktiengesellschaft--History.
Hoechst AG--History.
World War, 1939-1945--Atrocities.
Chemical industry--Political aspects--Germany--History--20th century.
E.I. du Pont de Nemours & Company. Elastomer Chemicals Department--History.
Imperial Chemical Industries, ltd.
Interessengemeinschaft Farbenindustrie Aktiengesellschaft.
Rubber, Artificial.
Neoprene.
Dyes and dyeing--Chemistry.
Dyes and dyeing--Germany.
Dye industry--Germany.
World War, 1939-1945--Technology.
Chemical industry--Germany.
Phenol.
Resorcinol.
Anthracene.
Carbazole.
Technology--Germany.
Butadiene industry.
Carbon-black.
Rubber chemicals.
Hounshell, David A. Science and corporate strategy: Du Pont R & D, 1902-1980.
Abbott Laboratories.
E.I. du Pont de Nemours & Company. Ammonia Department
E.I. du Pont de Nemours & Company. Biochemicals Department
E.I. du Pont de Nemours & Company. Cellophane Division.
E.I. du Pont de Nemours & Company. Central Research Department.
E.I. du Pont de Nemours & Company. Chambers Works.
E.I. du Pont de Nemours & Company. Chemical Department.
E.I. du Pont de Nemours & Company. Chestnut Run Laboratories.
E.I. du Pont de Nemours & Company. Development Department.
E.I. du Pont de Nemours & Company. Eastern Laboratory.
E.I. du Pont de Nemours & Company. Employee Relations Department.
E.I. du Pont de Nemours & Company--Employees.
E.I. du Pont de Nemours & Company. Engineering Department.

E.I. du Pont de Nemours & Company. Executive Committee.
E.I. du Pont de Nemours & Company. Experimental Station.
E.I. du Pont de Nemours & Company. Explosives Department.
E.I. du Pont de Nemours & Company. Fabrics and Finishes Department.
E.I. du Pont de Nemours & Company. Grasselli Chemicals Department.
E.I. du Pont de Nemours & Company. Organic Chemicals Department.
E.I. du Pont de Nemours & Company. Photo Products Department
E.I. du Pont de Nemours & Company. Pigments Department
E.I. du Pont de Nemours & Company. Plastics Department (1962-1976).
E.I. du Pont de Nemours & Company. Polychemicals Department
E.I. du Pont de Nemours & Company. Public Relations Department
E.I. du Pont de Nemours & Company. Rayon Department
E.I. du Pont de Nemours & Company. Textile Fibers Department
Eastman Kodak Company.
Endo Laboratories.
General Electric Company.
General Motors Corporation.
Hercules Incorporated.
Jackson Laboratory (E.I. du Pont de Nemours & Company).
Lazote, Incorporated.
Manhattan Project (U.S.).
Massachusetts Institute of Technology.
Rohm and Haas Company.
Union Carbide Corporation.
Acetates.
Ammonia.
Bonus system.
Cellophane.
Chemical engineering.
Dacron.
DDT (Insecticide).
Dyes and dyeing.
Fluoropolymers.
Leather, Artificial.
Lucite.
Magnetic tapes.
Methyl methacrylate.
Methanol.
Methylamines.
Musk.
Nylon.
Orlon.

Patents.
Pharmaceutical industry.
Polymerization.
Polypropylene
Rayon.
Safety glass.
Silicon.
Urea.
Carothers, Wallace Hume, 1896-1937.
Du Pont, Irénée, 1876-1963.
Greenewalt, Crawford H., 1902-1993.
Hayden, Oliver M. (Oliver Mills), 1893-1991.
Hueper, Wilhelm.
Jackson, Oscar R. (Oscar Raymond), 1855-1916.
Maxim, Hudson, 1853-1927.
Runge, Otto, 1881-
Schu̇pphaus, Robert C., b. 1861.
Sparre, Fin, 1879-1944.
American Telephone and Telegraph Company.
Atlas Powder Company.
Beyer-Semsan Company.
Directors of Industrial Research (U.S.).
E.I. du Pont de Nemours & Company. Central Research and Development Department
E.I. du Pont de Nemours & Company. Chemical Department
E.I. du Pont de Nemours & Company. Development Department
E.I. du Pont de Nemours & Company. Grasselli Chemicals Department
E.I. du Pont de Nemours & Company--History.
E.I. du Pont de Nemours & Company. Organic Chemicals Department
Hercules Powder Company.
Krebs Pigment & Chemical Company.
Antifreeze solutions.
Chemical industry--United States--History.
Cordura rayon tire cord.
Cronar polyester film.
Gunpowder, Smokeless.
Mylar polyester film.
Polyethylene terephthalate.
Research, Industrial--United States--History.
Stabillite (Propellant).
Tetraethyllead.

B. TURKISH SUMMARY/TÜRKÇE ÖZET

Yaklaşık 60.000 yıl önce, *Homo Sapiens* kendi "bağımsızlığını" ilan ederek doğada kendini keşfetti, böylelikle maddi uygarlığımızın temelleri atılmış oldu . Günümüze kadar maddi uygarlığımızda birçok yeni şeyler keşfedildi. Bu keşiflerin en önemlilerini ise kısa sayılabilecek bir zaman diliminde yapıldı. Bu zaman dilimi geçmiş 300 yıldaki teknolojik, bilimsel ve yenilikleri kapsamaktadır. İmparatorluk çağının sonuna gelindiğinde ulus devletlerin daha sistematik bilimsel ve teknolojik çalışmaları teşvik etmesiyle, hızlanmaya başlayan bu süreç Birinci Dünya Savaşı ve İkinci Dünya Savaşı sırasında ise en "yüksek" noktalarına ulaşmıştır (E. J. Hobsbawm 1994). Bu noktada, keşiflerin ve "aşırılıkların" yaşandığı bu dönem sonucunda kimya, elektrik-elektronik ve uzay alanında devrimsel nitelikte gelişmeler yaşanmıştır. Özellikle 1800'lerde, kimya bilimindeki ilerlemenin materyal, petrol, ilaç gibi birçok alanı da beraberinde geliştirdiği gözlemlenmiştir. Literatürde ilerlemenin boyutu ve ekonomiye katkıları üzerine önemli sayıda eser vardır. Bunların bazıları ekonomik gelişmelerin temellerini irdeleyen, bazıları ise kültürel ve coğrafi boyutları ile ilgilenen çalışmalardır. Bu çalışmalar temelde şu soruya cevap aramaktadır: *"Neden bazı ülkeler zengin, diğerleri fakir?"*. Elbette bu sorunun yanıtı birçok disiplinin sınırları içinde verilebileceği gibi disiplinler arası çalışmalar da soruya bilimsel bir yanıt verebilirler. Bu noktada, gelişmelerin ekonomik ve bilimsel temellerini irdelemenin "yenilik literatürü" açısından önemli bir uğraş olacağı düşünülmektedir. Bu noktadan hareketle, bu tezin ana konusunu oluşturan kimya alanındaki gelişmelerin mikro analizi genel çatı sorusunun bir kısmını anlamak açısından mühim olacaktır. Tezin araştırma sorusu ve hipotezleri, *neden ekonomik farklılıklar* (*divergence*) *var* ve *neden bazı ülkeler diğerlerine göre ekonomik, bilimsel ve teknolojik anlamda geridedir?* Sorusu ile birlikte düşünülmüştür. Bu nedenden dolayı seçilen ülkeler ve firmalar analiz edilirken bu "farklılıkların" temellerine de sorular sorularak cevaplar aranmıştır. Tezin ayrıntılarına geçmeden önce literatürde önemli çalışmaların bir kısmından bahsetmek gereklidir. Teknolojik farklılıkların temellerini tarihsel anlamda geçmişe bakarak analizlerini yapan önemli iktisat tarihçileri Mokyr ve Landes, bu farklılıkların kültürel ve sosyal kökenlerini çalışmalarında irdelemişlerdir . Buna göre birçok faktörün de etkili olduğu halde "kültür" ve "geliştirilmiş kurumların" kalkınma sürecinde ülkelerde farklılık yarattığını savunmuşlardır. Bu çalışmalara ek olarak, coğrafya faktörünün ekonomik ve teknolojik gelişmeye etki ettiğini savunan

Jared Diamond, ülkelerin ekvatora yakın yerlere yakın coğrafyalarda kuzeye nazaran daha az teknolojik gelişme kaydedebildiklerini çalışmasında savunmuştur (Diamond 1997). Diğer tarafta kurumsal (hukuk, para, finans) manada ülkelerin tercihlerinin, teknolojik kaderlerini belirlediğini savunan görüşlerde mevcuttur. Buna göre, bir ülkenin ne kadar *kapsayıcı kurumları* (inclusive) varsa o ülkenin yenilik ve teknolojik gelişmesinin yüksek olacağı ileri sürülmektedir (Acemoglu and Robinson 2012). Bu çalışmalara ek olarak, literatürde farklılıkların temelini daha mikro faktörleri inceleyerek cevap vermeye çalışan mühim eserler vardır. Joseph Schumpeter'in yenilik ve firma analizi bu anlamda literatüre bir katkı olmuş ve ondan sonra gelen çalışmaları da etkilemiştir. Schumpeter'a göre ilerleme sürecinin doğrusal olmaması bu nedenle de sürekli yenilik gibi bir durumun bir ekonomi için gerçek olmayacağını ileri sürmüştür (Schumpeter 1994). Bu nedenle, gelişmelerin temelleri ekonominin en mikro aktörlerine bakarak anlaşılabilirdi. Teknolojik ve bilimsel gelişmelerin kaynaklarını evrimsel anlamda incelemenin literatüre önemli katkıları olmuştur. Freeman, Mowery ve Nelson gibi yazarlar buradan hareketle bilimsel ve ekonomik gelişmelerin farklılıklarını ülke, sektör ve firma boyutunda anlamaya çalışmışlardır (C. Freeman and Soete 1997; Mowery and Nelson 1999; Nelson and Rosenberg 1993). Literatürdeki bu çalışmalar temelde yine aynı çatı sorusunun cevabını aramaktadır. Bu noktadan hareketle bu çalışmanın ana konusu şekillendirilmiştir.

Bu Türkçe özet (orijinali İngilizce yazılmıştır) yeniden yazılarak şu başlıkları içermektedir: tezin araştırma sorusu, amacı, kullandığı metodoloji, literatüre katkısı, temel bulgular, bölümlerin özetleri ve araştırma kısıtları. Buna göre sonraki başlıklarda tez hakkında daha detaylı bilgiler ve araştırma sonuçlarına yer verilecektir.

1.1 Tezin Araştırma Sorusu

Bu tezin temelde bir araştırma sorusu ve alt araştırma soruları vardır. Tezin ana konusu yirminci yüzyıl başlarında özellikle Avrupa'da başlayan kimya alanındaki gelişmelerin firma bazında incelenmesidir. Bu incelemenin daha dar bir çerçevede detaylı yapılabilmesi adına firma bazında bir seçim yapılmıştır. Buna göre iki farklı coğrafyada faaliyet gösteren iki farklı başarılı örnek seçilmiştir. Bunlar Alman kimya üreticilerinin (BASF, Bayer, Hoechst, AGFA) bir araya gelerek oluşturdukları IG Farben ve 1800'lerden beri Amerika'nın en büyük dinamit ve barut üreticisi olan Fransız temelli Du Pont'dur. Bu şirketlerin daha iyi analiz edilebilmesi için 1925 ve 1945 yılları arasındaki faaliyetlerine bakılmıştır. Bu konu çerçevesinde şirketlerin yenilik performanslarının farklılıklarının kaynakları ve etkili faktörlerin analizi araştırma konusu olmuştur. Tezin ana konusu şu araştırma sorusu ile çalışılmıştır:

AS (1): *Neden ve Nasıl 1925 -1945 arasında farklı coğrafyalarda faaliyet gösteren IG Farben ve Du Pont şirketlerinin yenilik performansları farklılaşmıştır?*

Bu soruya ek olarak alt araştırma soruları da ortaya çıkmıştır:

AS (a): *Ülkelerin tarihsel geçmişinin araştırma ve geliştirme faaliyetleri açısından firma düzeyinde etkisi nedir?*

AS (b): *Firmaların spesifik politikalarının kendilerine has performans göstermeleri yönünde etkili olmuş mudur?*

Tüm bu soruların cevaplarını bulmak adına tezin konusu irdelenmiştir. Buna göre birçok faktörün yanı sıra iki önemli faktör ön plana çıkmıştır. Bunlar firmaların *araştırma ve bilimsel faaliyetleri* ve *yönetimsel organizasyonları* olarak saptanmıştır. Bu soruların cevapları bu bölümlerde incelenmiştir. Temel bulgulara göre farklılaşmanın başlangıcı bu iki faktörün detaylı analiziyle ortaya çıkmaktadır. Bu bulgular tezin bölümlerine yer verilen başlıklarda açıklanacaktır. Bir sonraki başlıkta tezin yapılma amacına yer verilecektir.

1.2 Tezin Amacı

Bu tezin iki temel amacı vardır: birincisi, araştırma sorularına cevap bularak literatüre katkı sağlamayı hedeflemektir. Bu ana amacın dışında literatürde karşılaştırmalı, tarihsel vaka çalışmalarının az olmasından ötürü, yapılan bu çalışmanın yapılması gerekliliğidir. Daha yalın bir ifadeyle, yenilik literatüründe karşılaştırmalı vaka çalışmaları güncel firmalar ve şirketler için çoğunlukla yapılar olsa da tarihsel anlamda, geçmişe dönük konular genellikle tercih edilmemektedir. Buradan hareketle, tezin araştırmasına başlanmıştır. İkincisi ise tezin konu aldığı şirketlerin araştırma ve bilimsel aktivitelerinin spesifik incelenerek yenilik performanslarını nasıl etkilediğini tarihsel verilere dayanarak göstermektir. Bu amaç tezin ana konusunda var olan spesifik dönem için arşiv ve ikincil kaynak taramasıyla birlikte gerçekleştirilmiştir.

1.3 Metodoloji

Çalışmanın başında tarihsel metodolojilerin kullanılması planlansa da bu çalışmada temelde karşılaştırılmalı vaka metodu kullanılmıştır. Daha yalın bir ifadeyle, her iki şirketin 20 yıllık faaliyetlerinin tarihsel araştırılması ve hem genel literatürle hem de kendi içinde karşılaştırılmıştır. Genel olarak araştırma üç temel aşamaya ayrılmıştır. Buna göre öncelikle öncül araştırma yapılıp veri kaynakları saptanmış,

daha sonrasında bu kaynaklar için uzman (arşivci, tarihçi) görüşü de alınarak daha detaylı araştırma yapılmıştır. Bu detaylı araştırma sonucunda ortaya çıkan kaynaklara erişim için gerekli detaylar tartışılıp, kaynaklara ulaşılmıştır. Bu noktada Almanya ve ABD için farklı iki senaryo uygulanmıştır. Öncelikle Almanya'da olan kaynakların yerleri tespit edilmiş ve bu arşivlerin mail atılarak veri hakkında güncel bilgi talep edilmiştir. Buna göre, Berlin, Koblenz'deki devlet arşivleri (Bundesarchiv) ile ilk temas kurulup, gerekli seyahatler gerçekleştirilmiştir. Bu arşivlerde genel anlamda şirkete ait istatistiki bilgiler bulunsa da daha detaylı bilgiler, faaliyetlerine devam eden (BASF, Bayer) gibi firmaların özel arşivlerinde saklanmaktadır. Bu nedenden dolayı Leverkusen'de Bayer şirketi ile elektronik posta yoluyla iletişime geçilmiştir. Onların ellerindeki bazı veriler talep edilmiştir. Ayrıca Frankfurt'ta Hoechst ile iletişime geçilmiş ve veri kaynaklarının akıbeti sorulmuştur. Doğru verilerin çoğunluğu eskiden IG Farben'in yönetim binası, şimdi ise Frankfurt Üniversitesi'nin kullandığı yerin kütüphanesinde bulunmaktadır. Burada 5 günlük bir çalışma ile verilerin çoğunun fotoğrafları çekilmiştir. Daha sonra Türkiye'ye döndükten sonra düzenlenmek ve temizlenmek üzere çalışma tamamlanmıştır.

Amerika çalışmaları içinse farklı bir yol izlenmiştir. Buna göre, hala faaliyetlerine devam eden Du Pont'un öncelikle Türkiye ofisi ile görüşülmüş ve referans alınarak ABD'deki ofise gereken veriler için iletişime geçilmiştir. Du Pont şirketinin geçmiş arşivi Hagley Museum adı altında kısa bir süre önce dijitale dönüştürülüp internet ortamına yüklenmiştir. Çoğu arşiv verisine bu yolla ulaşılmıştır. Verilerin büyük bir kısmı kullanmaya hazır ve temiz olmakla beraber bazılarının detaylı okumalara yaparak ortaya çıkarmak gerekmiştir. Bu çalışmaların bir özeti aşağıda Tablo 1'de verilmiştir.

Tablo 1: Arşivlerin Yerleri ve İçeriklerinin Özetleri

Firmalar	Zaman Dilimi	Aktiviteler	Kaynaklar
DuPont	1802 - 2015[1]	Kimya mühendisliği, Malzeme bilimi, Tarım, Gıda ve tekstil	Dijital kataloglar Hagley Museum ve Kütüphanesi, Delaware Firma özel arşivleri, Wilmington
IG Farben	1925 - 1945	Boya, Kimya prosesleri, Organik kimya, İlaç	*Staatsbibliothek zu Berlin*, Berlin *Bibliothek der Humboldt-Universität*, Berlin *Library of Goethe University*, Frankfurt *BundesArchiv (1925 - 1939)*, Koblenz *BundesArchiv (1939 - 1945)*, Berlin *The Fritz Bauer Institute (Wollheim Memorial) Archives*, Frankfurt
BASF	1865 - 1925	Organik ve inorganik kimya, Boya, Soda	Firma özel arşivleri (Unternehmenarchiv, Ludwigshafen)
Bayer	1863 - 1925	İlaç ve çeşitli kimyasallar	Firma özel arşivleri (Bayer Werkarchiv, Leverkusen)
AGFA	1867 - 1925	Görsel, baskı sistemleri	Firma özel arşivleri (Cologne)

(1) Dow C*hemicals ile Du* Pont'un birleşme tarihini göstermektedir.

Bulunan verilerin temizliği ve düzenlenmesi yapıldıktan sonra, bölümlerdeki ilgili yerlere aktarımı yapılmıştır. Tezin içerisinde verilerin yoğunluğu ve analizlerde gösterilmek istenilen ilişki boyutu düşünüldüğünde, network analizinin mantıklı bir araç olacağı düşünülmüş, buna göre piyasadaki network programlarından çeşitli denemeler yapılarak *Graphcommons* programı bu analizler için kullanılmıştır. Bu tercihin ana nedeni programın kullandığı algoritmanın görsel anlamda daha hızlı ve iyi sonuçlar vermesinden kaynaklanmaktadır. Buna göre *Force Atlas 2* algoritması noktaları birbirine daha uygun ve hızlı bir biçimde dağıtmaktadır. Verinin sayısına göre yapılan bu tercih, ilgili bölümlerde kullanılmak üzere analize dahil edilmiştir. Ayrıca kullanılan bu aracın temel amaçlarından bir tanesi de birbiriyle ilişkili değişkenlerin gösteriminde kolaylık sağlamasıdır. Buna göre, ürün ve ürün kullanıcı ilişkileri matematiksel anlamda dağıtıldığında çıkan grafiğin daha manalı analizlere yardımcı olması söz konusudur.

Son olarak, kullanılan metrikler ve bunların anlamları tezin orijinalinde ayrıntılı bir biçimde anlatılmaktadır. Buradan hareketle tutarlı bir çalışma yapılması adına, toplanan veriler özenle temizlenip, sınıflandırılmıştır. Ek olarak, çalışmanın konu aldığı dönem itibariyle nadir ve zor bulunan eksik veriler, literatürde var olan önde gelen araştırmacıların çalışmalarıyla (Haber 1958, 1971; Reader 1970) çapraz kontrol edilerek çalışmaya dahil edilmiştir.

1.4 Yenilik ve Literatüre Katkı

Tezin ana konusunu oluşturan yenilik performanslarının karşılaştırılması hususunda, literatürde azımsanmayacak sayıda çalışmalar vardır. Fakat her çalışmanın kendine has metodu ve araştırma örüntüleri olmaktadır. Bu çalışmayı diğerlerinden farklı kılan iki önemli husus söz konusudur. Birincisi, araştırma konusunun kapsadığı dönemde incelenen şirketlerin karşılaştırılması. İkincisi ise, bu araştırma soruları için kullanılan verilerin birincil kaynaklardan edinilmesi ve bu verilerin analizinde araç olarak network yazılımının kullanılmasıdır. Bu iki yenilik literatürdeki konulardan bir tanesi olan *yenilik performansı analizlerine* farklı akademik katkılar sağlanmasına olanak tanımıştır. Buna göre, çalışmanın bulguları genel anlamda 3 grupta toplanabilir: organizasyon yapısı ve yönetimsel farklılaşmalar, araştırma ve geliştirme faaliyetlerinin yapılış biçimi, tarihsel geçmişin ve kurumların önemi. Bu bulguların desteklediği argümanlarla araştırma sorusuna cevap verilmiştir. Buna göre, iki farklı ülkede, aynı sektörde faaliyet gösteren iki firmanın farklılaşmasının beş temel sebebi bulunmaktadır:

1. Organizasyon yapılarında var olan merkeziyetçi ve merkeziyetçi olmayan unsurlar.
2. Araştırma ve bilimsel faaliyetler sürecinde firmaların izledikleri stratejiler.
3. Ülkelerinin ekonomik gücü ve doğal kaynakları ile alakalı geliştirilen stratejiler.
4. Dışa açıklık ve rekabet.
5. Kurumların etkisi ve bu kurumların dışarıdan müdahalelerle şekillenip yeniden firmaları etkilemesi.

Bu bulguların her biri özet olarak yukarıda sunulmuştur. Bir sonraki başlıkta bu bulguların tezin bölümleri kapsamında detaylı bilgileri verilecektir. Bu bilgilerden önce bu başlığın ana konusu olan tezde bulunan bulguların literatüre kattığı yenilikler arasında söylenilmesi gerekenler bulunmaktadır. Bu sebeple, literatür taraması yapılırken her bir bölümün kendi içerisinde bölüm kapsamı sınırlarında bir literatür özeti çıkarılmıştır. Bu özetle literatürde eksik kalmış yahut göz ardı edilmiş hususlar belirtilip, teorik altyapılar oluşturulmuştur. Bu altyapıların desteklediği

argümanlar sayesinde de bulgular sunularak yenilikçi yahut işlenmemiş, kendine has yerlerin altı çizilmiştir. Böylece, literatüre katkı sunulmuştur. Unutulmaması gereken hususlardan bir tanesi bu çalışmanın konu aldığı dönemde benzer çalışmalar bu kapsayıcılıkta yapılmamıştır.

1.5 Tezin Taslağı ve Bölüm Özetleri

Bu tez toplamda sekiz bölümden oluşmaktadır. Bu bölümler sırasıyla: giriş, metodoloji, teorik ve tarihsel arka plan, firmaların tarihleri, firmaların organizasyonel yenilik ve yönetimsel aktiviteler, araştırma ve yenilik aktivitelerin etkileri ve son olarak sonuç. Bu bölümlerin her biri kendi içinde giriş ve sonuç bölümleri olan ve literatür özeti yapan bir tasarım olarak kurgulandı. Bu başlığın altında bölümlere ilişkin özet bilgiler verilecek ve kısa kısa her birinden bahsedilecektir.

Giriş bölümünde, genel olarak tezin amacı, araştırma konusu, amacı ve bölümlerin özetleriyle bulgulara yer verilmiştir. Bulguların her bir bölüm içinde nasıl incelendiği ve bunların hangi metotlarla desteklendiğinin özeti bu bölüm içerisinde verilmiştir. Girişin içerisinde herhangi bir literatür özeti yapılmamış sadece genel hatlarıyla konunun seçimi noktasındaki mantıksal arka plana yer verilmiştir.

İkinci bölüm metodolojinin ve verilerin analiz edilmesi için gerekli olan araçların nasıl seçildiği ve neden seçildiğinin anlatıldığı bölümdür. Buna göre bu tezin metot olarak tercih ettiği metot karşılaştırmalı vaka analizi olarak ifade edilebilir. Bu metot ile seçilen iki farklı vakanın tarihsel ve ekonomik karşılaştırılması, birincil ve ikincil kaynaklardan yararlanarak bazı matematik temelli araçların kullanılmasıyla mümkün olmuştur. Buna göre detaylı bir çalışma öncesinde neler yapıldığının özetinin verildiği bu bölüme ek olarak kullanılan araçların niteliği ve seçim kriterleri de eklenmiştir. Temelde bu tezde elde edilen verilerin gösterimi iki şekilde yapılmıştır. Birincisi, verilerin kantitatif özellikli oluşundan dolayı analize doğrudan dahil edilmesi tercih edilmiştir. İkinci olarak ise, verilerin bazıları ilişkisel özelliklerinden dolayı (örneğin: kullanıcı ve ürün tercihleri arasındaki ilişki) network (ağ) veri programları kullanılmıştır. Bunun sonucunda elde edilen bilgiler karşılaştırma analizine dahil edilmiş ve ilgili bölümlerde sunulmuştur. Metot bölümü içerisinde seçilen network yazılımlarının özellikleri, algoritma temeli, kullanışlı olup olmaması gibi bilgilere yer verilerek, paket yazılımlar arasından nasıl seçim yapıldığı vurgulanmıştır. Bunun soncunda, bu tezde kullanılan araçlara uygun en iyi yazılım internet (web) temelli *Graphcommons* yazılımıdır. Bir kısmı açık kaynak olan yazılımın seçilmesindeki en önemli iki husus söz konusudur. Birincisi, programın dayandığı *Forceatlas 2* algoritmasıdır. Bu algoritmaya göre

grafiklerin dağıtımı ve ilişkilerin ortaya çıkarılmasında daha hızlı bir matematiksel algoritma kullanılmaktadır. İkincisi ise, yazılımının dayandığı altyapının kullanım kolaylığıdır. Diğer yazılımlar (*Gelphi*, *Pajek*) detaylı bilgiler sunsa da kullanım açısından kolay ve kullanıcı-dostu değillerdir. Bu sebepten ötürü karmaşık ağların gösteriminde daha kolay bir kullanıcı ara yüzü olan programı kullanmak için tercih edilmiştir. Metot bölümünde bunlara ek olarak, neden grafiksel veri önemlidir? ve neden kullanılmaktadır? Sorularına cevap bulmak amacıyla, tarihsel anlamda grafiksel verilerin ortaya çıkışı ve kullanılış amaçları, biçimleri özetlenmiştir. Bu doğrultuda, tezin konusunu oluşturan vakaların grafiksel veriye uygun yerleri tartışılıp, ortaya çıkan argümanlarla desteklenmiştir.

Son olarak, metodoloji bölümünde ayrıntılı olarak veri toplama şekillerine ve bu verilerin nasıl işlenip kullanılacak hale getirildiğine ilişkin bilgilere yer verilmiştir. Bu hususta, iki ayrı ülke başlığı altında sözü geçen verilerin alan çalışması ile nasıl elde edildikleri özetlenip, tartışılmıştır.

Üçüncü bölüm makro analizi içeren ve tezin konusuna teorik ve tarihsel arka planı sağlayan süreci irdeleyen bölümdür. Bu bölümde genel hatlarıyla iki ülkenin ekonomik kalkınmalarında söz konusu olan önemli faktörlerin tarihsel kronolojisine yer verilmiştir. Bu kronolojide seçilim yapılırken söz konusu tarihsel arka plan 1500'lerden 1900'lere kadar uzanmaktadır. Unutulmamalıdır ki, bu arka planın seçimi yapılırken Amerika ve Almanya'nın dayandığı ekonomik kalkınma süreçlerinin analizi yapılıp, kurumların bu firmaların ve sektörlerin oluşmasındaki etkileri tartışılmıştır. Bu noktada, bu tarihsel arka planın bilim ve araştırma kültürü açısından ne kadar önemli olduğu, bilim mirasının nasıl sektöre giden yolda pratik amaçlarla kullanılacak ürünlere dönüştüğü incelenmiştir. Özellikle, Alman eğitim sisteminin nasıl geçmişten IG Farben kurulana kadar ki süreçte evrildiğinin analizi yapılmaktadır. Genel anlamda, Almanya için geçmiş ticari ilişkiler, ekonomik kısıtlar, doğal kaynak kısıtları ve bilim altyapısının Alman kimya sektörü üzerinde önemli etkilerinin olduğu saptanmıştır. Buna ek olarak küresel anlamda ticaret ağları ve Almanya'nın hukuksal altyapısı piyasa süreçlerinde önemli etkilere sahip faktörlerdendir. Bu faktörlerin yanında, Almanya iki büyük dünya savaşı sırasında Kimya alanında atılım sayılabilecek yeniliklere ve gelişmelere ev sahipliği yapmıştır. Bunun sebepleri, bu bölümde irdelenmiş ve otoritenin bilim ve piyasa üzerinde nasıl bir etkiye sahip olduğu tartışılmıştır. Diğer taraftan, Amerika için ise, bu tarihsel analiz sonucunda bazı faktörlerin ön plana çıktığı görülmüştür. Bu faktörler sırasıyla: doğal kaynakların bolluğu, dışarıdan göç ve insan sermayesi çeşitliliği, piyasayı ve bireyselliği destekleyen kurumların varlığı ve ağır çelik, demir

sanayinin gelişmesi sonucunda ekonomik dışsallığı olan demiryolu, taşımacılık gibi sektörlerin kıta içindeki ekonomik ilişkileri birbirine bağlamasıdır. Faktörlerin detaylı analizi sonucunda kimya bilimi ve sektörünün gelişmesinde rol oynayan arka plan hakkında bilgilere yer verilmiş ve tartışılmıştır.

Son söz olarak üçüncü bolümde bu faktörlerin detaylı karşılaştırılması özetlenip, bölüme eklenmiştir. Ülke bazında anlamdaki tarihsel ekonomik farklılıkların evrimi incelenmiştir. Bölümün sonunda ise, Kimya'nın ekonomisi başlığı adı altında Kimya biliminin nasıl piyasalaştığı tarihsel ve teorik anlamda tartışılmıştır. Bu tartışma altında, bu tezin ana konusunun oluşturan sorunun teorik temellerinin ne olduğu araştırılmıştır. Elbette ki, bu bölümün sınırlarını aşan literatürün varlığı söz konusu olsa da sınırlandırılarak bu bölümde kimyanın ekonomik temellerine yer verilmiştir.

Dördüncü bölüm, üçüncü bölüme nazaran mikro analizlerin yapıldığı bölümdür. Bu bölümde, firmaların birbirlerinden nasıl farklılaştığı sorusunun cevabı aranmaktadır. Bu mikro analiz bölümünde başlıca şu faktörlerin analizi yapılmıştır: firmanın ekonomik ve teknik profilleri, kuruluş bilgileri, büyüklükleri, organizasyon yapıları, araştırma ve geliştirme kapasiteleri, otoriteyle ve piyasa ile olan ilişkileri. Bu anlamda ortaya çıkan verilerin bazıların ilişkisel özelliklerinden dolayı network araçları ile analiz edilmiştir. Bu bölümde ayrıntılı bir biçimde, firmaların birleşme (merger) networkleri, stratejilerini anlamak adına ürettikleri ürün ve kullanıcı arasındaki ilişkileri gösteren ağlara yer verilmiştir. Ayrıca kuruluş hikayelerinin nasıl gelecekteki araştırma ve yenilik stratejilerine yön verdiğini anlamak için firmaların tarihlerinde yer alan olayların o dönemdeki diğer bilimsel ve ekonomik olaylarla olan ilişkilerinin sözel analizi de bu bölüme dahil edilmiştir. Bunun sonucunda bölüm sonunda iki firmayı karşılaştıran bir tabloya yer verilerek bütün faktörler içinde iki faktörün daha önemli olduğuna karar verilmiştir. Bunlar araştırma anlayışı ve organizasyon yapılarıdır. Bu iki faktörün neden öne çıktığının en önemli sebeplerinden bir tanesi, iki firma arasında farklılaşma ve başarı hikayesinin yolunu açan başat belirleyici yahut ana değişken olmalarıdır. Bu bölümünde dışsal ve içsel faktörlerin nasıl stratejileri ve politikaları etkilediğinin analizi yapılmış buna göre bulgular tartışılmıştır. Bu hususta Alman IG Farben, 1939'a kadar içsel ekonomik faktörlerin ve dışsal ekonomik faktörlerin yönlendirmesiyle piyasada kendine yer edinmiştir. 1939'dan sonra Hitler yönetiminin baskıcı ve ülke açısından indirgemeci politikaları IG Farben'in araştırma ve bilimsel aktivitelerini etkilemiştir. Bu neden bilimsel anlamda programlar tepeden merkezi otorite tarafından yönetilmiş, bu anlamda yönetim tekelleştirilmiştir (monopolization). Bu sebeple, IG Farben

incelenirken Hitler öncesi ve sonrası dönem özelikle vurgulanmıştır. Diğer taraftan Amerikan Du Pont ise daha esnek yapıda piyasa gereğince stratejilerini geliştirmiş ve uygulanmıştır. Bu sebeple bilimsel ve araştırma faaliyetlerinde daha evrimsel sürecin etkili olduğunu söylemek yanlış olmayacaktır. Unutmadan sonuca varmadan önce, içsel faktörlerin (ki bunlar, yenilik faaliyetlerinin değişik yönetimsel stratejiler sonucunda farklılaşması, araştırma geleneklerinin üniversite-sanayi iş birliği çerçevesinde farklılaşması) ve dışsal faktörlerin (ki bunlar, artan rekabet ortamı ve yerel ve küresel talep) firmaların yenilik performanslarını doğrudan etkilediği bu nedenle irdelenmesi gerektiği bu bölümde tartışılmıştır.

Beşinci bölüm, bir önceki bölümde yapılan detaylı analiz sonucunda ortaya çıkan iki önemli faktörlerden bir tanesi olan organizasyonel yapıların iki firma düzeyinde karşılaştırılıp, yenilik faaliyetlerinin ve performansının bu faktörlerden firma düzeyinde etkilenip etkilenmediği sorusuna cevap aranmaktadır. Bu noktada yeni ve spesifik veriler elde edilip analiz için kullanılmıştır. Literatürde organizasyon yönetiminin firmaların yenilik performanslarını olumlu anlamda etkilediğini ortaya koyan çalışmalar söz konusudur (Tidd and Bessant 2016). Bu çalışmalar yenilikçilik performansının içsel (yani esnek sistemler, promosyon mekanizmaları, araştırma için hedefler belirleme) ve dışsal faktörler (piyasa talebi, ürün çeşitliliği ve rakipler arasındaki anlaşmalar) tarafından etkilendiğini de ileri sürmektedir. Buna paralel olarak beşinci bölümde vakaya konu olan şirketlerin yenilikçilik performanslarının içsel ve dışsal faktörlerden nasıl etkilendiğini spesifik olarak organizasyonel ve yönetimsel kararların bu performans üzerinde ne kadar etkili olduğu tartışılmıştır. İki vakadan ortaya çıkan en büyük bulgulardan bir tanesi yönetimsel anlamda merkeziyetçiliğin ne denli araştırma performansı ve dolayısıyla yenilikçilik performansını etkilediğini ortaya koymaktadır. Buna göre, her iki vakadaki firma boyutu büyük ve coğrafi olarak yayılmıştır. Bunun anlamı yönetimsel anlamda rutin ekonomik işleri ve büyük şirket kararlarını etkileyecek bir yapının her iki şirkette de kurulması gerektiğidir. İki şirkette de bu durum, Chandler'a göre bu kimi zaman dezavantaj kimi zaman da avantaj olarak gözlenmiştir. Ölçeğin büyümesi zorunluluğu bir anlamda yönetimin merkezi kararları gözeterek otonom yapıları desteklemesi zorunluluğunu ortaya çıkarmıştır (Alfred D. Chandler 1990). Bu sebeple, IG Farben kendi sistemi içerisinde daha merkeziyetçi bir yapıyla bunu devam ettirme politikasını 1939 yılına kadar sürdürmüştür. Daha yalın bir ifadeyle, IG Farben'in yönetimsel yapısı Du Pont'tan merkeziyetçilik bakımından farklılaşmaktadır. Bu farklılığın temel sebepleri arasında IG Farben'in hali hazırda kuruluş şekli gereği altı farklı firmadan oluşmasıdır. Bu firmaların geçmişten taşıdıkları yapıları, rutinleri, yönetim şekilleri ve politika alışkanlıkları vardır. Ayrıca,

geçmiş firmaların bazıları bu konuda yenilikçilik anlamında önemli performanslara ve kayıtlara sahiptirler. Bayer'in ve BASF'ın birleşmeden önceki araştırma faaliyetleri kimya alanında dünyada öncü ve yenilikçi örneklerdir. Tüm bunların hepsinin IG Farben üzerinde daha merkeziyetçi bir yapı kurma zorunluluğunu ortaya çıkarmıştır. Beklenenin aksine otonom araştırma ve geliştirme faaliyetleri IG Farben şirketinde savaş yıllarına kadar söz konusu olmamıştır. Bunu Carl Bosch ve Carl Duisberg'in yazışmalarından takip edebilmekteyiz (Heine 1990; Lindner 2008). Buna göre, IG Farben Du Pont'tan farklı olarak tüm araştırma ve geliştirme faaliyetlerinde merkezi kararlar alıp uyguluyordu. Gücün Frankfurt'taki konsülde alınan kararlarla bu denli tekelleştirilmesi, araştırma ve geliştirme faaliyetlerini ve şirketin ekonomik performansını etkilemiştir. Diğer taraftan ise, Du Pont bu tarz kararlarda daha otonom ve daha özgür bir yaklaşımı da benimsemektedir. Buna göre, tesislerindeki araştırma alanlarında ekipler kendi içinde özgür bir biçimde araştırma yapabildiği gibi merkezden piyasanın koşullarına göre de gelen sinyallere (alertness) tepki verecek şekilde de araştırmalarını yürütmüştürler.

Burada önemli bir noktayı vurgulamak gerekmektedir. Merkeziyetçilik ve firma içi özgürlük kavramlarının her sektörde farklı anlaşılabileceği aşikardır. Örneğin koordinasyonun ve zaman kısıdının mühim olduğu sektörlerde (taşımacılık) bilginin şirket içinde akışı ve nerede toplanacağının önemi daha yüksektir. Bu sebeple, bu gibi merkezi yapılara sahip sektörlerde otonom birimlerin söz konusu olması mümkün değildir. Fakat kimya sektöründe ve araştırma-geliştirme hatta çoğunlukla temel bilimin kullanıldığı sektörlerde bu kavramlar biraz anlamlarını kaybetmektedir. Örneğin, IG Farben için merkeziyetçi bir yapı söz konusudur denilebilir fakat laboratuvarlarda çalışmalar merkezden gelen bilgilere göre sürdürülürken başka tesadüfi buluşlar sonucunda araştırma faaliyetinin farklı alanlara kayması söz konusu olabilmektedir. Bu nedenle de farklı da olsa iki şirkette "esneklik" anlamında araştırma ve bilimsel faaliyetlerini sürdürmüşlerdir.

Beşinci bölümde irdelenen ve öne çıkan yönetimsel farklılıklardan bir tanesi de yönetimin üst düzeyinde olan insanların aldıkları eğitim ve şirketlerin bu yönetim kadroları ile şirketin geneli için uyguladıkları işe alma politikalarıdır. Bu anlamda yönetim kademesinde olanların eğitim ağlarını gösteren şekiller tezin içerisinde Şekil 16 ve Şekil 19 (Figure 16, Figure 19) olarak gösterilmiştir. Bu şekillerden yola çıkarak şu yargılara varmak mümkündür:

1. IG Farben yerel ve güçlü eğitim kurumlarından mezun yöneticilere sahiptir. Du Pont ise Alman kimya eğitimi ile bağlantılı ve Amerikan

üniversitelerinden mezun kimseler tarafından yönetilmektedir.

2. IG Farben'in yönetim kademelerinde Nobel ödüllü ve doktora derecesine sahip kimseler vardır. Du Pont ise doktora derecesine sahip kimseler ve Nobel ödüllü danışmanlara sahiptir.
3. IG Farben'in çalışanları arasında Berlin Teknik Üniversitesi ve Leipzig Üniversitesi kümeleri varken; Du Pont'ta MIT, Harvard ve Johns Hopkins Üniversiteleri kümeleri söz konusudur.

Bunların sonucunda işe alım stratejileri, bilgiyi şirket içinde kullanma stratejileri ve yönetimsel anlamda kurguladıkları sistemler bakımında şirketler farklılaşmakta bu farklılıklar ise yenilikçilik performanslarını etkilemektedir.

Altıncı ve sonuçtan önceki son temel bölüm iki şirketin araştırma ve yenilikçilik faaliyetlerini yakından inceleyen bir bölümdür. Bu bölümde özetle, her iki şirketin spesifik olarak araştırma çıktılarına (patentlerine), araştırma harcamalarına-bütçelerine, öğrenme süreçlerinin nasıl farklılaştığına ve araştırma politikalarının nasıl belirlendiğine dair bilgiler sunmaktadır. Bu bilgiler ışığında ilgili bölümde üç temel bulgunun varlığından söz edilebilir. Bunlar: araştırma motivasyonu, araştırma konuları ve öğrenme süreçleri olarak sıralanabilir. Araştırma motivasyonu iki şirkette de ilgili dönemde çok farklı olmuştur. Buna göre, IG Farben 1925'te faaliyetine başladığında daha temel bilim bazlı bir sistemi tesis ederek yola devam etmekteydi. 1939 ise daha pratik ve savaşın getirdiği faşist yapı sonucunda daha pratik araştırma konularıyla ilgilendiler. IG Farben genellikle ürün anlamında ürettikleri malları sanayi içinde ara-mal diye adlandırılan bir çeşitlilikte sunduklarından dolayı araştırma faaliyetlerini de bu malların geliştirilmesi üzerine kurgulamıştır. Bu nedenle daha bilimsel ve bilim için (sake of science) "karlı" bir şirket amacı gütmüşlerdir. Diğer taraftan Amerika'daki Du Pont şirketinin stratejisi epey ilginç ve çeşitlidir. Bir dönem şirket içerisinde yaşanan temel bilim ve pratik bilim tartışmaları söz konusu olsa da şirketin genel olarak bilimsel aktiviteyi yenilik için desteklediğini söylemek söz konusudur. Ayrıca, Amerikan sistemindeki pratik bilim, gündelik bilim bu dönemlerde önem kazanmış, Du Pont'ta bu noktada üniversitede yetişen kişilerden faydalanmıştır. Pratik bilimin bir faydası da piyasanın isteklerine hızlı cevaplar verebiliyor olmasıdır. Ürün bazında bakıldığında ise genel olarak IG Farben'in sektörde öncü yeniliklere imza attığı gözlemlenmektedir. Özellikle boya alanındaki buluşlar sayesinde dünya boya pazarında epey etkili bir rekabet gücünü elinde bulunduran şirket, organik kimya alanında da araştırma programları sayesinde ürün çeşitliliği konusunda öncüdür. Bunun yanında Du Pont, ürün çeşitliliği ve bunu destekleyecek araştırma programı konusunda IG Farben'i takip

etmiş fakat piyasanın isteklerini yahut firma stratejisi olarak piyasadaki boşlukları da iyi değerlendirmiştir. Naylon için yapılan araştırma ve geliştirme çabaları bunu göstermektedir.

Son olarak, öğrenme süreçleri bakımından iki şirkette kendine has bir biçimde şirket içi ve şirket dışı veri, malumat ve bilgi süreçlerini sürdürmüştür. Böylelikle, IG Farben şirket içinde gruplar arası bilgi alışverişini sağlamak amacıyla konferanslar, grup liderlerinin yönetimle etkileşime geçeceği komitelerin oluşturulması ve yayın yapma zorunluluğu gibi faktörler sayesinde şirket içi öğrenme süreçlerini yönetmişlerdir. Diğer taraftan Du Pont ise, yayın için promosyon mekanizmaları, gruplar arasında bilimsel rekabet ve üniversite ile iş birliği sayesinde güncel bilimsel ve pratik bilgilerden mahrum kalmayarak öğrenme süreçlerini yönetmiştir. Böylelikle iki şirket de birbirinden farklılaşsa da başarılı yenilikçi performanslarını 1925 ve 1945 arasında sergilemişlerdir. Savaşın araştırmaya kuşkusuz pozitif bir etkisi olmuş ve her iki şirket de bundan sonuna kadar yararlanmışlardır.

Bu tezin son bölümü sonuç bölümüdür. Bu bölümde genel olarak diğer bölümlerde tartışılan konular ve bulgulara yer verilmiş ve bu bulguların literatürdeki konumları tartışılmıştır. Ayrıca tezin ana sorusuna cevaplar aranmıştır. Buna göre bu tezin ana sorusuna cevap olarak iki önemli faktörün farklılaşmaya sebep olduğunun altı çizilmiştir. Bunlar organizasyonel yapının ve araştırma anlayışlarının iki şirkette de farklı olmasıdır. Buna göre cevap şu şekilde verilebilir:

> *Eğer temel ya da pratik bilginin gelişmesine sebep olacak bir sistem geçmiş bilimsel bir miras tarafından destekleniyorsa; ayrıca bu bilgilerin ise piyasaya göre şekillendirebilecek bir organizasyon yapısı tarafından teşvik ediliyorsa farklı coğrafyalarda başarılı yenilikçi firmalar ortaya çıkması söz konusudur.*

Bu bilgilere ek olarak, sonuç bölümünde tezin bilim ve teknoloji politikalarına muhtemel etkileri tartışılmıştır. Bu tartışma sonucunda beş ana başlık altında başarılı bir kimya sektörünün oluşabilmesi için gerekli hususlara yer verilmiş ve bunların tez bulgularıyla ilintisi irdelenmiştir. Buna göre:

4. *Eğitim kurumlarında temel bilimin desteklenmesi gerekliliği*: Her iki şirket örneğinin dayandığı başarılı eğitim geçmişi hikayelerinde bunu gözlemlemek mümkündür. Almanya'nın kimya, fizik ve matematik gibi alanlarda yaptığı yatırımlar sonucunda IG Farben gibi bilime dayanan bir sektörde başarılı bir şirketin ortaya çıkması tesadüf değildir.
5. *Devletin rolü*: İki örnekte de devletin etkilerinden bahsedilebilir. Savaş

dönemleri de dahil olmak üzere bazı durumlarda devlet piyasayı şekillendiren hatta yaratan bir role bürünmüştür. Bu nedenle, sektörün içinde faaliyet gösterecek firmalar için devletin rolü ve müdahaleleri önemlidir.

6. *Kapasite oluşturma*: bu her iki anlamda da firma ve devlet tarafından desteklenebilecek bir sistem mevzuudur. Bu nedenle politika yapıcıların mikro ve makro ölçekteki açıkları tespit edip bu noktada eylemlere geçmesi gerekmektedir.
7. *Güçlü kurumlar oluşturmak*: hem Almanya hem de Amerika kendi güçlü ve evrimsel süreçte gelişmiş, değişmiş ve dönüşmüş kurumlara sahiptirler. Örneğin, hukuk sistemleri, eğitim anlayışları ve rekabet yapıları bunlara örnek oluşturabilirler. Bu kısa dönemde politikalarda ufak yahut büyük değişiklikler sayesinde yapılabilecek ama etkilerinin uzun dönemde görülebileceği bir politikadır. Bu hususta, güçlü kurumları olmayan ülkelerin bu denli yoğun bilgi, birikim ve yenilikçilik gereken sektörlerde geç-kalan ülke (late-comer) olarak başarılı olamayacağını öngörmek zor değildir.
8. *Kümeleri ve yerel yapıları desteklemek*: Bu noktada Almanya da Amerika da benzer bir biçimde kimya endüstrisi öncesi var olan sanayi kümelerini politika anlamında desteklemişlerdir. Almanya'da Offenbach bölgesindeki organik kimya kümesinin devlet tarafından müşevvik edilmesi orada bugünün kimya devlerinin çıkmasının altyapısını hazırlamıştır. Benzer bir biçimde Daleware'da kurulan şirketin tedarikçileri ve diğer yüklenicileri için bir politika genel anlamda Amerika'da kimya sektörünün de önünü açmıştır.

Bunlar genel olarak sıralanan olası etkilerden bazılarıdır. Bu tezin konusu kapsamında genişletilebilir yahut sınırlandırılabilir.

Son olarak bu tezin araştırma sürecinde karşılaşılan birtakım zorluklar verilecektir. Bu zorlukların ifade edilmesi gelecekteki çalışmalar için de pozitif katkılar sunabilir. Temel olarak, veri sıkıntısından bahsedilebilir. Gelecek çalışmalar için yenilikçilik performanslarına IG Farben olarak değil, spesifik olarak birleşmeden önceki hallerine de bakılabilir. Örneğin BASF'ın arşivleri kullanıma açıktır ve BASF'ın faaliyetlerine bakmak Almanya kimya sektörü hakkında bir şeyler söyleyebilir. Buna ek olarak tarihsel anlamda seçilen zaman dilimi savaş öncesi ve sonrası olarak da incelenebilir. Böylece Alman arşivlerinden daha fazla faydalanmak söz konusudur. Gelecekte Almanya bu arşivleri dijital alanda kataloglayacaklar. Bu sebeple, ilerdeki

çalışmalarda veri için tüketilecek süre epey kısalabilir. Ayrıca, araştırma sorusu daha daraltılabilir böylece tek bir faktör üzerinden giderek detaylı analiz imkânı doğabilirdi. Bu husus da bu tezin sınırlarından bir tanesidir.

Son söz olarak, bu tezin ana konusu olan iki şirketin başarıları bir tesadüf değildir. Bunu yukarıda ayrıntılarıyla aktarılan ekonomik ve kültürel bir tarihin desteklediği bir gerçektir.

C. CURRICULUM VITAE

MUHSIN DOĞAN

METU • SCIENCE AND TECHNOLOGY POLICY STUDIES • ANKARA

+90 312 210 38 10 • +90 535 624 17 56

DMUHSIN@METU.EDU.TR • MUHSIN.DOGAN@ME.COM

CURRENT POSITION

Middle East Technical University, *Science and Technology Policy Studies*
Researcher in European Union Project, 2017 -

PREVIOUS POSITIONS

Middle East Technical University, *Science and Technology Policy Studies*
Research Assistant, August 2013 - September 2017

Middle East Technical University, *Department of International Relations*
Research Assistant, August 2011 - 2013.

Liberte Publishing House, **Art Director**, 2008 - 2011
Designed about 150 book covers published in national and international platforms and designed many posters, data and research ideas for international conferences.

Liberte Publishing House, **Graphic Designer**, 2006 - 2008

Serbest Çizgi Magazine, **Assistant Editor**, 2004 - 2006

Liberal Youth Association, **Assistant**, 2003 (March - August)

EDUCATION

Middle East Technical University, Science and Technology Policy Studies
PhD 2011 - 2018

(PhD Candidate 2013)
Emergence of Research and Innovation Activities in the Chemical Industry at the Beginning of the Twentieth Century: The Case of IG Farben And Du Pont

Middle East Technical University, Science and Technology Policy Studies
MSc 2008 - 2011
Project: *Making Sword in Medieval Japan: Role of Learning and Knowledge in the*

Process
Advisor: Tunç Medeni

Kırıkkale University, Department of Economics
B.S. 2003-2007

PROJECT WORKS

"FEUTURE - The Future of EU-Turkey Relations: Mapping Dynamics and Testing Scenarios"

as *a long term Assistant* 2016 - 2019
Horizon 2020: Research and Innovation Programme under Grant Agreement No 69297

"EU-Plaza Project - H2020"
as *Project Secretariat* 2016

"IMProving inclusion and lAbour marKet Transition for young adults in Europe through Lifelong Learning . IMPAKT-L2 - H2020"
as *Project Secretariat* 2016.

"1925-1945 Arasında Kimya Sektöründe İnovasyon ve Öğrenme Süreçleri Nasıl Farklılaştı? Alman IG Farben ve Amerikan DuPont Örneği"
funded by Scientific Research Project (BAP) with Assit. Prof. Dr. Semih AKÇOMAK
as a *researcher*, 2014 - 2016.

"SEARCH: Sharing Knowledge Assets: Inter-regionally Cohesive Neighborhoods (SEARCH) – EC FP7 Project"
as *Project Assistant* 2013 - 2014.

"GLOBELICS 2013 (International Conference)"
as *Assistant to Coordinator*, 2013.

"Evolution of Business Organizations in the European Periphery: Ottoman Empire and Turkish Republic, 1850-1950"
a four-year project sponsored by European Commission, Marie Curie Program
as *field researcher* in 2013.

"A Digital Online Platform on the Translations of Economics Texts into and from European Languages From the 18th to the 20th Century"
funded by European Commission
as *long term researcher* since 2012.

"Translation of Austrian Economics Books into Turkish"
funded by Private Sector Consortium
as *Art Director* between 2006 - 2011.

PUBLICATIONS

- Book -

AB'ye Üyelik Yolunda Türk Tarımı: Sorunlar, Zorluklar ve Fırsatlar, İstanbul: TÜGİAD, 2006.
(TÜGİAD Economics Prize 2006:
Scientific Research 1st Prize. with Prof. Dr. Mustafa Acar)

- Book Chapters -

Erden, Y., Durukan, C., Ertan, A. and **Doğan, M.** (Eds.), (2014), ***Ulusal İnovasyon Girişimi 2006- 2013 Dönemi Değerlendirme Raporu*** TÜSİAD-Sabancı Üniversitesi Rekabet Kurumu, İstanbul

- Book Contributions -

Avrupa Birliği ve Türkiye: Bir Ekonomik ve Siyasi Analiz, Ankara: Orion Yayınevi, 2006. (inside country profiles chapter)

Türk Tarımının Geleceği, Ankara: Orion Yayınevi, 2006.
(data collecting and analysing)

AWARDS

AB'ye Üyelik Yolunda Türk Tarımı: Sorunlar, Zorluklar ve Fırsatlar, İstanbul: TÜGİAD, 2006.
(TÜGİAD Economics Prize 2006:
Scientific Research 1st Prize. with Prof. Dr. Mustafa Acar)

CONFERENCE PAPERS, SEMINARS AND LECTURES

Why Some Countries are Technologically Developed, Others not? Middle East Technical University - Department of Architecture (Guest Lecturer) , October 16, 2015, Ankara

Hayek'in Ekonomi Politikalarına Bakışı: Kendiliğinden Doğan Düzen, Cosmos ve Taxis, (Speaker), ALT, 2015, Ankara

Bilgi, Keşif ve Girişimcilik (Speaker), ALT, July 21, 2011, Ankara

Avusturya İktisat Okulu: Bilgi ve Keşif Süreci (Speaker), ALT, May 5, 2011, Ankara

İnsan, İktisat ve Özgürlük, 6. Türkiye Üniversite Öğrencileri Bağımsız İktisat Kongresi,
Abant İzzet Baysal Üniversitesi - Bolu, March 6-8, 2008.

Ekonomik Özgürlükler ve Refah, 5. Türkiye Üniversite Öğrencileri Bağımsız İktisat Kongresi, ODTÜ-Ankara, March 4-6, 2007.

Adam Smith: Bir Liberal Filozof, LİGED Cuma Faaliyetleri, LİGED ofisi Ankara:

March 2006.

Türkiye'de İktisat Eğitimi Üzerine, 3. Türkiye Üniversite Öğrencileri Bağımsız İktisat Kongresi, Çukurova Üniversitesi- Adana, March 4-6, 2005.

ARTICLES AND OTHER WORKS

Japon Kılıçlarının Yapım Sürecinde Bilginin Rolü ve Piyasası Üzerine *Liberal Düşünce Dergisi*, Yaz-Güz S.59-60 C. 15 Y. 2010

Yeni Pazar Dinamikleri ve Rekabet, *Demokrasi Platformu Dergisi*, (with Prof. Dr. Mustafa Acar),
(forthcoming)

Ortaçağ Avrupası'nda Cadı Avları ve Kadın, *Liberal Düşünce Dergisi* (forthcoming)

Herşeyin Bedeli Var! *Serbest Çizgi Dergisi*, Sayı 32, Yıl 2006, s. 36-38

Amerika Silkelendi! *Serbest Çizgi Dergisi, Ekonomi Ek*'i, Sayı 2, Yıl 2006, s. 3-4.

Bir Fincan Kahvenin Kırk Yıl Hatırı Var mıdır? *Serbest Çizgi Dergisi, Ekonomi Ek'i*, Sayı 2, Yıl 2006, s. 3-4.

Devriminin Küba Ekonomisi Üzerine Etkileri, *Serbest Çizgi Dergisi*, Sayı 31, Yıl 2006.

Yeşil Çam Ormanında Küçük Çam Ağacı Olmak... *Serbest Çizgi Dergisi*, Sayı 31, Yıl 2006.

Adam Smith, *Serbest Çizgi Dergisi, Ekonomi Ek'i*, Sayı 1, Yıl 2006, s. 1-2.

Bir Tony Tan Hikayesi: Jollibee, *Serbest Çizgi Dergisi, Ekonomi Ek'i*, Sayı 1, Yıl 2006, s. 3-4.

ARTICLES IN POPULAR MEDIA

Tanrı İstemezse!, (Hürfikirler, 13.08.07), https://goo.gl/Cr7MBq

Milton Friedman..., (Hürfikirler, 20.11.06), https://goo.gl/UnnShw

AB ve Türkiye (ELMA, Electronic Liberal Magazine, 20.03.06) http://elma.liged.org.tr
(Accessed Date: 12.06.2006)

Everest İktisadı (ELMA, 05.08.05) http://elma.liged.org.tr
(Accessed Date: 12.06.2006)

Yapımcılar mı Suçlu Yoksa Ebeveynler mi? (ELMA, 11.11.05) http://elma.liged.org.tr
(Accessed Date: 12.06.2006)

Düz Vergi ve Laffer Etkisi, (ELMA, 11.03.06) http://elma.liged.org.tr
(Accessed Date: 12.06.2006)

ATTENDED WORKSHOPS, SEMINARS AND PROJECTS (SELECTED)

Joint Workshops on "Economic, Energy and Climate Change Drivers" Work Packages
September 26th-27th, 2016, METU, Ankara, TURKEY

EUROLICS Workshop on University-Industry Interaction
November 26th-27th, 2015, TEKNOKENT Conference Hall, METU, Ankara, TURKEY

The 11th GLOBELICS International Conference: Entrepreneurship, innovation policy and development in an era of increased globalisation
September 11th-13th, 2013,METU, Ankara, TURKEY

Karmaşık Ağların Yaratıcı Kullanımı (Burak Arıkan)
November 04, 2013, TTGV, Ankara

Austrian Economics Seminar Series;
Sosyal Bilimlere Hayekçi bir Bakış: Kompleksite ve Bilgi Problemi,
March 27 - May 22, 2013

Austrian Economics Colloquium, February 26-28, 2010, Ankara

Regional Workshop: Promoting a Free Society, ALT: Ankara, Mayıs, 23-26 2007.

Birleşmiş Milletler Kalkınma Ofisi (UNDP), "Ulusal İnsani Gelişme Raporunun Hazırlanması Konusunda Gençlik STK'larının Sorumlulukları" Ankara: 2006.

II. Liberal Gençlik Buluşması, Ankara: November 23-26, 2006

Hürriyet Mektebi, ALT, Ankara: September 29 – October 23-26 2006

Liberal Düşünce Kongresi, ALT, Nevşehir: November 3-5, 2006.

Özgürlük ve Demokrasi Sempozyumu, ALT, Ankara: May 14-15, 2005

I. Liberal Gençlik Buluşması, Ankara: November 1-2, 2005

Dr. Rolf Steltemeier: Almanya'da Liberal Gençlik Örgütlenmeleri, Ankara: December 2, 2004.

Cuma Faaliyetleri (Education Seminar Series for 8 Month),
1. Dönem, LİGED, Ankara: 2004-2005.

Cuma Faaliyetleri (Education Seminar Series for 8 Month),
2. Dönem, LİGED, Ankara: 2005-2006.

Cuma Faaliyetleri (Education Seminar Series for 8 Month),
3. Dönem, LİGED, Ankara: 2006-2007.

LANGUAGES

Turkish (Native)

English (Advanced)

German (Beginner)

RESEARCH INTERESTS

History of Economics
History of Science and Technology
History of Basic Sciences
Science Networks
Agriculture and European Union Integration
Austrian Economics and Methodology
Chemistry sector during the World War II
Data Visualization
Creative Network Mapping and Analysis

PERSONAL INTERESTS

Graphic Design and Data Visulation (Active Years: 2007 -) Designed about 150 book covers published in national and international platforms and designed many posters, data and research idea for international conferences.

Mountaineering (Active Years: 2005 -)

Photography (Active Years: 2003 -), Social projects to show the importance of nature and space photography since 2013, Personel Projects.

Scouting (Active Years: 2000 - 2008), Social responsibility projects and teaching activities on nature conservation and sustainable wild life.

PERSONAL EXIBITIONS

Stars like magic spirit (July 2-14, 2017)
Middle East Technical University, KKM Photo Exibition Hall

Cosmos: Lights from faraway (June 4-19, 2018, **upcoming**)
Middle East Technical University, KKM Photo Exibition Hall

D. TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü	
Sosyal Bilimler Enstitüsü	x
Uygulamalı Matematik Enstitüsü	
Enformatik Enstitüsü	
Deniz Bilimleri Enstitüsü	

YAZARIN

Soyadı : Doğan
Adı : Muhsin
Bölümü : Bilim ve Teknoloji Politikası Araştırmaları Ana Bilim Dalı

TEZİN ADI (İngilizce) : EMERGENCE OF RESEARCH AND INNOVATION ACTIVITIES IN THE CHEMICAL INDUSTRY AT THE BEGINNING OF THE TWENTIETH CENTURY: THE CASE OF IG FARBEN AND DU PONT

TEZİN TÜRÜ : Yüksek Lisans [ ] Doktora [x]

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