UNIVERSITAT ROVIRA I VIRGILI

EUROPEAN CHEMICAL INDUSTRY AND ITS INNOVATION POLICY WITH FOCUS ON LARGE CHEMICAL COMPANIES.

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European chemical industry and its innovation policy with focus on large chemical companies

DOCTORAL THESIS

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Preface

The chemical industry is one of the European Union's most internationally competitive and successful industries, embracing a wide field of processing and manufacturing activities. This research studies the current state of the European chemical industry and compares with chemical industry from other regions of the world. The study also covers the innovation trend, innovation policy of large chemical companies headquartered in Europe and various financial and non-financial factors that is affecting such policy.

With a workforce of 1.2 million and sales of €642 billion, it is one of the biggest industrial sectors. Output from the EU chemical industry covers a wide range of chemical products, supplying virtually to all sectors of the economy and providing a significant contribution to EU net exports. But the European chemicals industry is currently facing unprecedented challenges arising from strong competition from emerging countries, notably in Asia, the Middle East and Russia. R&D and innovation is the only way to bring the competitive edge of this industry in Europe. The European chemical industry's share of world chemical sales declined from 29.8 % in 2001 to 19.6 % in 2011 which translates into 34 % decline over a period of 10 years. As the global economy emerges from the financial crisis of 2007-2009, the chemical industry finds itself passing through a period of profound transformation. Profit margins have been shrinking; return on capital has been in steady decline while Asian chemical production in 2011 surpassed that of the rest of the world chemicals turnover.

Data for 2012 confirms that a significant recovery of the European chemicals industry occurred during the year. The European chemical industry, including the European Union and the Rest of Europe, is still in a strong position, posting sales of €642 billion in 2011 which is 23.4 per cent of world chemicals sales in value terms. Although Europe is losing its position in terms of global chemical sell, in terms of trade balance is doing well with export being 7 % higher than import. EU still leads the race with 19 out of top 50 global companies headquatered here, followed by Asia with 16. In terms of individual company's sale, BASF has almost double of chemical sales to that of its nearest competitor. Another trend, which is emerging is that the traditional oil companies such as Shell and Total are now investing heavily in chemical business and thus playing a significant role in the world chemical business.

In order to reach the objective of the current research, five hypotheses were tested. Based on the recommendation of previous researches, patent volume was taken as the metric for measuring innovation. In Europe, mechanical engineering has the highest number of granted patent while chemistry and electrical engineering were close second. In case of companies, BASF, Bayer and LyondellBasel are the top European patent applicants. It is seen in case of most European companies, 50 % of the first patent is applied in EU which can be due to the fact that the research is coming out of the laboratories in EU or the companies see higher value to protect their technology in the EU market. It is also interesting to see that in case of BASF, there is a steady fall of the EU´s share of the total first patent, which can be due to the effect of growth and subsequent shifting of focus on the emerging economies.

In case of EU, even though the Research & Development (R&D) spending in absolute term has remained almost the same over the years, it's percentage to total sale has fallen from 8.2 % in 1991 to 1.5 % in 2012. In case of china in 2012, there has been threefold increase of R&D investment in compared to that of 2006, while for other regions, the R&D spending has slightly increased. BASF has the largest R&D spending followed by Bayer as distant second. BASF is the largest chemical company and this high spending on R&D justifies its enormous R&D infrastructure. Bayer invests heavily in research specially in its pharmaceutical and crop science division. Syngenta showed highest percentage increase of R&D expenses in 2012 compared to it in 2007. Arkema and Linde both had a fall in R&D expenses in 2012 compared to 2007 and surprising Yara had very small R&D spending budget for both the years. Syngenta has the highest R&D intensity followed by Bayer and DSM. BASF has been investing in R&D in human capital by increasing the number of people in that department especially just after the financial crisis that hit in 2008, thus showing their clear strategy of R&D expansion.

Merger and Acquisition (M&A) is another factor that we evaluated during this study. Highest number of merger and acquisitions deals in chemical industry for last ten years were done in Asia followed by Europe and North America. For the last five years, EU chemical industry acquired a large number of non-chemical companies. It depicts a typical intent of these companies for diversification and acquiring knowledge which is not part of their core competencies. For most companies such as BASF, Air Liquide, Ineos, Evonik and Solvay, there is a strong inclination for acquisition of European companies while for some other companies such as Bayer, DSM and Arkema, there is a tendency to do acquisition more globally.

From the various data analyzed, it is seen that all the top European chemical companies actively participate in EU funded projects. The data for the last 20 years shows BASF is leader in participating in EU funded project followed by Bayer, Air Liquide and Evonik. Although the top chemical companies participate in lot of EU funded projects, there is a general tendency that they want to be a participant rather than be the coordinator. This may be due to the fact that this involves significant investment in resource to co-ordinate EU projects. There has been a significant redirection of skilled, sometimes highly skilled personnel in firms from R&D and innovation-related activities to compliance work as a result of the implementation of the REACH Regulation. Moreover, this regulation resulted in an increase in expenditure in R&D and related innovative activities. Rate of return from R&D investment was negatively impacted by REACH compliance costs. REACH regulation generated scope of innovative activities to include more work on new substances, particularly among large firms, who are also responsible for most innovation in the industry, but barriers to R&D and innovation in new substances still remain.

Europe has over three hundred chemical production sites, the majority of which are located in clusters and Germany hosts the largest 47 % of all European chemical clusters. There is a direct relation between the number of clusters in a particular country and number of granted EU patents in chemistry and chemical engineering. The big exception to the above stated relation is Switzerland. It has two chemical clusters but accounts for over 10 % of the granted EU patents which can be due to the fact that a lot of their research is done in specialized institutes and universities.

Chemical industry is a conservative industry and when starting the research, there was strong doubt that this industry will be slow to adopt digitalization. But it was observed during the study that the consumer pull, technology push and economic benefit that digitalization brings led the larger chemical companies, particularly in Europe to adapt digitalization in their main stream of business. The drivers of operational digitalization in larger chemical companies are: very complex supply chain, drive to innovate at very high pace, employee inclined to new technologies, new regulatory requirements such as

REACH and very fast information technology growth. The digitalization index study positioned chemical industry in Europe in seventh position among all growing industries in terms of adapting new digital tool in business. The study also positioned them at the fifth position in the growth rate which is higher than average. Another significant point that came out from the study is that the digital innovation in chemical industry has not happened smoothly across whole of Europe. The current study shows that digital marketing has taken innovation in marketing by storm. It is playing a key role in influencing purchasing decision both in case of business-to-consumer (B2C) and business-to-business (B2B) business model. The chemical companies which have been selling through traditional channels are moving to online tools. Several of the large companies we studied have an ecommerce website where they are selling their products. All the companies we studied have a very detailed website and every effort is being made to capture the traffic through search engine optimization (SEO). Although being late, the chemical industry is catching up in case of social media marketing. Every company we researched is present in more than one social media in order to promote their product apart from using blogs and article marketing which are two other innovative tools for marketing.

In the figures, graphs and tables, comma is used as the decimal separator while dot is used as thousand separators typical as in Spanish system.

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Chapter 1: Introduction

Contents

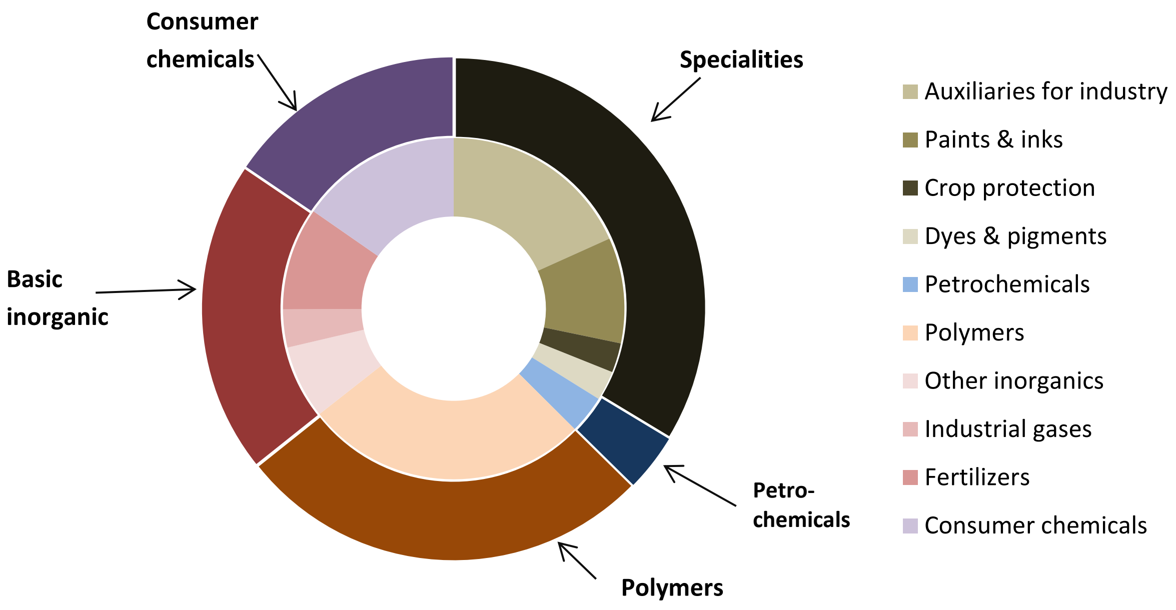
1.1 Introduction

According to Arora et al. (1998), the chemical industry is one of the largest and most R&D- intensive manufacturing sectors in all advanced economies, and its innovative patterns and productivity growth process can have profound impacts on economic growth as a whole. The chemical industry is present everywhere in our daily lives. Modern society and its life style are unthinkable without its products. More than any other manufacturing sector, this industry provides the technical basis for other economic activities, both in traditional sectors such as agriculture, construction, textiles, clothing footwear, and in technologically advanced industries ranging from automobiles, modern healthcare to electronics and oil & gas. The European chemical industry is facing major challenges as value chains increasingly move eastward, drawn by economic growth and market opportunities in Asia. Europe cannot base its growth on inexpensive resources and labour. Its major asset is knowledge, and innovation is therefore essential, for building a knowledge-based competitive economy and growth. The process through which resources spent in research and development (R&D) generates new ideas and the process of their diffusion are at the heart of the growth mechanism of modern market economies. In the recent study by Tullo (2013), out of the 50 top global chemical companies, 19 are headquartered in Europe (Table 1). They consist of 14, 5 % of Global chemical sale. The objectives of this research are to develop a comprehensive analysis of: 1. the innovation trend of the European chemical industry with special focuss on nineteen large chemical companies headquatered in Europe 2. the innovation policy that drive their new product development and growth. First part of the research consists of literature review and study of state of European chemical industry. In order to achieve the research objectives, five hypotheses have been laid down. The later part of the research tests these five hypotheses while the last part consists of further analysis of the findings and draws up conclusions. In this thesis report, in the figures, graphs and tables, comma is used as the decimal separator while dot is used as thousand separators.

1.2 Background of the current project

The European chemical industry is key for economic development and wealth, providing modern products and materials and enabling technical solutions in virtually all sectors of the economy. With a workforce of 1.2 million and sales of €642 billion, it is one of the biggest industrial sectors and an important source of direct and indirect employment in many regions of the European Union (Cefic, 2013). The European Union accounts for 19.6 % of the total sales of chemicals in the world (Cefic, 2013). The European chemical industry is based on the following six categories of products: Basic chemicals, Specialty chemicals, Petrochemicals, Polymers, Pharmaceuticals, Consumer chemicals.

Figure 1. The product mix of European chemical Industry

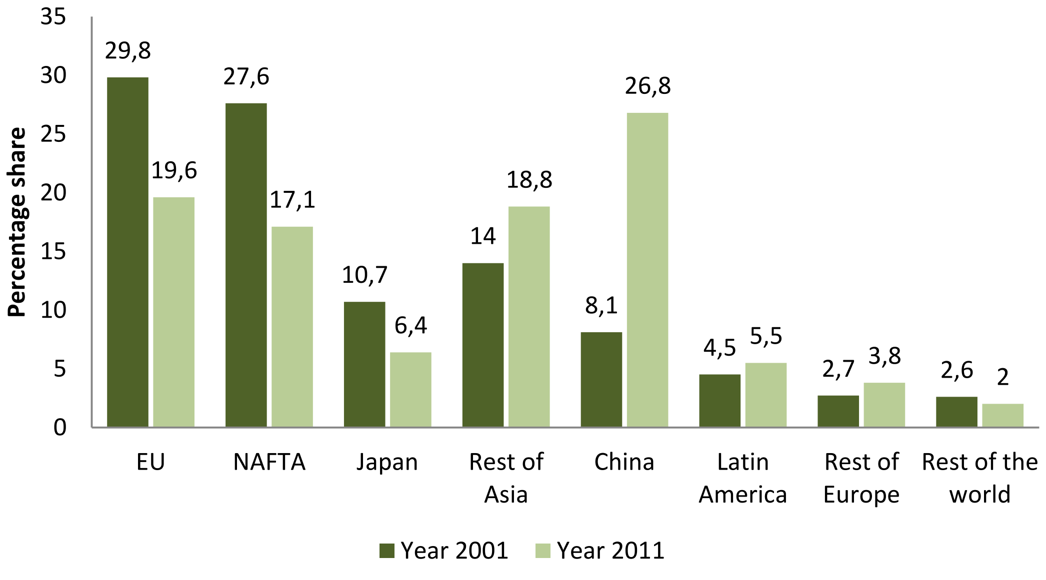


Data source: Cefic (2013)

In EU, there are around 29,000 chemical companies which employ a total staff of about 1.2 million. This is equivalent to 4% of the manufacturing industry's overall workforce. Employment in the industry has decreased by 2% annually over the past ten years. 4 % of all chemical companies have more than 250 employees and these are responsible for 72 % of all sales and 65% of total employment (EUROSTAT, 2013). They make a major contribution to the transfer of innovation generated upstream in the chemicals value chain to downstream manufacturing industry. As producers of basic and specialties, large chemical companies are often supplier to SMEs and also source for innovation.

Over the years, the European chemical industry has shown considerable resilience, strength and adaptability. In 2007, 12 out of the leading 30 chemical companies in the world were headquartered in Europe, representing 10 percent of world chemical sales for that year while in 2012, 11 of the top 30 global chemical companies were from Europe (Cefic, 2013). Like virtually every other industry worldwide, the European chemical industry has felt an enormous impact from the recent global recession. At its lowest point in March of 2009, the industry saw a monthly year-on-year decline of 13.2 percent, a figure that if annualized would represent an output decline of approximately EUR56 billion (Cefic, 2013). In Europe, the chemical industry saw massive reductions in demand for plastics, paint and man-made fibers, especially in key markets such as automotive and construction. This fall in demand led to a severe destocking by many companies, with some companies (particularly in the base chemicals, polymers and specialty chemicals sectors) watching their own output decline by 30 to 60 percent. The European chemicals industry is currently facing unprecedented challenges arising from the need to address: Strong competition from emerging countries, notably in Asia, the Middle East and Russia. The European chemical industry´s share of world chemical sales declined from 29.8 % in 2001 to 19.6 % in 2011 which translates in 34 % decline over a period of 10 years (figure 2).

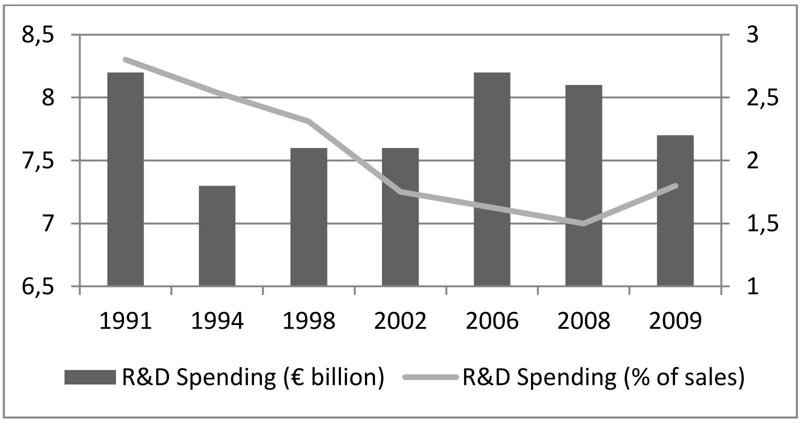
Figure 2. Contribution of each region to global chemical sales for the year 2001 and 2011



Data source: Cefic (2013)

Many of the challenges faced by the chemicals industry affect economic activity and society as a whole and manufacturing industry across the board. Innovation is indispensable to overcome these challenges and ensure the industry's further success. The chemicals industry has a key role through its enabling function for the entire economy. It shapes economic activities in other sectors. It is an irreplaceable provider of innovation to 'downstream' industries and an essential component of value chains that end with the great majority of consumer products. This means that the industry will always have a strategic, economic and social importance. Europe must retain a strong base in this sector, not only because of its economic weight, but also because of its ability to continually generate innovation critical to meeting the major challenges of modern societies. In European Union, there has been a decline in R&D spending in terms of absolute value as well as percentage of sales as shown in the figure 3.

Figure 3. R & D spending and R & D Spending as a percentage of total sales



Data Source: Cefic (2013)

1.3 Motivation for current research

Major asset of European chemical industry is knowledge, and a strong research base is, therefore, essential for building a knowledge-based competitive economy. Due to the multinational character of the large European chemicals industry and the tendency to relocate development activities closer to customers along the value chain, at least the 'D' component of R&D has gradually moved nearer to the large emerging markets. One reason for the relatively low overall R&D intensity is the fact that even today base chemicals – which require rather low investment in research – represent almost 60% of European industry's sales. This obscures much higher R&D investments in specialties and fine chemicals, advanced materials and other higher tech subsectors.

Corporate R&D in Europe is increasingly concentrated in large companies where revenues from base chemicals and commodities can be reinvested in research and innovation for new products and technologies. Large companies have generally maintained high R&D levels. In comparison, R&D expenditure in smaller companies is lagging far behind. Public funding varies greatly from region to region. Nevertheless, more private investment, in particular, is needed in R&D.

As far as chemical research in universities and research centres is concerned, the EU leads in terms of number of scientific publications. But it is performing less well compared to US in terms of citations of publications in chemistry, while being almost equal to the US in chemical engineering. However, an analysis of world scientific literature shows that the research output of China and India is growing much faster, with a higher degree of specialisation in chemistry and chemical engineering applied research.

It is the time for the big European players to prepare to defend their home markets, develop growth platforms based on innovation and better value capture and build the skill and scale required to compete. The key to survival for European chemical companies is based on innovation at three different levels-moving from bulk chemical production to the specialty end of the value chain, leveraging their traditional advantage in technology and establishing closer customer and competitor relationships through joint development agreements, acquisitions, value add services and other strategies initiatives (Schulz et al., 2012).

I am an engineer by education and have been working in the chemical industry for the last ten years in various technical and commercial roles. I have also earned a degree in business adminstration. This Technical knowledge along with Business expertise leads me to look globally in details in the chemical industry globally. During 2009, like other chemical companies, the company in which I am working was hardly hit by the global economic crisis. The sell plunged and share price hit the rock bottom. It was being observed that the European chemical industry is losing its ground both in market and also in total sales. Due to higher labor cost, stringent environmental regulation, and higher cost of production, the chemical production has been moving to Asia and Far East.

So, in perspective of the chemical industry scenario in Europe, the study is even more relevant. Moreover innovation is key for a sustainable and healthy European chemicals industry. The project starts with understanding the Euopean and global chemical industry. It then studies the innovation that this industry has seen in the recent past. There is also an intent to understand the trend and the factors that influence such innovation in nineteen large chemical companies headquartered in Europe.

1.4 Research objective

The objective of this research is to understand the current state of European chemical industry and answer the following question and sub-questions. The central question that this research is supposed to answer is to determine the "*Innovation Policy of European chemical companies with focus on large chemical companies*". The sub questions that will be answered under this principle questions are:

i) What is the trend in innovation of European chemical industry with focuss on nineteen large chemical companies headquartered in Europe?

ii) What are the determinants or variables in these nineteen large chemical companies which drive their innovation policy?

We will now analyze deeply each of the research question:

i) <u>What is the trend in innovation of European chemical industry with focuss on nineteen large chemical companies headquartered in Europe?</u>

This part of the research will focus on very large chemical companies which are headquartered in Europe. According to ranking of top 50 chemical companies based on total chemical sale for 2012 as published by Tullo (2013), it appears that 19 of them are headquartered in Europe (table 1). The study will focus on the innovation trend of these

19 companies. The study will also look in general trend of patenting of European chemical industry.

Table 1. The top 19 chemical companies in Europe for the year 2012 based on total sales in chemical products

	Company	Headquarter		Company	Headquarter
1	BASF	Germany	11	Yara	Norway
2	Shell	Netherlands	12	DSM	Netherlands
3	LyondellBasell	Netherlands	13	Lanxess	Germany
4	Bayer	Germany	14	Syngenta	Switzerland
5	Ineos Group	Switzerland	15	Borealis	Austria
6	AkzoNobel	Netherlands	16	Arkema	France
7	Air Liquide	France	17	Eni	Italy
8	Evonik	Germany	18	Styrolution	Germany
9	Solvay	Belgium	19	Total	France
10	Linde	Germany			

Data source: Tullo (2013). Table: Author

In order to answer this question, the project will investigate the patent profile of these chemical companies. The patent granted trend for last 10 years will be analyzed along with the geographical distribution of the patents. As it has been mentioned earlier, due to the economic crisis, the European chemical industry has been significantly affected, so this trend evolution will also consist of comparative study with important economies such as USA, Asia pacific, and Japan.

According to the legal requirement, all German companies are supposed to provide information about their R&D activities in their annual report. In case of companies outside of Germany, some of the information is expected to be obtained through the annual report while the rest will be available from their corresponding websites.

ii) What are the determinants or variables in these nineteen large chemical companies which drive their innovation policy?

This question will investigate the various industrial, financial and economic factors that influence significantly the innovation trend that was observed earlier. In order to answer this question, the R&D investment of these companies for the last 5 years will be analyzed. Along with that, we will measure several financial and non-financial indicators such as the intensity of R&D, collaboration with universities and environmental regulations.

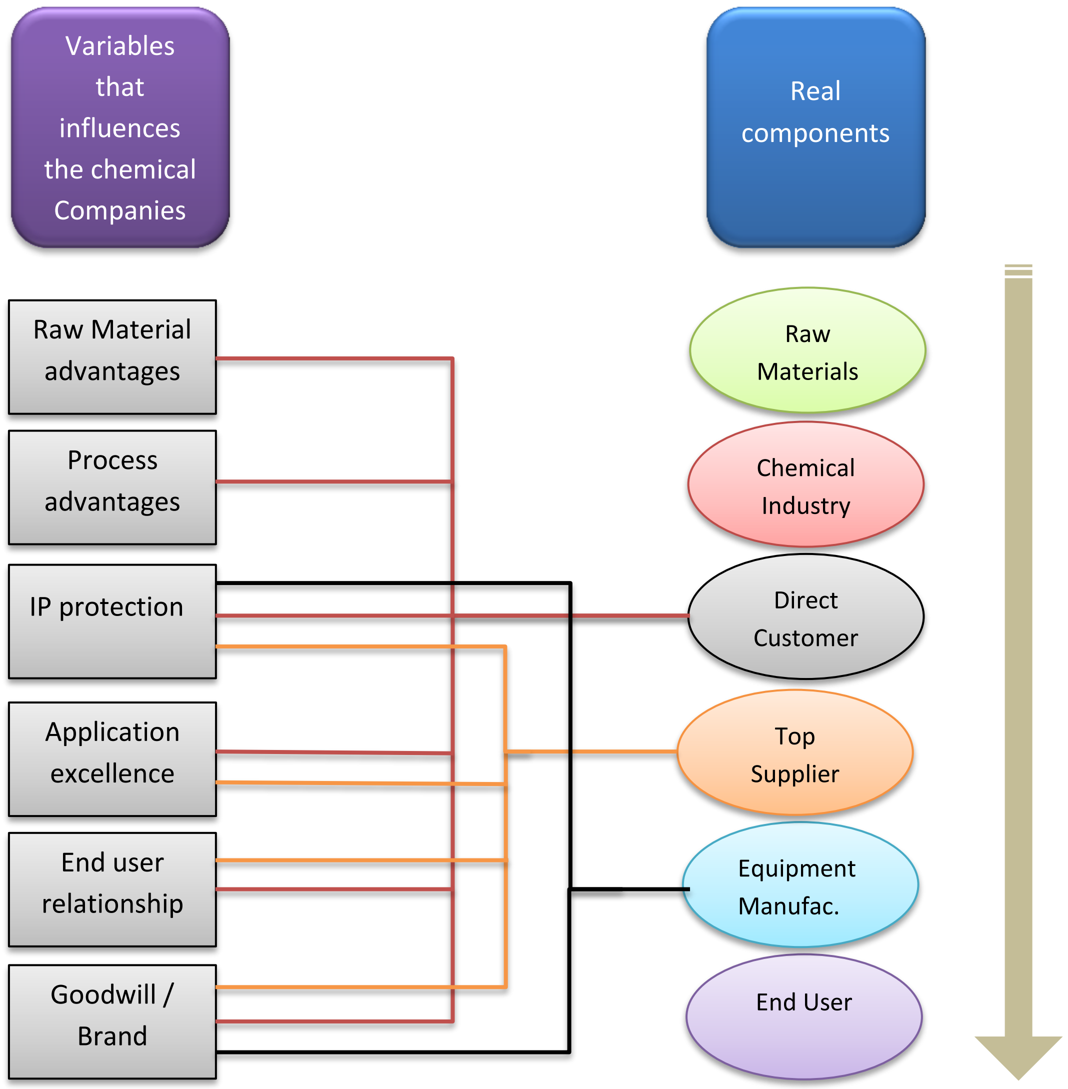
By answering these two questions, we should be able to obtain the research objective of the current project which is to establish the innovation policy of these nineteen large chemical companies that are headquartered in Europe.

1.5 Impact of Innovation on Chemical Industry

Innovative solutions will help the chemical industry transition from a traditional supplier role of being paid by the ton of material to play a more important and indispensable role in the industry value chain. There are several ways to meet this goal. As shown in figure 4 below, every value chain component has sweet spots that companies can use, to control the development of the industry and earn above average, sustainable returns. In chemical industry, these include materials advantage, process excellence, IP protection and application know-how and they reach far beyond the chemical industry to have an impact on end users.

Innovation is the platform that has driven the chemical industry throughout its entire history. With these trends in place, we have seen many established market chemical companies over the last ten years drive an increased focus on research and technology applications, moving ever further towards the speciality end and consumer of the value chain.

Figure 4. Impact of innovation on chemical industry value chain



Many forward thinking chemical companies already have local-market specific R&D center.

1.6 Structure of the thesis

The figure 5 shows the structure of the current thesis. It has seven main components and several sub-components. The first step is to define the research problem and identify the questions that the research will answer. Then we move to the next stage of the research where we look into the existing theories and literature around the current topic. Once we have a through understanding of the research made until now, we look into the hypothesis that we are planning to prove or nullify in this research. After the hypothesis has been established, we look into the design plan for research and also select the methodologies of the research. Next, we look into details of various factors that affect the innovation trend of large European companies. Once the data is collected, it is analyzed for understanding the trends and impact. From the analyzed data we will make conclusion and further recommendation for future research. The research is written in fourteen chapters. The following section gives an overview what each of the chapter covers:

Chapter 1: The first chapter explains the problem that the current European chemical industry is facing and justifies why innovation is the only way for them to regain their position as the leader in world in terms of production and sell of chemical product. This chapter also explains the motivation of the current project and the objective that the project supposed to achieve.

Chapter 2: The second chapter consists of literature review and critical analysis of the scholarly publication. The literature review covers not only the publications relating to chemical industry but also innovation in certain other manufacturing sector. It is divided into six broad categories.

Chapter 3: The third chapter covers the fundamental concepts of innovation and the objectives that drive innovation in a company. The later part of the chapter establishes the five hypotheses for the current research that will be tested in the later and justifies the selection of such hypothesis.

Chapter 4: The fourth chapter talks about the global chemical industry and compares the European chemical industry with the chemical industry from other region in terms of various economic metrics. It also shows how the recent global economic crisis has affected the chemical industry. It explains the composition of European chemical industry and gives an overview of each of the nineteen companies which we are studying in this research.

Chapter 5: The fifth chapter covers the methodologies that will be followed for doing the current research. It consists of two broad sections, the first one covering various sources for data collection. The second part consists of explaining the tools that will be used for data analysis.

Chapter 6: The sixth chapter talks about the innovation trend of the top European chemical companies. It explains the patenting trend of the chemical industry in general and makes deep analysis of various patenting metrics of the top chemical companies headquartered in Europe.

Chapter 7: The seventh chapter deals with the research and development spending of the European chemical industry over the years. It also makes analysis of the R&D investment of the chemical companies which are under study.

Chapter 8: The eighth chapter explains the concept and reason for merger and acquisition. It shows analysis of the M&A trend of the European chemical industry and the companies under study. The last part of this chapter gives examples of cases where the companies went for M&A to acquire innovation.

Chapter 9: The ninth chapter covers the joint development work that companies undertake among themselves or with specialized research centers. The chapter focusses on the various European research partnerships and analyses the data of various EU level research collaborations.

Chapter 10: The tenth chapter explains the REACH environmental regulation and its impact on the innovation of European chemical industry. The chapter analyses the survey data obtained by a previous research done by EU chemical agency in order to understand the impact of chemical regulation on innovation.

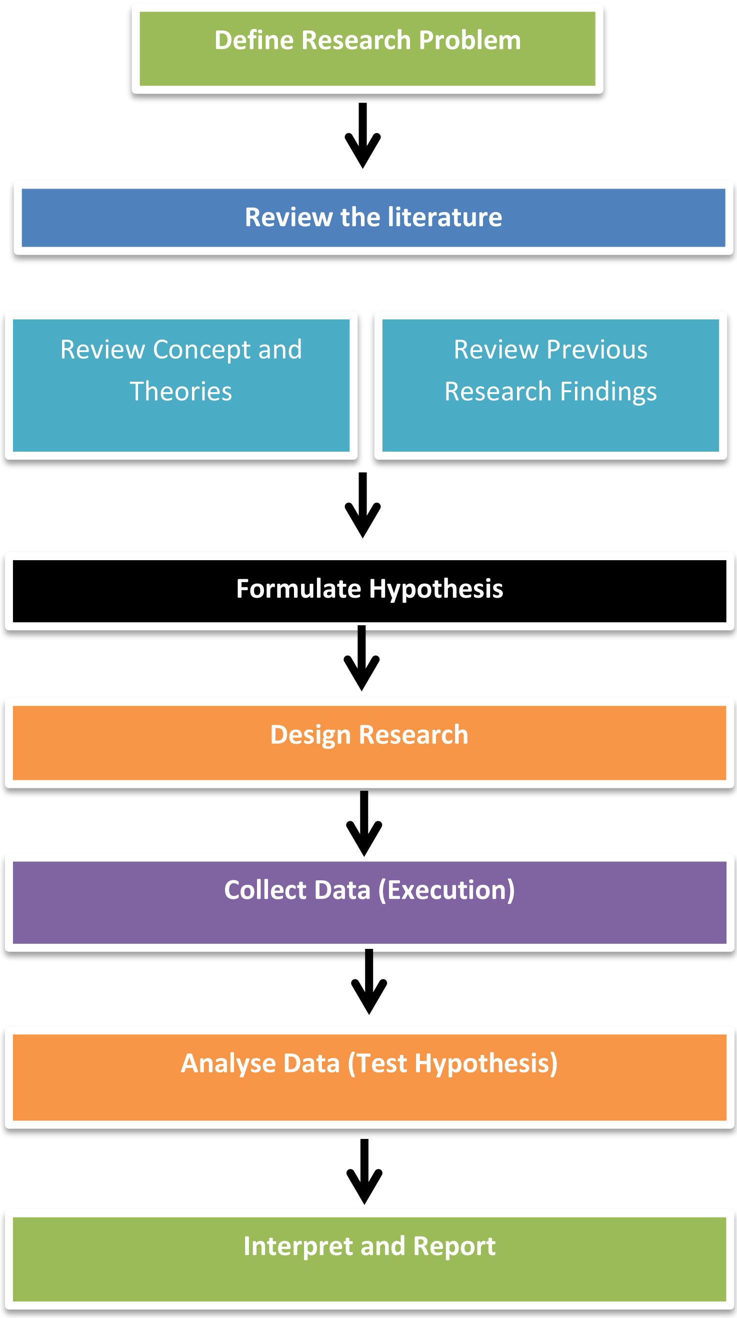
Chapter 11: The eleventh chapter talks about the various chemical clusters existing in Europe and their compositions. It also gives examples of cases where chemical cluster has played a significant role in driving innovation among its member companies. This chapter also builds up a relation between geographical distribution of the chemical companies in Europe and its impact on patenting trend.

Chapter 12: The twelfth chapter explains the trend of digitalization in various functions in chemical industry. The second part of this chapter focusses on digital marketing and explains in details the digital marketing strategy the top European chemical companies are pursuing in order to gain access to a larger customer base.

Chapter 13: The thirteenth chapter concludes the findings of the current research. It revisits the five hypotheses that we established earlier and makes explanation if we accept or reject those hypotheses.

Chapter 14: The fourteenth chapter is the last chapter of this research and talks about the future studies that need to take place based on the current learnings and conclusions.

Figure 5. The structure of the thesis



Source: Author

1.7 Summary

This chapter gives an overview of the current state of European chemical industry and shows a steady fall in terms of global share of the chemical sale. Europe has more than 29000 chemical companies with 4 % of them having more than 250 employees. In 2007, 12 of the leading chemical companies in the world were headquartered in Europe, representing 10 percent of world chemical sales while in 2012, 11 out of the 30 companies were from Europe. It also states that the chemical industry in Europe is in difficult situation and only innovation can bring it to the top position which it once enjoyed. The impact of the innovation on chemical industry has also been explained in details along with the motivation for the current project. It is stated that large companies headquartered in Europe are preparing their home markets, develop growth platforms based on innovation and better value capture and build the skill and scale required to compete. The objective of the project is explained by addressing the research questions and sub-questions. The last part of the chapter describes the structure of the current thesis and its seven main stages. It also gives an overview of the content of each chapter of the thesis.

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Chapter 2: Literature review

Contents

2.1 Introduction

A literature review is an account of what has been published on a topic by accredited scholars and researchers. The aim of the current literature review is to find out various concepts and ideas of the past research relevant to the current project, then critically evaluate, analyze and connect or disconnect them in order to have a flow of thoughts and ideas for the current research. The literature review has been done with the focus on understanding various theories and common practices in terms of innovation especially for large companies with emphasis on chemical industry and also consists of critical evaluation of each of the literatures in order to understand the gaps in those studies. Even though we have witnessed fall and subsequent rise of innovation in Chemical industry, theoretical understanding of the input variables and financial – and non-financial determinants of this innovation trend in large chemical companies is largely underdeveloped. The literatures available in this area have been divided into several groups as shown in the following matrix in figure 6. Dividing the literatures into various groups and sub-groups helps us to look deep into each of them. Innovation has been a topic for discussion and research for the last 25 years and organizing them according to the direction of research is a daunting task. Although internet has been a great source of information with most scholarly literature available online, the hard copy version available from the university library was also taken into consideration during this exercise.

2.2 Overview of the current literature review

The six subjects or groups in which the whole literature review was divided into are:

1. Fundamental understanding of innovation
2. Input variables for innovation
3. Activities for innovation
4. Output variables for innovation and its impact
5. Barrier to innovation.
6. Digital innovation in marketing

Although the main focus of this literature review is on the chemical industry , in particular, large chemical industries in Europe, detailed attention is also given to literatures from other manufacturing sector as their experience can be incorporated in the future innovation strategy of large chemical companies.

The literature review on fundamental understanding focusses on:

- Innovation definition and general understanding of innovation process
- Innovation process in chemical industry
- Innovation process in other manufacturing sectors

The publications around input variable for innovation consist of the following sub topics:

- Investment in R&D
- Organizational structure that influence innovation
- Investment in human capital
- Training and development of the employee to carter innovation
- Environmental regulations in Europe such as REACH which influences the innovation path
- Size of the organization
- Geographical distribution of innovation activities and cluster effect

The third section consists of literatures focusing on activities under taken during the innovation process and it comprises of four sub topics:

- Patent activities such as searching previous patents and writing new patents for the current invention
- Inter-industry R&D collaboration
- Collaboration of industry with academia such as universities and research institutes
- Business strategies specially for large chemical industries and other manufacturing sectors which encourage innovation

The fourth section consists of publication around output variables of an innovation process and its impact on the company which is again sub-divided into:

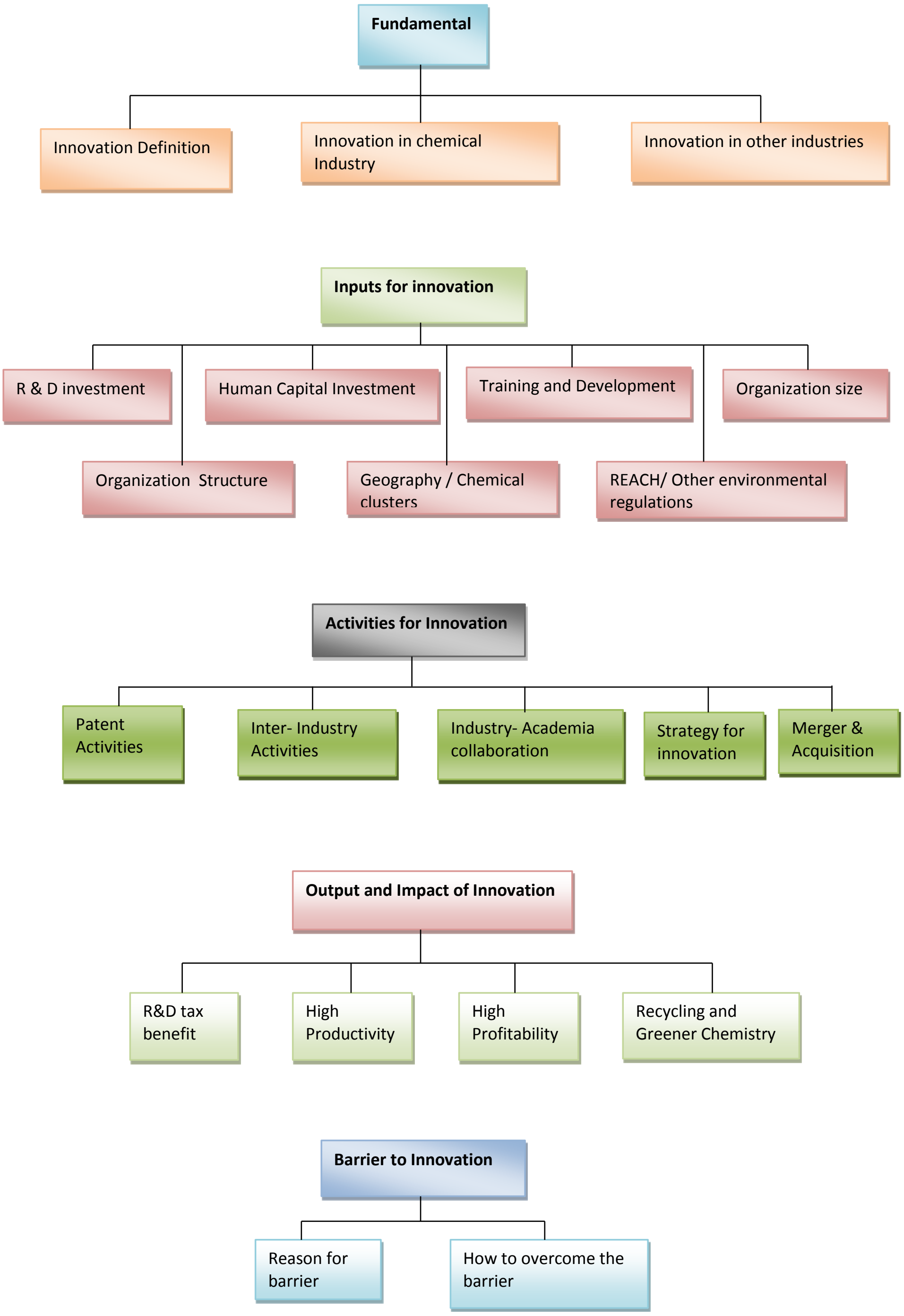
- R&D tax benefit
- Increase in productivity and sale
- Increase in profitability
- Increased research in greener chemistry

The fifth section of this literature review focusses on two questions around the barrier to innovation as faced by the companies:

- What are the barriers to innovation?
- How to avoid such barriers?

The last section of the literature review focusses on marketing innovation with emphasis on digital marketing.

Figure 6. The matrix of the field of publications as found in the current literature review



Source: Author

2.3 Literature analysis

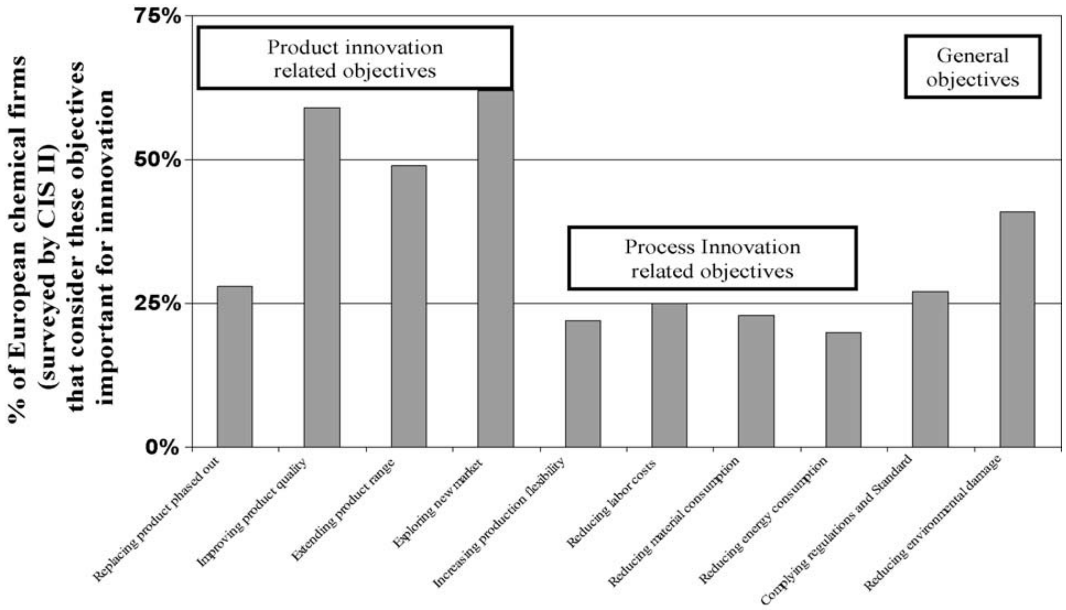
In the following sections, we go deeper into the literature analysis of the various topics and sub-topics as earlier mentioned.

2.3.1 Fundamentals of innovation for chemical and other manufacturing sectors

The publications done by various researchers tend to explain the fundamental of innovation. This section focusses on both the product & process innovation which are two pillars of innovation of large chemical industry and studies the literature both in chemical industry and also other large manufacturing sectors. Johson (2001) defined what innovation is and how is it related to entrepreneurship. Similar basic understanding was shown by Nelson (1993) and Lundvall (2009). Lundvall (2009) further laid down the fact that innovation is seen as an outcome of a collision between technological opportunities and user needs with the focus is upon the interaction between producers and users of innovation. Achilladelis et al. (1990) examined the mechanisms and dynamics of the process of innovation in the chemical Industry. Quinn (1983) stated that innovation process can be chaotic, but need to be managed well to achieve the end result.

The purpose for innovation for European chemical industry was surveyed and the figure 7 shows the factors chemical companies perceive as the drivers for both product and process innovation. The survey shows that exploring new market is the main driving force for innovation for European chemical industry.

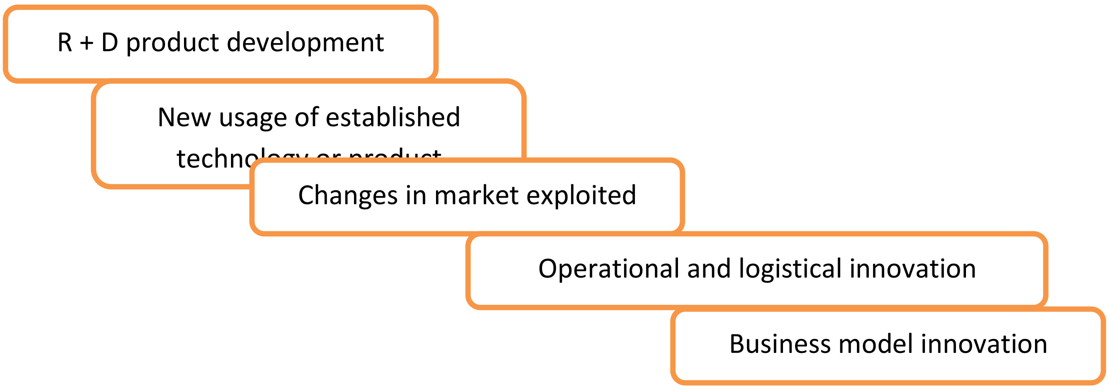
Figure 7. Objectives of innovation in the European chemical industry (Eurostat, 2001)



Source: Ren (2009)

Johnson (2001) studied the process of innovation and stated how a big organization with a significantly larger infrastructure can generate innovation internally. He laid down five different form of innovation in the company as seen in the chart below (figure 8):

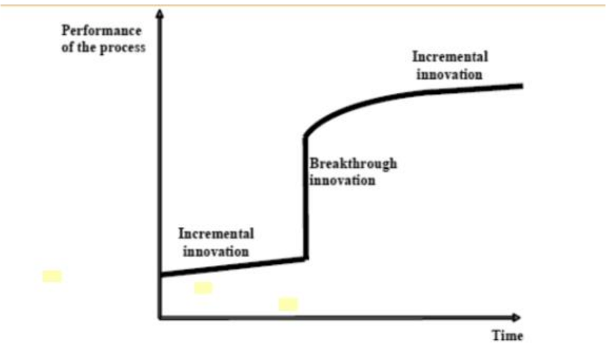
Figure 8. Different form of innovations in a large organization



Source: Johnson (2001)

Similar attempt of defining innovation particularly for chemical sector has been made by Dal Pont et al. (2013) with the chart (figure 9) showing the trend of the innovation process as seen in chemical sector.

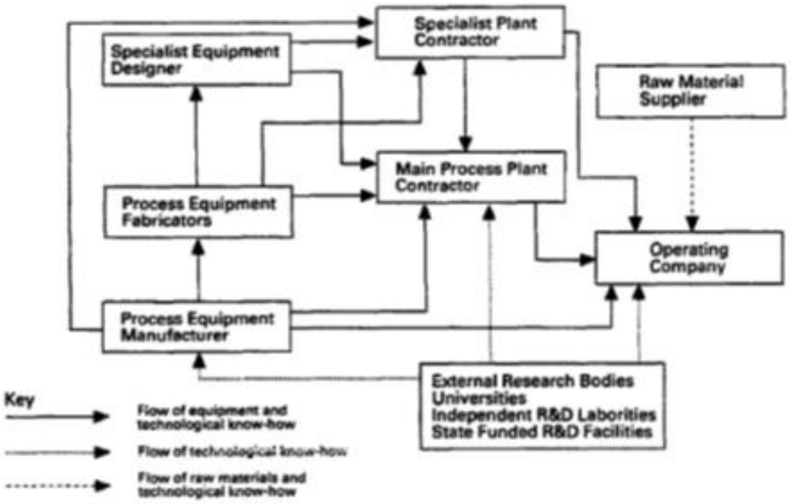
Figure 9. Different form of innovations in a large organization



Source: Dal Pont et al. (2013)

On the other hand, research done by Hutcheson et al. (1996) focused on sources of technical innovation in the network of companies providing chemical process plant and equipment. They found out that appropriate alliances between contractors and equipment manufacturers can not only help to reduce plant design, procurement and erection costs, but also offer a means to counter the competitive threat from more specialist firms; in particular the large equipment manufacturers that possess their own project contracting skills. They outlined the matrix of such innovation process as seen in figure 10.

Figure 10. The innovation matrix for the chemical industry innovation

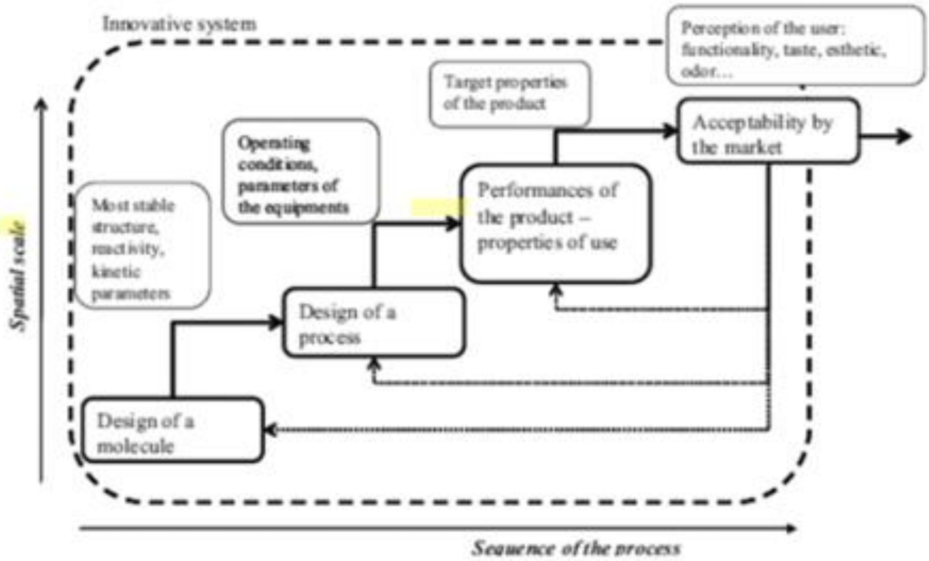


Source: Hutcheson et al. (1996)

Furthermore, their study showed that “collaborating type innovation” offers a means of generating scope for technological competitive advantage, whilst sharing cost and risk. Abratt and Lombard (1993) work was based on a study of 51 specialty chemical firms in South Africa to identify the major determinants of product innovation in the specialty chemicals industry. The result showed that these firms` innovation is customer driven, but deficiencies were uncovered with respect to product predevelopment activities, attention paid to marketing, and the apparent lack of synergy with existing technologies achieved by new products specialty chemical firms. The drawback of this research is they do not provide a recipe for product innovation success and state that the solution to be found by each firm will depend ultimately on their own external and internal environments.

In the latest work of Dal Pont et al, (2013), they also elaborated the sequence of innovation of a large chemical company as shown in figure 11:

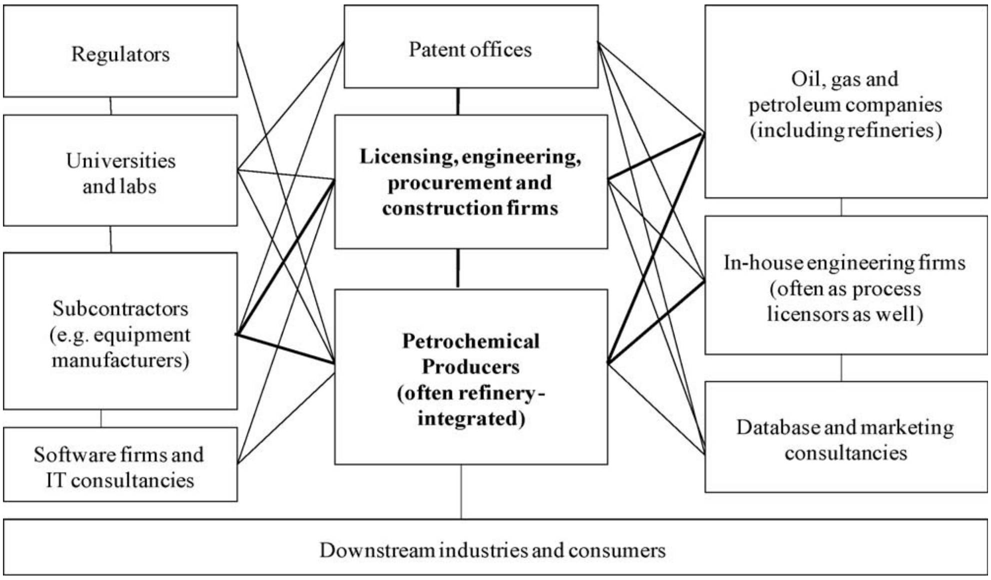
Figure 11. Sequence of innovation in large chemical company



Source: Dal Pont et al. (2013)

Similar effort was undertaken by Ren (2009) to build a chart showing the relation between the various innovators in the petrochemical industry (figure 12). This study was based on interview conducted by him.

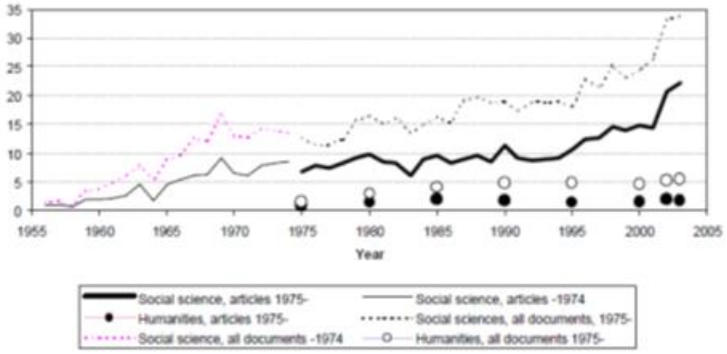
Figure 12. Innovators and networks for innovation in petrochemical processes (based on various interviews)



Source: Ren (2009)

Stetter and Lieb's (2000) work was a historical over-view of innovation in crop protection industry from its earliest beginning to present day and attempted to portray how research based crop protection industry was prepared for the current and future challenges. Considerable space was dedicated to the discussion of trends in research. Fagerberg's (2003) research is another example of interest in innovation research by showing the trend of citation and publication in innovation related topics as seen in the graph below (Figure 13). It can be argued that this graph reflects the fact that no single discipline deals with all aspects of innovation, and that in order to get a comprehensive overview of the role played by innovation in social and economic change, a cross-disciplinary perspective is a must.

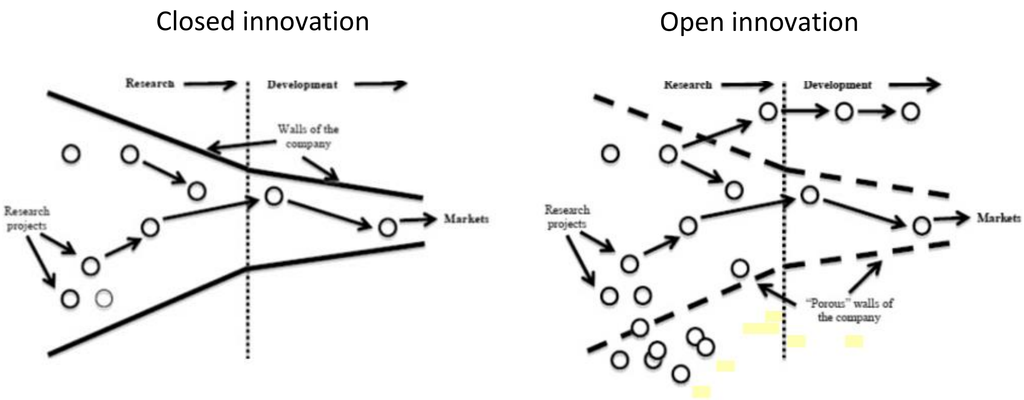
Figure 13. Trend of publication and citation with word innovation in title (10000 social science articles were studied)



Source: Fagerberg (2003)

In large chemical companies, there has been an evolution of tradition from closed innovation to open structure (figure 14) as they go global for their R&D activities (Chesbrough, 2003).

Figure 14. Large chemical industry transitioning from closed innovation to open innovation

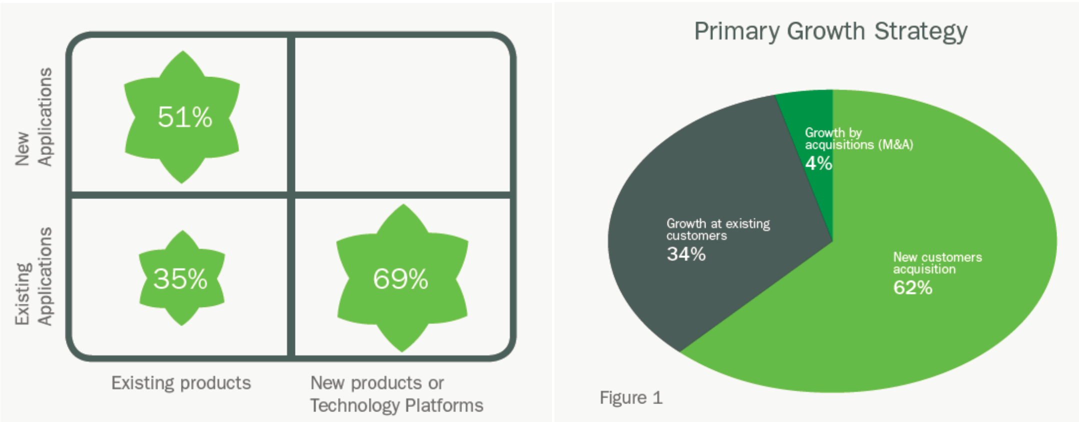


Source: Chesbrough (2003)

There have been several studies done on European chemical industry and its innovation status under economically difficult situation. Colombo (1986) appraised the prospective for the European chemical industry at a time of economic crisis when forecast rates of economic growth for the next two decades were continuing to decline. He examined the key issues in the chemical industry-its changing geography, industrial redeployment, the change from product chemistry to function chemistry, and the problems of scientific and technological innovation and its consequences for industry and society. Cooper and Kleinschmidt (1993) found out what separated a new-product winners from losers in chemical industry and stated that the key to new-product success were quality of execution of the activities that comprised the innovation process, early and sharp project and product definition, a strong team leader together with an accountable, multidisciplinary team. Earlier Colombo (1980) claimed that the chemical industry was inherently innovative industry and highlighted key innovation in the chemical industry between 1930 and 1970. He also focused on constraints or barrier to innovation in the chemical industry. Walsh (1984) studied the rate, direction and scale of invention and innovative activity in the chemical industry over the period l930-1980 and the findings suggested that the importance of both “demand pull” from the customer and “discovery push” from the R&D are equally important for invention and innovation in the chemical industry. ATKeray (2012) stated most of the growth in the past 25 years has been driven by Asia, which now owns almost half of global chemical sales. The report also predicted that key end markets of chemical industry such as automotive, construction, and pulp production are all set to surge in Asia, resulting in growing local demand for chemicals. The indications are that Europe may become the global pressure point for plant closures.

The study from European Commission Enterprise and Industry (2009) stated some ways of bringing innovation to European chemical industry. The key factors outlined are: the move to a more sustainable use of resources, topical innovation network, cross-cutting chemical solutions through the value chains, the quality and quantity of R&D and effectiveness of innovation, intellectual property, fighting against counterfeiting, regulations in chemical industry, education and attracting new talent in the chemical industry. Based on the survey by Specialchem (2012), the matrix below shows the challenges of new business development and the path for success (figure 15).

Figure 15. Challenges and new business growth strategy in the European chemical industry

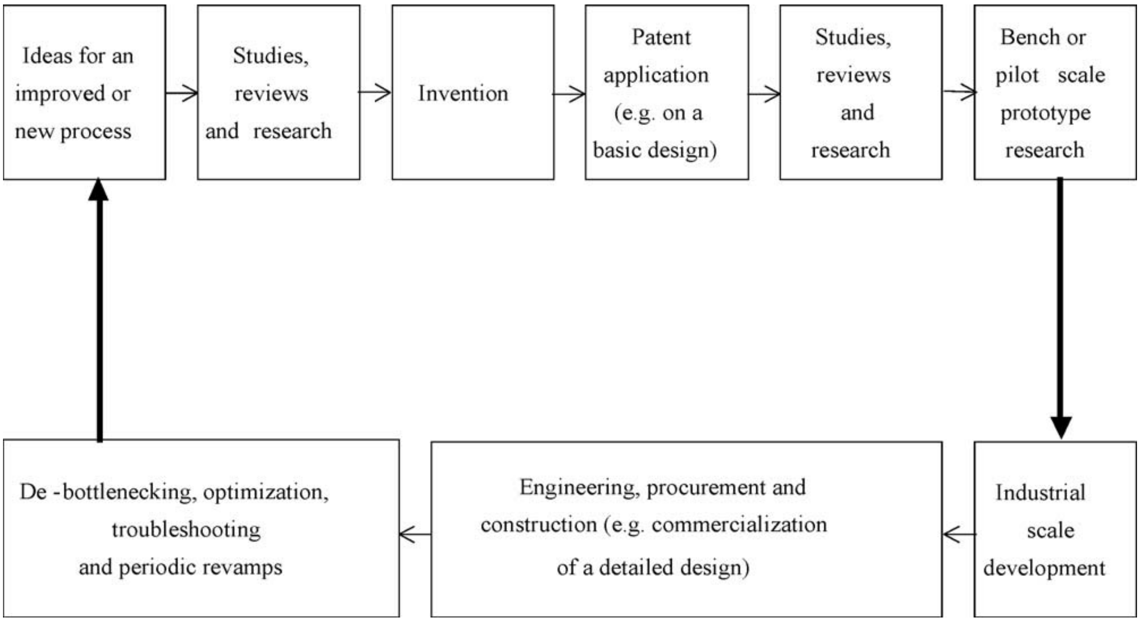


Source: Specialchem (2012)

Arvanitis and Villavicencio (2000) gave an overview of the chemical innovation system of industrialized countries and Mexico. Only 12 per cent of surveyed companies introduced some new product not existing elsewhere and thus the vast majority of chemical companies are moderate innovators looking mainly at copies or adaptations of already known products. In case of Mexican chemical companies, 18 per cent of the companies do not spend anything, 39 per cent spend less than 2 per cent of their sales and more than 40 per cent of the companies spend more than 2 per cent of their sales on R&D. The study of Heinzelbecker (2005) was about the future of European chemical industry with strong focus on innovation in order to remain competitive.

Ren (2009) established the typical sequence of innovation as seen in the chemical industry (figure 16).

Figure 16. A simplified procedure for innovation in petrochemical processes (based on interviews; feedbacks between various steps are omitted)



Source: Ren (2009)

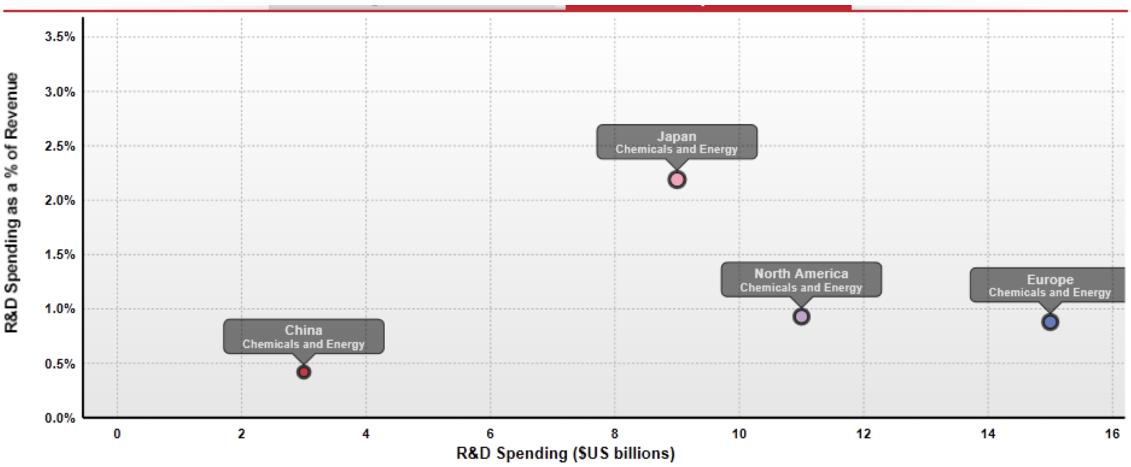
2.3.2 Inputs for innovation

This section focusses on the variables that influences innovation process

2.3.2.1 R&D: Spending

Scott (2012) in his study stated that investment among the top 50 R&D spenders in chemical industry increased by 7.3% in 2010, with BASF spending the most across the industry. He also said that while the amount of money spent determined the scale of R&D activity, a corporate culture that encouraged openness and collaboration also is key to efficiently converting R&D projects into commercially viable products. The top 50 global investors in chemicals R&D in 2010 increased their spending an average 7.3% compared to 2009. Same companies on average reduced R&D spending by 1.7% in 2009 compared to 2008, reflecting the pessimistic outlook for chemical companies at the start of 2009 (Tullo, 2013). Going back another year and the R&D spending in 2008 was higher by an average of 5.7% when compared with 2007. Booz&co (2014) analyzed the R&D investment of 1000 innovative chemical and energy companies around the world which showed for year 2012, investment in R&D by chemical companies in Europe was significantly higher than that located in North America and Japan (figure 17).

Figure 17. R&D spending in different regions for 1000 innovative chemical companies



Source: Booz&co (2014)

BASF invested most heavily in R&D, spending $1,941 million in 2010, followed by Dow Chemical, DuPont, and Mitsubishi Chemical, all of which invested more than $1.5 billion in R&D in 2010 (Tullo, 2013) . The group of 10 highest-ranked investors in chemicals R&D is dominated by producers of agricultural chemicals—with seven of the 10 top R&D investors having a major play in this field. The only top 10 R&D firms without major chemical activities are DSM, Mitsubishi Chemical and Sumitomo Chemical. Monsanto leads the pack of agchem pure-play firms, with 11% of its sales invested in R&D in 2011, followed by Syngenta with 9%. Flavors and fragrances production is another R&D-intensive sector, with International Flavors and Fragrances (IFF) in 2010 spending 10% of its sales on R&D, Symrise spending 7%, and Givaudan 5%. Merck KGaA, which is predominantly a fine chemicals group, in 2010 spent 7% of its sales on R&D (Davis, 2013). Gases firms are among those that spent the least percentage of sales on R&D in 2011 with Praxair and Air Products each spending 1%.
Average R&D spending as a proportion of sales has changed little during the past few years, with an average of 3.4% in 2010, down from 3.6% in 2009 and 3.3% in 2008 (Tullo, 2013).

2.3.2.2 Organizational structure

An organizational structure is such activities as task allocation, coordination and supervision, which are directed towards the achievement of organizational aims. Previous studies have shown a close relation between organization structure and innovational activities. The key contributors to R&D outcomes and innovation were found to be managerial and strategies that relate to each of the three elements; posture and direction, systems, and adjustment processes (Roberts and Bellotti, 2002).

Based on data from 32 Taiwanese companies, Jung and Wu (2003) found that there is a direct and positive link between a style of leadership that has been labeled as ‘‘transformational’’ and organizational innovation. They also indicated that transformational leadership has significant and positive relations with both empowerment and an innovation-supporting organizational climate. The former is found to have a significant but negative relation with organizational innovation, while the latter has a significant and positive relationship. The study of better understanding of business-driven innovations towards more sustainable chemical products and processes by Visser et al. (2008) showed that the objective of business-driven innovation was to place more sustainable products in upcoming markets. Commercial managers played an important role in the innovation processes, whereas environmental managers hardly played a role at all. Most innovations are indirectly triggered by new regulations in frontrunner countries, which were regarded as indications of future market changes.

Argyres and Silverman (2004) studied the relation between a firm’s organizations of research —specifically, its choice to operate a centralized or decentralized R&D structure —and the type of innovation it produces. The study proposed that by reducing the internal transaction costs associated with R&D, coordination across units, centralized R&D will generate innovations that have a larger and broader impact. Pisano (1991) suggested that various governance structures such as forward vertical integration, backward integration and various form of collaboration between new and established firms helps to generate innovation.

2.3.2.3 Human capital investment

Human capital, generally seen as a set of knowledge, abilities and skills of the individuals, used in the activities that stimulate economic growth and development, was considered to be a stimulus of the innovation process. In most economic literatures that were reviewed, it was mentioned the existence of three types of human capital: firm-specific human capital, industry-specific human capital and individual-specific human capital. Because the first two types of human capital refer to the abilities and knowledge valuable only within a specific firm or industry, they have a limited impact on the innovative activity within a region or state. In contrast with these two, individual-specific human capital implies knowledge that is applicable to a large range of firms and industries (Schultz, 1961). Considering that individuals abilities and skills that can be improved and so they can change the way they act, human capital is seen to be an important source of competitive advantage to individuals, organizations and even to societies, having a huge capacity of innovation induction. Regarding the decision to innovate or not that firm must initially make, Landry et al. (2002) have provided strong evidence that diverse forms of human capital influence this decision. Hoecker and Nettelbreker (2004) focused on accelerating the process of innovation through New Bonus system as seen in Degussa.

Based on longitudinal data from thirty-five UK organization, Shipton et al. (2005) showed that there was growing evidence available that suggest that effective HRM systems – incorporating sophisticated approaches to recruitment and selection, induction, appraisal and training – were key to organizational innovation in products and production technology. The study further showed that organizational innovation was enhanced where there was a supportive learning climate, and inhibited (for innovation in production processes) where there is a link between appraisal and remuneration. Bontir and Fitz-ez (2002) study also established the same result that there is a strong relationship between human capital management and innovation and business development.

Two large French and Swedish firms were studied between 1987 -1993 by Ballot et al. (2001) in order to understand the effects of human and technological capital on productivity. They constructed measures of a firm's human capital stock, based on their past and present training expenditures and confirmed that firm-sponsored training and

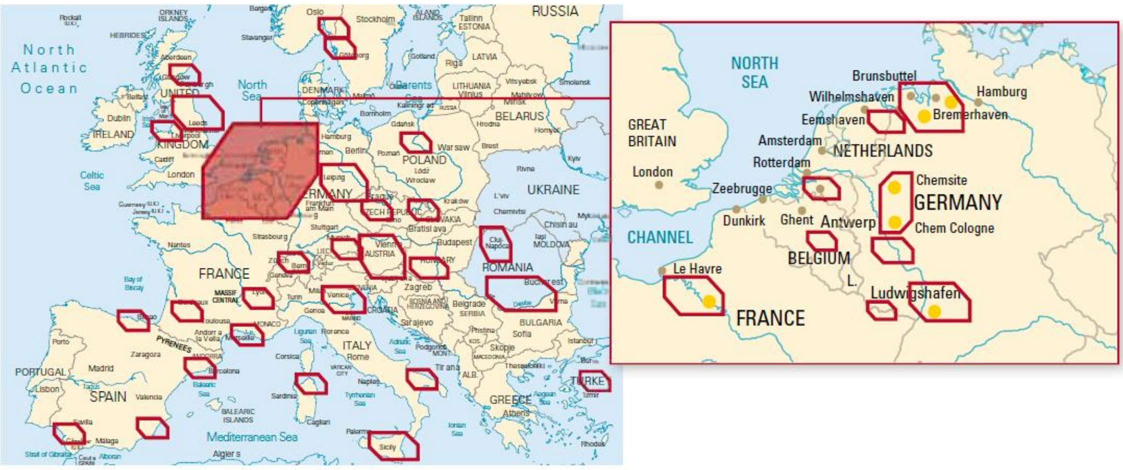
R&D expenditure are significant inputs in the two countries, although to a different extent, and have high returns. However, except for managers and engineers in France, they did not find evidence of positive interactions between these two types of capital. Sterlacchini (2008) examined the relationship between the economic growth of European regions and their knowledge and human capital endowments. The share of adult population with tertiary education and the intensity of R&D expenditures in value-added emerge as the most effective factors enhancing the growth of GDP per capita recorded, during 1995–2002, by the regions belonging to twelve countries of the former EU15. Moreover, remarkable disparities arise among the regions of different countries. In particular, only within North European countries there is a significant relationship between regional growth and the intensity of R&D and higher education. Bottazi and Peri (2003) using R&D and patent data for European Regions in the 1977–1995 period found that spillovers are much localized and exist only within a distance of 300 km. However the size of these spillovers is small, so doubling R&D spending in a region would increase the output of new ideas in other regions within 300 km only by 2–3%, while it would increase the innovation of the region itself by 80–90%.

Popescu and Diaconu (2008) stated that there is a double way relation between the capacity of innovation induction and the stock of human capital. The practice generated by innovation may imply the construction of some connections that involves a better knowledge, training and a support for the continuing preparation process. The competition generates innovation among firms but it also primes a process of human capital accumulation, at an individual level. In order to cope in the innovative environment, the employees need to make efforts in accumulation and developing their own innovative capacities.

2.3.2.4 Geography and chemical company clusters

Successful companies in many industries are concentrated in a moderate number of locations, rather than being distributed evenly across different geographies. Europe continues to be a large market for chemical products. While other markets, particularly in Asia, register strong growth, the absolute size of the European market continues to provide a strong basis for European clusters serving customers in this region. The figure 18 below shows the prominent clusters of chemical companies in Europe.

Figure 18. Major Chemical Clusters in Europe



Source: KPMG International (2010)

According to Deloitte (2012), the chemical industry in the Netherlands forms part of one of the strongest chemical clusters in the world, the interconnected Antwerp-Rotterdam-Rhine-Ruhr Area (ARRRA). This cluster is responsible for a huge array of products that supply the competitive European manufacturing industry for both domestic and export markets and consist of some of the Europe's largest chemical companies. Another region where we find a lot of large chemical companies is in Germany. According to German Trade & Invest (2011) report Germany is Global heavyweight for the Chemical Industry clusters. In order to cope with the global economic down turn, the reports says that the German Chemical Industry is in transformation from commodities to specialties , moving ahead in formation of innovation alliances and investing in research of new materials and cross-sector technologies.

2.3.2.5 REACH and other chemical regulations

REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals. It entered into force on 1st June 2007. It streamlines and improves the former legislative framework on chemicals of the European Union (EU). The study of Center for Strategy & Evaluation Services (2012) provides an interim evaluation of the impact of the REACH Regulation on the innovativeness of the European chemical industry and the survey findings and interviews suggest that there has been a significant redirection of skilled, sometimes highly skilled, personnel in firms from R&D and innovation-related activities to compliance work as a result of the implementation of the Regulation. One of main drivers of the REACH Regulation has been the view that the gathering, capture and dissemination of data from the chemical industry will act as a spur to product conception, development and marketing (Bergkamp, 2013). The evidence from the fieldwork also suggests that links with universities and networks developed by companies have tended to focus on the compliance/ regulatory elements of REACH. As to the effect of the REACH regulation on the availability external funding from the private sector, there have not been, as far as we could identify, any funds launched or targeted specifically to support innovation or substitution initiatives (or compliance costs) under REACH (Kefford, 2013). Respondents to a survey as well as some firms interviewed indicate that there has been some long term shift in the orientation of R&D and innovative activities towards more HSE related goals linked to REACH, however this is usually not just related to REACH but part of a general appreciation of movements in the market (Bergkamp, 2013). There has been some widening in the scope of innovative activities as a result of the Regulation to include more work on new substances, particularly among large firms, who are also responsible for most innovation in the industry, but barriers to R&D and innovation in new substances still remain (Gubbels et al., 2013). Another survey respondent – think that REACH has not provided enough IPP to promote innovation and the fieldwork has confirmed that extensive activity in the areas of product, process, marketing and innovation change is occurring as a result of the implementation of the Regulation (Kamptmann, 213). However, in many instances companies have considered these activities to ensure compliance with the Regulation as a distraction from their normal, planned innovation activities and to be unintended consequences of the Regulation. A point that has been made often about the effect of the Regulation is that the issues around compliance and related costs and constraints do make some non-EU locations more attractive for undertaking innovative activities and based on the evidence provided, it appears that some such delocalisation of innovative activities has occurred, although REACH may not always have been the only or even the main driver (Schenk et al., 2013).

Petry et al. studied in 2006 that REACH could pose a challenge to the operation of the market economy in the EU and all stakeholders support the broad objectives of REACH but the different stakeholders cannot agree on the proposed content and design of the REACH system. Further findings from Bronckers and Van Gerven (2009) are the provisions are often unclear and ambiguous, and, probably, unworkable in its current form. In view of its scope, the impact of these regulations will be experienced by most manufacturing businesses in the EU.

The study done by Angere et al. (2006) gives no indication that REACh adoption will bring significant drawbacks to companies. This also states that the emerging regulation will bring challenges for individual companies, especially for small and medium-sized ones, but for the European chemical industry as a whole, there is no question that it will be able to cope with REACh burdens without losing its global competitiveness. Askham et al. (2012) presented in their paper how REACH aspects can be considered at the same time as environmental and economic performance indicators. Presentation of several indicators at once enhances the ability of product developers to understand complex trade-offs between different health and environmental aspects in the product development process. Green chemistry technologies are emerging slowly, but the relatively low proportion of green chemistry patents to all other chemical patents indicates that many industrial sectors are not rapidly moving toward greener chemistry-based process and manufacturing strategies. More effort and focus on green chemistry by these industrial sectors is needed to enable sustainable practices (Kerton and Marriot, 2013).

2.3.2.6 Organization size

Koberg et al. (2002) showed that different mixes of environmental and organizational variables were significant predictors of incremental and radical innovation. According to them, factors that favored incremental innovation included environmental dynamism, age and size of the firm, intra-firm structural linkages, and the age of the CEO. On the other hand, Damanpour (1992) stated that the factors that favor radical innovation include environmental dynamism, intra-firm linkages, experimentation, and transitioning or sequencing from one project or product to another. Acs and Audretsch (1988) presented a model suggesting that innovative output is influenced by R&D and market structure characteristics and also stated that the total number of innovations is negatively related to concentration and unionization, and positively related to R&D,

skilled labor, and the degree to which large firms comprise the industry; and these determinants have significant effects on large and small firms.

Syeonidis' (1996) surveys showed that there is little evidence in support of the Schumpeterian hypothesis that market power and large firms stimulate innovations. R&D spending seems to rise more or less proportionally with firm size after a certain threshold level has been passed, and there is little evidence of a positive relationship between R&D intensity and concentration in general. However he further stated, positive linkages between concentration/size and innovative activity can occur when certain conditions are met, including high sunk costs per individual project, economies of scale and scope in the production of innovation rents.

Vaccaro et al. (2012) showed that due to prominent role within organizations, top management has the ability to greatly influence innovation. The study also indicates that smaller, less complex, organizations benefit more from transactional leadership in realizing management innovation. On the other hand, larger organizations need to draw on transformational leaders to compensate for their complexity and allow innovation to flourish. Similar finding were obtained by Damanpour and Schneider (2006). They found that organizational characteristics and top managers' attitudes toward innovation have a stronger influence than environmental and top managers' demographic characteristics and also found no difference in the direction of effects of any antecedent, but did find differences in the significance of effects of several antecedents, on the phases of innovation adoption. Contradictory results were obtained by Camison-Zornoza et al. (2004) in their study as they confirmed the existence of a significant and positive correlation between size of an organization and innovation.

2.3.3 Activities for innovation

This section consists of activities undertaken in order to achieve the desired innovation for the company. The sub-topic under this topic is dealt in details in the following section.

2.3.3.1 Patent activities

Research productivity or innovation capacity is typically measured by the ratio of patents to R&D activities. A patent is a set of exclusive rights granted by a sovereign state to an inventor or their assignee for a limited period of time, in exchange for the public disclosure of the invention. An invention is a solution to a specific technological problem, and may be a product or a process. Patents are a form of intellectual property. Research productivity at the firm level is inversely related to patent quality and the level of demand, as predicted by theory and patent quality is positively associated with the stock market value of firms (Lanjouw and Mark Schankerman, 2002). The procedure for granting patents, requirements placed on the patentee, and the extent of the exclusive rights vary widely between countries according to national laws and international agreements. Typically, however, a patent application must include one or more claims that define the invention. These claims must meet relevant patentability requirements, such as novelty and non-obviousness. The exclusive right granted to a patentee in most countries is the right to prevent others from making, using, selling, or distributing the patented invention without permission (Krestel, 1997). Another innovation indicator, the propensity rates equal the percentage of innovations for which a patent application is made**.** Arundel and Kabla's (1998) study stated the propensity rates for product innovations average 35.9%, varying between 8.1% in textiles and 79.2% in pharmaceuticals. The average for process innovations is 24.8%, varying from 8.1% in textiles to 46.8% for precision instruments. Only four sectors have patent propensity rates, for both product and process innovations combined, that exceed 50%: pharmaceuticals, chemicals, machinery, and precision instruments. Regression results that control for the effect of industry sector show that patent propensity rates increase with firm size and are higher among firms that find patents to be an important method for preventing competitors from copying both product and process innovations (Scherer, 1965). The effect of secrecy is not so straightforward. Firms that find secrecy to be an important protection method for product innovations are less likely to patent, as expected, but secrecy has little effect on the propensity to patent process innovations (Arundel, 2004). The R&D intensity of the firm has no effect on patent propensity rates for both product and process innovations and the sector of activity has a strong influence on product patent propensities but very little effect on process patent propensities, after controlling for the effect of other factors. The low rate in many sectors, indicates that great caution must be taken when using patents as a measure of innovative output, particularly when these rates are adjusted downwards by another 30% to account for the percentage of patent applications that are rejected or withdrawn (Arundel and Kabla, 1998). Patents are a particularly poor measure of innovativeness in sectors such as food and tobacco, petroleum refining, basic metals, automobiles, and other transport equipment. In these sectors, the large majority of innovations are not patented. On the other hand, in chemical industry, patent is a very good indicator of innovation. Patents could still be used to compare the innovativeness of firms within specific sectors if the most economically valuable patents were still patented (Pavitt, 1984). On the other hand, Macdonald (2003) stated that the patent is supposed to be a means to an end, that end being innovation. Whether the innovation comes from the protection the patent affords the inventor, or from the dissemination of the information of invention the patent allows, the patent is not meant to be an end in itself.

Chen and Chang (2007) examined the relationships between corporate market value and four patent quality indicators – relative patent position (RPP), revealed technology advantage (RTA), Herfindahl–Hirschman Index of patents (HHI of patents), and patent citations – in the US pharmaceutical industry. The results showed that RPP and patent citations were positively associated with corporate market value, but HHI of patents was negatively associated with it, while RTA was not significantly related to it. Arora (1997) stated how firms use patents depends upon industry structure, and in turn, affects industry structure. In the 19th century, market leaders in the chemical industry combined patents and secrecy to deter entry. In bulk organic chemicals and petrochemicals, chemical producers use licensing as an important means of generating revenue from process innovations. Moreover, instead of being associated with discrete innovations, patents are more typically associated with technological areas, and firms often patent to Wall off those areas. The history of the chemical industry also shows that the role of patents is much broader than merely excluding competitors, and has changed in response to changes in industry structure. Patents were used to facilitate technology transactions within cartels, and were used to stabilize cartels by preventing entry into new markets by non-cartel firms. More generally, patents play a crucial role in facilitating a market for technology because the strength and scope of patents affect not only the incentive to invest in research, but also the efficiency with which new knowledge is transferred to others.

Webb and Dernis (2005) presented a preliminary set of European and international citation data tables designed to enable researchers to become familiar with the subject and undertake a range of analyses. Squicciarini et al. (2013) contributed to the definition and measurement of patent quality. They proposed a wide array of indicators capturing the technological and economic value of patented inventions, and the possible impact that these might have on subsequent technological developments. The measures proposed build extensively upon recent literature, rely on information contained in the patent documents, and are calculated on patent cohorts defined by the combination of the technology field and the year of filing of patents. Guellec and Potterie’s (2001) paper presented three new patent-based indicators of internationalisation of technology reflecting international cooperation in research and the location of research facilities of multinational firms. They witnessed both an increasing trend towards the globalisation of technology in the OECD area and large cross-country differences in the extent of internationalisation. Nordic countries have a particularly high propensity to collaborate together. Dernis and Khan (2004) stated that patents taken in various countries to protect inventions can be linked together to build triadic patent families: a set of patents taken at the European Patent Office (EPO), the Japanese Patent Office (JPO), and the US Patent and Trademark Office (USPTO) that share one or more priorities. Thomson Reuter (2013) explains the methodology used to determine the 2012 Top 100 Global Innovators, developed by Thomson Reuters and approved by several leading IP-centric organizations. The data used for this ranking was calculated and analyzed from Thomson Reuters Derwent World Patents Index® (DWPISM), Derwent Patents Citation IndexTM, Quadrilateral Patent Index™, and Thomson Innovation®, the IP intelligence and collaboration platform.

2.3.3.2 Inter-industry activities

Firms establish alliances for many reasons. Salient among the incentives to collaborate is the possibility of bringing together complementary assets owned by different organizations (Nohria and Garcia Pont, 1991; Gulati, 1995). For instance, two companies may establish an alliance when each one possesses strength in a different stage in a product's value chain, such as when one firm has manufacturing expertise and a second one controls a distribution channel. Second, firms may form coalitions to defray costs and share risk when they undertake high-cost (capital- or development-intensive) projects or very speculative strategic initiatives (Hagedoorn, 2002). It has also been suggested that the resources acquired from an alliance partner can facilitate a firm's efforts to alter its competitive position (Kogut, 1988), as well as that corporations in concentrated industries utilize alliances to collude or to gain market power at the expense of other competitors (Pfeffer and Nowak, 1976).

Empirically, researchers have observed an association between the propensity to enter into alliances and a variety of organizational attributes, including firm size, age, scope, and resources (Shan, Walker, and Kogut, 1994). Stuart stated that large firms and those that possess leading edge technological resources are positioned to be the most valuable associates. The paper also argued that alliances are at once pathways for the exchange of resources and signals that convey social status and recognition. Particularly when one of the firms in an alliance is a young or small organization or, more generally, an organization of equivocal quality, alliances are tantamount to inter organizational endorsements: they build public confidence in the value of an organization's products and services and thereby facilitate the firm's efforts to attract risk adverse customers. The investigation of Wallsten (2000) showed that firms with more employees and that appear to do more research win more grants, but the grants do not affect employment. Semitiel-Garcia and Noguera-Mendez (2012) did a case study for Spain of the structure of inter-industry systems and the diffusion of innovations for a period over a thirty- five year period. They concluded that interconnectivity among different actors (persons, countries, firms, etc.) generally implies multiple and overlapping linkages making up complex networks and allowing for a wide range of flows (ideas, affects, goods, technology, etc.). Firms interact with other business and non business institutions, implying learning processes and also material and immaterial flows making up networks and innovation.

2.3.3.3 Industry-Academia collaboration

Accelerated transfer of knowledge, technology, know-how, and people from university to industry is a subject of great interest to academics, industry leaders, and policymakers in recent years. Of particular interest is what role (if any) the research university can and should play in the post-Cold War economy (Branscomb, 1993). Meanwhile, the institutions of higher education are under pressure to increase the flow of new knowledge, know-how, and people to industry and society at large. Mansfield (1990) suggested that about one-tenth of the new products and processes commercialized during 1975-85 in the information processing , electrical equipment, chemicals, instruments, drugs, metals, and oil industries could not have been developed (without substantial delay) without recent academic research. A study by Lee (1995) also throwed the idea that the universities participate actively in local and regional economic development, facilitate commercialization of academic research, and encourage faculty consulting for private firms. Mansfield's (1990) study showed that the average time lag between the conclusion of the relevant academic research and the first commercial introduction of the innovations based on this research was about 7 years (and tended to be longer for large firms tan for small ones). A later study from Mansfield (1997) showed that the time lag can be considerably lower than 7 years. Further work of Mansfield and Lee (1996) showed that the interface between industry and the universities is of key importance in the promotion of technological change in many industries. There is intense interest in the characteristics of universities that have contributed most importantly to industrial innovation in various fields. It is also little known about the determining factors which universities firms will support to do R&D. Freitas et al. (2012), relying on a representative sample of firms in the Italian region of Piedmont, examined the characteristics and strategies of firms that interact with universities under different governance modes. The results indicate that ignoring personal contractual arrangements with individual researchers, as the previous literature does, amounts to overlooking at least 50% of university–industry interactions. Lee's (1996) study suggested that in most cases, universities rarely get involved in close business partnership with private industry by way of, for example, start-up assistance or equity investment.

The research of Fontana et al. (2006) goes one step further to find the determinants of research cooperation between firms and Public research organizations (PROs) for a sample of innovating small and medium-sized enterprises (SMEs). The results of the analysis point to two major phenomena. First, the propensity to forge an agreement with an academic partner depends on the 'absolute size' of the industrial partner. Second the openness of firms to the external environment, as measured by their willingness to search, screen and signal, significantly affects the development of R&D projects with PROs. In fact, firms that outsource research and development, and patent to protect innovation and to signal competencies show higher levels of collaboration. Fuentes and Dutrenit (2012) studied deeper into the three stages of interaction between a public research organizations and industry which can be conceptualized as: drivers of interaction, channels of interaction, and the perceived benefits from collaboration. The results show that all channels of interaction play an important role in determining benefits; however, they differ in terms of their impact on short- or long-term benefits for firms. The later study of Mansfield (1997) confirmed his previous study of 1990 that in absence of university-industry R&D collaboration, over 10% of the new products and processes introduced in these industries could not have been possible without substantial delay. But there also seems to have been a significant change to it.

2.3.3.4 Business strategy

Business strategies are the major initiatives taken by a company's top management on behalf of owners, involving resources and performance in internal and external environments. Whenever a business enterprise is established, it either explicitly or implicitly employs a particular business model that describes the design or architecture of the value creation, delivery, and capture mechanisms it employs. The essence of a business model is in defining the manner by which the enterprise delivers value to customers, entices customers to pay for value, and converts those payments to profit. It thus reflects management's hypothesis about what customers want, how they want it, and how the enterprise can organize to best meet those needs, get paid for doing so, and make a profit (Teece, 2010). Colombo and Garrone (1996) observed for 95 major US, European and Japanese firms, during the period 1980-86 inter-firm technological collaborations is the strategy. R&D cooperation and to a lesser extent R&D contracted out are found to have a significant positive effect on internal R&D but only if the companies have absorptive capacity in the form of a full-time staffed R&D department. At the same time, firms are found to be more frequently engaged in R&D cooperation, the more they spend on internal R&D (Veugelers, 1997). With respect to the determinants of the decision of the innovative firm to produce technology itself Make. or to source technology externally Buy., it was found that small firms are more likely to restrict their innovation strategy to an exclusive make or buy strategy, while large firms are more likely to combine both internal and external knowledge acquisition in their innovation strategy (Veugelers and Cassiman, 1998).

Vega-Jurando et al. (2008) survey of Spanish technology companies indicated that the firm's technological competences, derived from in-house R&D, are the main determinant of product innovation. They also suggested that in the presence of high levels of such competences, the technological opportunities deriving from non-industry agents become less important as determinants of innovation and also show that the determinants of innovation vary depending on the industrial sector and the degree of novelty of the product developed. Veugelers and Cassiman (1998) finding suggested in addition to important size effects explaining innovation, high perceived risks and costs and low appropriability of innovations do not discourage innovation, but rather determine how the innovation sourcing strategy is chosen. Strategy of financing of R&D provides a potentially important channel to link finance and economic growth with innovation.

Progressive chemical companies are grasping the opportunity to develop products and technologies that offer positive social and environmental benefits beyond their own operations in other, downstream industries. The chemical sector can also play a significant role in developing solutions for a cradle-to-cradle, zero-waste economy (ATkearney, 2013). Arora et al. (2000) found that investments in chemical plants in the LDCs are greater, the greater is the number of technology suppliers that operate in the first world. A major contribution of this paper was to identify an important but understudied mechanism through which technology is made available.

Eder's (2002) analysis showed that innovation leading to alternative synthetic pathways and a shift to selling services instead of products have especially high potentials for both strong positive ecological effects and to be important factors for competitiveness. The utilisation of these potentials depends, however, on whether different types of innovation barriers can be overcome. Suggestions are made as to how to develop policy measures to facilitate this. Frenz and Lambert's (2012) study used exploratory data analysis techniques to develop typologies of innovation modes or strategies for groups of firms which are IP/technology innovating, marketing based innovating, process modernizing, wider innovating and networked innovating. Westmore (2013) established an empirical link between R&D and patenting, as well as between these measures of innovation intensity and MFP growth. Innovation-specific policies such as R&D tax incentives, direct government support and patent rights are found to be successful in encouraging the innovative activities associated with higher productivity growth. The settings of framework policies relating to product market regulation, openness to trade and debtor protection in bankruptcy provisions are found to be important for the diffusion of new technologies. Nobel and Birkinshaw (1998) showed that: (1) each type of R&D unit is managed primarily through a different mode of control; (2) local and international adaptors both focus their communication on their internal corporate network; and (3) international creators have strong internally and externally oriented networks of relationships.

Marketing and R&D strategies need to be aligned to increase the return from investment in new technologies. A new portfolio approach integrating market and technology portfolios to support market-oriented R&D planning is developed. The integrated portfolio is based on objective market and patent data and empirical evidence that the respective portfolio dimensions impact a company's business performance. This contributes significantly to the relevance of the proposed integrated portfolio approach for strategic planning (Ernst et al., 2004). Since the end of the 1990s, attempts are being made to combine short term financial interests with long term innovation requirements. Many of these attempts can be classified under the heading of Open Innovation, which may be viewed as a company's endeavour to profit from external knowledge without making heavy internal investment in long term research (Wit and Meyer, 2010).

2.3.3.5 Merger and Acquisition for innovation

Strategic alliances have grown in numbers, expressing the importance that this form of organization has for the strategies of many companies. M&As have already been known to companies for a much longer period of time. As far as innovation is concerned, the effect of increased competition through new products and processes has been put on the agenda of both practitioners and academics. The role of M&A in driving innovation appears as significant as the role of R&D, and acquisitions with an innovation focus appear to enhance firm value and performance both in the short term around acquisition announcement and in the long-run after deal completion. Beers and Dekker (2009) stated innovating firms are significantly more involved in acquisition activities than non-innovating firms, which suggests that acquisitions are a strategy to gain access to new technologies or knowledge. According to Mandel and Carew (2011), acquisitions need not diminish competitiveness, even as they accelerate innovation and job growth and periods of high levels of acquisition have also been periods of rapid job growth. Their findings are when done correctly, acquisitions in the technology sector can and have encouraged innovation by bringing new products to market faster and more effectively; and acquisitions and innovation in the technology sector are positively associated with economic growth and job creation.

Using a panel of 535 European, American, and Japanese firms for the years 1987-1997 Arora et al. (2000) found restructuring to be an important component in the observed changes in R&D intensity. They showed that restructuring affects R&D both through changes in size and through changes in the composition of business portfolios, and that these effects differ across industry segments. Hagedoorn and Duysters (2002) explored the preferences that companies have as they use alternative external sources of innovative competencies such as strategic technology alliances, mergers and acquisitions, or a mix of these. The analysis demonstrates that these options are influenced by both different environmental conditions and firm specific circumstances, such as those related to protecting core businesses. Walsh and Lodorfos (2002) focused on strategies of chemical companies on mergers, acquisitions, de-mergers and divestments as the mechanism to move out of their traditional chemical boundary and to diversify into, or increase their reliance on, higher value-added areas such as drugs, agrochemicals, designer crops, specialty chemicals, advanced materials and catalysts, with an increased R&D focus on the life sciences, IT and biotechnology, and of genomics, proteomics and bioinformatics.

Sevilir and Tian (2011) found a significant positive association between the M&A volume of a firm and both the number and the significance of the patents the firm obtains subsequent to its M&A. The results show the target firm's R&D intensity as well as its patent outcomes prior to the acquisition are positively related to the acquirer's contemporaneous as well as subsequent innovation output. These results suggest that acquiring innovative firms enhances the innovation output of the acquirer and the positive association between M&A and innovation output is more pronounced for mature and older firms. To the extent that such firms face greater difficulty in organizing and undertaking innovation internally due to incentive problems, this result suggests that acquiring innovation may be a more efficient strategy for such firms than investing in it internally and M&A activity leads to superior long-term stock price performance if the target firm is more innovative.

Mergers and acquisitions (M&A) in the chemical industry will increase, from a low in 2012, driven by favorable financing conditions, geographic expansion, Asian consolidation, and favorable feedstock conditions in Canada, the United States, and Mexico (ATkearney, 2013). The investor will be those with strong balance sheets, growing home markets, access to financing, and the confidence to invest despite an uncertain global economic outlook. This report presents a review of M&A activity, based on an analysis of all completed deals in the chemical industry in the period 2001-2012 and provides an outlook for 2013 (KPMG, 2013). M&A will remain a strategic instrument in the industry; however, chemicals players need to make it an integral part of their business strategy. To succeed in this environment, they must build the right capabilities along the full M&A life cycle and move toward the largely unknown territory of cross-regional deals (Boo&co, 2014). Cefis and Sabidussi´s (2011) results showed that M&A activities performed in the previous 3-5 years have a positive and significant effect on all innovation dimensions we have investigated with the exception of the R&D and innovation efficiencies in terms of new products for the market. Acquisition motivated by knowledge barriers in the innovation process affect the probability of positive innovative sales positively while acquisitions motivated by other reasons than innovation barriers affect this probability negatively (Beers and Dekker 2009).

Using a large and unique patent-merger dataset over the period 1984 to 2006, Bena and Li (2013) showed that companies with large patent portfolios and low R&D expenses are acquirers, while companies with high R&D expenses and slow growth in patent output are target firms. M&A activity has significantly shaped the chemical industry landscape in the recent past, and it will continue to do so. Chemicals companies are constantly in quest of growth in an industry that offers ever-fewer and ever-smaller attractive growth segments and where incumbents face greater competition from upstarts in developing markets (Booz&co, 2014). Further, technological overlap between any two firms has a positive effect on transaction incidence, and this effect is reduced for firm pairs that overlap in product markets. We also show that acquirers with prior technological linkage to their target firms produce more patents afterwards. Beers and Dekker (2009) concluded that synergies obtained from combining innovation capabilities are important drivers of acquisitions. Beers and Dekker (2009) states lack of knowledge as a barrier to innovate increases the chance of acquiring assets of other firms although not significantly while lack of finance as a barrier to innovate increases significantly the chance of divesting assets.

Non-technological M&As appear to have a negative impact on the acquiring firm's post-M&A innovative performance. With respect to technological M&As, a large relative size of the acquired knowledge base reduces the innovative performance of the acquiring firm (Cloodt et al., 2006). The absolute size of the acquired knowledge base only has a positive effect during the first couple of years after which the effect turns around and we see a negative effect on the innovative performance of the acquiring firm. The relatedness between the acquired and acquiring firms' knowledge bases has a curvilinear impact on the acquiring firm's innovative performance. This indicates that companies should target M&A 'partners' that are neither too unrelated nor too similar in terms of their knowledge base (Beers and Dekker, 2009).

2.3.4 Output and impact of innovation

This section deals with the literature around the output variables of innovation and its impact on the company pursuing innovation strategy.

2.3.4.1 R&D Tax benefit

In an effort to increase their level of innovation many countries have turned to
fiscal incentives for R&D, often involving substantial sums of taxpayers' money. Economists, however, have generally been skeptical of the efficacy of tax incentives. One cause of this skepticism is the view that R&D is not very sensitive to changes in its (after tax) Price. Tax incentives are effective in increasing R&D intensity. This is true even after allowing for permanent country-specific characteristics, world macro shocks and other policy influences (Bloom et al., 2000). Ernst and Spengel (2011) came to similar conclusión that tax Incentives has a very positive impact on research and development and patent Applications. As large firms maintain offices in various countries, they are in the best position to optimally divide their R&D activities and patent earnings to take advantage of tax benefits. They also mention that targeted tax incentives would strengthen Germany's position as a center for research and it is

particularly important for chemical industry which will improve business competitiveness while also creating and securing jobs. An analysis of twenty industrialized countries showed that reducing the combined corporate income tax rate by ten percentage points increases the average number of patent applications filed by a firm in these countries by 0.09 which means that for every 1,000 patent applications, 90 additional applications would be filed (Hall and Reenen, 2000).

Many countries are promoting optimization of R&D operations including re-location as part of their innovation-led economic development strategies. R&D tax incentives are an important component of these strategies and countries offering R&D tax incentives are often regarded as a favourable location for internationally-mobile R&D (Deloitte, 2012). The report by Hall and Reenen (2000) give country by country R&D tax incentives and also states that a few regimes offer tax benefits for capital investments in R&D, while most offer incentives for operational costs, i.e., wages, supplies and contractor fees. Some countries offer particularly lucrative incentives, subject to few restrictions on the location of the qualified research activity, funding of R&D, ownership of IP, etc.; while others offer basic incentives with significant limitations, including eligible industries, qualified costs, and applications procedures. Most research incentives are designed to encourage companies to maintain a certain level of R&D, with additional incentives for increased research spending (Russo, 2004).

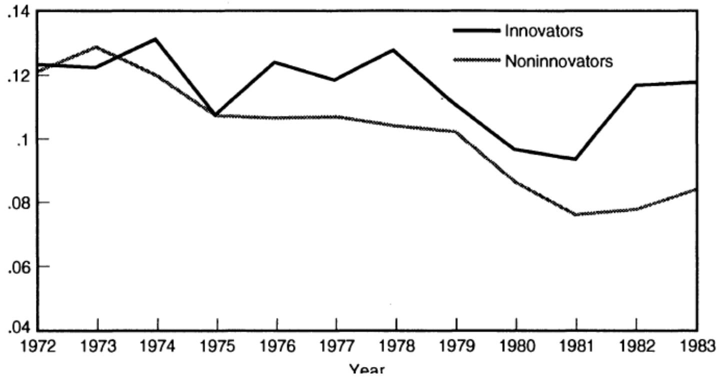
The study from KPMG (2012) stated that many EMEA countries that may once have inadvertently discouraged investment in R&D by requiring expenditure to be capitalized now permit a current tax deduction for the cost of R&D activities. Many also allow enhanced deduction and/or social tax credit for R&D cost. The net cost of performing R&D should be considered in conjunction with the strategy for managing the potential IP created by successful research. Short term measures implemented by governments as economic stimulus package in response to the global financial crisis, such as accelerated deduction programs for investment intangible depreciable assets are worth taking into account as these may top up existing benefits delivered through R&D incentives (Lokshin and Mohnen, 2013).

2.3.4.2 Higher productivity and profitability

Innovation is vital to a healthy, competitive economy and is one of the principal drivers of growth. Innovative economies are more productive and grow faster. Innovation is the secret to competitive advantage in today's rapidly changing environment, but how does a company ensure an innovative environment (Higgins, 2009)? Similar thought was expressed by Lengnick-Hall (1992) and states innovation, technology advances, and competitive advantage are connected by complex and multidimensional relationships.
The study conducted by Abernathy (1985) showed the capacity of an innovation to influence the established systems of production and marketing. The paper brought together fresh analytical thinking and evidence to inform policy and emphasised the need to focus on facilitating collaboration between organisations, driving innovation across all sectors of the economy, maximising the effectiveness and connectivity of the innovation ecosystem and transforming the public sector into a major driver of innovation.

The report from NESTA (2009) presented the pilot version of NESTA's Innovation Index. The aim of the Innovation Index project is to provide a basis for better policymaking about innovation by developing and deploying significantly improved measures of innovation in the UK. Nås and Leppãlahti (1997) studied the relationships between innovative activity, profitability and firm growth in Norwegian industry in 1992 and showed that there is a close positive relationship between the three. Geroski et al. (1993) study showed that the number of innovations produced by a firm has a positive effect on its profitability, but the effect is, on average, only rather modest in size and it is, of course, possible that this kind of reward is commensurate with the efforts made by the firms themselves. They also observed that although innovators seem to enjoy higher profit margins because of the specific innovations they introduce, substantial permanent differences in the profitability of innovating and non-innovating firms also exist that are not closely timed with the introduction of specific innovations as seen the graph in figure 19.

Figure 19. Average profit margin of UK manufacturing firms between 1972 and 1983



Source: Geroski et al. (1993)

Both product and process innovation have a positive impact on firm's productivity, especially process innovation. Among SMEs, larger and older firms seem to be less productive (Hall et al., 2009). Similar findings were observed by Geroski (1993) where he concluded that innovative activity have a larger positive effect on total factor productivity growth.

2.3.4.3 Greener chemistry

Green Chemistry is a relatively new emerging field that strives to work at the molecular level to achieve sustainability. The field has received widespread interest in the past decade due to its ability to harness chemical innovation to meet environmental and economic goals simultaneously. Anastas and Eghbali (2009) defined the green chemistry and its impact in driving research with focus on large innovative chemical companies. Green Chemistry has a framework of a cohesive set of twelve principles, which have been systematically surveyed in this critical review. In this study, they concluded Green Chemistry has shown that through innovation, companies can be economically more profitable and more environmental benign at the same time. After reviewing the literatures, it seems that although an impressive amount of work has been done by practitioners of Green Chemistry around the world, the achievements of the past is pale in comparison to the power and potential of the field (Constable et al., 2002).

After studying all 3200 green chemistry patents which were granted in the US patent system between 1983 and 2001, Nameroff et al. (2004) found that university and government sectors place greater emphasis on green chemistry than most industrial sectors. Nameroff et al. `s (2004) also stated that Green chemistry patents are an indicator of environmental innovation and R&D. They found that university and government sectors place greater emphasis on green chemistry than most industrial sectors. Worldwide, the emphasis on green chemistry technology relative to chemical, plastic, rubber, and polymer technologies has increased since 1988 (Beach and Anastas, 2009). The United States appears to have a competitive advantage in green chemistry with the most rapid growth in the emphasis on US green chemistry patents coincides with revisions to major US environmental laws in the late 1980s and early 1990s. However, the ratio of green chemistry patents to patents in other areas of chemical sciences in heavily regulated industries are low, suggesting that these industries did not necessarily embrace green chemistry as a means to reduce their regulatory burden (Epiccoco et al. 2014). Nameroff et al (2004) study showed in the time frame of their reseach, 24 % of all green patents were from Europe and the graph (figure 20) below shows the rising trend of green patent in US.

Figure 20. The green chemistry patent in US over the years

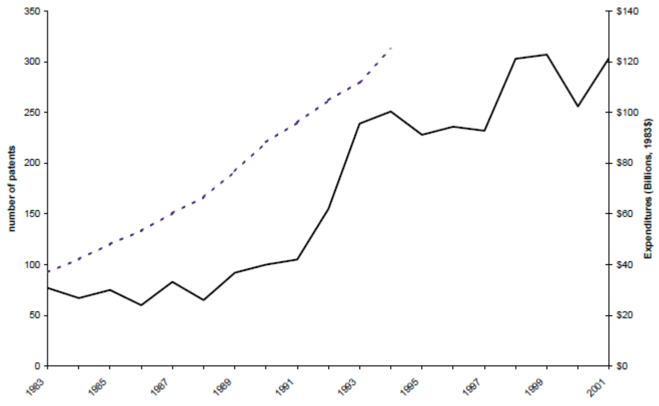


Fig. 1. US green chemistry patents (solid line) granted over the time period 1983–2001. US Pollution Abatement and Control Expenditures (Vogan, 1996) are indicated by the dashed line.

Source: Nameroff et al. (2004)

Clark (1998) stated that the drive towards clean technology in the chemical industry and the emergence of green chemistry related issues in chemical research and education are unlikely to be short term ‘fashions’and is already becoming evident that the more successful chemical manufacturing companies of the future will be those that can exploit the economic, legislative and public image advantages that a clean technology approach to chemical manufacturing can provide. The term 'Green Chemistry' was first coined by the US Environmental Protection Agency (EPA) in the early 1990s and major interest in green chemistry in the US began in earnest with the passage of the 'Pollution Prevention Act' of 1990 (Constable et al., 2002). Thus Green Chemistry becoming a formal focus of the EPA in 1991. Kerton and Marriot (2013) in their book emphasized that the more successful chemistry researchers and educationalists will be those that can appreciate the value of green chemistry in innovation, application and teaching. While Liu et al. (2013) states that many exciting new greener chemical processes are being developed it is clear that a far greater number of challenges lie ahead. In two of the largest generic areas of chemistry, acid catalysis and partial oxidations, there are countless processes operated by almost every type of chemical manufacturing company, producing products of incalculable value yet also producing almost immeasurable volumes of hazardous waste (Liu et al., 2013) and so new greener chemistry is needed.

The drive towards clean technology in the chemical industry with an increasing emphasis on the reduction of waste at source requires a level of innovation and new technology that the chemical industry is beginning to adopt (Kidwai and Mohan, 2005). The green chemistry revolution provides an enormous number of opportunities to discover and apply new synthetic approaches using alternative feedstocks; ecofriendly reaction conditions, energy minimizations and the design of less toxic and inherently safer chemicals. It focusses on examples of interest of green chemistry in industry, education, Atom efficiency, energy conservation and also suggests several green alternative chemicals in place of currently used non-green chemical products and process (Kerton and Marriot, 2013).

Jimenez-Gonzalez et al (2011) presented a number of different green metrics that can be used to assess a chemical process or system in the Pharmaceutical Industry, but can be extended to other type of chemical enterprises. It should have become clear that there is not one unified metric available to measure the 'greenness' of a chemical process. The green metrics one chooses to use must be adapted for their context and continuously evaluated as to their utility, applicability and appropriateness. They should also be tested and validated regularly to ensure that they are successfully driving towards the desired goals set by the organization (Androas, 2005). Schwarzmann and Wilson (2009) criticized the US chemical policy and identified three gaps in the Toxic Substances Control Act of 1976 (TSCA). They also mentioned several regulations and states that Chemicals policy should be comprehensive, transparent, market driven, functioning governance, cross-disciplinary, new science and systems-thinking which at the end will drive innovation. They also discussed about the EU regulation to control the toxic chemicals.

2.3.5 Barriers to innovation

This section deals with the literature around barriers to innovation and also the ways to overcome such barrier.

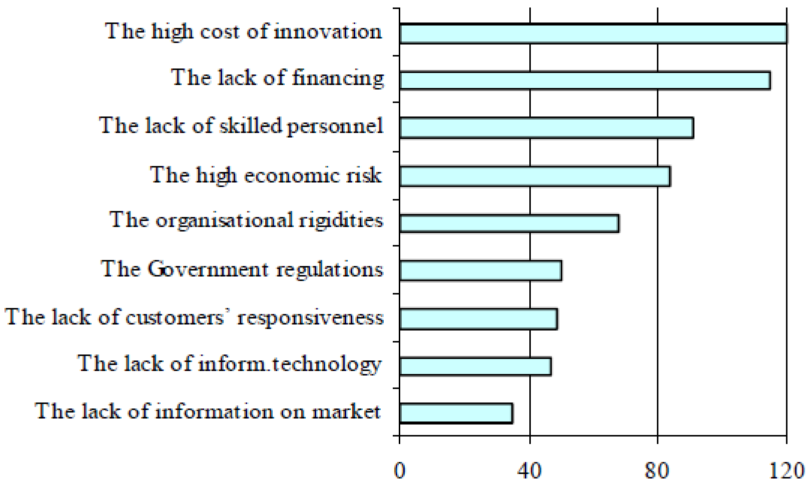
2.3.5.1 What are the barriers to innovation?

Barriers to industrial innovation have been studied extensively in other technological areas. GE's 2013 Global Innovation Barometer returned results that indicated that over 90% of global executives and 88% of U.S. executives believe that innovation is a strategic priority and that 92% said that it was the main ingredient for a more competitive economy (GE, 2013). At the same time, over 90% of all new products introduced to the U.S. market every year fail, and the U.S. ranks only 10th in innovation behind countries such as Finland and Hong Kong (Curtis, 2013).

A recent European Union study on the barriers to efficiency identified economic, behavioral, and organizational barriers, such as tax incentives, accountancy practices, and the low status of managers in some organizations (Foxen, 2002). Hadjimanolis (1999) conducted in Cyprus, a small less developed country, a research on barrier to innovation. The study provided some interesting clues to the innovation practice in small less developed countries. Some barriers similar to industrialized countries (e.g. in supply of finance and skilled labour) were found, but many differences as well noticed, as expected from the peculiar environment of a less technologically developed country. The role of Government policies was of particular importance. The finding from the study conducted by Madrid-Guijarro et al. (2009) could be used in the development of public policy aimed at supporting and encouraging the innovation among SMEs in

Spain. Government policies that encourage and support innovation among all firms, especially small firms, can help countries remain competitive in a global market. Understanding barriers can assist managers in fostering an innovative culture by supporting new ideas or by avoiding an attitude that creates resistance to new ideas. Thölke et al. (2001) reflected three key areas of concerns: How to minimize risks when launching a new product on the market?, How to manage fragmented markets with existing resources?, How to maximize conversion of opportunities into sales?. They also suggested some remedies to tackle these issues. The study from Silva et al. (2007) laid down the barrier for innovation as shown in figure 21.

Figure 21. The barriers to innovation



Source: Silva (2007)

Engineers in petrochemical plants are often occupied with ''putting out fires'' (troubleshooting). Little time is left for understanding current energy use or collecting information on innovative energy-efficient technologies. Small projects receive even less manpower than larger projects. A study done by IBM (2006), the five barriers for innovation that were identified are: inadequate funding, risk avoidance, siloing, time commitments, incorrect measures. Getting the start-up funds for an innovation often means taking money away from an established program. Getting the money at just the right time is also problematic since organizations often work on annual funding cycles that don't match up well with real-world opportunities. But broader thinking on needs and resources can help innovators move their ideas along. The work by Segarra-Blasco et al. (2007) laid similar factors which act as barrier to innovation as shown below:

1. *Cost barriers*
- Lack of internal funds
- Lack of external funds
- Direct innovation costs too high
2. *Knowledge barriers*
- Lack of qualified personnel
- Lack of information on technology
- Lack of information on markets
- Barriers to finding partners for innovation
3. *Market barriers*
- Market dominated by established enterprises
- Uncertain demand for innovative goods or services
- Lack of demand for innovation

2.3.5.2 How to overcome barriers to innovation?

Cahill (2012) outlines some of the ways to overcome barriers to innovation. The suggested methods as laid by him are:

1. Clearly-articulated innovation and IP strategy based on competitive intelligence
2. Execution plan with process owners and milestones
3. Success metrics
4. Risk-adjusted estimate of the business value that will be created
5. Detailed analysis of the investment required for effective execution of the strategy.

Similar points are laid down by Hanselman (2013) to overcome the barriers to innovation in a manufacturing company. Peterson (2010) in her study identified the barriers to innovation and stated the methods as how to overcome each of these barriers through project initiated through R&D, better engagement of the team members, open customer-centered and iterative, engage employees to participate in innovation, foster a culture of innovation and drive ideas to action to generate organic growth.

2.3.6 Marketing Innovation

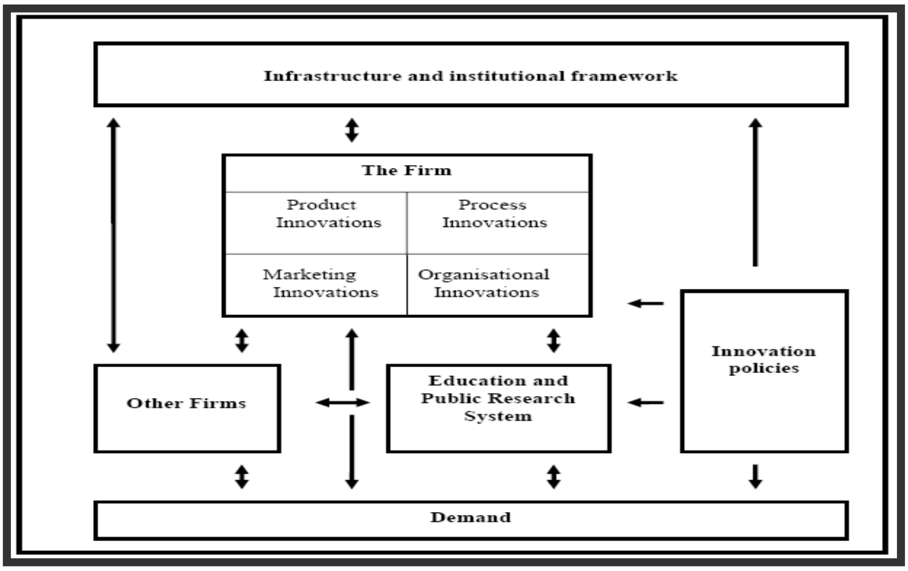
Marketing is a well-developed methodological science and is constantly changing its rules according to the needs and developments taking place in and around it. To establish itself in the new era, it has begun adapting the new methods of virtues to come to terms with the new paradigms of business. The role of marketing in the development of business is intact but the way it was executed is radically changing due to contributions made by satellite communication and extensively developed scientific devices.

According to UNESCO (2012), marketing Innovation is implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. It also states that it includes better addressing customer needs, opening up new markets, or newly positioning a firm's product on the market thus increasing firm's sales; Marketing method such as digital marketing that was not previously used for part of a new marketing concept or strategy.

There have been several books and publications focussing on marketing innovation in the field of digital marketing but none has been focussing on the chemical industry. It makes use of electronic devices (computers) such as personal computers, smartphones, cellphones, tablets and game consoles to engage with stakeholders. Similar comments are made by Chaffey and Ellis-Chadwick (2012) that digital marketing applies technologies or platforms such as websites, e-mail, apps (classic and mobile) and social networks.

UNESCO (2012) stated that in a firm there are four types of innovation: Product, Process, Organizational and Marketing. It also commented that innovation in marketing many a times is over looked (figure 22).

Figure 22. The various types of innovation in a firm



Source: UNESCO (2012)

Doyle and Bridgewater (1998) stated the importance of market-led innovation and gave example of several case studies as illustrations of successful market-led innovation. They also explained the innovation process, obstacles to innovation, and the role of marketing in building successful new product and services. The case study showed that innovation is the result of a complex set of processes and it depends upon the organization´s marketing ability, its strategy, the resources, networks and process it builds, together with the culture and leadership in the firm. Gupta and Malhotra (2013) in their work conceptualize a model for fostering innovation in marketing by virtue of the competitiveness that is an outcome of the collaboration between international and local firms working together in emerging markets.

Digital Marketing can be through Non-internet channels like TV, Radio, SMS, etc or through Internet channels like Social Media, E-mails ads, Banner ads, etc. Social media marketing is a component of digital marketing (Chaffey and Smith, 2012). Many organizations use a combination of traditional and digital marketing channels; however, digital marketing is becoming more popular with marketers as it allows them to track their Return on Investment (ROI) more accurately compared to other traditional marketing channels (Greenberg and Kates, 2013).

Chaffey and Ellis- Chadcoick (2012) examined how industrial business-to-business (B2B) firms could interact with their products' end-users via social media in order to receive new ideas, feedback and solutions to improve their innovation process. They proposed a framework to assess how social media and crowdsourcing can be integrated in an industrial B2B context. The results of this work reveal significant practical challenges to overcome before social media can be effectively utilized in the industrial B2B sector as a fully functioning crowdsourcing enabler.

Two big changes in digital world are social and mobile. Social media has already revolutionized marketing and mobile marketing has finally become mainstream. According to Kalpan (2012), other key components of digital marketing are content marketing, digital body language, inbound marketing, marketing automation, remarketing, earned, owned and paid media, the Ladder of Engagement and many more. With additional digital marketing channels and platforms, the complexity of manging e-marketing has become more challenging.

The study from Damian (2014) showed that despite the wonderful new tools available to marketers (many of which are free or cost-effective), overall, that customers are still confronted with an awful lot of sloppy marketing. Web site that underperform; Facebook questions or comments that aren´t answered; telephone or email leads that aren´t followed up; poor integration with offline communications that complicate or even contradict basic marketing principles. Time-compressed, information-fatigued customers are angry and statisfaction levels are wavering.

Chaffey and Smith (2012) give examples where companies have achieved success with digital marketing tools. It is relatively easy to give customers the attention they deserve. It is easier to learn about customer needs. It´s also easier to tailor and target relevant content and relevant products and services to the right customer. Its a question of systems- organizing processes and systems and resources in a more cost-effective manner.

Damian (2014) forecasted that customers would start to consolidate their choices too fewer, better, added-value sites and services. Many have not implemented or refined many of the core digital marketing capabilities while many have not implemented or refined many of the core digital marketing techniques, such as search engine optimization, partner marketing, personalized web recommendation, A/B and multivariate testing and automated email contact strategies.

Wymbs (2011) proposed that there is a need for a radical redesign of the marketing curriculum as the rapidly emerging digital economy is challenging the relevance of existing marketing practices. This article described the need for a fundamental change in the teaching of marketing in today's environment, performs a curriculum audit of existing digital marketing initiatives, and then details a new curriculum reflective of marketing in a digital age and an approach to implement it. Royle and Laing (2014) suggested that there are digital marketing skills gaps in industry, but these skills gaps are not clearly identified. The research aims to specify any digital marketing skills gaps encountered by professionals working in communication industries. From the study they found that a lack of specific technical skills; a need for best practice guidance on evaluation metrics, and a lack of intelligent future proofing for dynamic technological change and development are skills gaps currently challenging the communication industry. It was also identified that there are challenges of integrating digital marketing approaches with established marketing practice due to key skills gap.

2.4. Summary:

The current literature review gives a very comprehensive picture about the research in the field of innovation especially in manufacturing sector. The literature review shows that there has been considerable amount of research done in innovation. Various aspects of innovation have also been studied in details covering various industries. Some of the methodologies which have been used for previous study for other industry can be used for the current project. Even though we have witnessed fall and subsequent rise of innovation in Chemical industry, theoretical understanding of the input variables and financial – and non-financial determinants of this innovation trend in large chemical companies is largely underdeveloped. As a result this current research is even more interesting. The literature research shows that there have been several discussions and concerns about the European chemical industry losing its ground but none of them talks about the strategy the companies are taking to overcome the challenging situation. Some literatures talk about the innovation matrix of both chemical and petro chemical industry. There was significant evidence from the literature that large chemical companies are transitioning from a closed to open innovation strategy. There has been concern shown by several researchers about the new product development process in chemical industry. They also suggested by reducing the internet transaction costs associated with R&D, coordination across units, centralized R&D will generate innovations that have a larger and broader impact. Most of the research emphasized on human capital and a double way relation between the capacity of innovation and the stock of human chemical. Many previous researches have shown that successful companies in many sectors are concentrated in a moderate number of locations, rather than being distributed evenly across geography. There have been several researches done on the impact of the new chemical regulation REACH on the European chemical industry. In many instances companies have considered the activities around the compliance with the Regulation as a distraction from their normal, planned innovation activities and to be unintended consequence of the regulation. Most researches focused on the quality rather than volume of the patent, but still argued that patent is a key indicator of R&D activities and innovation. Accelerated transfer of knowledge, technology, know-how, and people from university to industry is a subject of great interest to academics, industry leaders and policy makers in recent years.

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3. Innovation and the hypotheses for the research

Contents

3.1 Introduction

Innovation is the process of translating an idea or invention into goods or service that creates value or for which customers will pay. Innovation is a new idea, device or process and is viewed as the application of better solutions that meet new requirements, in articulated needs, or existing market needs. This is accomplished through more effective products, processes, services, technologies, or ideas that are readily available to markets, governments and society and is at the heart of economic change. This chapter deals with the fundamentals and basic theory of innovation. It states various types of innovation commonly seen in the industry and the strategies commonly undertaken by the companies in order to achieve that goal. In this chapter we also look into the fact why companies are inclined to innovation and what benefit it brings to them. We also look into the source of various types of innovation and its impact on the companies. The later part of this chapter covers the hypothesis that is planned to be tested for the current research and the justification of selecting those hypothesis and parameters that would be used for testing them.

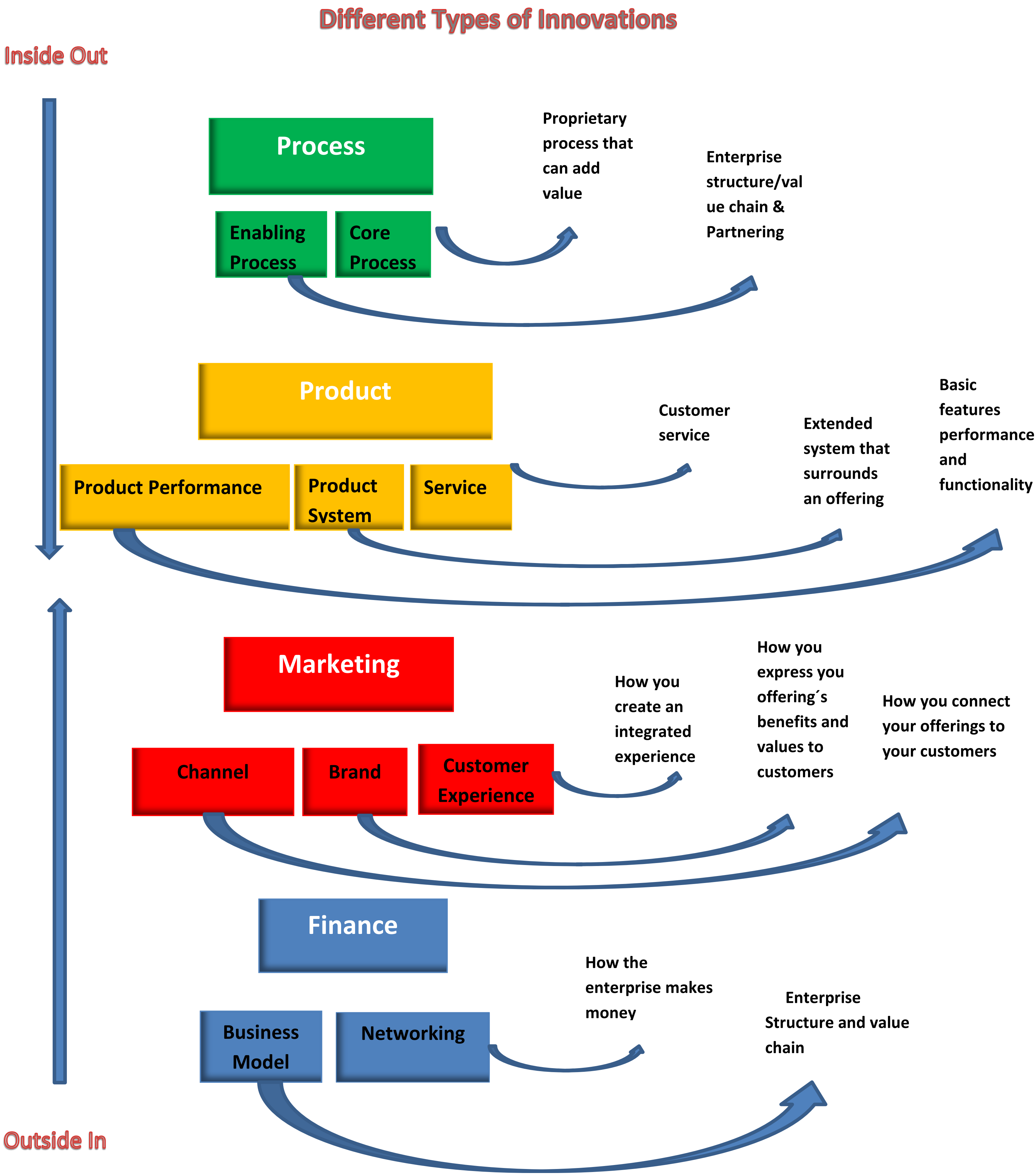
3.2 Innovation in an industrial environment

Schumpeter (1934) comments that “radical” innovations shape big changes in the world, whereas “incremental” innovations fill in the process of change continuously.
Various types of innovations as proposed by Schumpeter (1934) are:

- introduction of a new product or a qualitative change in an existing product;
- process innovation new to an industry;
- the opening of a new market;
- development of new sources of supply for raw materials or other inputs;
- changes in industrial organisation.

According to UNESCO (2012), the innovation in a company can be broadly divided into four types: Product innovation, Process Innovation, Marketing innovation, Innovation in Finance. This can be sub-divided into ten group of innovation as shown in the figure 23. The innovation in a company can be inside-out or outside-in.

Figure 23. Ten different types of innovation in any business



Source: Author

The options open to a firm which wants to innovate are of three kinds: strategic, R&D and non-R&D (European Commission, 2010):

- **Strategic:** To make decisions about the types of markets they serve, or seek to create, and the types of innovations they will attempt there.

- **R&D:** Some of the options relate to R&D are:
  – undertake basic research to extend its knowledge of fundamental processes related to what it produces;
  – develop product concepts to judge whether they are feasible and viable, a stage which involves prototype design, development and testing; and further research to modify designs or technical functions.

• **Non-R&D:** The firm may engage in many other activities that do not have any straightforward relation to R&D, and are not defined as R&D, yet play a major role in corporate innovation and performance:
– it can identify new product concepts and production technologies via its marketing side;

3.3 Objectives and Sources of innovation

It is recommended that a firm's reasons for engaging in innovation activity should be identified via its economic objectives in terms of products and markets, and how it rates a number of goals that process innovation can bring within reach. The question should relate to all of its innovation activities.

The main objectives for innovation are (European Commission, 2010):

- Replace products being phased out through:
  extend product range:
  develop environment-friendly products;
- Maintain market share through:
  increase market share;
  open up new markets (abroad or new domestic target groups)

- Improve production flexibility and lower production costs;
- Improve product quality and Improve working conditions;
- Reduce environmental damage.

There are various sources for innovation as laid down below:

Internal sources within the firm or business group:

- in-house research and development;
- production;
- marketing;
- other internal sources.

External market/commercial sources:

- competitors;
- clients or customers;
- acquisition of disembodied technology;
- consultancy firms;
- patent disclosures;
- professional conferences, meetings and journals;
- fairs and exhibitions.

3.4 The impact of innovations on the performance of the enterprise

Metrics can be important levers of innovation – for driving behavior, as well as evaluating the results of specific initiatives. Companies like 3M and Google have had innovation metrics for years – the most noteworthy that 10% of employees' time is dedicated for experimentation with new opportunities. Defining the right metrics for any business can be tricky. There's generally no one right answer and agreeing on what to measure can feel more like art than science.

The heart of the problem is that today's competitive environment is radically different from the industrial environment in which traditional innovation metrics were born. Because most metrics programs begin with benchmarks of established companies that have been successful with new products, metrics tend to revert back to traditional measures of R&D or technology investment and effectiveness.

Various indicators can be used to measure the impact of innovations on the performance of the firm. These indicators are:

- Number of patents filed in the past year
- Annual R&D budget as a percentage of annual sales
- Percentage of sales from products introduced in the past X year(s)
- The proportion of sales due to technologically new or improved products;
- The results of innovation effort
- The impact of innovation on the use of factors of production.
- Number of active projects
- Number of ideas submitted by employees or number patent applications

3.5 Hypothesis for this study

In the current research, we will like to accept or reject some of the hypothesis related to innovation in chemical Company in Europe. The five hypotheses that we want to test are:

Hypothesis 1: Chemical companies in Europe, particularly large chemical companies have over the years a positive upward trend in innovation.

Hypothesis 2: Large chemical companies are focusing on research and development by increasing R&D spending.

Hypothesis 3: Large chemical companies in Europe are using re-organization in terms of merger & acquisition and also university collaborations to promote their innovation.

Hypothesis 4: Innovation in European chemical industry is influenced by chemical clusters, geographical distribution of the chemical companies and by new chemical regulation (REACH).

Hypothesis 5: Chemical industry in Europe is stepping into digitalization to bring innovation in marketing.

3.6 How to test the hypotheses?

Now we will explain the approaches that will be taken to test these hypotheses.

Hypothesis 1: Chemical companies in Europe, particularly large chemical companies have over the years a positive upward trend in innovation.

Although both industrial and academic researchers have tried to measure significance or impact of innovations using several methods, there is no commonly accepted way to measure innovation. Some authors have used qualitative data such as expert or manager interviews to determine the most radical innovations in the industry (see for example Achilladelis et al., 1990; Green et al., 1995; Henderson, 1993). Anderson and Tushman (1990) combine qualitative methods with quantitative data. These measures of innovation have two main drawback. First, in many studies evaluation of radicality is based on subjective assessments by managers, industry experts, or customers and reliability of these measures is context-dependent. Second, collecting this qualitative data is time- and resource-consuming.

The two weaknesses of innovation measures discussed above can be, however, addressed by patent-based measures as described in this study. First, by definition, patents provide a relatively objective measure of new knowledge. Patents are required to describe something novel and not obvious; to be patented "an invention must be something not already known from prior publication, or not a part of the experience of those skilled in the art" (Walker, 1995). Patents thus provide a good measure of technologically new knowledge as defined above. Several studies have recently used patents as a measure of innovation performance (Dutta and Weiss, 1997; Henderson and Cockburn, 1994).

According to Arundel and Kabla (1998), for chemical and pharmaceutical industry, there is a good relationship between innovations and patenting which is not be the same for other industry. The evidence from empirical study from Acs et al. (2001) suggests that patents provide a fairly reliable measure of innovative activity. Similar view is represented by the study by Thomson Reuter (2013), where they used patents as the indicator to rank top 100 innovative companies in the world. For our current research, we will consider number of patents applied and granted as the indicator of innovation. The study by Breiztman (2013) shows that large firms have a higher percentage of both granted patents and patent applications than small companies and this is especially noticeable during the recession of 2008-09.

Second, in addition to the methodological strengths of patent-based measures, also the availability of patent data motivates the use and research on patent-based measures of innovation. Electronic access to patent data through for example EPO and US Patent and Trademark Office databases has increased the use of patents in industrial and academic research (Pavitt, 1988; Walker, 1995). Arora and Gambardella (1994) further argue that the importance of patents as innovation appropriability mechanisms will be increasing in many industries in the future as several technological disciplines become more universal and the knowledge will be easier to articulate for patenting. Thus, patents are even more likely to be used as measures of innovation in future research.

Based on these previous researches, patent data was selected as the metric for current research for measuring the innovation trend of the large chemical companies headquartered in Europe. In the first hypothesis we want to test if there is a proper trend in innovation of the European chemical industry and large companies in particular.

Hypothesis 2: Large chemical companies are focusing on research and development by increasing R&D spending

R&D is an activity involving significant transfers of resources among units, organisations and sectors and especially between government and other performers. R&D expenditure refers to resources actually spent in R&D activities, rather than only budgeted. Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development. The second hypothesis will test if the large European chemical companies are focussing more on R&D by increasing allotment for R&D spending.

Hypothesis 3: Large chemical companies is using re-organization in terms of Merger & Acquisition and also university collaborations to promote their innovation.

Beers and Dekker (2009) stated innovating firms are significantly more involved in acquisition activities than non-innovating firms, which suggests that acquisitions are a strategy to gain access to new technologies or knowledge. Mandel and Carew (2011), state that acquisitions accelerate innovation and job growth while Arora et al. (2001) find restructuring to be an important component in the observed changes in R&D intensity. So the first part of this hypothesis tests if the merger and acquisition has any impact on innovation of large chemical companies of Europe.
Mansfield (1990) suggested that about one-tenth of the new products and processes commercialized during 1975-85 in the information processing , electrical equipment, chemicals, instruments, drugs, metals, and oil industries could not have been developed (without substantial delay) without recent academic research. The second part of the hypothesis tests the impact of university and research institute collaboration in driving innovation for the companies under study.

Hypothesis 4: Innovation in European chemical industry is influenced by chemical clusters, geographical distribution of the chemical companies and by new chemical regulation (REACH).

A business cluster is a geographic concentration of interconnected businesses, suppliers, and associated institutions in a particular field. Clusters are considered to increase the productivity with which companies can compete, nationally and globally. Clusters are also very important aspects of strategic management. The first part of this hypothesis test the impact of chemical clusters on innovation tendency of European chemical industry.

REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. It also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals. Second part of the hypothesis tests the impact of REACH on innovation of the chemical industry in Europe.

Hypothesis 5: Chemical industry in Europe is stepping into digitalization to bring innovation in marketing.

Companies across industries are racing to migrate from "analog" approaches to customers, products, services, and operating models to an always-on, real-time, and information rich marketplace. Some leaders are redesigning their capabilities and operating models to take full advantage of digital technologies to keep step with the "connected" consumer and attract talent. Others are creating qualitatively new business models — and tremendous value — around disruptive digital opportunities. In doing so, these companies secure not only continued relevance, but also superior returns. Digital marketing is marketing that makes use of electronic devices (computers) such as personal computers, smartphones, cellphones, tablets and game consoles to engage with stakeholders. Social Media Marketing is a component of digital marketing. Many organizations use a combination of traditional and digital marketing channels. This hypothesis test whether the European chemical industry has already adopted digitalization in their business and specially in marketing.

3.7 Summary

Innovation is defined as a better solution which has significant impact to business in improving its position and profitability. There are ten different types of innovation available. We will test five hypothesis related to innovation in large chemical companies which are head quartered in Europe. The first hypothesis will test the trend of innovation in large chemical companies head quartered in Europe while the remaining four will test the impacting factors of such innovation trend.

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4. European chemical industry and the top European chemical companies

Contents

4.1 Introduction

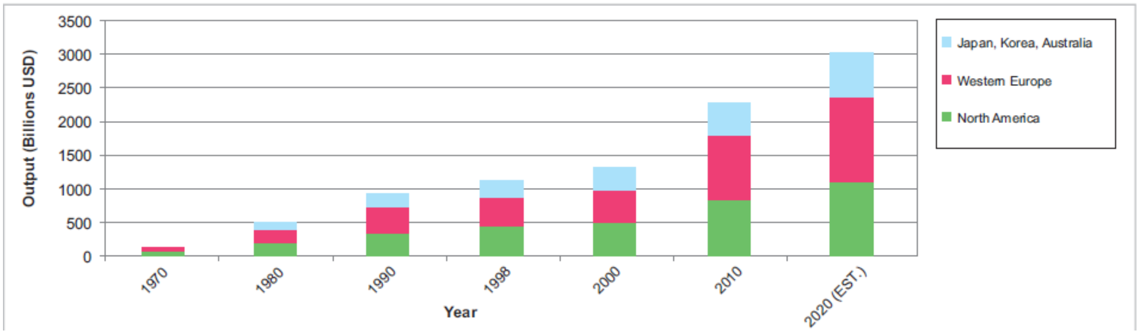
The global chemicals industry has grown rapidly over the past several decades. Within the last decade in particular, this growth has been driven primarily by dramatic growth in developing countries and countries with economies in transition. The industry is undergoing dynamic change, with a range of external factors presenting industry executives with vastly divergent challenges in different regions of the world. Fundamentally, the industry continues to be driven by two main factors: Global GDP dependence, which necessitates vastly different behaviors in emerging markets which continue to expand (albeit at volatile rates); Europe, where embedded structural issues point to long-term stagnation; and the US where a sustained economic recovery seems to be taking hold; and Global issues including population growth and middle class expansion; food and water shortage; energy and climate change, all of which drive demand for chemical products under the mantra of making life better and our planet healthier – continuing to drive the march downstream and the search for higher value, science-based chemical products. This chapter gives an overview of the global and European chemical industry and explains how the industry was affected by global economic crisis. In the later part of the chapter, we talk in details each of the nineteen chemical companies under current study.

4.2 Global chemical industry

The global chemicals industry has grown steadily over the past several decades. Chemical industry data cited by OECD indicate that global chemical industry output was valued at US$ 171 billion in 1970. In 2010, industry sources valued

Global output at US$ 4.12 trillion. The figure 24 shows as how the output of the chemical companies is increasing steadily for last 40 years in the developed economy. It is seen in the graph that the largest growth has happened in the last decade with Western Europe playing a significant role.

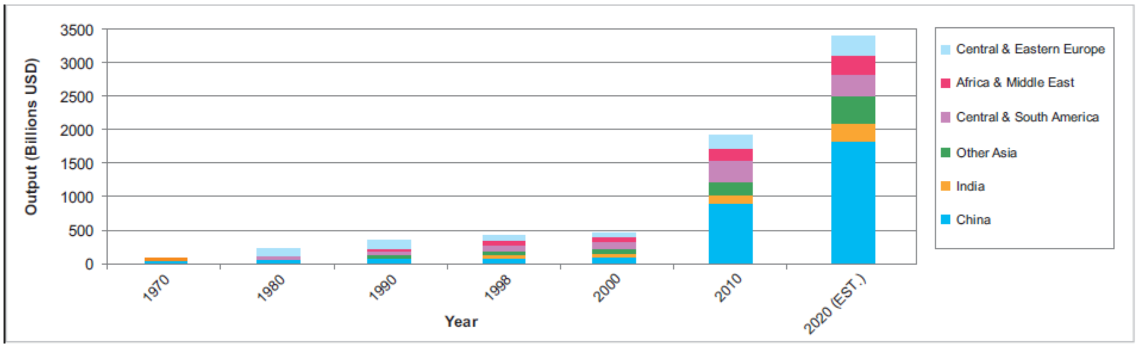
Figure 24. Chemical output in the developed region



Source: Chemical Outlook (2012)

In the figure 25, we see that the chemical output from the developing economy is expected to be higher than developed economy for the year 2010.For last fifteen years; Asia has played a very significant role in boosting chemical output.

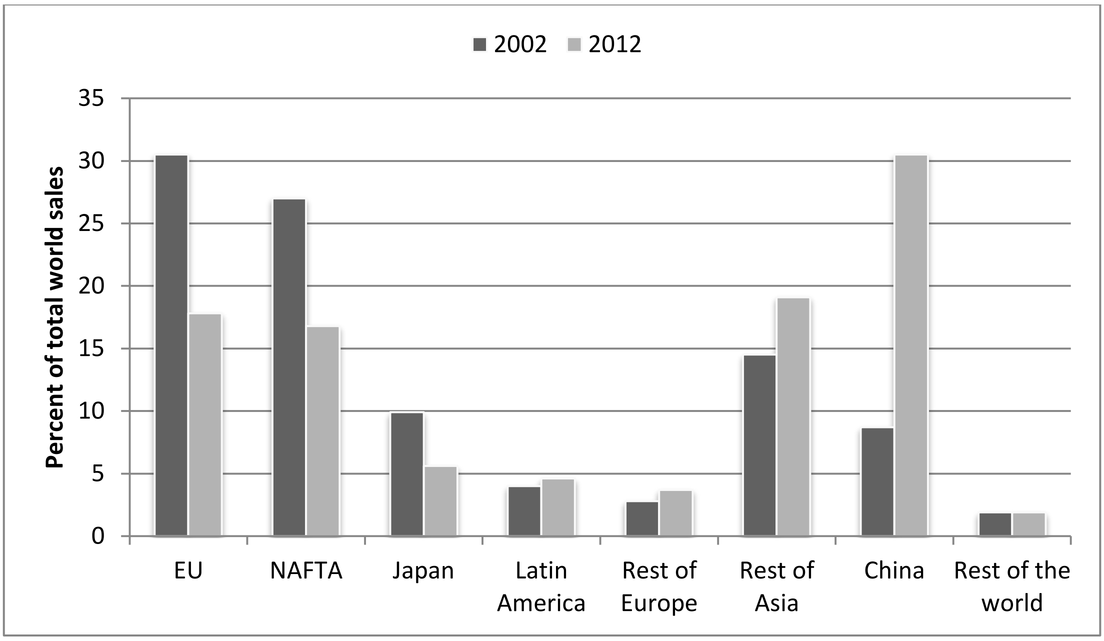
Figure 25. Chemical output in the developing region



Source: Chemical Outlook (2012)

Figure 26 is the comparison as how global market share of chemical industry is changing from region to region for the last ten years. EU has been losing largest share in terms of percentage followed by NAFTA region and as commented earlier, China and rest of Asia is gaining ground.

Figure 26. Chemical product over different region



Data source: Cefic (2013). Author's calculation and graph

4.3 Recent Economic crisis and its effect on global chemical industry

The financial crisis of 2007–2008, also known as the Global Financial Crisis and 2008 financial crisis, is considered by many economists to have been the worst financial crisis since the Great Depression of the 1930s. It threatened the total collapse of large financial institutions, which was prevented by the bailout of banks by national governments, but stock markets still dropped worldwide. In many areas, the housing market also suffered, resulting in evictions, foreclosures and prolonged unemployment. According to the U.S. National Bureau of Economic Research (the official arbiter of U.S. recessions) the U.S. recession began in December 2007 and ended in June 2009, and thus extended over 18 months. The figure 27 shows the Dow Jones Industrial Index for the last ten years. It is evident that the economic crisis started in 2007 and showed its extreme effect in early of 2009. Since then, it has steadily improved for last five years. The crisis rapidly developed and spread into a global economic shock, resulting in a number of European bank failures, declines in various stock indexes, and large reductions in the market value of equities and commodities.

Figure 27. Dow Jones Industrial Index for last ten years

Source: Google Finance 1 (2014)

As the global economy emerges from the Great Recession of 2007-2009, the chemical industry finds itself passing through a period of profound transformation. Profit margins have been shrinking; return on capital has been in steady decline. The recent recession has only exacerbated the problems. The figure 28 shows the trend of Dow Jones Chemical Index and it is plunge to rock bottom in the 2008 and early 2009 depict how intensely the chemical industry was affected by the great recession was mentioned earlier.

Figure 28. Trend of the DOW Jones Chemical Index

Source: Google Finance 1 (2014)

4.4 Overview of European chemical industry

During those years of 2008-09, the commodity side of the business has been investing in large-scale advantaged capacity in developing markets and thus struggling with overcapacity. Among the fragmented specialty producers in developed markets, competition was growing fiercer, end markets are in chaos, and rationalization continues. Integrated players, wary of declining profits on the commodities side, are searching for ways to shift their portfolios to include more specialized products (Deloitte, 2010). The analysis shows that profitability has suffered in both the commodity and specialty sectors. The chemicals industry has an extremely broad range of customers. Only 30% of the combined output of the chemicals and pharmaceuticals industries is sold to private households and other end users (KPMG International, 2009). The rest goes to other industries, services and agriculture. The table 2 gives an overview of the European chemical industry, indicating that there are 28600 chemical enterprises in Europe. It is also a big employer, employing 1160000 persons.

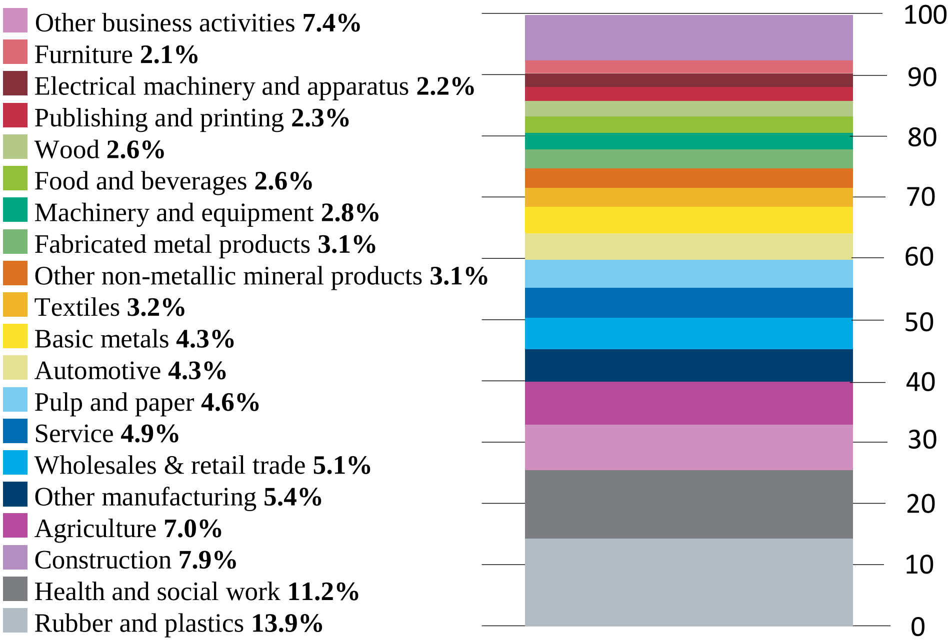
Table 2. Important data of European chemical industry

	Value
Main indicators	
Number of enterprises (thousands)	28,6
Number of persons employed (thousands)	1.160
Turnover (EUR million)	490.000
Purchases of goods and services (EUR million)	389.000
Personnel costs (EUR million)	60.000
Value added (EUR million)	111.000
Gross operating surplus (EUR million)	51.000
Share in non-financial business economy total (%)	
Number of enterprises	0,1
Number of persons employed	0,9
Value added	1,9
Derived indicators	
Apparent labour productivity (EUR thousand per head)	95,3
Average personnel costs (EUR thousand per head)	52,3
Wage-adjusted labour productivity (%)	182,0
Gross operating rate (%)	10,3

Source: EUROSTAT (2013)

The EU chemicals industry supplies virtually to all sectors of the economy. It has a pivotal position in the industrial value chain: raw materials and feedstock are transformed into tailor-made solutions for customers in the chemicals industry itself, as well as all other industries further down the value chain. The chart (figure 29) below shows that the chemical industry underpins virtually all sectors of the economy and its strategies impact directly on downstream chemicals users. The big industrial customers of chemicals are rubber and plastics, construction, pulp and paper, and the automotive industry. Nearly two-thirds of chemicals are supplied to EU industrial sectors, including construction. More than one-third of chemicals are supplied to the other branches of the EU economy such as agriculture, health and social work, services, and other business activities.

Figure 29. The chart showing the percentage of output of EU chemical industry consumed by customer sector



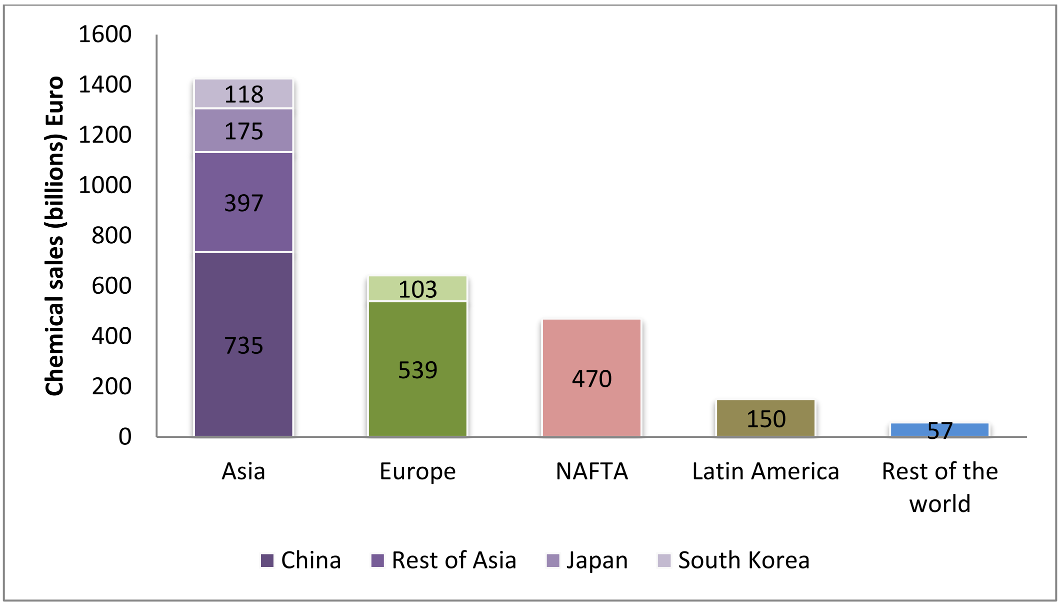
Data source: Cefic (2013)

4.4. 1 Chemical sales

The European chemical industry is facing major challenges as value chains increasingly move eastward, drawn by economic growth and market opportunities in Asia. A new, more competitive environment is taking shape, giving rise to state-controlled players and emerging chemical giants. Fragile economic conditions require managing volatility on a playing field where trade flows gradually change direction. Understanding what these challenges mean, and more importantly, identifying the right strategic options to thrive in this new competitive environment are at the top of every chemical executive´s agenda. Since the mid-1980s, the global chemical industry has grown by 7 percent annually, reaching € 2.4 trillion in 2010. Most of the growth in the past 25 years has been drive by Asia, which now owns almost half of global chemical sales (Cefic, 2013).

As seen in the graph in figure 30, Asian chemical production in 2011 surpassed that of the rest of the world chemicals turnover and was valued at €2744 billion. Data for 2011 also confirms that a significant recovery of the European chemicals industry occurred during the year. The global sales in value terms were up in 2011 by 11.6 per cent compared with 2010. Emerging economies contributed largely to the worldwide recovery of the sector during the past two years 2010 and 2011. The European chemicals industry, including the European Union and the Rest of Europe, is still in a strong position, posting sales of €642 billion in 2011 which is 23.4 per cent of world chemicals sales in value terms. Worldwide competition is getting fiercer, however, witnessed by the European Union losing its top ranking in terms of sales to China for the third consecutive year (figure 30). Chemicals sales in Asia are more than double that of the European Union. When taken together, Europe, Asia and the North American Free Trade Area account for 92.5 per cent of world chemicals turnover (Americanchemistry, 2013).

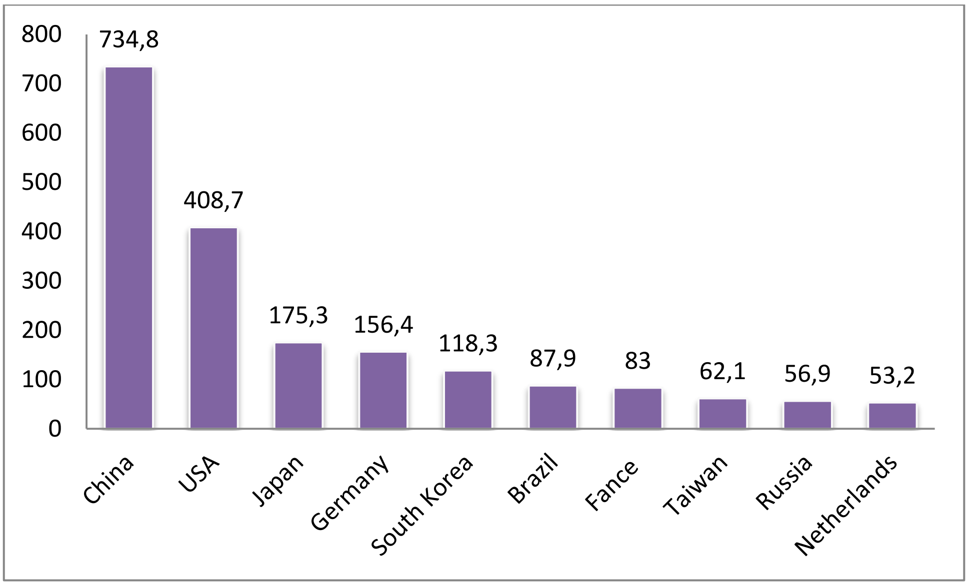
Figure 30. World chemical production



Data source: Cefic (2013)

If we compare country by country production, China - by far is the biggest chemicals producer in 2011. In 2011, the 30 largest chemical-producing countries had a combined turnover of €2447 billion. Twelve of the top 30 major countries are Asian, generating chemicals sales of €1278 billion, which represents nearly 52.2 per cent of the 30 top producing markets and 46.6 per cent of the share of world chemicals sales. Eight of the top 30 major chemicals-producing countries are European, generating chemicals sales of €480 billion (figure 31). This figure represents 19.6 per cent of the top 30 and 17.5 per cent of the share of world chemicals sales (Cefic, 2013).

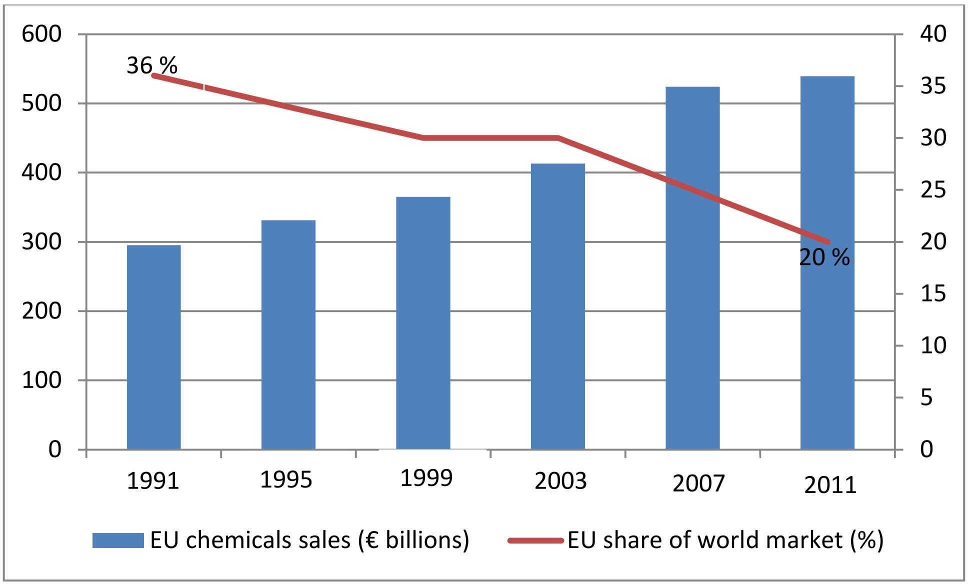
Figure 31. Top ten chemical producers for the year 2011



Source: Cefic (2013); Graph: Author

EU´s share of the market of chemicals nearly halved in 20 years. Developments during the previous 20 years from 1991 to 2011 indicate that the European Union was in a much stronger position in 1991 than today, posting sales of €295 billion in 1991, 36 per cent of world chemicals sales in value terms. Chemicals sales have been growing continuously during this 20 years period, increasing in value terms by 83 per cent. The level of world chemicals sales increased, however, threefold in 2011 compared to 10 years ago, posting sales of €819 billion in 1991 to €2744 billion in 2011 (figure 32). As a consequence, the EU chemicals market share nearly halved in 20 years, from 36 per cent in 1991 to 20 per cent in 2011 (Based on Cefic, 2013 raw data).

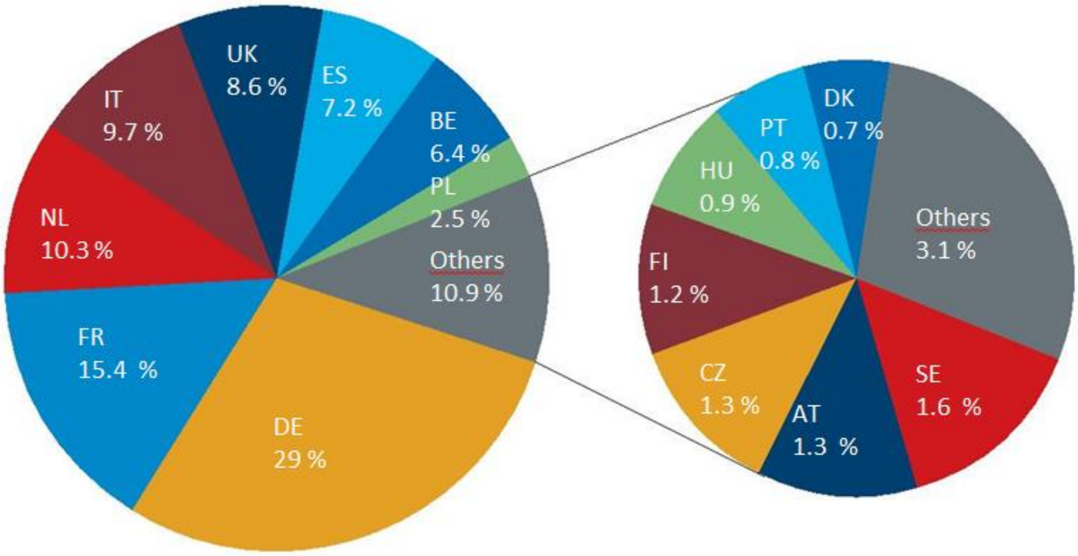
Figure 32. EU Chemical sales and EU share of world market in percentage



Data source: Cefic (2013)

Eight countries accounted for 90 per cent of European chemicals production. Germany remains the largest chemicals producer in Europe, followed by France, Netherlands and Italy (figure 33). Together, these four countries generated in 2011, 64.4 per cent of EU chemicals sales, valued at €347.2 billion. The share rises to nearly 90 per cent, or €480.3 billion, when the United Kingdom, Spain, Belgium and Poland are included. The other 19 EU countries in 2011 generated 10 per cent of EU chemicals sales, valued at €58.8 billion, mainly attributed to four EU countries – Sweden, Austria, Czech Republic and Finland.

Figure 33. Sales of each country in Europe and percentage sales

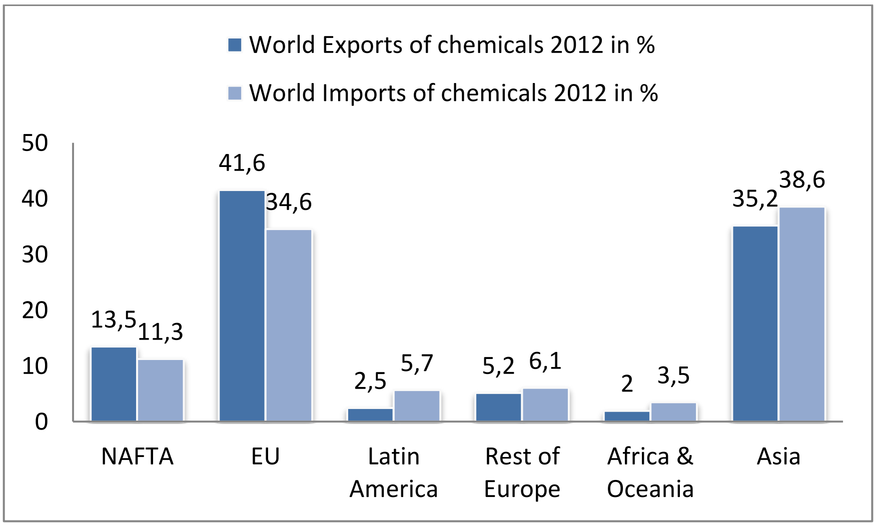


Source: Cefic (2013)

4.4.2 Intercontinental chemical trade

Although Europe is losing its position in terms of global chemical sell, in terms of trade balance is doing well with export being 7 % higher than import. In case of Asia, although the gap is reducing between the export and import, but it is importing more than exporting (figure 34).

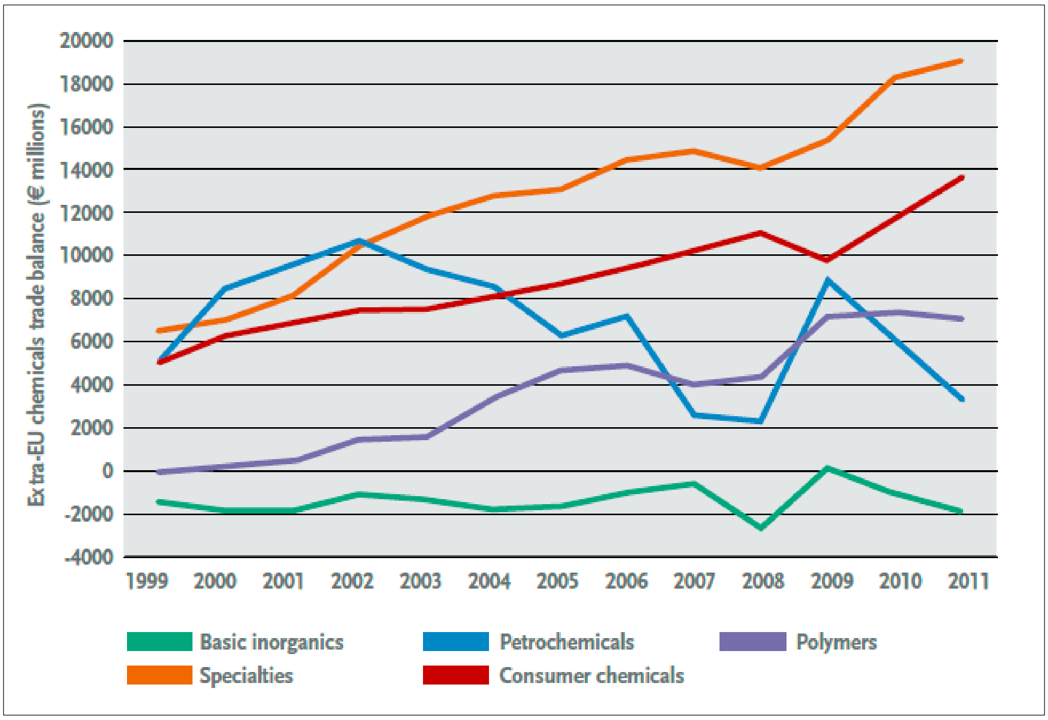
Figure 34. The export and import of chemical products over different regions



Source: Cefic (2013)

Specialty and consumer chemicals in 2011 accounted for 77 per cent of extra-EU chemicals trade surplus. The EU chemicals trade surplus in 2011 reached nearly €41.7 billion. Specialty chemicals accounted for 36 per cent of the EU chemicals trade surplus, with a value of €16.8 billion. The consumer chemicals subsector had the second strongest external trade performance, contributing €16.1 billion to the EU trade surplus, followed by polymers at €8.4 billion and petrochemicals at €7.5 billion. Basic inorganics experienced a trade deficit of €1.9 billion – the only sector with a trade deficit since 1994 (figure 35). Sectorial analysis shows that specialty chemicals and consumer chemicals performed well in 2010. The trade surplus in these sectors increased by 23 per cent and 18 per cent respectively in 2010 compared with 2009. Polymers registered a comparably low 10 per cent increase in terms of trade surplus in 2010 compared with 2009. Petrochemicals in 2010 registered a decline in overall trade surplus, however, of 20 per cent (Cefic, 2013).

Figure 35. Extra EU-trade balances for various product families

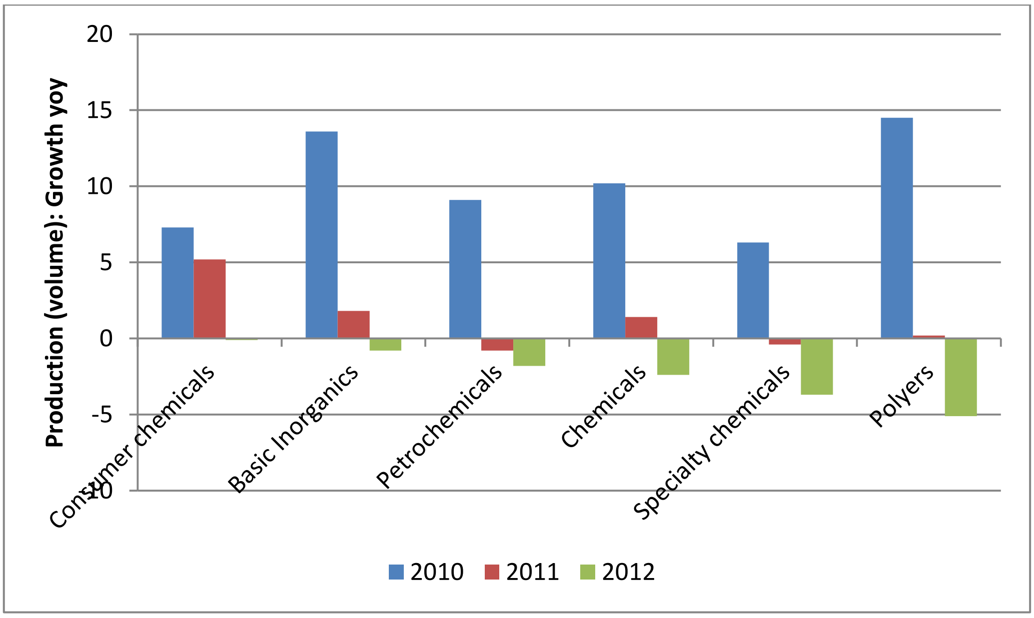


Source: Cefic (2013)

Polymers and specialty chemicals are registering the fastest decline in 2012. As shown in figure 36, growth in EU chemicals production in 2010 was spectacular and stronger than expected. Furthermore, a lot of uncertainty surrounds the prospects for full-year

2012. Latest data show that EU chemicals production fell by 2.4 per cent in the first nine months of 2012 compared with the same period in 2011. Data for the first nine months of the year point to EU chemicals production remaining 6.2 per cent below the 2007 peak levels. The 2.4 per cent year-on-year output decline during the first nine months of 2012 was mainly led by two sectors: polymers and especially specialty chemicals, which registered the fastest decline in 2012 compared to the other chemicals subsectors (Cefic, 2013). Looking ahead, the European chemicals industry continues to face relentless global competition. Access to raw materials and energy at globally competitive prices remains a prerequisite for a successful recovery for the EU chemicals sector.

Figure 36. Production volume growth or decline year over year

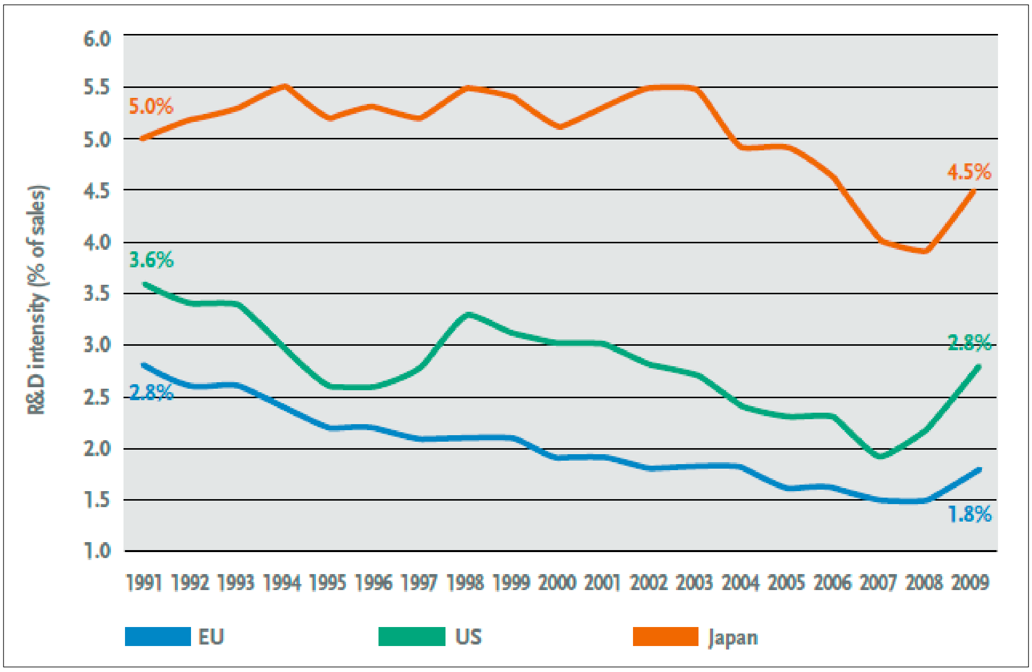


Source: Cefic (2013). Graph: Author

4.4.3 R&D in chemical industry

The high value-added products of the chemicals industry continuously open up new fields of application, paving the way to progress and innovation in other industries. Typical examples are health, food, consumer goods, aerospace and car manufacturing, telecommunications, electrical engineering and electronics. Wide variations in research and development (R&D) efforts are observed across the chemicals industry. Turning R&D into innovation is becoming increasingly important in relation to the competitiveness of the region. Analysing the ratio of R&D spending to sales of the chemicals industry (R&D intensity), it can be observed that during the 19-year time period from 1991 to 2009, the R&D intensity level in the European Union was far below that of Japan and slightly lower than in the United States. The EU R&D intensity is equal to two per cent on average during the years 1991 to 2009, while the same ratio is equal to 2.8 per cent in the United States and to 5.1 per cent in Japan (figure 37).

Figure 37. R&D intensity of EU, USA and Japan over a period of 19 years



Source: Cefic (2013)

4.4.4 Structure of European chemical industry

Table 3 shows the distribution of the chemical enterprises in Europe according to its size. The European Union breaks the size into two broad categories: SME (Small and medium enterprise) and large enterprise. Large enterprise are those that employs more than 500 people, while the enterprises that have less than 500 employee fall under SME. The SME is further divided into micro, small and medium enterprise. Even though large enterprises consist of 3 % of the total chemical enterprise, they employ 56 % of the chemical industry work force. So their role in European chemical industry growth and employment is significant.

Table 3. Number of European chemical enterprises according to their size and number of persons employed

	Number of enterprises (thousands)	Number of persons employed (thousands)
All enterprises	28,6	1.160,0
All SMEs	27,3	510,5
Micro	18,1	55,0
Small	6,4	145,5
Medium-sized	2,8	310,0
Large	0,9	650,0

Source: EUROSTAT (2013)

4.5 European top chemical companies

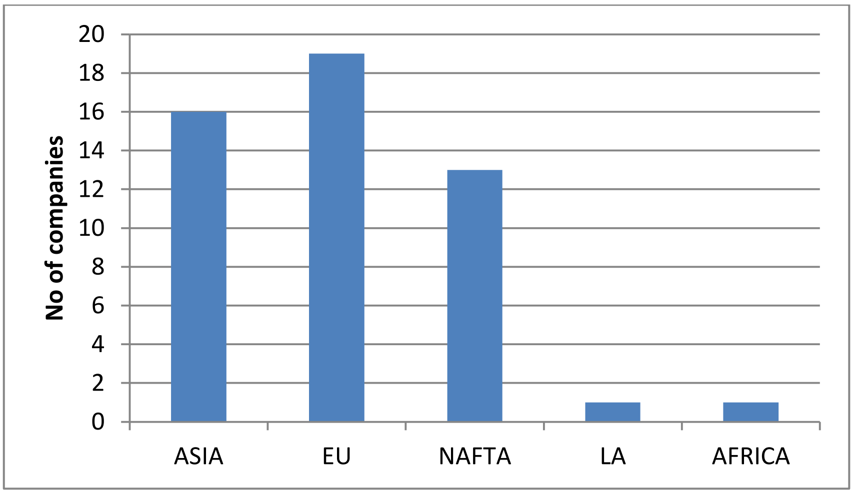
Table 4: The top 19 chemical companies in Europe for the year 2012

	Company	Headquarter		Company	Headquarter
1	BASF	Germany	11	Yara	Norway
2	Shell	Netherlands	12	DSM	Netherlands
3	LyondellBasell	Netherlands	13	Lanxess	Germany
4	Bayer	Germany	14	Syngenta	Switzerland
5	Ineos Group	Switzerland	15	Borealis	Austria
6	AkzoNobel	Netherlands	16	Arkema	France
7	Air Liquide	France	17	Eni	Italy
8	Evonik	Germany	18	Styrolution	Germany
9	Solvay	Belgium	19	Total	France
10	Linde	Germany			

Source: Tullo (2013). Author´s calculation

Based on the data published by Tullo (2013), the table 4 shows the top 19 chemical companies head quartered in Europe from the list of 50 top selling global chemical companies. The current research is to lay down the innovation policy of these 19 companies and study its impact on profitability.

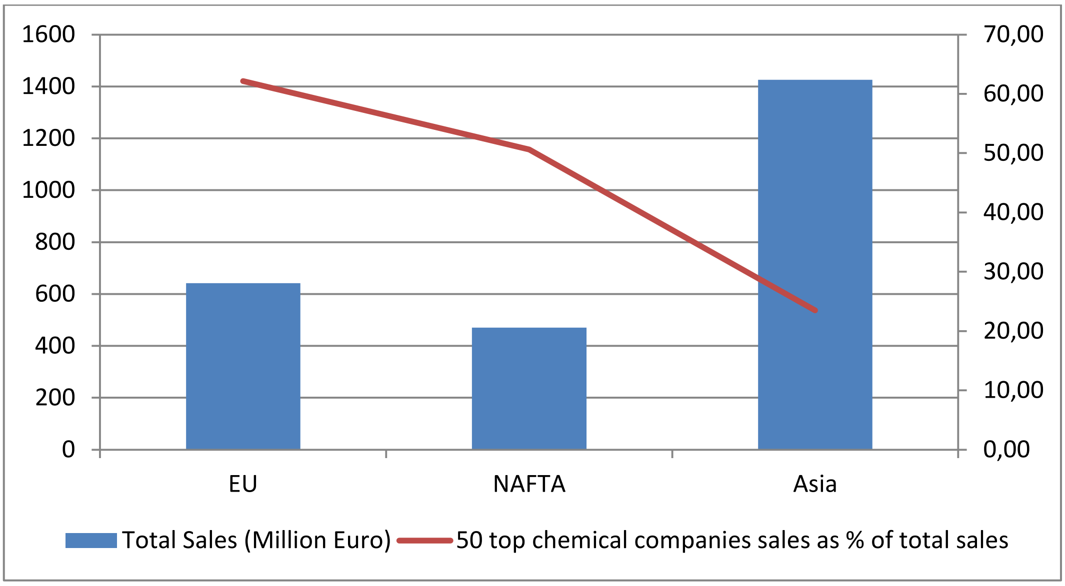
Figure 38. Distribution of world´s top 50 chemical companies according to geographical regions



Data Source: Tullo (2013); Author's calculation and graph

The chart (figure 38) above shows the distribution of world's top 50 chemical companies according to geographical regions. It is interesting to see that EU still leads the race with 19 out of top 50 companies followed by Asia with 16.

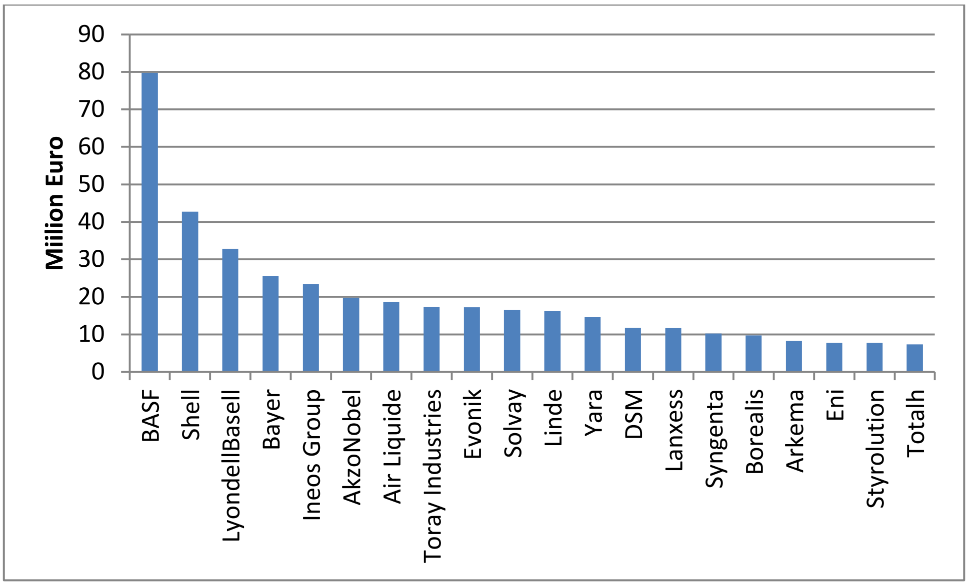
Figure 39. The percentage of sales of the top 50 chemical companies to total sales in particular region



Data source: Cefic (2013) and Tullo (2013). Author's calculation and Graph

The figure 39 shows the total sales of the top three regions and the percentage of sales of the top 50 companies to the total sales of that region. We have seen that in the list of 50 top chemical companies, 19 are from Europe. These 19 companies contribute to 63 % of European chemical sales which further emphasizes the importance of analyzing the innovation strategies of these companies.

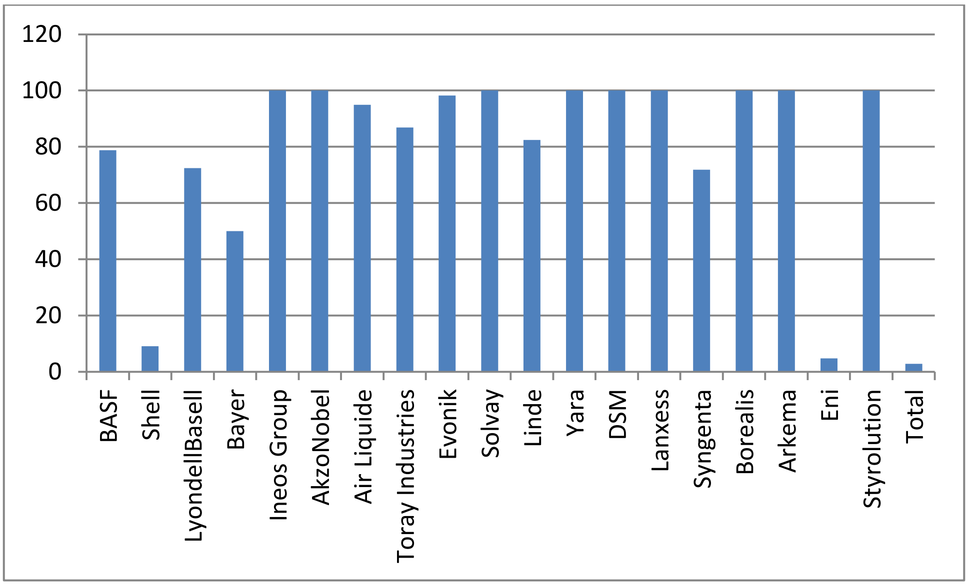
Figure 40. The chemical sales for the top 19 chemical companies in Europe



Data source: Tullo (2013). Graph: Author

The figure 40 above shows the chemicals of the top 19 companies. It is interesting to see that BASF has almost double of chemical sales to that of its following competitor. Another aspect, which is coming up is that the traditional oil companies are now investing in chemical business and thus playing a significant role in European chemical sales.

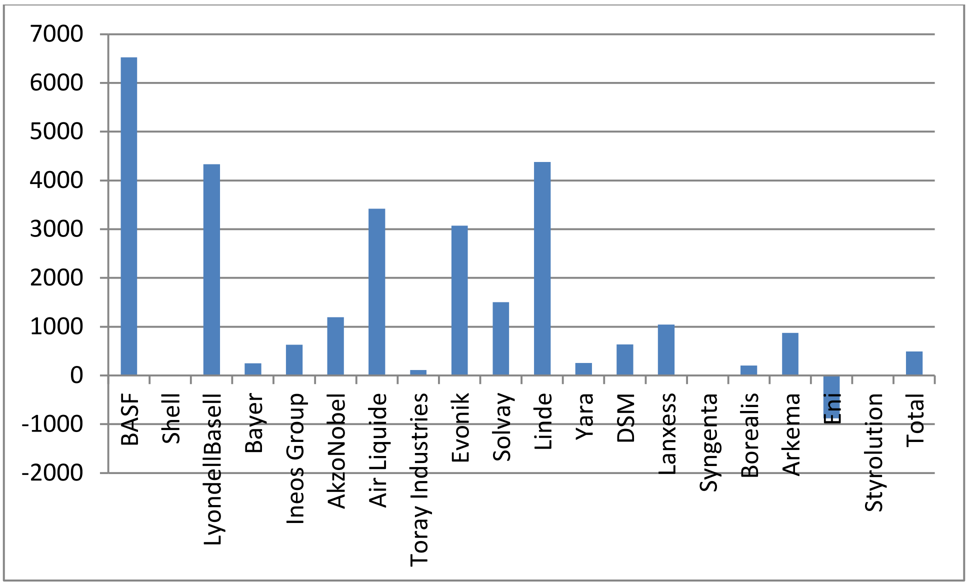
Figure 41. Chemical sell as a percentage of total sales of top European chemical companies



Data source: Tullo (2013). Graph: Author

The figure 41 above shows how much percentage of their revenue is from chemical product sales. Apart from the three companies (Shell, Eni, Total), most of the other companies have a very high percentage of chemical sales as a percent of total sales. It is interesting to note, even though BASF is the largest chemical company in terms of sales, it´s chemical sales is slightly lower than 80 % of the total sales. Many large chemical companies have diversified into the pharmaceutical and bioscience industry, which brings to them significant profitability as seen in Bayer (figure 42).

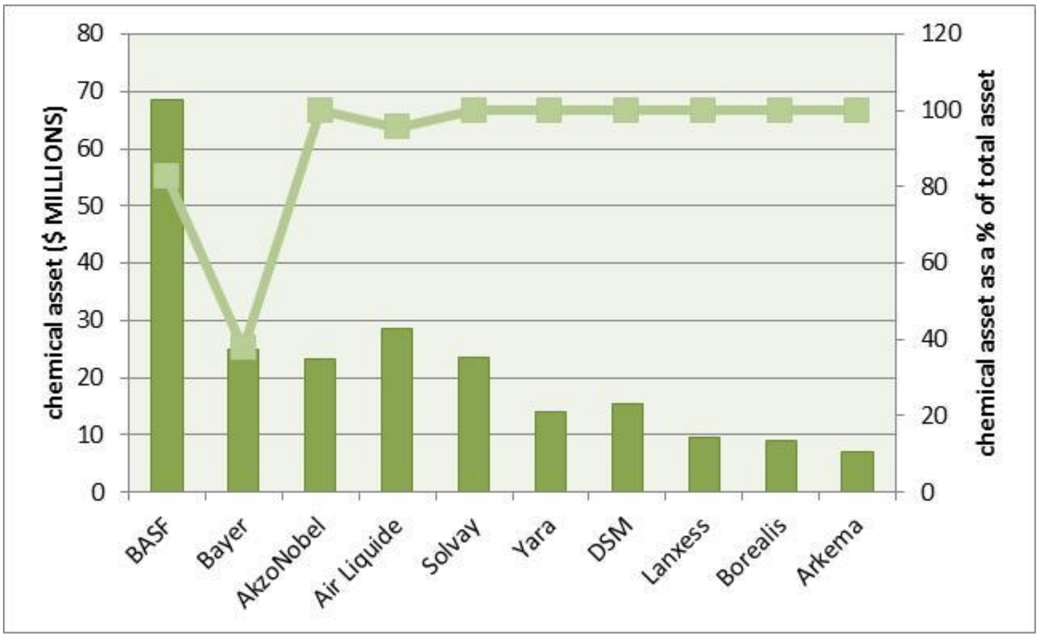
Figure 42. Operating profit as obtained from chemical sales



Data source: Tullo (2013). Graph: Author

The top five companies in chemical sales profitability are BASF, Lyondell Basel, Air Liquide, Evonik, and Linde. Most other companies, even though has a high volume of sales, the profitability percentage is significantly low.

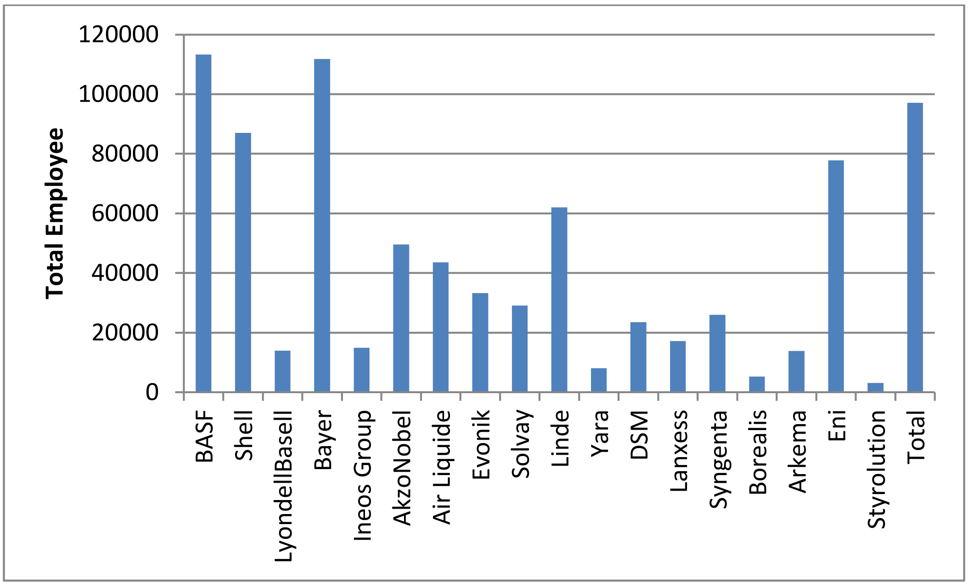
Figure 43. Chemical Assets and chemical assets as a percentage of total asset



Data source: Tullo (2013). Graph: Author

The bar in figure 43 shows the chemical assets. BASF is way ahead compared to others in terms of capital asset. It is interesting to see that Bayer´s chemical asset is only around 40 % of the total asset, which can be attributed to a diversified company. Most other companies in this analysis are pure chemical companies with their chemical asset being almost 100 % of their total asset (figure 43).

Figure 44. Total employees of the top 19 chemical companies (included in this chart are employees assigned to different business sector apart from chemical industry)



Data source: Wikipedia (2014). Graph: Author

From the figure 44, we can see in case of companies who are almost wholly dedicated to chemical industry, BASF and Linde are the top employers. Although the three oil companies Shell, ENI and TOTAL are large employers, but a significant portion of their work force is engaged in their oil and gas business.

4.6 Analysis of each company of the top EU chemical company

We will now analyze each of the top chemical company in details.

4.4.1 BASF

BASF SE is a Germany-based chemical company which diversifies its activities into five business segments:

1. Chemicals, providing basic products and specialties including nitric acid and methanol, among others;
2. Performance Products, providing products for the coatings and paints industry, cosmetics, detergents, products for the paper industry and performance chemicals, among others;
3. Functional Materials & Solutions that develops coating products, catalysts and construction chemicals, among others;
4. Agricultural Solutions, providing active ingredients and formulations for the improvement of crop health and yields, and Oil & Gas segment (exploration, production and natural gas trade) (Google Finance2, 2014).

The segment Plastics (producing engineering plastics, polyamides and polyurethane solutions), divested as of January 1, 2013, is since then incorporated into segments Chemicals and Functional Materials & Solutions. On October 31, 2013, the Company got 71% stake in Verenium Corp after takeover offer. The figure 45 shows the share price trend over last 10 years.

Figure 45. The share price trend for last ten years of BASF as recorded by ETR stock exchange

Source: Google Finance2 (2014)

4.4.2 Royal Dutch Shell

Royal Dutch Shell plc (Shell) is an independent oil and gas company, based in the United Kingdom. It operates in three segments:

1. Upstream: Upstream combines the operating segments Upstream International and Upstream Americas, which are engaged in searching for and recovering crude oil and natural gas, the liquefaction and transportation of gas, the extraction of bitumen from oil sands and converting it into synthetic crude oil,

and wind energy.

2. Downstream: Downstream segment is engaged in manufacturing, distribution and marketing activities for oil products and chemicals, alternative energy (excluding wind), and carbon dioxide (CO2) management.

3. Corporate: Corporate segment represents the key support functions, such as Shell's holdings, treasury and self-insurance organization.

In January 2014, Royal Dutch Shell plc completed the acquisition of Repsol S.A.'s liquefied natural gas (LNG) portfolio outside North America.

Figure 46. Royal Dutch Shell share price for last 10 years as recorded at NYSE

Source: Google Finance2 (2014)

4.4.3 LyondellBasell

LyondellBasell Industries N.V. is an independent chemical company. The Company's chemicals businesses consist of processing plants that convert volumes of liquid and gaseous hydrocarbon feedstock into plastic resins and other chemicals. Its Houston refinery processes crude oil into fuels, such as gasoline, diesel and jet fuel. Its segments include Olefins and Polyolefins-Americas (O&P-Americas), Olefins and Polyolefins-Europe, Asia, International (O&P-EAI), Intermediates and Derivative s (I&D), Refining & Oxyfuels and Technology. Its O&P-Americas and O&P-EAI products include olefins, polyolefins and polypropylene (PP) compounds. I&D products include acetyls and ethylene derivatives. Refining & Oxyfuels include gasoline and alkylate. Technology includes PP process technologies land polyolefin catalysts. On January 4, 2012, refinery operations were suspended at its Berre refinery in France.

4.4.4 Bayer

Bayer AG is a German management holding company with core competencies in the field of health care, nutrition and high-tech materials. It's business operations are organized into three subgroups:

1. Health Care, involved in the research, development and manufacture of health products for people and animals,

2. Crop Science, en gaged in the crop protection and non-agricultural pest control, and

3. Material Science, that provides polymers, and develops solution for a range of applications, supported by the service companies Bayer Business Services, Bayer Technology Services and Currenta.

It operates through numerous subsidiaries, affiliated companies as well as joint ventures located in Europe, Latin America, Africa, Middle East, North America as well as the Asia/Pacific region, such as Bayer Chemicals AG in Germany, Cotton Growers Services Pty. Limited in Australia and Bayer IsraelLtd in Israel, among others. In July 20 13, it acquired Steigerwald Arzneimittelwerk GmbH.

Figure 47. Bayer share price for last ten years as recorded at OTCMKTS

Source: Google Finance2 (2014)

4.4.5 Akzo Nobel

Akzo Nobel NV is a manufacturer of paints, coatings and specialty chemicals based in the Netherlands. The Company operates within four segments.

1. Within Buildings and Infrastructure segment, it manufactures decorative paints, protective, powder and coil coatings, and wood finishes for construction industry.

2. Transportation segment offers specialty and powder coatings for automotive parts, peroxides, metal alkyls, and automotive, marine, yacht and aerospace coatings.

3. Consumer Goods segment supplies finishes, adhesives and powder coatings for wood, specialty finishes for electronics, packaging coa tings, surfactants, polymers and amines used in manufacture of soap, personal products and detergents.

4. Within Industrial segment, it produces bulk chemicals, specialty chemicals, pulp and paper (Wikipedia, 2014).

In October 2013, it divested its Building Adhesives business; and acquired 50% stake and management control of Sadolin PaintsOman SAOC through joint venture agreeme nt with Omar Zawawi Establishment LLC.

Figure 48. Share Price of Akzo Nobel for ten years as recorded at AMS stock exchange

Source: Google Finance2 (2014)

4.4.6 Air Liquide

Air Liquide SA is a France-based company engaged in the production of oxygen, nitrogen, hydrogen and other industrial and medical gases. The Company divides its activities between Gas and Services and Engineering and Construction.

1. Gas and Services activities are divided by customer segments: large industries, which manages production units for customers in the steel, chemicals and refining industries;

2. Industrial merchants, which supplies gases and services to industries of all sizes requiring variable quantities; healthcare, which supplies medical gases, among others;

3. Electronics, which supplies gas and services for the production of semi-conductors, flat panels and photovoltaic panels (Wikipedia, 2014).

In May 2013, it acquired a majority of Healthy Sleep Solutions. In July 2013, it acquired HELP! and Ventamed. In September 2013, it acquired Voltaix Inc. In November 2013, Groupe G orge acquired through its subsidiary the robotics business activities of Air Liq uide SA's Air Liquide Welding France.

Figure 49. The share Price trend as recorded by EPA stock exchange

Source: Google Finance2 (2014)

4.4.7 Evonik

Evonik Industries AG (Evonik) is a Germany-based company engaged in the specialty chemicals sector. It has five business segments:

1. Consumer Health and Nutrition , Resource Efficiency, Specialty Materials, Services and Real Estate. The Consumer Health and Nutrition produces specialty chemicals, principally for applications in consumer goods, animal nutrition and

pharmaceutical sectors.

2. The Resource Efficiency segment provides solutions for environment-friendly and energy-efficient products.

3. The Specialty Materials produces polymer materials and their preproducts, and additives.

4. The Services segment mainly provides services for Evonik's chemicals segments and Corporate Center, but also serves third parties.

5. The Real Estate segment comprises Evonik's portfolio of residential real estate and a 50% stake in THS (Wikipedia, 2014).

4.4.8 Solvay

Solvay SA, (Solvay), is a Belgium-based, internationally operating chemical industrial group.

1. Solvay's Chemicals division produces materials for high tech applications such as electronics, barium and strontium compounds, calcium chloride, caustic soda, chlorinated products, magnesium products, peroxygen products, polyglycerols, precipitated calcium carbonate, soda ash and sodium bicarbonate.

2. The Plastics division produces specialty polymers for the aerospace, energy, automotive and healthcare industries, among others. The Plastics division further includes vinyls for building & construction, consumer goods, healthcare and wire & cable, and plastic pipes and fittings (Pipelife).

3. The Rhodia division focuses on fostering strategic technologies through research and development, partnering with other companies, supporting start-ups a nd investments in venture capital funds (Solvay, 2014).

In October 2013, the Company announced the acquisition of privately-held Chemlogics. Share Price trend of Solvay S A as recorded at EBR stock exchange.

Figure 50. Share Price trend of Solvay S A as recorded at EBR stock exchange

Source: Google Finance2 (2014)

4.4.9 Linde

Linde AG is a Germany-based company engaged in the gas and engineering sectors. It operates three divisions:

1. Gases: The Gases Division includes Healthcare, producing medical gases; and Tonnage ,as its two global business units; as well as the two business areas Merchant and Packaged Gases, offering liquefied andcylinder gases, and Electronics. The Co mpany's products are used in the energy sector, for steel production, chemical processing, environmental protection and welding, as well as in food processing, glass production and electronics.

2. Engineering (core divisions): The Engineering division offers planning, project development and construction of turnkey industrial plants used in fields, such as petrochemical and chemical industries, in refineries and fertilizer plants, to recover air gases, to produce hydrogen and synthesis gases, to treat natural gas, and in the pharmaceutical industry.

3. Gist:. The Gist division covers logistics services of the Company's subsidiary Gist (Linde, 2014).

Figure 51. Share price trend of Linde AG as recorded at ETR stock exchange

Source: Google Finance2 (2014)

4.4.10 Yara

Yara International ASA (Yara) is a Norway-based chemical company that converts energy, natural minerals and nitrogen from the air into products for farmers and industrial customers.

1. The Company produces ammonia, nitrates, nitrogen, phosphorous, potassium (NPK), and specialty fertilizers.

2. The Company operates in three segments: the Industrial segment, which develops and sells chemicals and carbon dioxide (CO2), as well as technologies and services to non-fertilizer industries;

The Upstream segment includes ammonia a nd fertilizer plants and phosphate mines, and the Downstream segment includes sales and marketing network for fertilizerproducts and agronomic solutions. The Company's portfolio ranges from single nutrient fertilizers to complex compounds and micronutrients for feeding plants. The Company's portfolio contains products and integrated solutions for optimizing industrial processes, water treatment and preventing air pollution (Yara, 2014).

Figure 52. Share Price trend of Yara International ASA as recorded at OTCMKTS stock Exchange

Source: Google Finance2 (2014)

4.4.11 DSM

Koninklijke DSM NV is a Netherlands-based science company, which is active in health, nutrition and materials sectors. It operates within three main business areas, namely

1. Life Sciences: The Life Sciences area comprises such segments, as Nutrition, which serves the food and beverage, feed, personal care and pharmaceutical industries in over 60 countries, and Pharma, which offers medicine ingredients.

2. Materials Sciences: The Materials Sciences area comprises such segments, as Performance Materials, which manufactures materials used in the automotive, aviation, electrical and electronics, marine, sports and leisure, paints and coatings, and construction industries, and Polymer Intermediates, which produces raw materials for synthetic fibers and plastics, among others.

3. Innovation Center: The Innovation Center area develops solutions for medical device and biopharmaceutical industries, bioconversion of feed stocks and the development and application of smart coatings, among others (DSM, 2014).

Figure 53. Share Price trend of DSM N. V. as recorded at AMS stock Exchange

Source: Google Finance2 (2014)

4.4.12 Lanxess

Lanxess AG is a Germany-based chemical holding company. Its activities are divided into three main segments.

1. The Performance Polymers segment encompasses the activities of the Lanxess Group in the production of rubber and plastics, and includes Butyl Rubbers, Performance Butadiene Rubbers, Technical Rubber Products andSemi-Crystalline Products business unit s.

2. The Advanced Intermediates segment isengaged in the development, production and marketing of industrial and fine chemicals and includes Basic Chemicals and Saltigo business units.

3. The Performance Chemicals segment combines the Group's application-oriented activities in the field of process and functional chemicals ,and includes Material Protection Products, Inorganic Pigments, Functional Chemicals, Leather, Rhein Chemie, Rubber Chemicals and Ion Exchange Resins business units (Lanxess, 2014). The Company operates worldwide through its subsidiaries.

Figure 54. Share Price trend of Lanxess AG as recorded at ETR stock Exchange

Source: Google Finance2 (2014)

4.4.13 Syngenta

Syngenta AG is a Switzerland-based company engaged in production of products for crop productivity. The Company's businesses include herbicides, insecticides and fungicides for crop protection, field crops, vegetables and flower seeds, seed care products and turf, garden, home care and public health products. The Company diversifies its operations into four geographical segments (Europe, Africa and Middle East; North America; Latin America and Asia Pacific), which represent the integrated Crop Protection and Seeds business areas, as well as a separate global segment Lawn and Garden.

1. The Crop Protection business is active in herbicides, insecticides and fungicides manufacture. The Seeds business produces and sells seeds for growing corn, soybeans, sunflower, and sugar beet, among others.
2. The Lawn and Garden business offers a range of products for use in the flower genetics, ornamentals, consumer lawn and garden, and Turf and landscape markets (Wikipedia, 2014).

Figure 55. Share Price trend of Syngenta AG as recorded at VTX stock exchange

Source: Google Finance2 (2014)

Subsidiaries of Syngenta AG: New Farm Crops , Northrup King Co (NK), Hilleshög, Sluis & Grut, Rogers.

4.4.14 Total SA

Total SA is a France-based integrated international oil and gas company. It is an integrated international oil and gas company and a chemicals manufacturer. Total engages in all aspects of the petroleum industry,

1. Upstream operations (oil exploration and production, together with activities related to natural gas),

2. Refining & Chemicals (refining, petrochemicals, speciality chemicals, crude oil trading and shipping)

3. Marketing & Services (focused on the supply and sale of petroleum products, together with activities related to renewable energy).

In April 12, 2013, it inaugurated the partnership with Veolia Environment S A the Osilub plant. In July 2013, it sold its TIGF (Transport et Infrastructures Gas France), gas transport and storage business. In September 2013, it announced the transfer to The National Gas Company of Trinidad &Tobago of all of its E&P assets in Trinidad through the sale of Total E&P Trinidad B.V and Elf Exploration Trinidad B.V.
Figure 28: Share Price trend of Total SA as recorded at NYSE stock Exchange (Total, 2014).

Figure 56. Share Price trend of Total as recorded at NYSE stock exchange

Source: Google Finance2 (2014)

4.4.15 ENI

Eni SpA is an Italy-based multinational oil and gas company. It operates through seven segments.

1. The Refining & Marketin g segment focuses on refining and marketing of petroleum products.
2. The Eni Trading covers group services in commodity trading, shipping and derivatives.
3. The Chemicals covers the production and sale ofpetrochemical products.
4. The Engineering & Construction includes the services for the oil and gas industry.
5. The Exploration & Production focuses on exploration,development and production of oil and natural gas.
6. The Gas & Power covers the supply, regasification, transport, storage, distribution and marketing of naturalgas, power generation and electricity s ales.
7. The Other Activities segment handles the corporate, financial and service

components (Eni, 2014).

In December 2013, it acquired a 30% stake in Est Reti; as result of the transaction it holds a 100% stake inEst Reti. In January 2014, it sold a 60 % stake in Arctic Russia to Yamal Development (Eni, 2014).

Figure 57. Share Price trend of Eni SpA as recorded at BIT stock Exchange

Source: Google Finance2 (2014)

Subsidiaries of Eni Spa: AGI, Eni Gas & Power, Polimeri Europa, Saipem, Snam, Syndial

4.4.16 Arkema

Arkema SA is a France-based company which specializes in the manufacture and marketing of chemical products. The Company operates through its two business segme nts: Industrial Chemicals and Performance Products. The Industrial Chemicals division offers the production of acrylics,polymethyl methacrylate (PMMA), hydrogen peroxide, fluoro chemicals and thio chemicals, and includes such brands as Forane, Albone, Norsocryl, Altuglas and Sarbio. The Performance Products include the production of technical polymers, specialty chemicals and functional additives. The Company's products are used in the construction, automotive and transportation, health, electrical and electronics, agricultural and packaging industries, among others. In April 2013, it acquired a majority stake in AEC Polymers. In October 2013, it inaugurated the new Sumitomo Seika superabsorbent plant on the Carling site, which makes the overall superabsorbent production capacity of the Carling facility up to 47,000 ton/year (Arkema, 2014).

Figure 58. Share Price trend of Arkema SA as recorded at EPA stock exchange

Source: Google Finance2 (2014)

The subdiaries of Arkema are: Alphacan, Altuglas International, Arkema Inc., Ceca, Coatex, MLPC International, Oxford Performance Materials, Resinoplast (Wikipedia, 2014).

4.7 Conclusions

The European chemical industry supplies product to almost all sector of the economy and there are in total 28600 small, medium and large chemical companies in Europe. As observed from Dow Jones Chemical Index, the financial crisis that hit the world in 2008- 2009 affected severely the chemical industry. The largest product segment of EU chemical industry is rubber and plastic which is around 14 % of total chemical production. In terms of world chemical sell, Asia is the leader followed by Europe which is almost 50 % of the Asia´s sell. In terms of top chemical producing country, China leads the list followed by USA and Japan. EU´s share of world chemical market is falling from 36 % in 1991 to 20 % in 2011. R&D intensity of EU´s chemical industry is much lower than that of Japan and USA. There is largest number of top 50 chemical companies headquartered in Europe. Among the top chemical companies in Europe, BASF has the highest turnover. BASF is way ahead compared to others in terms of capital asset. It is interesting to see that Bayer´s chemical asset is only around 40 % of the total asset, which can be attributed to a diversified company. During the individual chemical company study, it was observed that the share price of most of the companies fell steeply down during the financial crisis of 2008-09, but at the same time it can be stated that they recovered their value in subsequent years.

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5. Methodologies to perform this research

Contents

5.1 Introduction

It is vital to pick right methodologies for a particular research. The research will dictate the kind of research methodology to use to underpin the work and methods to use in order to collect data. The current research will consist of three broad steps: Main data collection, Accessory data collection, Data analysis. Each of the broad steps can consist of several activities. The first step, which is the main data collection, consists of collecting the historical data of patent and other financial data from the existing literature, databases and documents. The second step, which consists of accessory data collection, is to collect data from already concluded interviews with various government agencies and chemical companies regarding innovation and its trend. The third step or data analysis step, consists of statistical analysis of the available data to draw conclusions. This section explains how this data will be collected and how it will be analyzed.

5.2 Data Collection

The research consists of several sub topics and each have different source for the historical data. I will now discuss how the data will be obtained for each research theme:

5.2.1 Patent

The method that will be used to collect patent data is similar to the method used by Thomson Reuter (2003). It will be collected from the following data source:

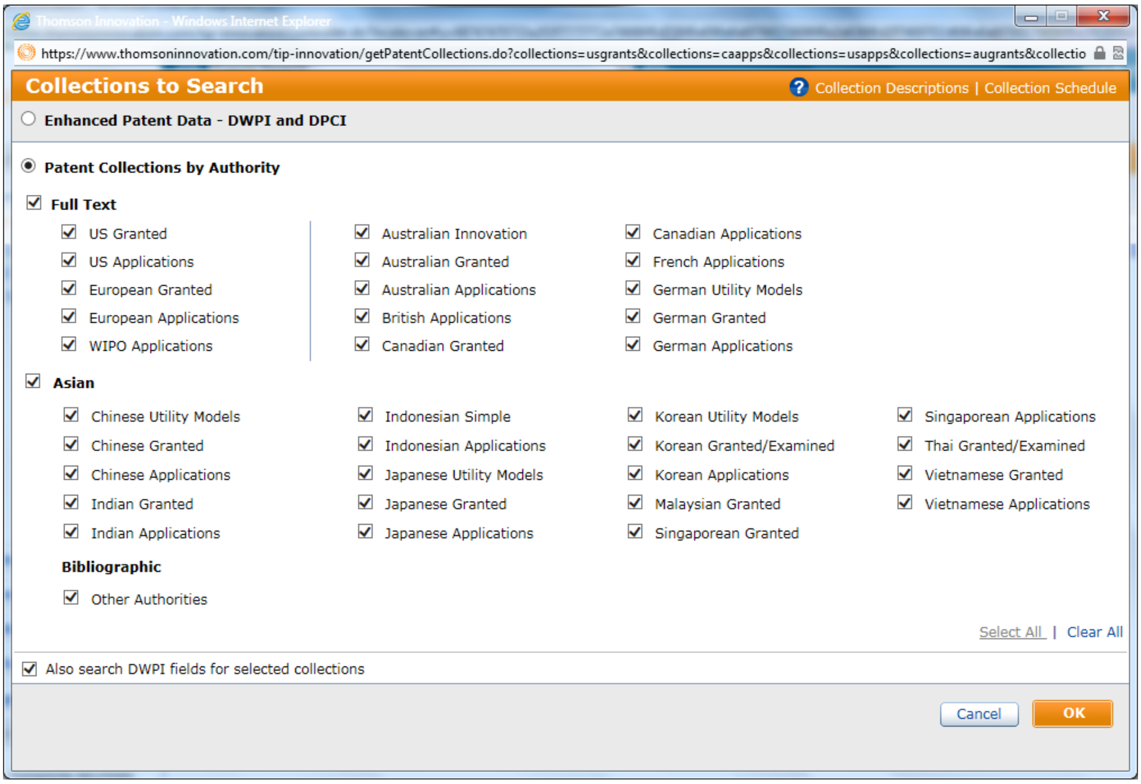
1. Thomson Innovation Database
2. European Union Patent Database
3. US patent Database

Thomson Innovation, from Thomson Reuter, brings together the world's most comprehensive international patent coverage and the industry's powerful intellectual property (IP) analysis tools. The key characteristics of the database are:

•Access to Most Relevant and Comprehensive Global Data to IP Research
•Help to make IP Decisions
•Streamline Your Work with Powerful Productivity and Collaboration Tools
•Also helps to transform Information into Intelligence

The figure 59 shows the screen shot as how Thomson Innovation search engine is organized to search the most important patent office databases. It searches patent according to patent family. This prevents counting twice a patent if applied separately in two different countries. The database also covers the scientific publications related to different patent families. Depending on which box is clicked, applied and granted patent can be separately selected. In case, both applied and granted check boxes are select, the patent which is counted as granted will not be again counted as applied in order to avoid duplication.

Figure 59. The search window for selecting the patent offices on Thomson Innovation



Source: Thomson innovation (2014)

European Union Patent Database:

European Union Patent Database is obtained from European Patent Office (EPO). It has offices in Munich, The Hague, Berlin, Vienna and Brussels. The patent data can be obtained directly from these offices or also online.

US Patent Database:

US Patent Database has a complete source of the inventions that has been patented in USA. It has several searchable tools which enable the user to filter data according to his need. It can be accessed online.

5.2.2 Research and Development Spending

Investigative activities that a business chooses to conduct with the intention of making a discovery that can either lead to the development of new products or procedures, or to improvement of existing products or procedures. Research and development is one of the means by which business can experience future growth by developing new products or processes to improve and expand their operations.

Many expenses are associated with the research and development for developing company's goods or services. R&D expenses are a type of operating expense. These types of expenses are incurred in the process of finding and creating new products or services. R&D expenses can be relatively minor, or they can easily run into the billions of dollars for large corporations. R&D expenses are usually the highest for industrial, technological, healthcare and pharmaceutical firms. Some companies reinvest a significant portion of their profits back into R&D, as they see this as an investment in their continued growth.

The information about the R&D expenses is obtained from:

1. The previous publications in the technical journals.
2. Annual Reports of the companies as published at the end of each financial year which contains the financial and other business related metrics for the company. These reports are available online.

5.2.3 Business Deals: Merger and Acquisition

M&A can be defined as a type of restructuring in that they result in some entity reorganization with the aim to provide growth or positive value. One of the key reason for merger and acquisition is acquisition of Know-how to push further the R&D platform and innovation.

The M&A data will be obtained from Thomson One database of Thomson Reuter. Thomson ONE features market quotes, earnings estimates, financial fundamentals, press releases, transaction data, corporate filings, ownership profiles and research from Thomson Financial. Mergers & Acquisitions Deals - data is available for over 400,000 M&A deals, including global transactions since 1977.

Figure 60 shows the screen shot as how the Thomson One Deal database looks like. The over view of the deals are arranged both graphically and in dataset. The queries for the searches are very flexible and allow us to select data of the deals of each company or each sector of the industry and also for different geographical region.

Figure 60. Screen shot of Thomson one database containing data of M&A

Source: Thomsonone (2014)

Following types of data will be collected for the research:

- Merger & Acquisition data for the chemical industry: Europe, Asia, North America, South America.
- M&A data of each of the 19 companies.
- Acquirer: Europe, Asia, North America, South America.
- Target: Europe, Asia, North America, South America.
- Target non-chemical sectors.

Figure 61. M&A deals as divided in different geographical region

M&A Market Overview > **Regional Comparison**

Regional Comparison

Worldwide Announced M & A Target Region Comparison

Target Primary Nation Region	Current Year Ranking Value inc. Net Debt of Target ($Mil)	Mkt. Share	Number of Deals
Americas	1,147,927.04	50.9	11523
Europe	581,975.62	25.8	13865
Asia-Pacific (ex Central Asia)	395,517.08	17.6	9263
Japan	90,146.74	4.0	1670
Africa/Middle East/Central Asia	38,034.56	1.7	965
Subtotal with Target Primary Nation Region	2,253,601.04	100.0	37286
Subtotal without Target Primary Nation Region	-	0.0	0
Industry Total	2,253,601.04	100.0	37286

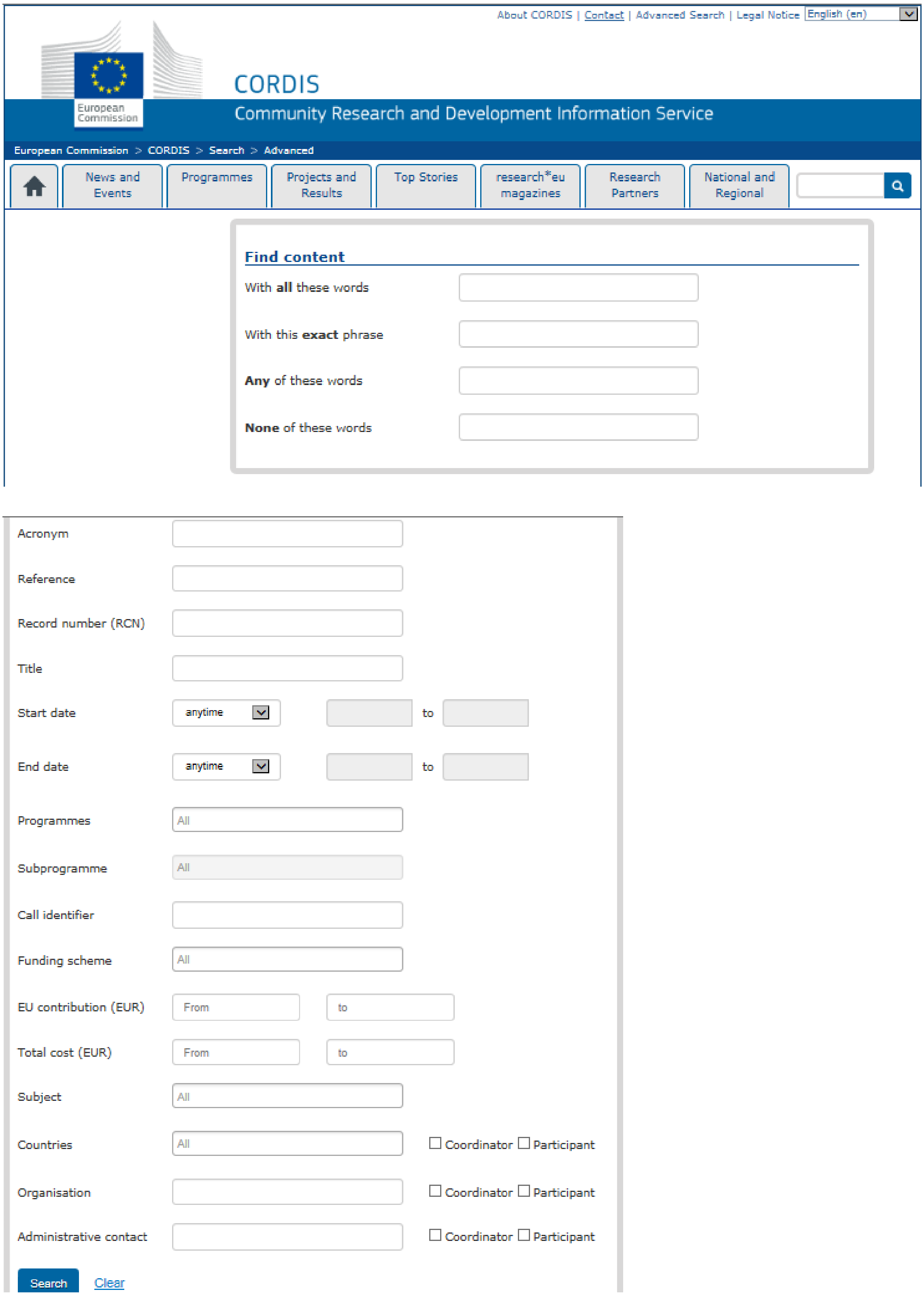
Source: Thomsonone (2014)

5.2.4 Collaboration with other companies & universities for research

The current project focuses on European Union funded project to understand the collaborations that are happening in research and development between the industries on one hand and industries with academia on the other hand.

The details about the projects will be available from Community Research and Development Information Service. It has a database where the Europe Union supported projects are recorded. For this study we will consider the F5, F6 and F7 framework project.

Figure 62. European Union funded project information database search screen



Source: European Union (2014)

5.2.5 Impact of chemical Regulation on Innovation of EU chemical Companies

REACH is the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals. It entered into force on 1st June 2007. It streamlines and improves the former legislative framework on chemicals of the European Union (EU). The main aims of REACH are to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals, the promotion of alternative test methods, the free circulation of substances on the internal market and enhancing competitiveness and innovation. The data for REACH is obtained from a survey done by Center for Strategy and Evaluation Study (CSES), UK in 2011. The question was so formulated in order to understand the impact of chemical regulation, REACH on the innovation of European Chemical industry.

The survey was launched in September 2011 and remained open for six weeks. Respondents were given the opportunity to answer in terms of a given role as defined by the REACH regulation:

- Manufacturer of chemical substances or preparations
- Importer of chemical substances or preparations
- Producer of articles that contain chemical substances
- Importers of articles that contain chemical substances
- Formulator (mixer) of chemical substances or preparations
- End users of chemical substances or preparations in professional activities or in industrial activities where substances or preparations are used as processing aid and do not form part of the final product
- Distributor/ retailer of chemical substances, preparations or articles that contain chemical substances intended to be released
- Other roles

The survey questionnaire was translated into the 22 official EU languages, and respondents accessed the survey through a single web page. The link to the survey was distributed through various European, national and regional associations and organisations that CSES identified and who were asked to forward the link to their member associations and companies. The Commission services and ECHA also promoted the survey through their communication channels.

There were 577 responses. The largest group of respondents were manufacturers of chemical substances (33.3%) followed by formulators (mixers) of chemical substances (21%). The remaining responses were relatively evenly spread between the other roles.

Some of the questions that were put on the survey are as follows (CESE Survey, 2012):

Q1. Please indicate in what role you will be answering this questionnaire.

Q2. In which sector of the economy is your firm mainly active?

Q3. Chemicals and chemical products (subdivisions) you are mainly dealing with.

Q4. In which country is your business located?

Q5. How many chemical substances did you place in the market in 2010 (including substances contained in articles)?

Q6. Company size.

Q7. Please indicate what kind of business you are in and where yours headquarter is based.

Q9. Approximately what percentage of your turnover was spent on Research & Development (R&D) in 2010?

Q10. What would you say the sources of your innovations are in general? If more than one, please rank in importance (1st as most important, 3rd as least important).

Q11. Has the development of, or access to, any of the following sources of information acted as a stimulus to product conception and innovation in your organisation?

Q12. Was the additional cost for testing of new substances (as opposed to the situation for existing substances) a disincentive to innovation for you before the REACH Regulation was implemented?

Q13. Statistics on successfully completed PPORDs per year

Q14. What percentage of resource is diverted from innovation to REACH compliance?

Q15. Filling in knowledge of gaps on existing substances and/ or uses, uncovering hidden potential?

Q16. The REACH Regulation has shifted the centre of gravity in terms of the safety assessment of existing chemicals to manufacturers/industry. Has it upheld certain barriers for research activities on new substances? Have changes impacted the balance of interests for research activities and what is the current centre of interest (new substances vs. new uses for old substances)?

Q17. What has the experience of various measures within the Regulation to support R&D been?

Q18. What has been the effect of measures in the Regulation intended to limit the number of animals used in testing stages? Did the requirements related to the reduction of animal tests impact the industry capacity to introduce new substances or to develop new uses for existing substances?

Q20. Are there any implications for the supply of laboratory capacity?

Q21. What has been the impact of REACH on the development of business cases for innovation projects (e.g. rates of return, risk, uncertainty).

Q22. Have these factors led to better products?

Q23. The cost of REACH and its impact on the landscape of innovative companies

Q24. Toll manufacturing strategy

Q25. REACH impacts on the costs of setting up new companies (start-ups / spin-offs).

The data obtained from this survey as reported by CSES will be further analyzed in order to evaluate the impact of REACH on innovation of large chemical companies.

5.2.6 Cluster

A business cluster is a geographic concentration of interconnected businesses, suppliers, and associated institutions in a particular field. Clusters are considered to increase the productivity with which companies can compete, nationally and globally. Clusters are also very important aspects of strategic management.

The data from cluster is obtained from:

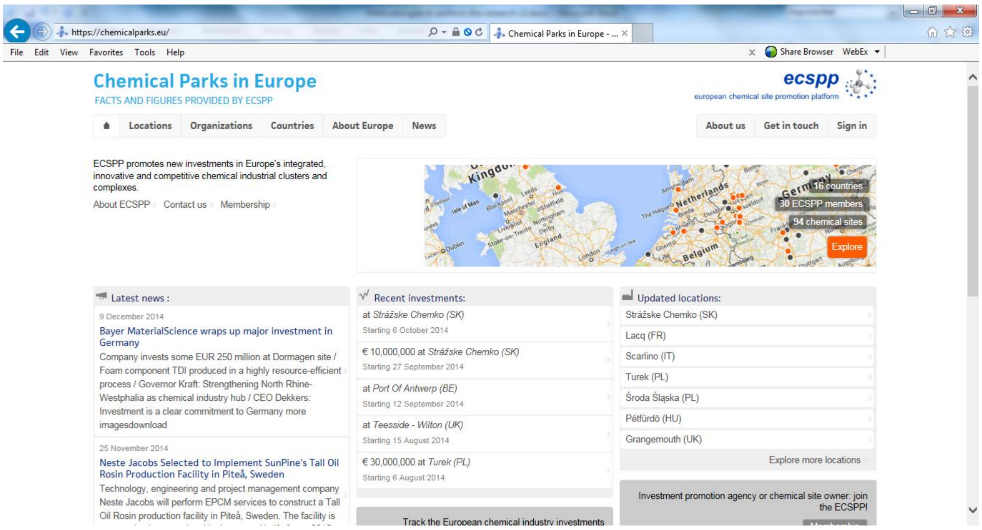
1. The previous published literatures which contain specific case studies of the innovation of some the bigger EU chemical clusters.
2. The websites relating to chemical clusters which provides information and data around those clusters and updates around them.

There are several websites which give significant information about the chemical clusters. They are the following:

1. Chemical Parks in Europe:

The chemical park in Europe is rich source of information of all the chemical clusters in Europe. The data is provided by European chemical site promotion platform. The website also updates regularly the news and investments at various clusters (figure 63).

Figure 63. Chemical cluster information as obtained from the chemical park website

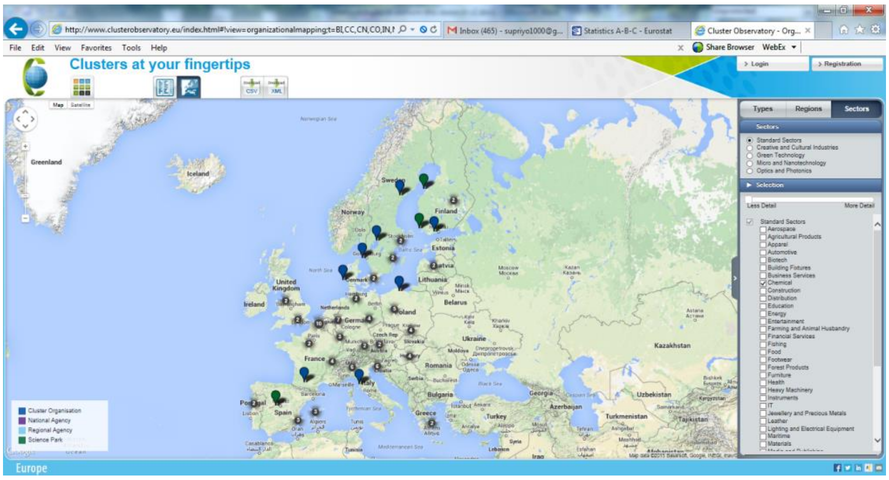


Source: ECSPP (2014)

2. Cluster Observatory

The European Cluster Observatory is a single access point for statistical information, analysis and mapping of clusters and cluster policy in Europe that is foremost aimed at European, national, regional and local policy-makers as well as cluster managers and representatives of SME intermediaries (figure 64).

Figure 64. The European Cluster Observatory showing the chemical clusters in Europe



Source: European Cluster Observatory (2014)

Apart from the above mentioned website which provides European Level information about the chemical clusters, there are few other which provides country specific chemical cluster. The websites worth mentioning are:

1. German Chemical Cluster
2. Antwerp chemical cluster.
3. Lyon / Rhon Alpes chemical cluster.

5.2.7 Digital Innovation and digital marketing innovation in EU large chemical companies

There has been drive to digitalization in chemical industry in general and marketing effort in particular. There are three sources from which the data can be obtained.

1. Digitalization of the Chemical Industry

The data on the digitalization of the chemical industry and the digital structure can be obtained from previous literatures. Some authors have pointed out how digitization is playing a vital role in doing their business.

2. Digital index of the industries in Europe

Booz&Co consultancy performed a survey in 2012 to understand the digitalization of the prime industrial sector of the European Economy. Since chemical industry was also covered in this survey, I am using this data set to compare the level of digitalization of large European chemical companies. The industry digitization index is derived from data gathered by Eurostat, the European Union's statistical agency. Among other statistics, the program captures data on how many companies have deployed various elements of digital infrastructure, tools, platforms, and management capabilities and policies.

In creating the index, the data was broken into four separate dimensions, each of which is defined by several sub-factors and components. The four dimensions summarize the following underlying data points:

- Input: The extent of digital processes in the procurement stage of the business, including data points regarding the use of computer networks as well as electronic transmissions suitable for automatic order processing.
- Processing: The degree to which processes are integrated, both internally and with external partners. The internal integration sub-factors include data points regarding

existence and use of digital technologies such as ERP and CRM, as well as the use and purpose of internal information sharing among different organizational functions. External integration comprises activities such as electronic data interchange or supply chain management, which includes the use of electronic data transmissions to and from business partners both upstream and downstream.

- Output: The importance of digital processes in the sales function, including the use of computer networks as well as electronic transmission of data suitable for automatic sales processing.
- Infrastructure: The sophistication of the underlying IT technology, focusing on the presence and use of computers and computer networks (wired and wireless) as well as the presence and type of connection to the Internet, including the use of fixed and mobile broadband or other fixed connections such as cable or leased lines.

Then, by logically aggregating the results of the data collected for each dimension within each industry, the study was able to construct both the overall index and a deeper understanding of the progress each industry has made in each of the four dimensions.

3. Digital Marketing

As the digital marketing landscape continues to grow at a rapid pace, marketers are faced with new challenges and opportunities within this digital age. The websites of each of the chemical company will give us a detailed view of all the strategy that these companies are using in the field of digital marketing.

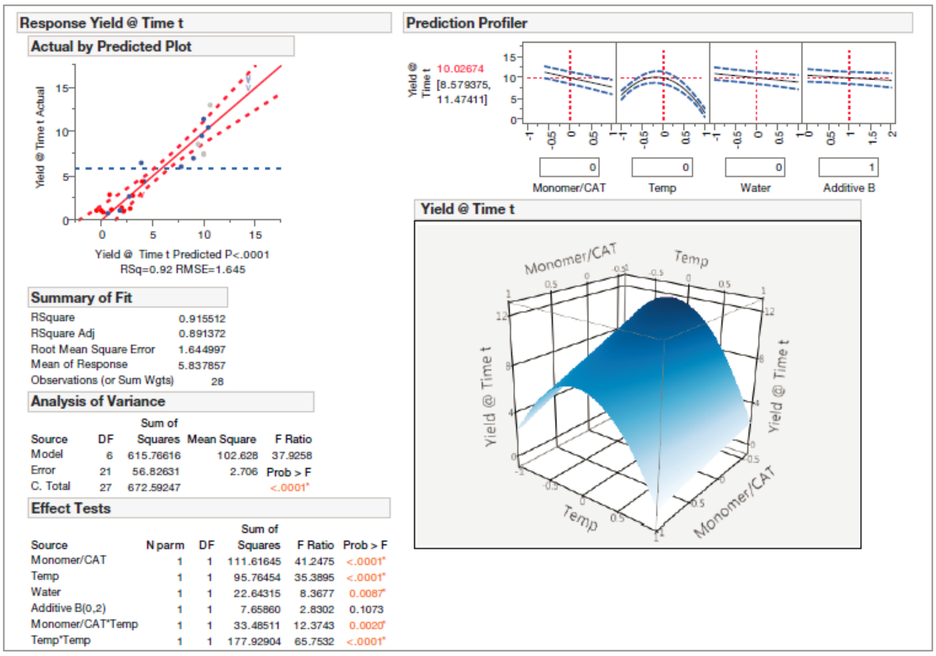
5.3 Data analysis

The last part of the research consists of data analysis, interpretation and test the hypothesis. In order to analyze the data and it´s trend, Microsoft Excel will be used. Apart from this, in order to make advanced statistical analysis, JMP software from SAS will be used.

JMP (pronounced "jump") is a computer program for statistics developed by the JMP business unit of SAS Institute (figure 65). JMP is used in applications such as Six Sigma, quality control and engineering, design of experiments and scientific research.

The software is focused on exploratory analytics, whereby users investigate and explore data, rather than to just confirm a hypothesis.

Figure 65. Example of the modeling functionality and data fit of the JMP Software



Source: Author

5.4 Summary

As explained above, there is a detailed plan to obtain the data for various components of the research. The research consists of first giving an overview of current situation of European chemical industry and then testing five hypotheses around innovation focusing on large chemical companies head quartered in Europe. The data around European chemical industry and the global perspective is obtained from databases and publications of the various government agencies in the field of chemical industry. The data around patents will be obtained from the Thomson Innovation and patent offices. R&D data is obtained from previous publications and annual reports of the companies. Merger and Acquisition (M&A) deals data is obtained from Thomson One database. The university and industry collaboration information is obtained from European Union research website. The data of REACH impact on nnovation is obtained from survey conducted by CSES. The information about the clusters are obtained form previous literature and the websites. The information around innovation in marketing through digitalization is obtained through individual company website and also through market research. As explained earlier, there is a detailed plan to obtain the data for various components of the research. Based on the data collected, there will further statistical analysis of the data into order to test the hypotheses that were laid down in earlier chapter.

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6. Innovation trend of the top European chemical companies

Contents

6.1 Introduction

Patent is defined as a government authority or license conferring a right or title for a set period, especially the sole right to exclude others from making, using, or selling an invention. It may be granted to a firm, individual or public body by a national patent office. Patent propensity rate is a potentially valuable indicator for innovative activities. Patents are undoubtedly one of the instruments that firms use to capture values from innovation and R&D activities. Among the few available indicators of technology output, patent-based indicators are probably the most frequently used. As explained in chapter 2, most of the researchers support the idea of using patent data as the metrics of measuring innovation. This chapter will test the first hypothesis of this research, i.e. test if there is a positive trend in innovation of large chemical companies headquartered in Europe. The patent data will be extensively used for this analysis.

6.2 Patent process

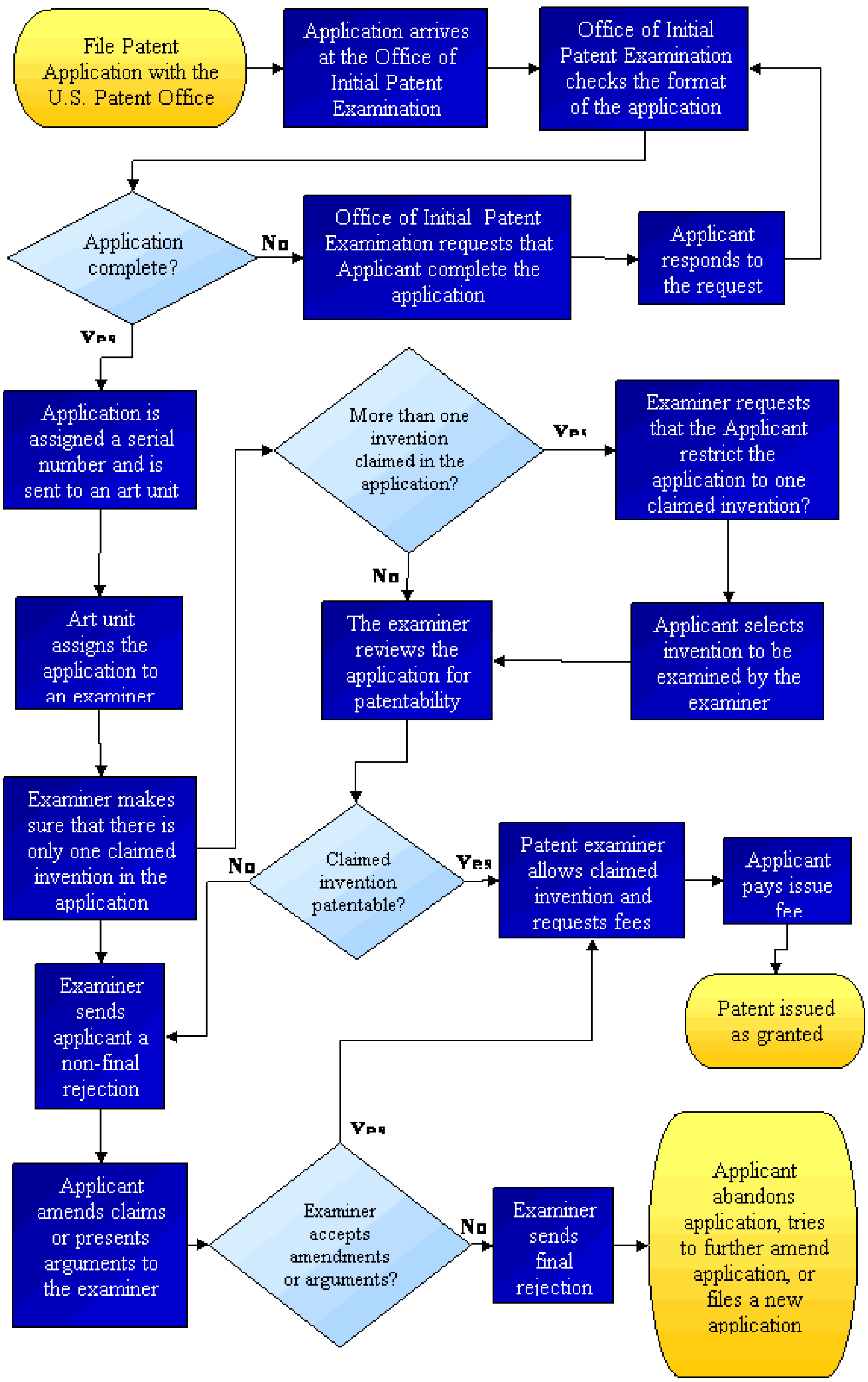
The most commonly used indicators are counts of patent family that share a number of common elements. This section focuses on patent landscape of the top chemical companies in Europe. The list of the top nineteen chemical companies includes three oil companies. So as not to mix up chemical patents with other patents, these three companies are ignored in this study.

The patent process (Inventor basics, 2013) as according to the US Patent office consist the following broad steps (figure 66):

- Step 1, Applicant - Has the invention already been patented?
    - If already patented, end of process
    - If not already patented, continue to Step 2
- Step 2, Applicant - What type of Application is being filed?
    - Design Patent or Plant Patent or Utility Patent
- Step 3, Applicant - Determine Filing Strategy
- Step 4, Applicant - Which type of Utility Patent Application to file?
    - Provisional or Non provisional
- Step 5, Applicant - Consider expedited examination
    - Prioritized or Accelerated or First Action Interview program

- Step 6, Applicant - Who Should File?
  - File yourself (Pro Se) or Use a Registered Attorney or Agent
- Step 7, Applicant - Prepare for electronic filing
  - Application processing fees and Apply for a Customer Number and Digital Certificate
- Step 8, Applicant - Apply for Patent using Electronic Filing System as a Registered e-Filer
- Step 9, USPTO - USPTO examines application
  - Check Application Status
  - Allowed?
    - Yes, go to Step 12
    - No, continue to Step 10
- Step 10, Applicant - Applicant files replies requests for reconsideration, and appeals as necessary
- Step 11, USPTO - If objections and rejection of the examiner are overcome, USPTO sends Notice of Allowance and Fee(s) due
- Step 12, Applicant - Applicant pays the issue fee and the publication fee
  - USPTO Grants Patent

Figure 66. US patenting process flow chart

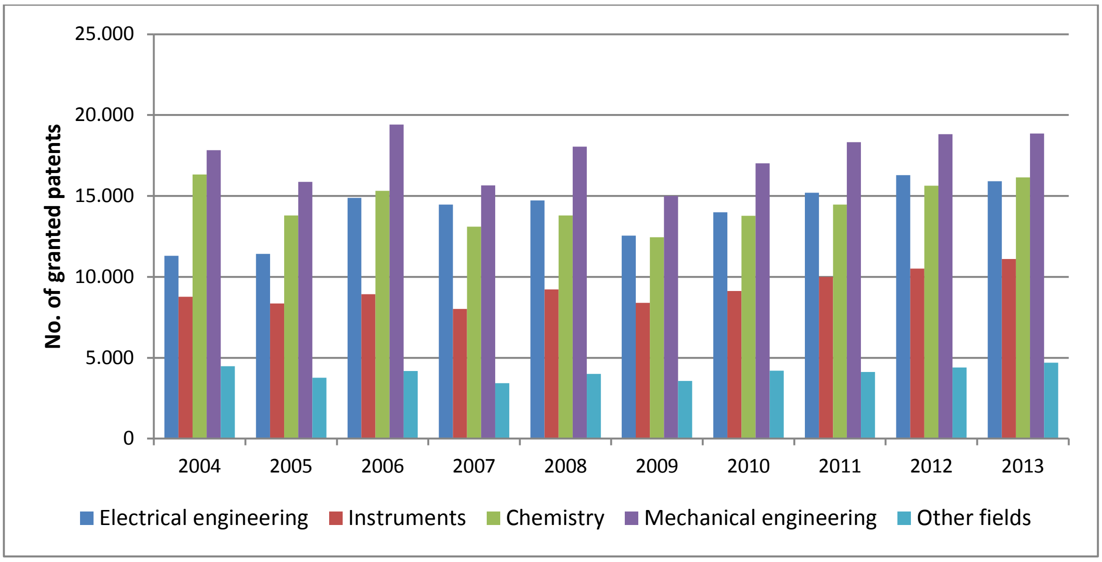


Source: Inventor basics (2013)

6.3 Patent Data Analysis

Patents having effect in most European states may be obtained either nationally, via national patent offices, or via a centralized patent prosecution process at the European Patent Office (EPO). The EPO is a public international organization established by the European Patent Convention. Since this study is focused on large European companies headquartered in Europe, we focus first on the patent activities at the European Patent Office. Figure 67 compares the patents granted to the chemical and chemical-related industry with other leading industries in Europe (electrical engineering, instrumentation and mechanical engineering. The bar graph shows that mechanical engineering has the highest number of patents granted while chemical engineering and electrical engineering are a little behind in second and third place. It also shows that the number of patents granted to the chemical industry was lowest in 2009, which is when the global economic crisis hit and the chemical industry was badly affected.

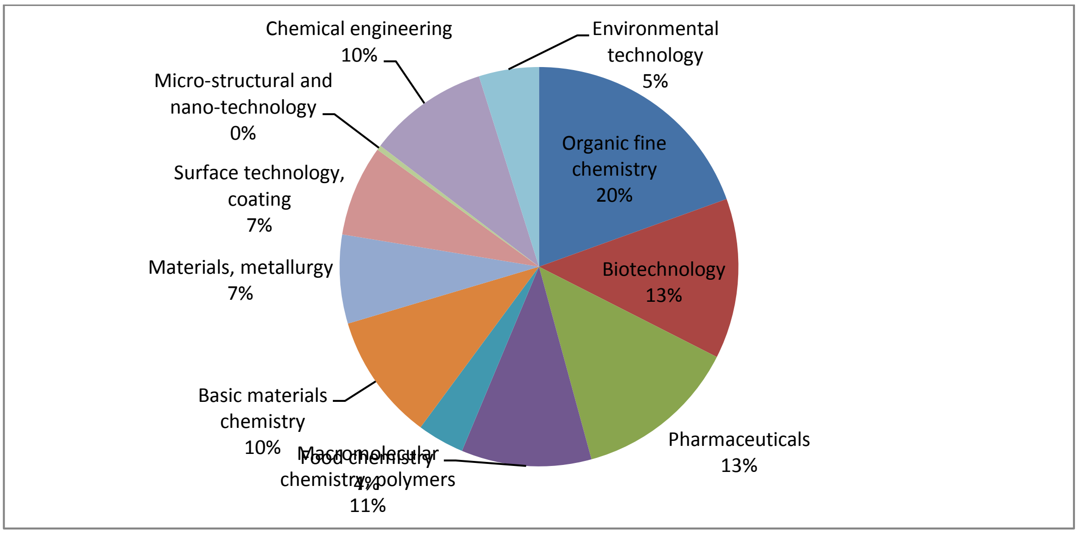
Figure 67. Number of patent granted at European Patent Office in various sectors



Data source: European Patent Office (2014). Graph: Author

According to the European Patent office, the chemical or chemical engineering sector consists of eleven subsectors. Figure 68 shows how the total number of patents granted for 2013 was distributed among various sub-sectors. Fine organic chemistry has the highest share of chemistry patents followed by pharmaceuticals and bio-chemistry. We will discuss patenting in this sector further below. Patents in the basic materials sector also make a significant contribution to the total number of patents. On the other hand, research into food chemistry, environmental technology and nanotechnology was insignificant.

Figure 68. Patent granted at European Patent Office for various subsector for chemistry for the year 2013



Data source: European Patent Office (2014). Graph: Author

We look now deep into the fine organics chemistry patenting. The table 5 shows the application for 2013 in the sector of organic fine chemistry. The companies marked yellow are the companies which are under our study. Seven out of the top twenty five companies belong to the list of the top chemical companies in terms of sales which are headquartered in Europe. Based on the following data, where it was seen that BASF is the largest applicant of patents, BAYER surpasses BASF in terms of organic fine chemistry application of European Patent.

Table 5. Top applicants for organics fine chemistry patent application at European Patent Office

Rank	Organic fine chemistry	Applications
1	BAYER	337
2	BASF	310
3	UNILEVER	175
4	HOFFMANN-LA ROCHE	123
5	NOVARTIS	121
6	L'OREAL	112

7	MERCK KGAA	108
8	BOEHRINGER INGELHEIM	105
9	JOHNSON & JOHNSON	99
10	DSM	95
11	SYNGENTA	86
12	SANOFI	78
13	KAO	76
14	PROCTER & GAMBLE	72
15	DOW CHEMICAL	68
16	SOLVAY	65
17	EVONIK	59
18	HENKEL	58
19	EXXON MOBIL	56
20	MERCK & CO	53
21	SHELL	51
22	BRISTOL-MYERS SQUIBB	47
23	LONZA	45
24	COLGATE-PALMOLIVE	43
25	DUPONT	41

Source: European Patent Office (2014)

The table 6 below is an extract of a table of the top 100 companies in terms of patent application to European Patent Office for the year 2013. The first column shows the ranking in the original list of top 100 companies. We see only six chemical companies from our top twenty chemical companies appear in this list. As always BASF is leading the table with over 1500 patent applications.

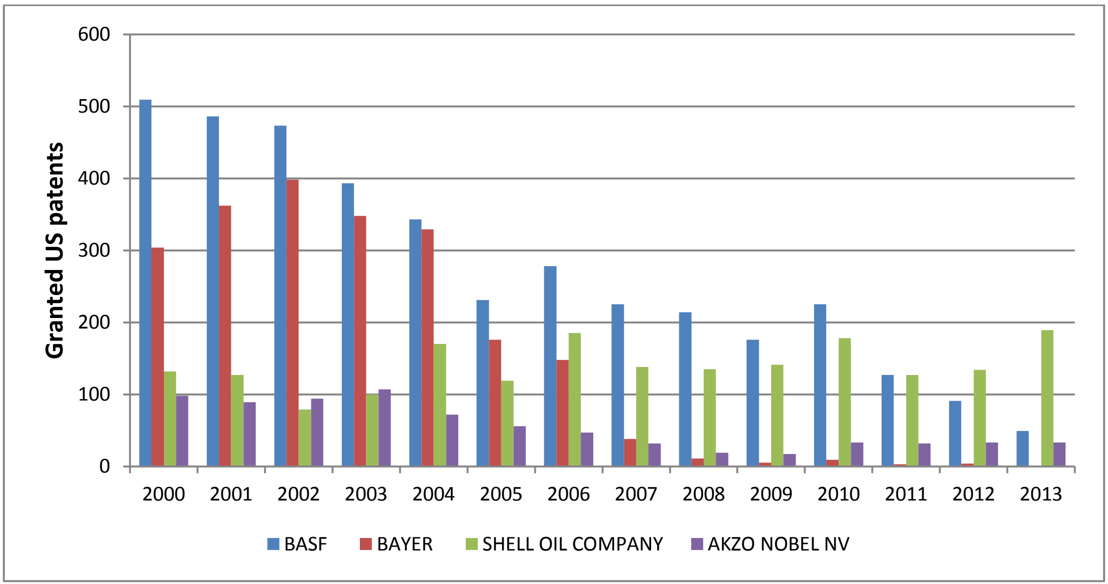
Table 6. Extract of the table showing the ranking of the top European chemical companies in the total ranking of top 100 companies in terms of highest patent application at the European Patent Office for 2013

Rank	Company	Applications
5.	BASF	1577
16.	BAYER	850
23.	DSM N.V.	659
52.	EVONIK AG	360
61.	SOLVAY	313
68.	SHELL	272

Source: European Patent Office (2014).

Now let us focus on US patent. The United States Patent and Trademark Office (USPTO or Office) is an agency of the U.S. Department of Commerce. The role of the USPTO is to grant patents for the protection of inventions and to register trademarks.
It serves the interests of inventors and businesses with respect to their inventions and corporate products, and service identifications. Through the preservation, classification, and dissemination of patent information, the Office promotes the industrial and technological progress of the economy. The graph in figure 69 below shows the granted US patent for the top European companies. We could see BASF, Bayer, Shell and Akzo Nobel as the only companies that made it to the top of this list. It is interesting to see that apart from Shell, all other companies having a falling tendency over the years in terms of granted patents.

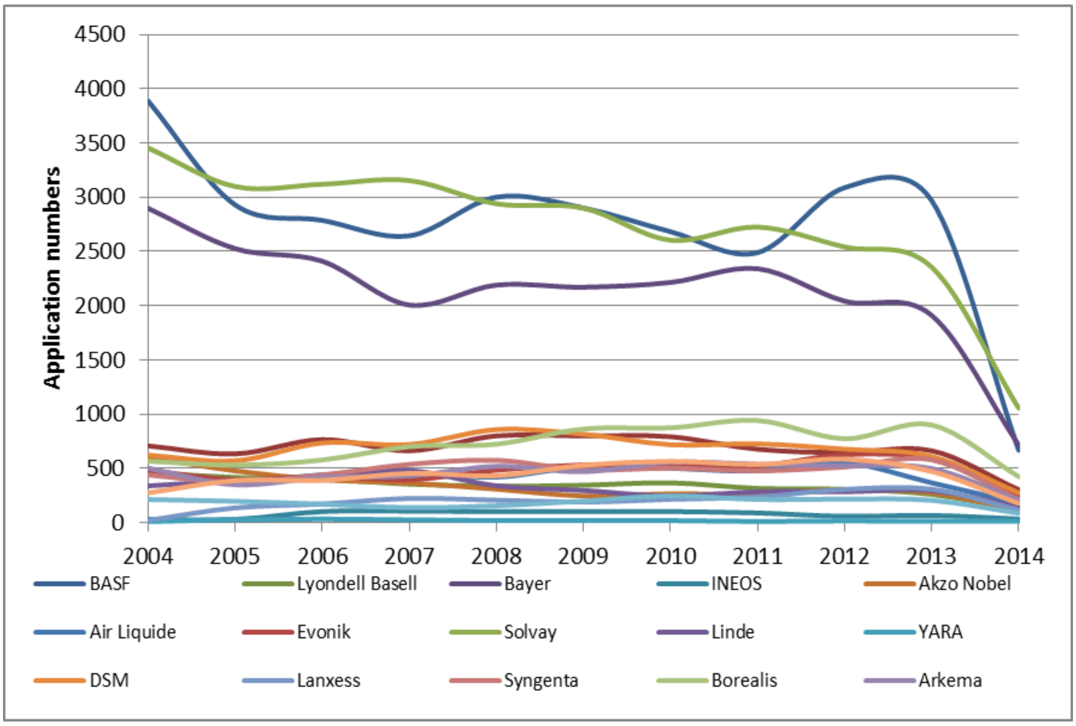
Figure 69. Granted US patent for the top European chemical companies for the last 14 years



Source: US Patent Database (2014). Graph: Author

Figure 70 shows the patent applications made by these companies over the last ten years to the leading patent authorities throughout the world. In order to avoid counting of the same patent applied for in two countries more than once, we counted patent families instead of the number of actual patents. A patent family is a set of patents taken out in various countries to protect a single invention (when the initial application in one country – the priority – is then extended to other countries). In other words, a patent family is the same invention disclosed by a common inventor(s) and patented in more than one country. BASF, Bayer and Lyondell Basel are the leading applicants. All other companies made considerably fewer applications, while Solvay showed an upward trend. So these three companies are at the forefront of research and development.

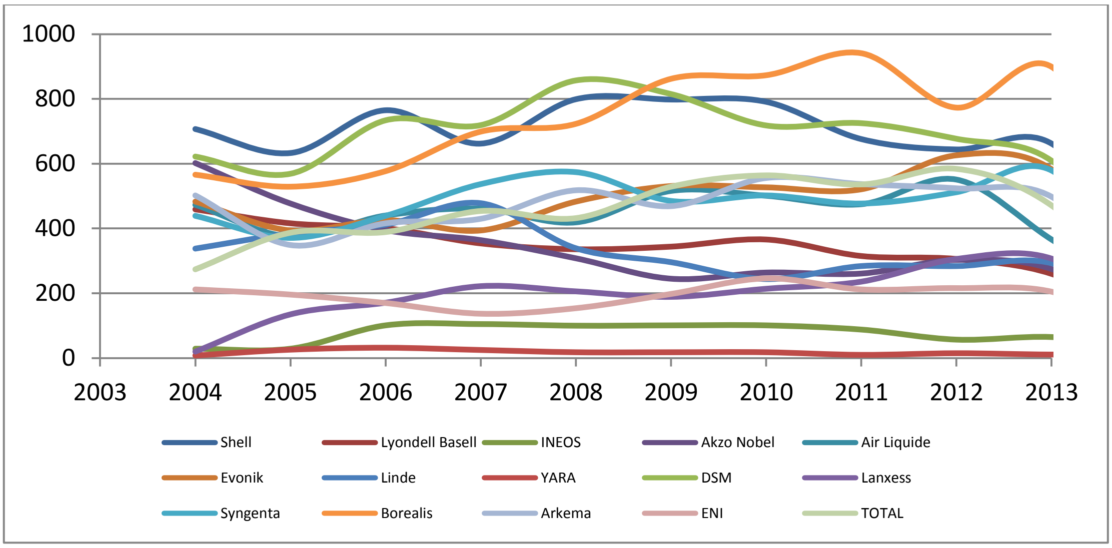
Figure 70. Global patent application and patent related document publication



Data source: Thomson Innovation (2014). Author's analysis

We now focus in more details on the companies which applies less than 1000 patents per year (figure 71). In this sub-group of companies Borealis, Shell and DSM are the leaders. These are followed by a group of companies whose application ranges between 350 and 400 patents per year. It was also surprising to see that there were few companies whose patent application was less than 100 per year. This also confirms that all companies do not have the same level on focus on innovation or patenting.

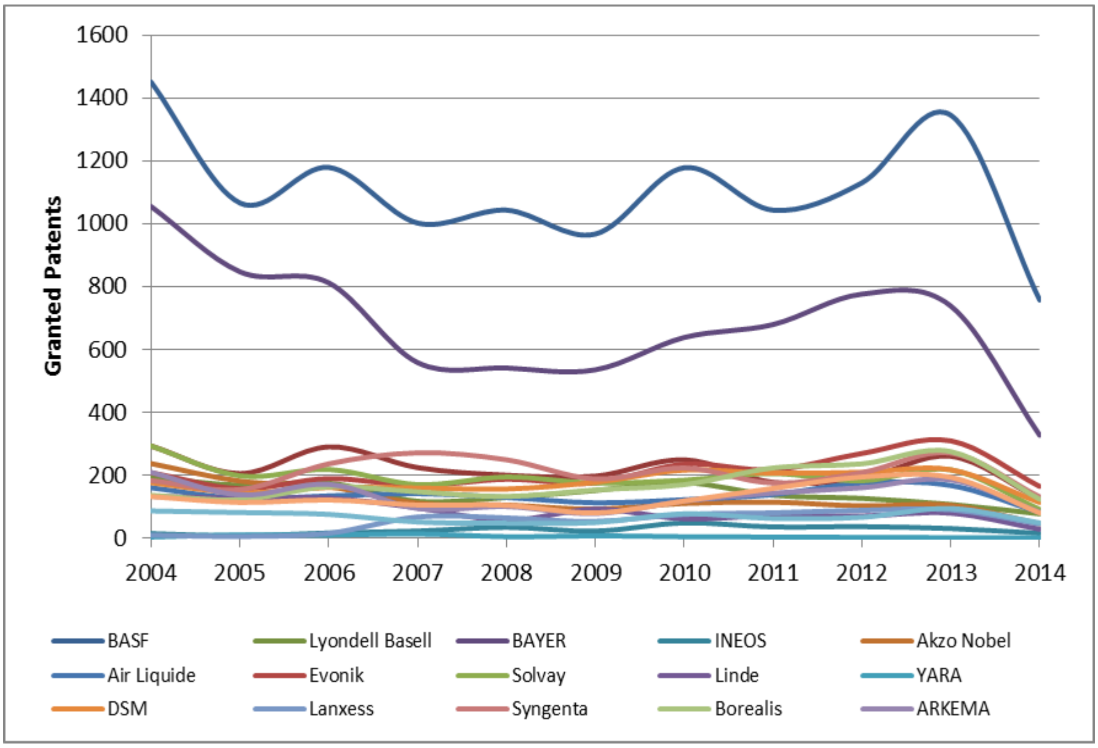
Figure 71: Global patent application and patent related document publication



Data source: Thomson Innovation (2014). Author's analysis

The graph below (figure 72) shows the number of patent families granted to the top fifteen chemical companies in Europe. The patents granted were searched for in the database of the most important patent authorities: US, Europe, Australia, Canada, Germany, China, India, Japan, Korea, Singapore and Vietnam. On the basis of the patents granted, the companies can be divided into highly patenting companies, medium patenting companies and low patenting companies. BASF has highest number of patents granted followed by Bayer. Likewise, in both cases, there was a fall in the number of patents granted between 2004 and2009. Then they seem to have recovered. For the year 2014, we have considered data until the middle of the year. Many of the companies fall in the range of 150 to 250 patents granted, which we can consider as medium innovative companies. In this study we also found a few of the companies whose focus on patent has been very low, thus have very few patent granted.

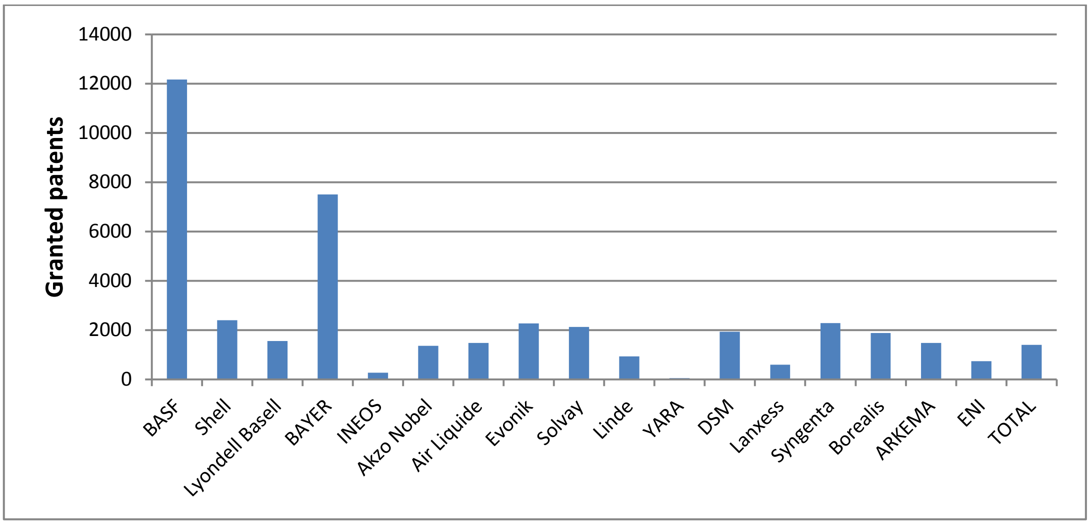
Figure 72. Granted patent of the top chemical companies at the important patent offices



Data source: Thomson Innovation 2014. Author’s analysis

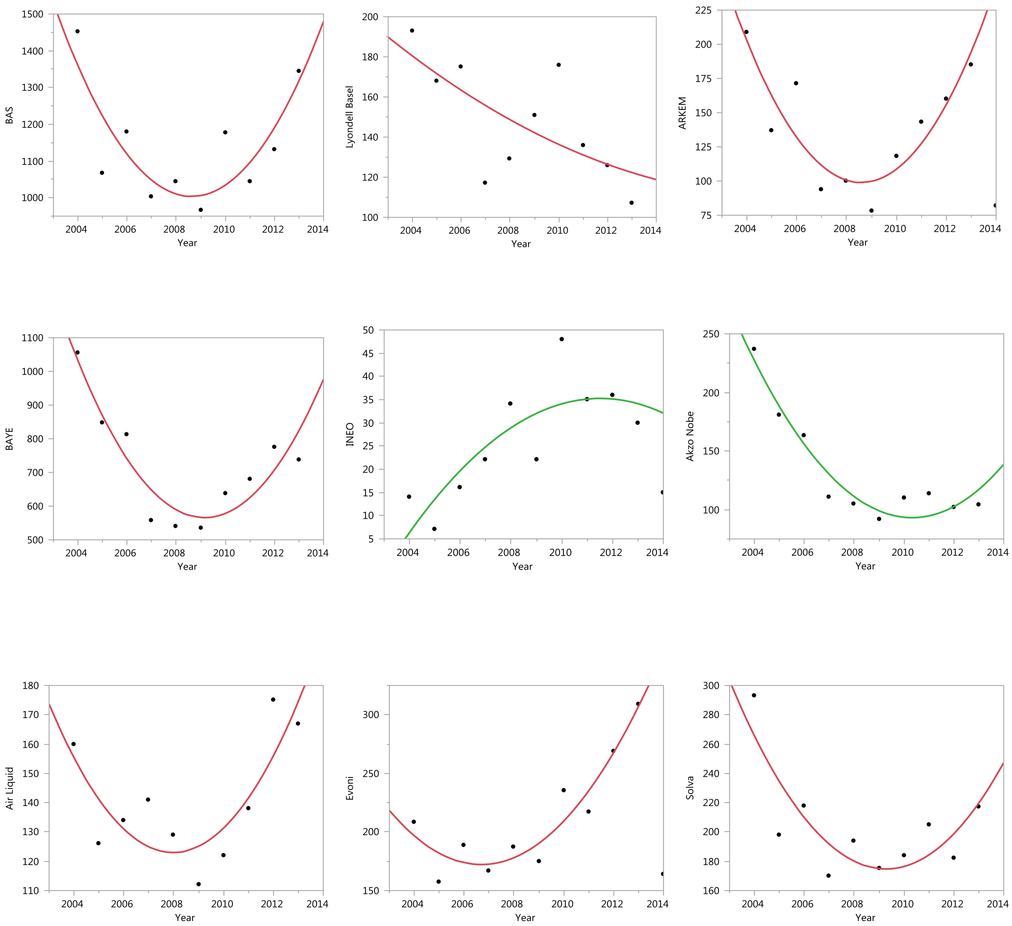
The bar chart below shows the total number of patents in terms of families granted for last ten years at all major patent offices. Like the previous trends, BASF is leader in terms of granted patents followed by Bayer. Shell, Evonik, Solvay, Syngenta all have in total slightly above 2000 patents families granted.

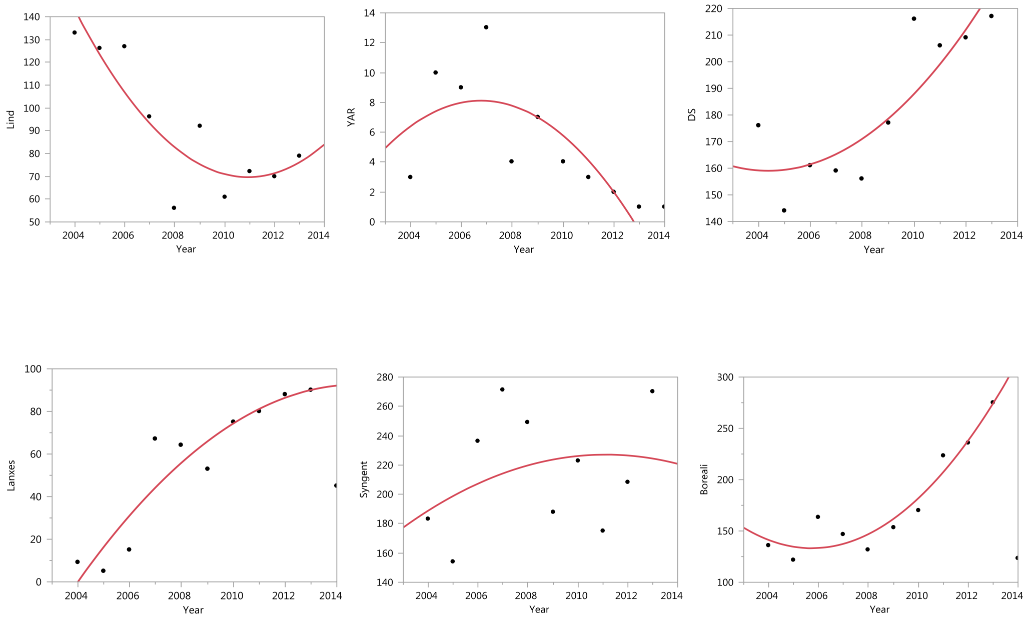
Figure 73. Total granted patent for the top chemical companies for the last 10 years



Data source: Thomson Innovation 2014. Author's analysis

Figure 74. The trend of patent granted of the specific companies



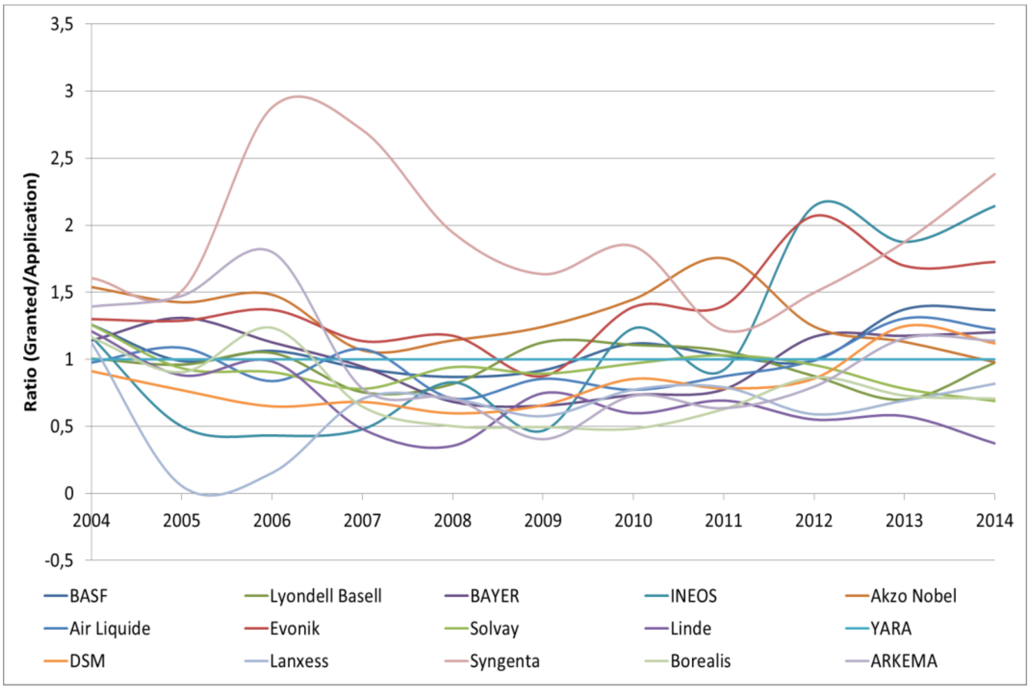


Source: Thomson Innovation (2014). Author’s analysis

In figure 74, we see the trends of patent granted for each of the companies. Polynomial of second degree is used as the curve for fitting. It is seen that in many cases, the curve is in a U-shaped form. The bottom of the U- shape is seen generally for the year 2008 and 2009, which corresponds to the year of global economic crisis. This is particularly true for BASF and Bayer which has the highest number of granted patents.

It is generally believed that the more research companies do the more patent applications they will make. It is also believed that the quality of research can be judged by the number of patents granted. Graph 75 below shows the ratio of patents granted to patents applied for in one particular year. It can be seen that in most cases the ratio is between 0.5 and 1.5 which suggests that both the research and the patent applications are of high quality. In many cases the ratio is above one. This is because a patent application can take a few years before it is granted. So in some cases the number of patents granted is higher than the number applied for in one particular year.

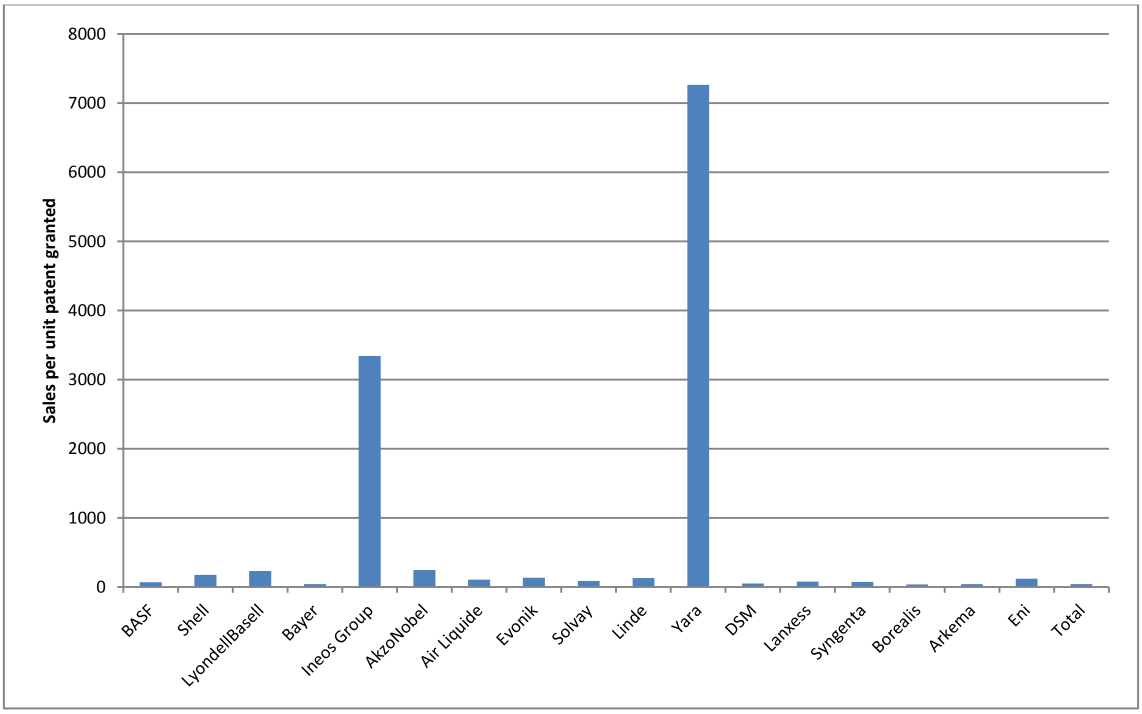
Figure 75. Ratio of application to granted patent for the top chemicals of Europe



Data source: Thomson Innovation (2014). Authors' analysis

Figure 76 is an interesting analysis as the amount of sales per patent applied. It is evident that Ineos and Yara have a very high value which is definitely due to less focus on patenting.

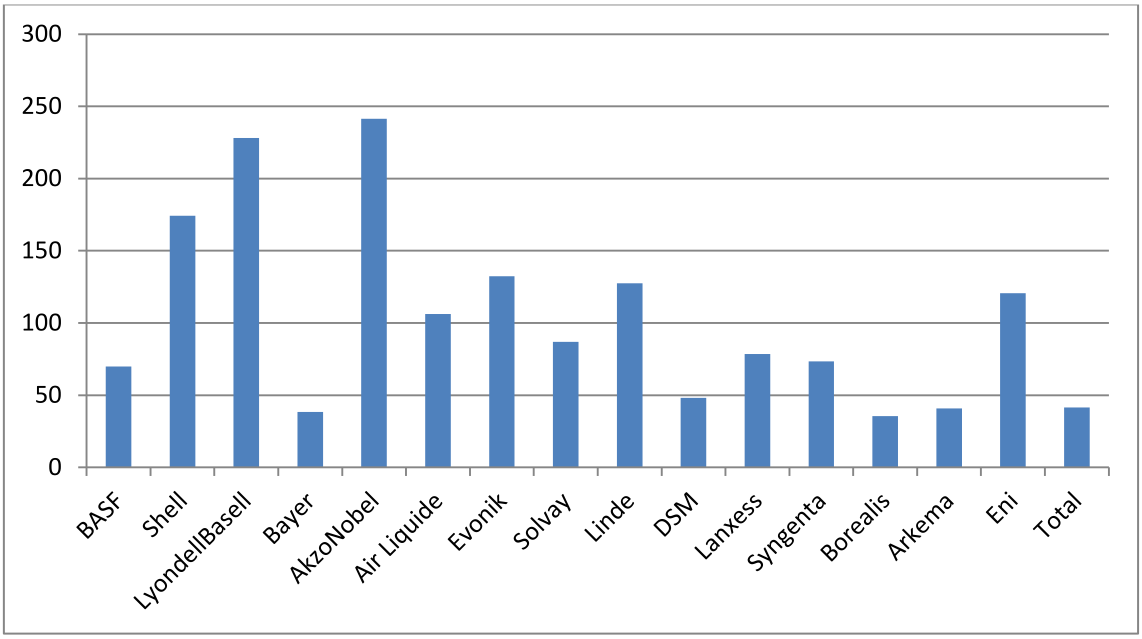
Figure 76. Sales per unit of granted patent



Data source: Thomson Innovation (2014). Author's analysis

Since the data from Yara and Ineos makes us difficult to see and compare other companies, the figure 77 shows better how are rest of the companies doing in term so sales per unit patent application. Bayer and Basf due to very large number of patent application have a lower ratio.

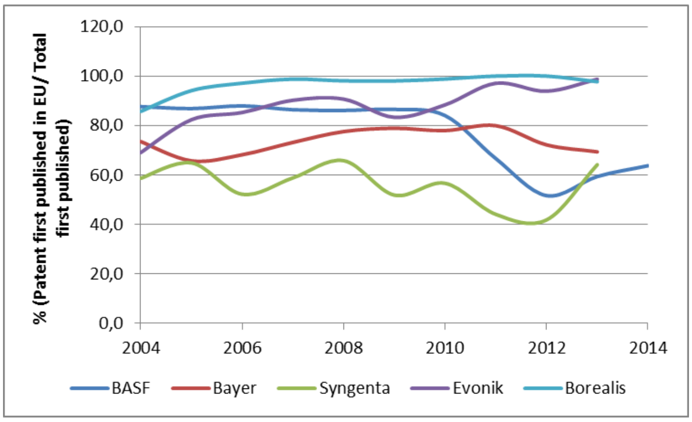
Figure 77. Sales per unit of granted patent for the companies whose ratio value is small



Data source: Thomson Innovation (2014). Author's analysis

The figure 78 shows the percentage of the patents of a particular family that were first applied in EU compared to total global application of the first patent of that family for the companies having highest granted patents. It is seen in most cases, 50 % of the first patent is applied in EU which can be due to the fact that the research is coming out of the laboratories in EU or the companies see higher urge to protect their technology in the EU market. It also interesting to see that in case of BASF, there is a steady fall of the EU share of the total first patent, which can be due to the effect of growth of the emerging economies.

Figure 78. Percentage of patent first published in EU compared to total patent published first time



Data source: Thomson Innovation (2014). Authors' analysis

4.4 Conclusion

Patent application until a patent is granted is a complex process consisting of several steps. Chemistry is a leading sector in which high volume of patents are granted at the European Patent Office of which organic fine chemistry, bio-chemistry and pharmaceutical are the key business sector. Only five of the large selling European chemical companies feature in the top 25 fine organic chemistry patent applicants for 2013 which is concerning in terms of their innovation policy. BASF, Bayer and Akzo Nobel have a falling in number of US granted patents over last 14 years as they focuss more on the emerging economies. BASF and Bayer have over the years had largest number of granted patents. For most of the companies that were studied, the first patent of a patent family is applied and granted at the European Patent Office. From the trend analysis for the first hypothesis test, it is seen that most companies did not have an upward trend for the last 10 years. It was seen for BASF and Bayer that they had a downward trend until 2009 and then there was sharp rise in the number of granted patent. This trend was also seen in case of many other companies analyzed. It can be concluded that the global crisis that hit the economy in 2008 – 09 had a negative effect on patenting and innovation.

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7. R&D spending of the top European chemical companies

Contents

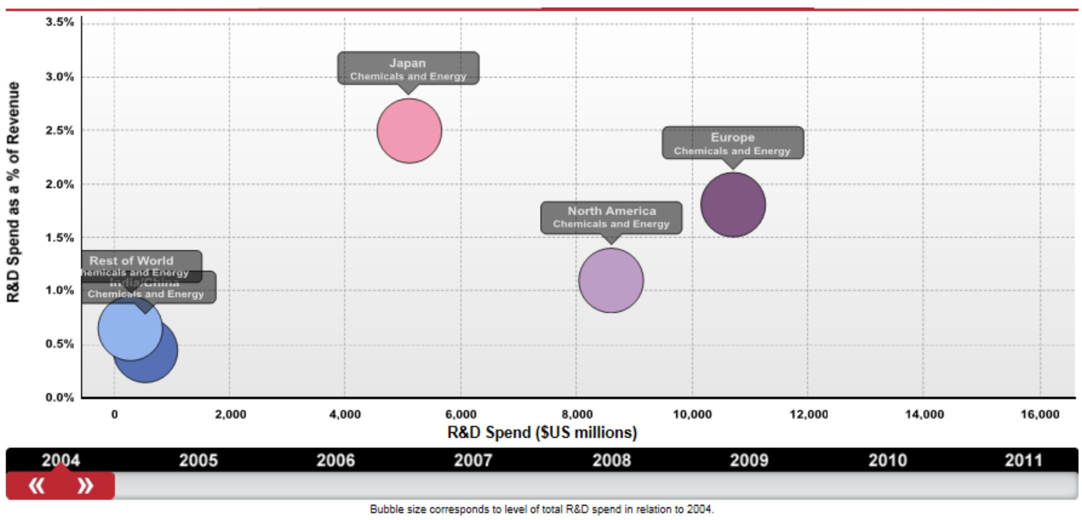
7.1 Introduction:

European leadership in science, research and technology is the pillar to becoming a key player in the field of innovation. While innovation is more than research and development, the link between research in chemistry (and related sciences) and innovation is particularly strong in the chemicals industry. Overall, it is necessary to increase the quantity of research. Excellence in science and research must get more opportunities to unfold its inherent impact on open innovation along technology driven paths. In general, companies are urged to review their R&D plans and to extend corporate research programmes to medium and long term objectives. In this chapter we will test the second hypothesis of this research, i.e. if the large chemical companies which are headquartered in Europe are increasing their R&D activities by spending more in R&D. The R&D spending is studied both globally over different regions in the chemical sector. Then a deep drill is made to understand the R&D spending and R&D intensity of the companies under study. A bivariate analysis is made to see if there is any relationship between patent application and R&D spending.

7.2 R&D Spending

Product innovation, competitiveness, sustainability and resource efficiency provide important opportunities for differentiation and, potentially, growth. Innovation will have high positive impacts in economic terms such as improving the performance and competitiveness of existing industries, the development of new industries and solutions as in products and services; in social terms, such as keeping and creating new high value-added jobs and leading to healthier and more comfortable lives; and in environmental terms such as reducing the pressure on our resources by increased efficiency through optimised production processes and products.

Figure 79. Comparative study of R&D spending and R&D intensity of chemical industry in different regions of the world

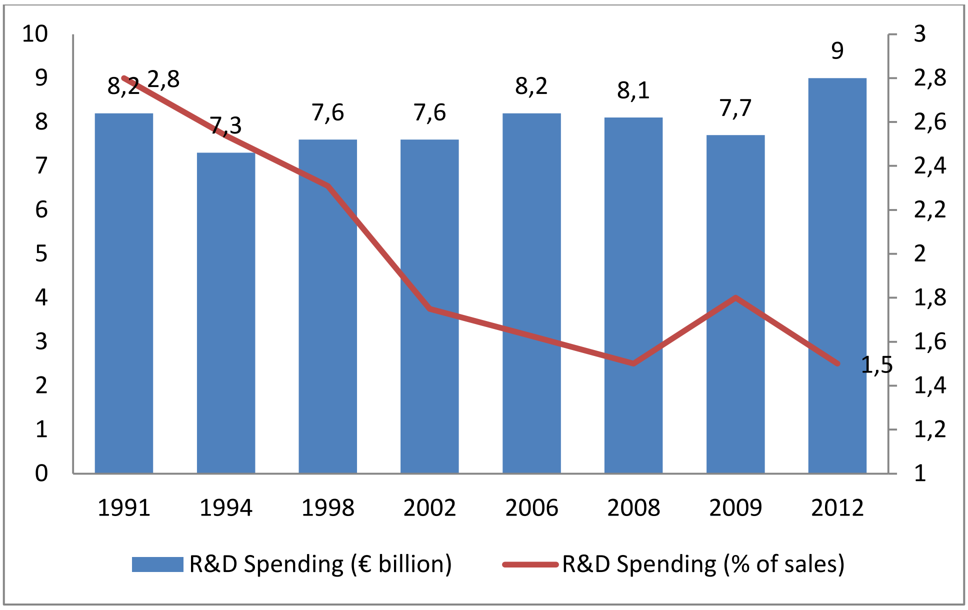


Source: Booze (2014)

Figure 79 compares the R&D activity of the chemical industry in different regions of the world for the year 2011 with 2004 taken as base year. The data is divided into seven regions: Europe, North America, Japan, India / China and Rest of the World. In terms of absolute value, European chemical industry is the biggest spender with almost $10,500 million followed by North America of around $ 8,500 million while Japan is distant third with around $ 5,000 million. R&D spending for India / china in chemical industry is very low. In terms of R&D intensity which is the ratio of R&D spending to revenue expressed as percentage, Japan is the leader followed by Europe.

The European chemical industry is therefore uniquely placed to grow in the internal market as well as develop as a global leader for development –driven product and breakthrough. Many of the challenges faced by the chemicals industry affect economic activity and society as a whole and concern manufacturing industry across the board. Innovation is indispensable to overcome these challenges, avail of related opportunities and ensure the industry's further success. This means that the industry will always have a strategic, economic and social importance. Europe must retain a strong base in this sector, not only because of its economic weight, but also because of its ability to continually generate innovation critical to meeting the major challenges of modern societies. In European Union, there has been a decline in R&D spending in terms of absolute value as well as percentage of sales as shown in the figure 80.

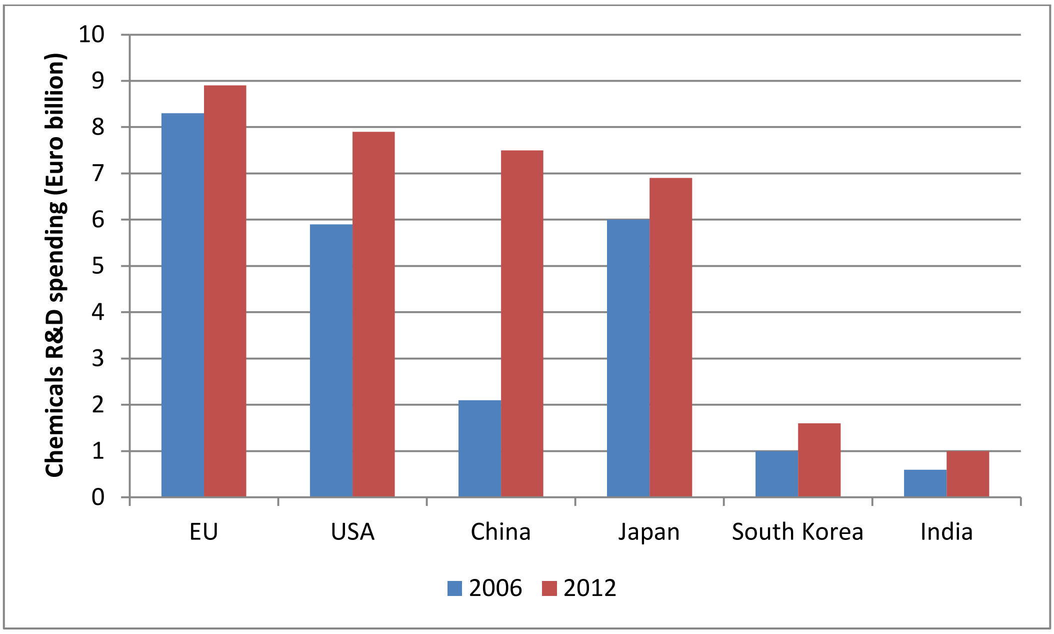
Figure 80. R&D spending and R&D spending as a percentage of total sales



Source: Cefic (2013)

Even though the R&D spending in absolute term has remained almost the same over the years, it is way ahead compared to other geographical regions. In China there has been threefold increase of R&D investment in 2012 compared to that of 2006. For Other regions, the R&D spending has slightly increased (figure 81).

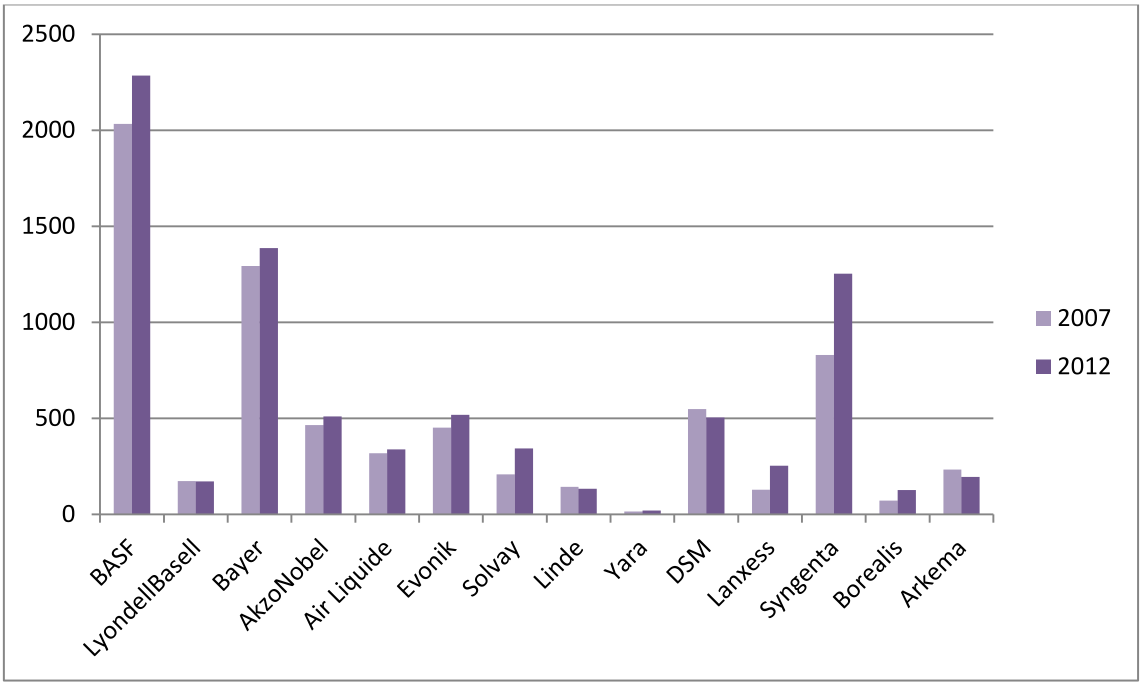
Figure 81. R&D spending of different geographical region in 2012 compared to 2006



Source: Cefic (2013). Graph: Author

Now we will like to understand the strategy large chemical companies are adopting in terms of R&D spending and investment. BASF has largest R&D spending followed by Bayer as distant second. BASF is the largest chemical company and this high spending on R&D justifies its enormous R&D infrastructure. Bayer invests heavily in research specially its pharmaceutical and crop science division. Syngenta showed highest possible increase in 2012 of R&D expense compared to it in 2007. On the other side of spectrum, we see Arkema and Linde have fallen in 2012 of R&D expenses compared to 2007. Yara had very small R&D spending for both the years (figure 82).

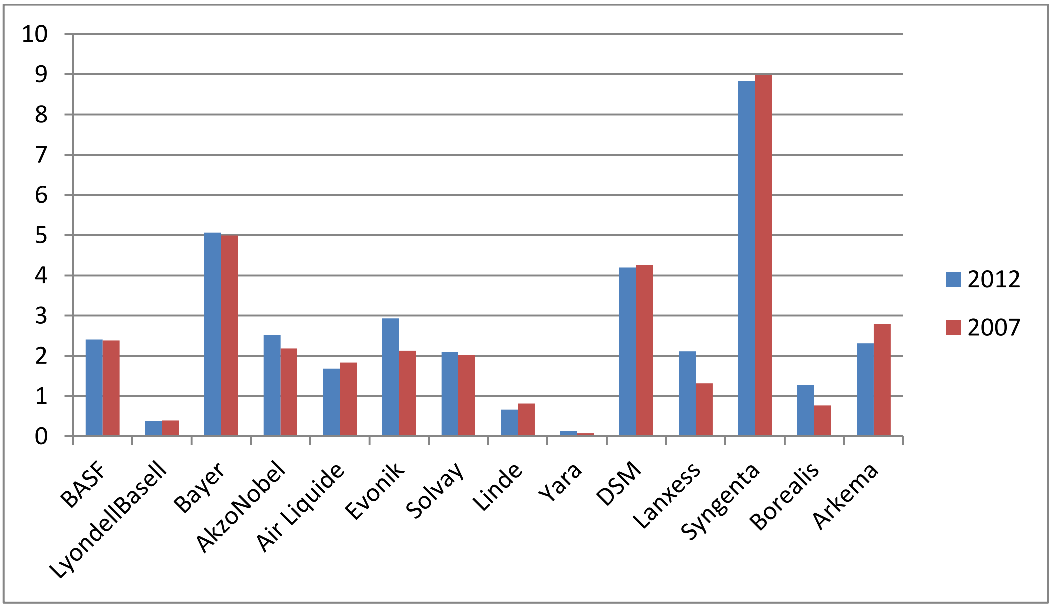
Figure 82. Investment in R&D for the top European chemical companies



Source: Cefic (2013). Author's calculation

R&D intensity is the ratio of the R&D investment to total sales and expressed as percentage. This is an index to show how efficient is R&D in bringing up the sales of a company. Syngenta has the highest R&D intensity followed by Bayer and DSM (figure 83).

Figure 83. R&D intensity of top chemical companies of Europe

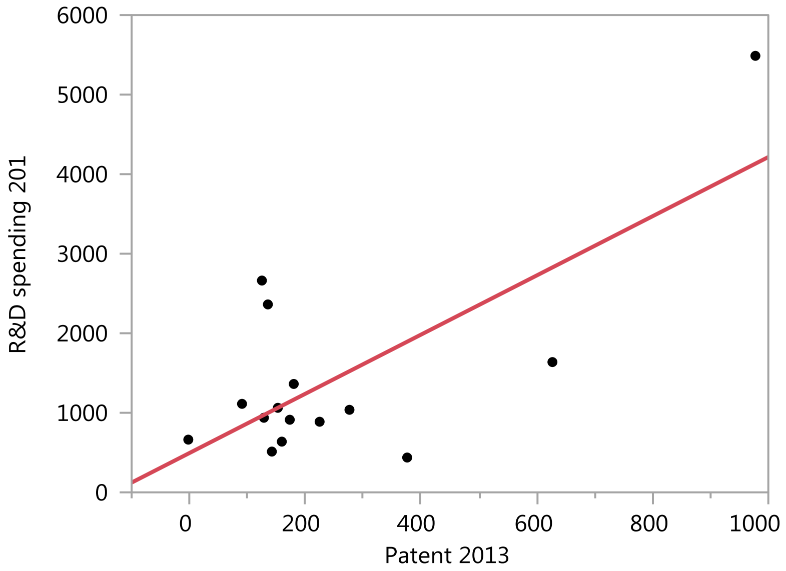


Source: Cefic 2013. Author's calculation

High R&D intensity means although there is high investment in R&D, this is not translated into Sales. Companies invest in R&D in order to develop new products which will increase its sales. But if the investment on R&D is not bringing new sales that means the money on R&D is not well spent. This results in a very high R&D intensity which is not good for any company. It can be noticed that many of the chemical companies is around 2 % in terms of R&D intensity such as BASF, Akzo Nobal, Air LIquide, Evonik, Solvay, and Arkema. Bayer also shows a high R&D intensity of 5 % which can be attributed to their high investment in crop science and pharmaceutical products. LyndollBasell and Yara has very low R&D intensity which can be due to very low level investment in R&D.

Figure 84 shows the relation between R&D spending for 2012 and patent application for 2013. There are two sets of population that can be seen on the chart. One set consisting of high amount of both R&D spending and patents which is seen on the upper right points on the chart. These are from BASF and Bayer. Then there is a scatter of points in the lower left part of the graph where most of the other chemical companies appear. They generally have a lower R&D budget and also as a result of it there is less number of patents applied.

Figure 84. Bivariate Fit of R&D spending 2012 By Patent 2013



Source: Tullo (2013) and Thomson Innovation (2014). Author's Calculation

Linear Fit

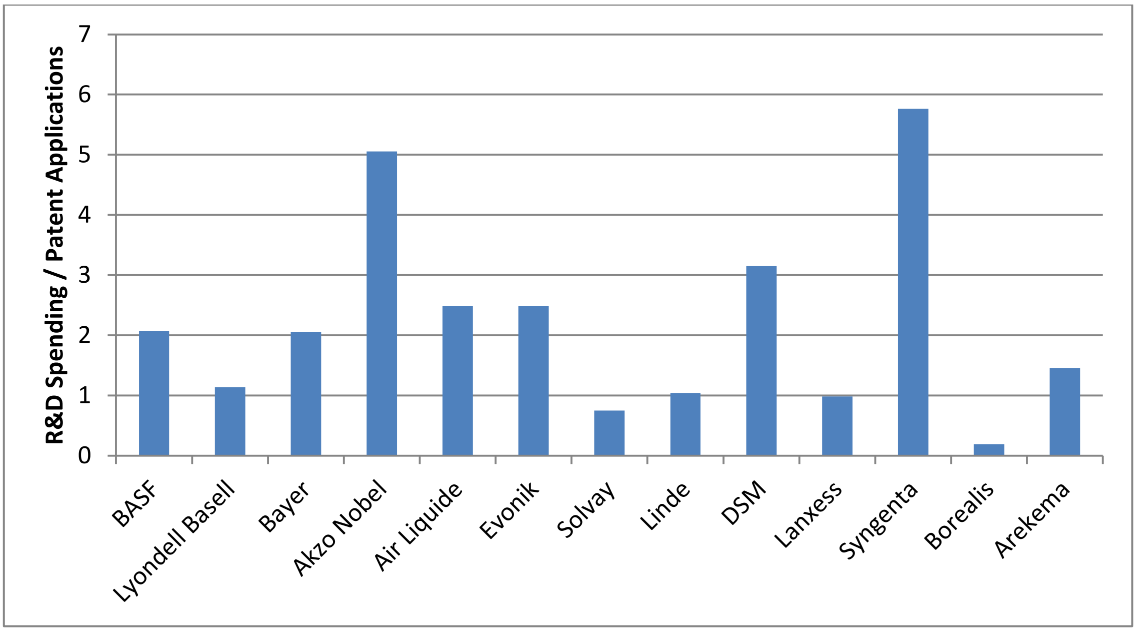
R&D spending 2012 = 494,49936 + 3,7204511*Patent 2013

Summary of Fit

RSquare	0,51637
RSquare Adj	0,479167
Root Mean Square Error	926,7978
Mean of Response	1434,533
Observations (or Sum Wgts)	15

The red line shows the line fit of the data point. The RSquare of the fit is above 0.5 which makes it more interesting and shows that there is some degree of relationship between the amount of patent applied and the R&D spending a year earlier.

Figure 85. Patent intensity ratio



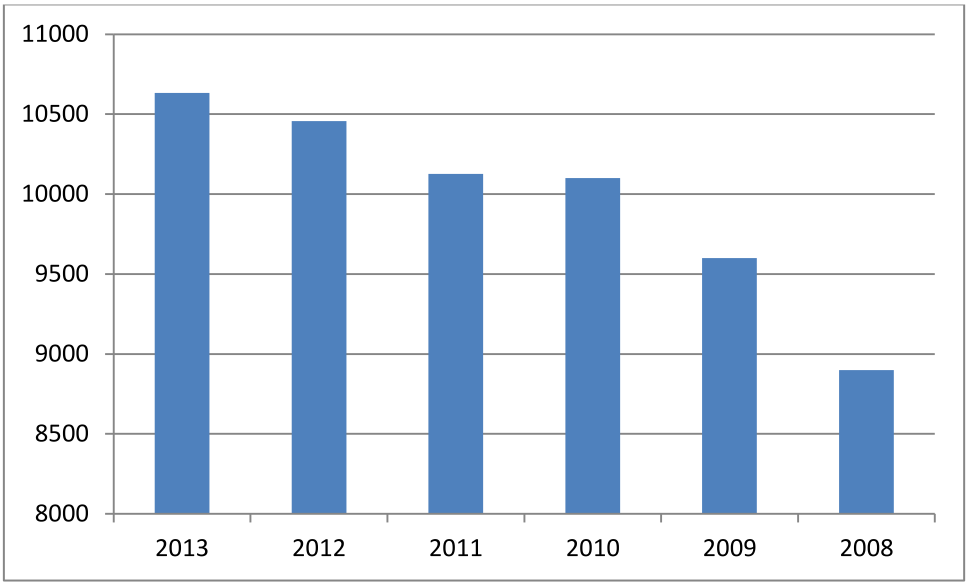
Source: Thomson Innovation (2014). Authors' calculation

Another way of measuring how efficiently is the R&D spending is how many patent applications has this resulted. Figure 6 shows the ratio of the R&D spending to patent applications. It is assumed in this data analysis that the patent is applied after one year of research, that means the R&D spending is taken for 2012 while patent application data is taken for 2013. Bayer and BASF, who have the largest patent granted are both around 2 while few are also below one. The companies whose ratio is low tend to show that their R&D is more efficient in generating patent applications or ideasn (figure 85).

7.3 Further R&D spending studies for specific companies

From the previous analysis, we have seen BASF and BAYER have the largest number of granted patent in the list of nineteen chemical companies that we are studying. So we will like to understand this on their R&D spending strategy. Figure 6 below shows that BASF has been investing in R&D by increasing in the number of people in that group. It is interesting to see that just after the financial crisis that hit in 2008, BASF has been increasing its work force in R&D, thus showing their strategy of R&D expansion (figure 86).

Figure 86: Number of people working in R&D in BASF



Source: BASF Annual Report (2008-2012). Author's analysis

The table 7 below shows how the R&D budget is spent in BASF. Until 2012, there was an expenditure head plastics, but from 2013 this does not exist. This is an interesting way of re-organizing the portfolio based on business need. Functional materials are given a much higher research focus. Chemicals and oil & Gas budget in terms of percentage is also increased over the years.

Table 7. R&D spending of BASF in several segments

Segment	**2013**	**2012**	**2011**	**2010**	**2009**
Chemicals	10	8	8	9	9
Plastics		9	9	10	9
Performance Product	20	20	21	19	20

Functional Materials & Solutions	20	14	12	12	12
Agricultural Solutions	26	25	26	26	25
Oil & Gas	3	2	1	1	1
Corporate Research & Otheres	21	22	23	23	24

- All the numbers in this table are in percentage of the total R&D spending

Source: BASF Annual Report (2009-2013). Author’s analysis

Bayer's expenditure on R&D is divided into three broad segments: materials, agricultural and heath. Pharmaceutical is the largest sector of R&D spending and this also results in largest number of patents for the company. Over the years, Bayer is slightly increasing its research focuses on crop science (table 8).

Table 8: R&D Spending of Bayer in different segments

Segments	**2013**	**2012**	**2011**	**2010**	**2009**
Material Science	7	8	8,1	7,6	7,5
Crop Science	27	26	24,7	23,6	23,8
Heath Care					
Pharmaceutical	52	52	53	57,4	67,3
Consumer	12	13	13,4	10,3	

Source: Bayer Annual Report (2010-2014). Author’s calculation

7.4 Conclusion

Europe makes the largest spending in research and development in chemistry and chemical engineering. BASF, Bayer and Syngenta are the largest spender in R&D while Syngenta, Bayer and DSM are highest in terms of R&D intensity. Most companies have a patent intensity ratio of around two or below. BASF has been increasing its R&D work force significantly over the last five years. It is focusing more on research on functional materials. Bayer is increasing its research in crop science. So the second hypothesis is proved true for most of the chemical companies that they have been increasing their R&D spending over the years, especially in last 5 years.

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8. Innovation through Merger and Acquisition

Contents

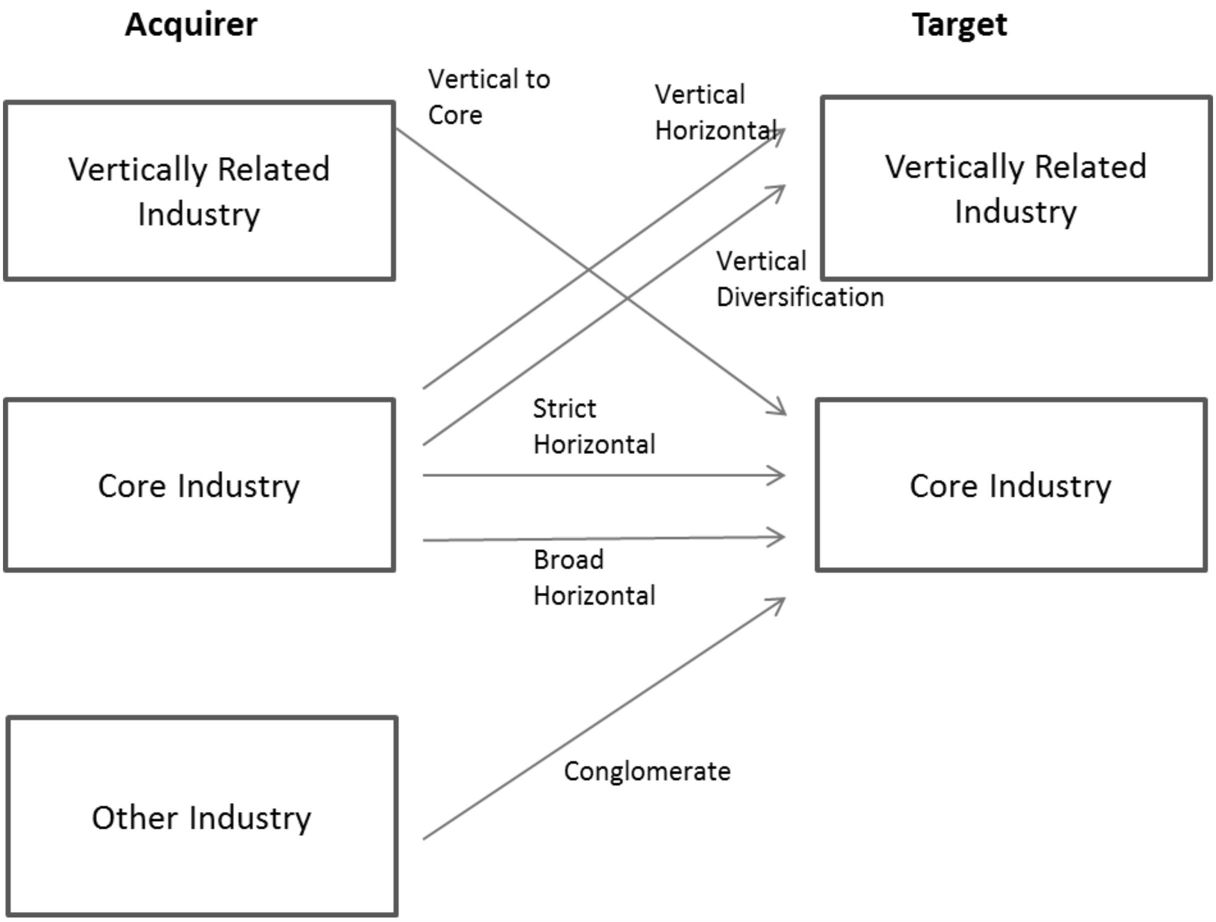
8.1 Introduction

An extensive body of research establishes that firms spend considerable amount of resources to acquire other firms in order to promote growth, improve efficiency, achieve risk reduction, and secure competitive advantage with respect to competitors in the product market. Both Merger and Acqusition (M&A) and innovation are instruments for growth and competitive advantage. Therefore they are fundamental to each firm's competitive strategy. Usually, both instruments have been studied separately, but much less in conjunction. Although we have a detailed understanding of these traditional motives of M&A, there has been relatively little research on the effect of M&A activity on the innovation output of a firm This is unfortunate as both processes – the process of innovation and the process of mergers and acquisitions - are intimately connected. The impact of mergers on innovation can only be rigorously assessed, if the converse direction of influence - mergers caused by innovation - is accounted for. Therefore this review tries to take a balanced view on both processes and to point out links between them. Nevertheless, the focus is on the impact of mergers on innovation. In this chapter we will test the third hypothesis of this research that is if the large chemical companies take M & A to acquire innovation.

8.2 Merger, Acquisition and innovation matrix

Chemical firms have played a prominent role in the wave of international M&As, accounting for some of the biggest international mergers of the decades. There are various reasons why a company acquires another. The figure 1 divides the acquirer´s specialty as vertically related industry, core industry or other industry. So an acquirer with vertical related industry will try to acquire a core industry in its sector or other sector. An acquirer with core industry specialty in a particular sector would acquire a company either having core specialty in another sector or having strong foot hold in the vertically related industry of the acquirer (figure 87).

Figure 87. Various reasons and strategy for acquisition of companies

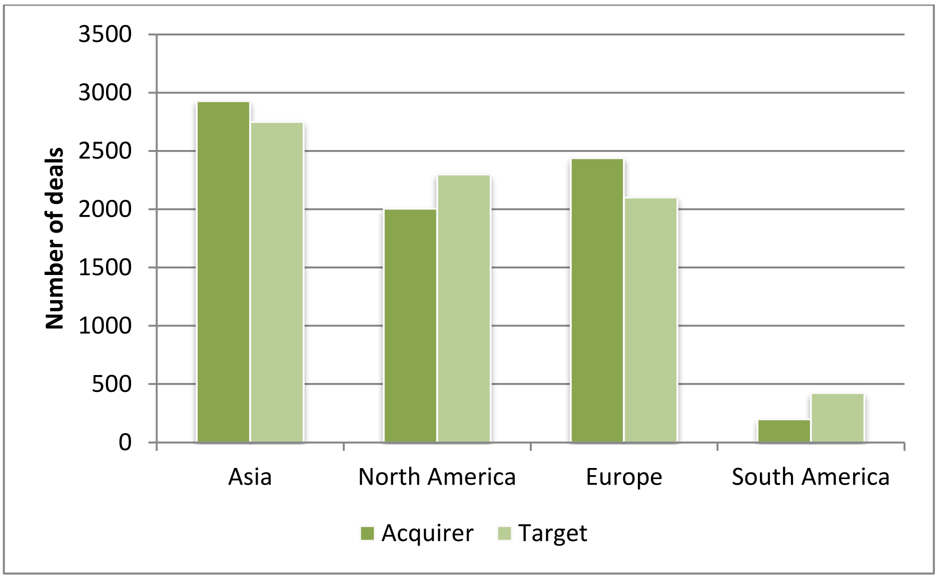


Source: Ornaghi et al. (2004)

We now turn to the diversification strategies and the extent of ownership control over acquired firms. In particular, we compare intra-regional and international M&As, and attempt to provide explanations for these differences when they exist. We pay particular attention to the R&D intensity of the industries. Using standard industrial code (SIC code) of the target and the acquiring companiesand the distinction between core chemicals and vertically related industries, we identified six different diversition strategy as explained earlier in the figure above. When both companies belong to core chemicals, there are two types of acqusitions: Strict and Broad horizontal. When the acquirer had a product line in core chemicals and the target firm belongs to one of the vertically related industries, we get vertical integration. Vertical-Horizontal is the case when the acquiring company was already present in the target firm´s industry and vertical diversification is the opposite of it. Figure 88 breaks down the acquisition deals over the last 10 years involving chemical companies according to region. The dark green bars show the number of deals in which the acquirer was located in a particular geographical region. The fact that the acquirer is located in a particular geographical region does not mean that the target is also located there. The light green bars show the geographical location of the target company.

Most of the deals were in Asia followed by Europe and North America. As we have already discussed, the purpose of the acquisition is to grow in the current market or diversify in the newer market. In many of the deals the target companies are active in sectors other than the chemical sector. So, apart from market diversification, the purpose of these deals is to gain R&D knowledge about the target companies' products. This is another way of innovating faster than by internal development.

Figure 88. Number of deals for last 10 years with the location of the acquirer and the target companies

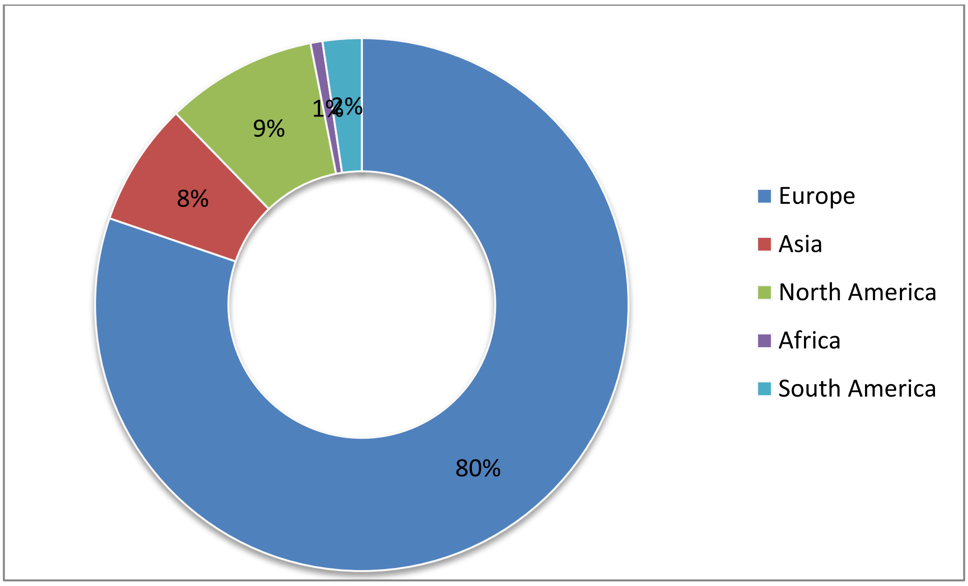


Source: Thomsonone (2014)

8.3 Acquisitions and Mergers of European of chemical companies around the world

As stated earlier, the chemical industry around the world is very active in going for mergers and acquisition either to organically grow or acquire know-how. It is seen that highest deal activities were done in Asia followed by Europe and North America. This can be due to higher availablility of cash in Asia or more market opportunity in this region. As we already discussed, the purpose of the deals are to have organic growth in the same market or diversification in the newer market. It is observed in many deals that the target company is active in a different sector than that of the chemical sector of the acquirer company. So the purpose of such deal apart from market diversification is to gain the R&D knowledge of a given product. This has been another way of gaining innovation faster than internal development.

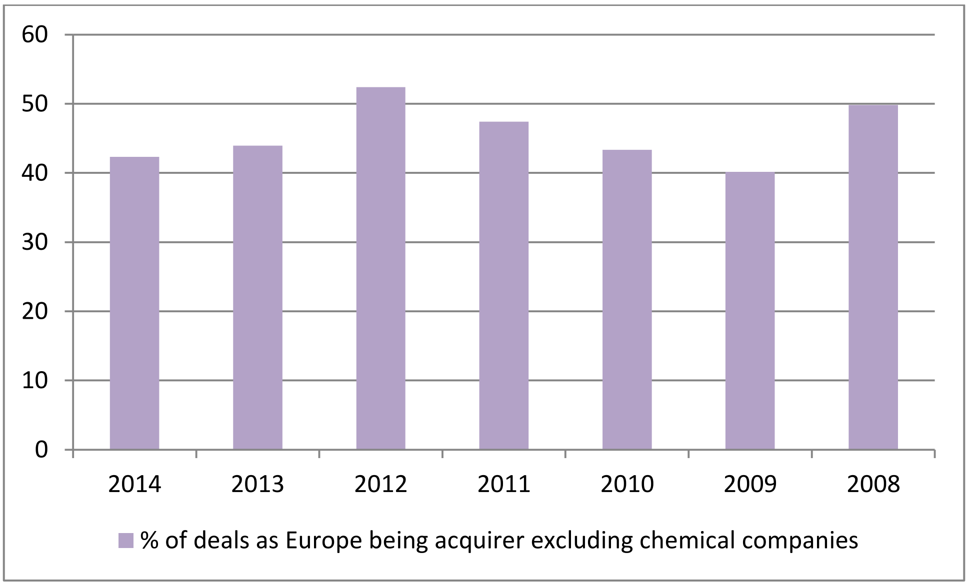
Figure 89. Geographical distribution of the target chemical companies when the acquirer company is located in Europe



Source: Thomsonone (2014). Graph: Author

Figure 89 shows how the target chemical companies are geographically distributed when the European chemical companies are the acquirer. It is seen that when the acquirer chemical companies are located in Europe, they prefer to acquire a European company. Acquisition from other region is very nominal moving around 8 to 9 % for Asia and North America respectively.

Figure 90. Percentage of deals in which European companies being the acquirer and the target companies are non-chemical companies



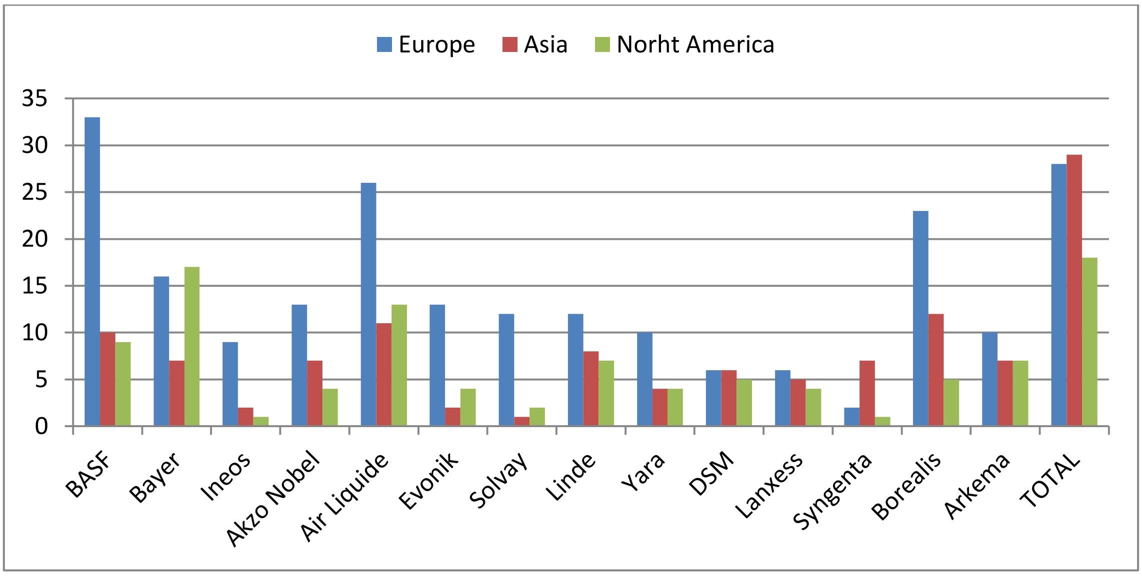
Source: Thomsonone (2014). Author's calculation, Graph: Author

If we see in details the acquiring strategy of European chemical companies over the last five years (figure 90), it is observed that a huge percentage of acquisition is done for non-chemical companies. It depicts a typical intent of these companies for diversification and acquiring know-how which is not part of their core competencies.

8.4 Top European companies' acquisition strategy

The figure 91 shows the acquisition strategy of the top chemical companies headquartered in Europe. It shows a mixed strategy of acquisition over various geographical regions. For most companies such as BASF, Air Liquide, Ineos, Evonik and Solvay, there is a strong inclination for acquisition of European companies. On the other side, for some other companies such as Bayer, DSM and Arkema, there is a tendency to do acquisition more globally.

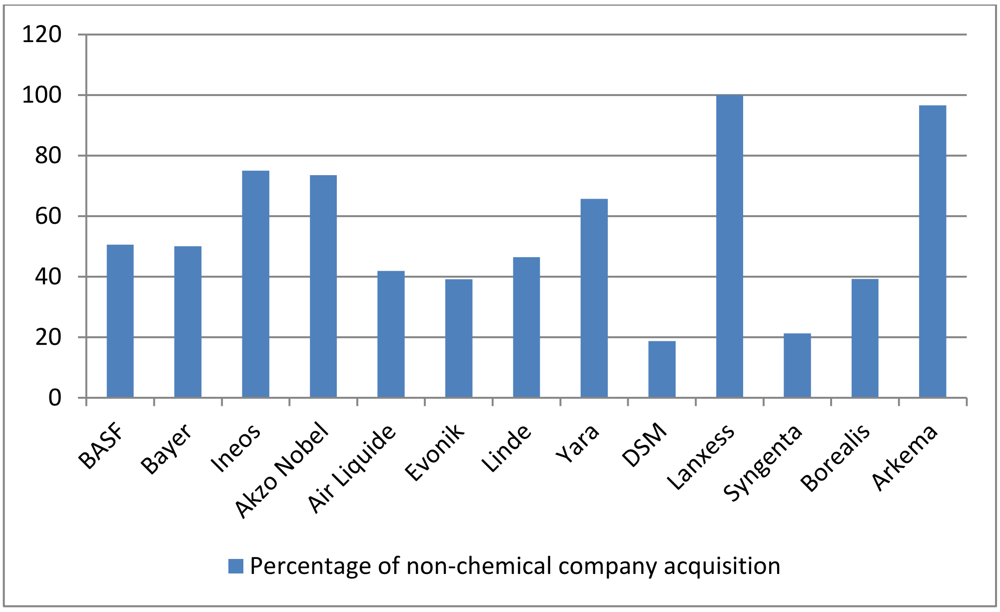
Figure 91. Geographical distribution of acquisition of top chemical companies around Europe, Asia and North America



Source: Thomsonone (2014). Author's calculation and graph

The figure 92 shows the percentage of non-chemical company acquisition of the large European chemical companies for the last ten years. These companies have huge competencies in chemical and related sector, but lacked the know-how of some other sectors they wanted to step in.

Figure 92. Percentage of non-chemical companies acquired by the top chemical companies for the last 10 years



Source: Thomsonone (2014). Author's calculation and Graph

So they acquired companies from other sector to quickly gain the technical knowledge and thus accelerate the innovation. It is seen Lanxess and Arkema mainly stick its acquisition strategy for chemical company, while for BASF which is the largest chemical company of the world, almost 50 % of their acquisition were outside chemical sector. A similar trend was observed for Bayer, who published one of the highest number of patents for the last ten years. They acquired 50 % of the companies outside their core competences of chemical and pharmaceutical. So it is seen that most of the large chemical companies in Europe are using acquisition as a tool for acquiring the know-how and knowledge from sectors where they did not have core competency.

8.5 Individual company analysis

We will now study in details some of the deals that the top chemical companies under took in recent past and the reasons for such deals. We have picked up those deals whose purpose was to acquire a new product development or a new process or technology. The basic deal information was taken from Thomsonone 2014 database, and it is followed by further analysis in order to justify the main cause of such deal. For each deal, the first statement states the details of the deal while the second statement states the actual reason for the acquisition (Thomsonone, 2014).

1. BASF

1. BASF New Business GmbH a unit of BASF SE, acquired the entire share capital of Deutsche Nanoschicht GmbH, a Rheinbach- based provider of coating technologies services, in a leveraged buyout transaction. 06/06/2013 GERMANY

- The purpose of the transaction for BASF SE was to bring new innovative technology to market.

2. BASF AS (BASF), a wholly-owned subsidiary of BASF SE, completed a tender offer to acquire the entire share capital of Pronova BioPharma ASA. 11/21/2012 NORWAY

- The purpose of the transaction was for BASF AS to strengthen its position in the market for omega-3 fatty acids.

3. BASF SE of Germany acquired Becker Underwood Inc (Becker), an American based manufacturer and wholesaler of specialty bio-agronomic and colorant chemical products. 09/20/2012 US

- The purposes of the transaction were for BASF SE and Becker Underwood Inc to develop and market new types of products for agriculture and expand their business particularly in the seed treatment market, to create a global business unit with the integration of their businesses, and to create value for their customers.

4. BASF SE of Germany acquired ITWC Inc, a Malcom- based manufacturer of polyurethane systems and polyester polyols solutions. 07/03/2012 US

- The purposes of the transaction were for BASF SE to expand market in North America, to offer new products and to strengthen its operations.

5. BASF SE acquired Equateq Ltd, a London-based manufacturer of chemicals. 05/09/2012 UK

- The purpose of the transaction was for BASF SE to extend its omega-3 products for the pharmaceutical and dietary supplement industries.

2. Bayer

1. Bayer AG acquired the entire share capital of STEIGERWALD Arzneimittelwerk GmbH, a Darmstadt-based manufacturer of pharmaceutical products. 05/16/2013 GERMANY

- The transaction was for Bayer AG to strengthen its position on the pharmacy products manufacturers market.

2. Evelyn Acquisition Co, a special purpose acquisition vehicle formed by Bayer HealthCare LLC, a majority- owned unit of Bayer AG's Bayer Healthcare AG subsidiary, completed its tender offer to acquire the entire share capital of Conceptus Inc (Conceptus), a Mountain View-based manufacturer and wholesaler of permanent birth control devices. 04/29/2013 US

- The purpose of the transaction was for Bayer HealthCare LLC to broaden its portfolio in the field of contraception and to offer new products to its clients.

3. Bayer CropScience AG, a unit of Bayer AG, agreed to acquire PROPHYTA Biologischer Planzenschutz GmbH, a Malchow-based provider of biotechnology research services. 01/08/2013 GERMANY

- The purposes of the transaction were for Bayer CropScience AG to strengthen its fruits and vegetables business and to allow new products and solutions into its portfolio.

4. Bayer HealthCare LLC, a majority-owned unit of Bayer AG's Bayer Healthcare AG subsidiary, acquired Teva Animal Health Inc, a Saint Joseph-based manufacturer and wholesaler of animal health products, from Teva Pharmaceutical Industries Ltd. 09/14/2012 US

- The purpose of the transaction was for Bayer HealthCare LLC to offer new products and services to their clients.

5. Bayer CropScience AG of Germany, a unit of Bayer AG, acquired AgraQuest Inc, a Davis-based biotechnology company. 07/03/2012 US

- The purposes of the transaction were for Bayer CropScience AG to build a leading technology platform for green products, to create synergies and value to the company and its customers, to strengthen its strategically important fruits and vegetables business and to expand its existing biological pest control portfolio.

3. Ineos Group

1. INEOS Enterprises Ltd of UK, a unit of INEOS Group AG, agreed to acquire two production facilities of Sasol Solvents Germany GmbH, a Hamburg-based manufacturer of solvents and a unit of Sasol Ltd. 12/17/2013 GERMANY

- The purpose of the transaction was for INEOS Enterprises Ltd to expand its product portfolio.

2. Ineos Barex AG, a unit of INEOS Group AG of Switzerland, agreed to acquire the Polyacrylonitriles Business owned by Mitsui Chemicals Inc, a Minato, Tokyo-based manufacturer and wholesaler of chemical products. 05/27/2013 Japan

- The purposes of the transaction were for Ineos Barex AG to create synergies and strengthen its operations.

3. INEOS Group AG of Switzerland signed a Letter of Intent to merge its European chlorvinyls activities with the European chlorvinyls activities of Solvay SA, in the formation of a joint venture. Upon completion, INEOS was to own 50% and Solvay the remaining 50% interest of the joint venture. 05/07/2013 BELGIUM

- The purpose of the transaction for INEOS Group AG was to strengthen its operations and create synergies, for Solvay SA was to focus on its core assets.

4. Ineos ChlorVinyl of the UK, a unit of Kerling PLC, acquired PVC business of Tessenderlo Chemie NV, a Tessenderlo-based manufacturer of inorganic chemicals, for EUR 110 mil (USD 158.914 mil) in cash. The transaction was to include VCM, Chlor-Alkali, part of Organic Chlorine Derivatives in Belgium, Netherlands and France. 06/14/2011 BELGIUM

- The purposes of the transaction were for Tessenderlo Chemie NV to transform itself into a specialty group and for Ineos ChlorVinyl to strengthen its operations.

5. INEOS Nitriles of the US, a unit of INEOS Group Ltd, acquired the Teesside located Seal Sands Site of BASF SE of Germany, a Ludwigshafen-based manufacturer of chemical products. 03/13/2008 UK

- The purpose of the transaction for BASF SE was to divest its Seal Sands Site as part of its strategy and to focus on the core assets of its polyamide value chain.

4. Akzo Nobel

1. Salvador AG, a wholly-owned subsidiary of Akzo Nobel NV (Akzo), completed a tender offer by acquiring the remaining 29.5% stake, or 5.872 mil ordinary shares, which it did not already own, in Schramm Holding AG (Schramm), an Offenbach-based manufacturer of coating solutions, for EUR 7.318 (USD 10.101) in cash per share, or a total value of EUR 42.972 mil (USD 59.313 mil).

Concurrently, Akzo agreed to acquire a 70.5% interest in Schramm. 06/30/2011 GERMANY

- The purposes of the transaction were for Akzo Nobel NV to expand its presence in Ania and to strengthen its operations on the speciality coatings market.

2. - Akzo Nobel NV (Akzo) of the Netherlands acquired the carved-out coatings business of SSCP Co Ltd, a Seongnam-based manufacturer of coating materials, for an amended total value of KRW 52 bil (USD 44.876 mil). Originally, Akzo agreed to acquire the carved-out coatings business of SSCP Co Ltd, a Seongnam- based manufacturer of coating materials, for a total value of KRW 54.25 bil (USD 50.995 mil). 06/30/2011 SOUTH KOREA

- The purpose of the transaction was for Akzo Nobel NV to strengthen operations in specialty plastic coatings.

3. Akzo Nobel NV (Akzo) of the Netherlands acquired a 70.5% interest, or 14.033 mil ordinary shares, in Schramm Holding AG (Schramm), an Offenbach-based manufacturer of coating solutions, from SSCP Co Ltd, for EUR 142 mil (USD 205.197 mil) in cash. Concurrently, Akzo launched a tender offer to acquire the remaining 29. 5% interest in Schramm. Upon completion, Scramm will be delisted from Hong Kong Stock Exchange. 06/30/2011 GERMANY

- The purposes of the transaction were for Akzo Nobel NV to expand its presence in Asia and to strengthen its operations on the specialty coatings market.

4. Akzo Nobel Industrial Finishes AB of Sweden, a unit Akzo Nobel NV, acquired the wood adhesives activities of Kronochem GmbH (KG), located in the Czech Republic, Romania, Bulgaria and Slovakia, a Bischweier- based manufacturer of chemicals. KG was a unit of Kronospan GmbH. 04/28/2009 CZECH REPUBLIC

- The purposes of the transaction were to strengthen Akzo Nobel Industrial Finishes AB's portfolio and boost its technological capability.

5. - Akzo Nobel Farbe & Heimtex GmbH, a unit of Akzo Nobel NV's Akzo Nobel Deco GmbH unit, acquired Joh Peters sen GmbH & Co KG, a Viersen-based manufacturer of paints, wallpapers, carpets. 01/14/2009 GERMANY

- The purpose of the transaction for Akzo Nobel Farbe & Heimtex GmbH was to strengthen its business.

5 Air Liquide

1. Air Liquide SA to acquire Plug Power Inc for USD 2.60 million

- The purpose of the transaction was for Plug Power Inc to strengthen its operations.

2. Schuelke & Mayr GmbH of Austria, a unit of Air Liquide SA, acquired Merz Hygene GmbH, a Frankfurt am Main-based manufacturer of disinfenction products, from Merz GmbH & Co KGaA. 05/03/2013 GERMANY

- The purpose of the transaction was for Air Liquide SA to strengthen its position on the hygiene products market.

3. Air Liquide Canada acquired Arrow Welding & Industrial Supplies Inc, a Edmonton-based wholesaler of industrial equipment. 01/22/2013 CANADA

- The purpose of the transaction is to strengthen and expand the presence of Arrow Welding in its primary market.

4. Societe d'Exploitation de Produits Pour les Industries Chimiques SA, a unit of Air Liquide SA, acquired BiotechMarine SAS, a Pontrieux-based manufacturer and designer of cosmetics products. Terms were not disclosed. 01/07/2013 FRANCE

- The purpose of the transaction was for Air Liquide SA to reinforce its position in the field of healthcare specialty ingredients.

5. Air Liquide Industrial US LP, a unit of Air Liquide SAs American Air Liquide Holdings Inc, acquired Progressive Resources Inc, an Elk City-based provider of oil field services. 01/03/2013 US

- The purpose of the transaction was for Air Liquide Industrial US LP to expand its product offering and operations to its clients.

6. Evonik

1. Evonik Industries AG of Germany, a unit of RAG- Siftung, acquired SurModics Pharmaceuticals Inc, a Birmingham-based manufacturer of pharmaceuticals, from SurModics Inc, for USD 30 mil in cash. 11/01/2011 US

- The purposes of the transaction were for SurModics Inc to focus on its full resources to advance its core Medical Device and IVD businesses and to strengthen SurModics' company profile.

2. Evonik Industries AG of Germany, a unit of RAG- Siftung, acquired the Solsilc plant of of Fesil AS, a Ranheim-based manufacturer and wholesaler of ferrosilicon (FeSi) and silicon metal (SiMetal). 10/31/2011 NORWAY

- The purpose of the transaction was to further develop and industrialize the Solsilc-process.

3. Evonik Industries AG (Evonik), a subsidiary of RAG-Stiftung, acquired the entire share capital of Hanse chemie AG, a Geesthacht-based manufacturer of chemical products. Concurrently, Evonik planned to acquire Nanoresins AG. 03/25/2011 GERMANY

- The purpose of the transaction was for Evonik Industries AG to strengthen its operations on the chemical specialities market.

4. Evonik Industries AG (Evonik), a subsidiary of RAG-Stiftung, acquired the entire share capital of nanoresins AG, a Geesthacht- based manufacturer of nanoparticles. Terms were not disclosed. Concurrently, Evonik acquired hanse chemie AG. 03/25/2011 GERMANY

- The purpose of the transaction was for Evonik Industries AG to strengthen its operations on the chemical specialities market.

5. Evonik Industries AG, a subsidiary of Rag- Stiftung agreed to acquire Resomer business of Boehringer Ingelheim Pharma GmbH & Co KG. 01/14/2011 GERMANY

- The purpose of transaction was for Evonik Industries AG will complement the EUDRAGIT business of Evonik - functional excipients for oral dosage forms - and will strengthen Evoniks pharmaceuticals market segment in line with its stated strategic intent. Additionally Evonik will be able to expand its expertise in new pharmaceutical application areas.

7. Solvay

1. Solvay SA of Belgium acquired Chemlogics Group LLC, a Paso Robles-based manufacturer of specialty chemicals, for USD 1.345 bil in cash. 10/07/2013 US

- The purposes of the transaction were for Solvay SA to strengthen its Novecare business and other key operations, offer new products, and expand geographical and market presence. As a result of the acquisition, synergies is expected to be accretive.

2. Rhodia Inc, a unit of Solvay's SA Rhodia SA subsidiary, agreed to merge its certain assets with certain assets of OAO "SIBUR Holding", a Saint Petersburg-based manufacturer of petrochemical products, and unit of SIBUR Ltd, to form a joint venture named Ruspav. Upon completion, Rhodia is to own 50% and SIBUR HOLDING the remaining 50% of the joint venture. 10/09/2012 RUSSIA

- The purpose of the transaction was for OAO "SIBUR Holding" to allow to offer new products and services to its clients as well as to expand presence in selected markets.

3. Solvay SA of Belgium acquired a fluorspar mine, from N&N Group. 01/13/2011 BULGARIA

- The purpose of the transaction was for Solvay SA to extend development of its fluorinated chemicals business.

4. Solvay SA of Belgium acquired a 13% stake in ACAL Energy Ltd, a Cheshire-based manufacturer of fuel cell system. 12/03/2008 UK

- The purpose of the transaction was for ACAL Energy Ltd to accelerate the development of its fuel cell technology FlowCath.

5. Solvay Pharmaceuticals SA to acquire Innogenetics NV for USD 340.46 million

- The purpose of the transaction was to continually develop and expand Solvay Pharmaceuticals SA's diagnostic business.

8. Linde

1. Linde AG of Germany agreed to acquire Calea France SAS, a Sevres-based provider of home health care services. 12/17/2012 FRANCE
- The purpose of the transaction was for Linde AG to improve position on the French homecare market.

2. Linde Canada Ltd, a unit of Linde AG, acquired Contact Welding Supplies Ltd, a London-based manufacturer and wholesaler of industrial, medical and specialty gasses and related welding products. 10/02/2012 CANADA
- The purpose of the transaction was for Linde Canada Ltd to strengthen its market in the southwestern Ontario.

3. Linde AG acquired the Continental-European homecare business of Air Products & Chemicals Inc, an Allentown-based manufacturer and wholesaler of gases and chemicals. 01/09/2012 GERMANY
- The purposes of the transaction were for Linde AG to expand its competencies and scale up its product and service offering.

4. BOC Ltd, a wholly-owned unit of the BOC New Zealand Holdings Ltd subsidiary of Linde AG's BOC Group PLC unit, acquired the remaining 50% interest, which it did not already own, in Elgas Ltd, a liquefied petroleum gas {LPG} manufacturer and wholesaler, from its joint venture partner, AGL Energy Ltd. 10/02/2008 AUSTRALIA
- The purpose of the transaction was for Linde AG to further achieve synergies in its gas production and distribution operations.

9. YARA

1. Yara International ASA of Norway agreed to acquire H+H Umwelt-und Industrietechnik GmbH, a Hargesheim-based manufacturee and wholesaler of catalytic reduction systems. 01/13/2014 GERMANY
- The purpose of the transaction was for Yara International ASA to develop its portfolio of NOx reduction systems.

2. Yara International ASA of Norway agreed to acquire ZIM Plant Technology GmbH, a Hennigsdorf-based manufacturer of irrigation monitoring products. 11/18/2013 GERMANY

- The purpose of the transaction was for Yara International ASA to improve its position within the growing fertigation segment.

3. Yara International ASA agreed to raise its stake to 35% from 30% by acquiring a further 5% stake in Burrup Holdings Ltd, an ammonia manufacturer, from Mr. Pankaj Oswal. 09/16/2008 AUSTRALIA

- The purposes of the transaction were to increase Yara International ASA's position in a low-cost gas area and to strengthen its contractual rights to downstream upgrading and marketing from Burrup Holdings Ltd in an interesting market for both its industrial and fertilizer products.

4. Yara International ASA acquired Saskferco Products Inc (SP), a manufacturer of nitrogen fertilizers, from Mosaic Co (MC) and Investment Saskatchewan Inc (IS), for an estimated 1.6 bil Canadian dollars ($1.59 bil US). 07/14/2008 CANADA

- The purpose of the transaction was for Mosaic Co to focus on their core potash and phosphate businesses, with the proceeds from the sale to be used for the planned expansions of their Saskatchewan potash mines and other non US assets.

5. Yara International ASA of Norway acquired the remaining 65% interest, which it did not already own, in Phosyn Ltd, a manufacturer of pesticides and chemicals. 03/22/2006 UK

- The purpose of the transaction was for Yara International ASA to expand its specialty plant nutrition business

10. DSM

1. DSM Venturing BV of the Netherlands, a unit of Koninklijke DSM NV, acquired an undisclosed minority stake in Viocare Inc, a Princeton- based developer of wellness and nutrition-based software. 09/13/2011 US

- The purpose of the transaction was for Viocare Inc to further expand and mature its business.

2. DSM Venturing & Business Development of the Netherlands, a unit of Royal DSM NV, acquired an undisclosed minority stake in Bioprocess Control AB, a Lund- based manufacturer of automation equipment for biogas producers. 01/11/2010 SWEDEN

- The purpose of the transaction was to optimize the production efficiency of biogas processes of the companies.

3. DSM Venturing & Business Development of the Netherlands, a unit of Royal DSM NV, acquired Segetis Inc, a Golden Valley-based manufacturer of monomers. 01/07/2010 US

- The purpose of the transaction was to increase DSM Venturing & Business Development's focus on exploiting synergy between its Life Sciences and Material Sciences activities.

4. DSME E&R Ltd, a majority-owned unit of Daewoo Shipbuilding & Marine Engineering Co Ltd, acquired an 80% interest in Sunshin Exploration & Mining Co Ltd, a Seoul-based gold mining company. 11/10/2009 SOUTH KOREA

- The purpose of the transaction was for DSME E&R to step into gold mine business.

11. Lanxess

1. Lanxess AG of Germany acquired PCTS Specialty Chemicals Pte Ltd, a manufacturer and wholesaler of speciality chemicals, from Nipsea Technologies Pte Ltd, a unit of Nippon Paint Co Ltd. 04/05/2013 SINGAPORE

- The purposes of the transaction were for Lanxess AG to gain access to a complementary portfolio of biocides and to expand the business in Asia-Pacific region.

2. LANXESS AG acquired Bond-Laminates GmbH, a Brilon- based manufacturer of carbonfibre strengthened plastics from Ringstad Cato AS. Terms were not disclosed. 09/12/2012 GERMANY

- The purpose of the transaction for LANXESS AG was to strengthening its innovative product portfolio of lightweight materials to the automotive industry.

3. - LANXESS AG of Germany acquired an undisclosed minority stake in BioAmber Inc, a Plymouth-based manufacturer of organic chemicals. 02/22/2012 US

- The purpose of the transaction was for LANXESS AG to strengthen its operations in the renewable raw materials market.

4. Lanxess Corp, a subsidiary of Lanxess AG, acquired Verichem Inc, a Pittsburgh-based manufacturer of biocides. Terms were not disclosed. 11/10/2011 US

- The purposes of the transaction were to broaden global biocide manufacturing platform and strengthening focus on megatrend urbanization.

5. Rhein Chemie Rheinau GmbH, a wholly-owned subsidiary of LANXESS AG, acquired the tire release agent business of Wacker Chemie AG, a Munich-based manufacturer and wholesaler of chemicals. 07/08/2011 GERMANY

- The purpose of the transaction was for Rhein Chemie Rheinau GmbH to concentrate on its core business through streamlining its portfolio of products and solutions.

12. Syngenta

1. Cimo Compagnie Industrielle de Monthey SA, a unit of Basf SE and Syngenta AG, agreed to acquire a power plant in Monthey from Alpiq Holding AG, a Lausanne-based provider of electric utility services. 12/13/2013 SWITZERLAND

- The purpose of transaction was for Cimo Compagnie Industrielle de Monthey SA to strengthen its operations in the field of electricity production.

2. Syngenta Crop Protection AG of Switzerland, a unit of Syngenta AG, completed a tender offer to acquire the entire share capital of Devgen NV, a Ghent- based manufacturer of biotechnology products. 09/21/2012 BELGIUM

- The purposes of the transaction were for Syngenta AG to reinforce its position in global rice market, to expand its toolbox for development of integrated rice offers and to expand RNAi technology for new biological insect control solutions. The purposes of the transaction were for Devgen NV to reach growers more quickly, enabling vital improvements in crop productivity and protection.

3. Syngenta AG acquired Pasteuria Bioscience Inc, an Alachua-based biotechnology company. 09/19/2012 US
- The purpose of the transaction was to allow Pasteuria Bioscience to sell its products to the global market.

4. Syngenta AG of Switzerland agreed to acquire the Professional Products insecticide business of El du Pont de Nemours & Co Inc {DuPont}, a Wilmington-based manufacturer of chemical and electronic products. 08/29/2012 US
- The purposes of the transaction were for Syngenta AG to expand their presence, increase their portfolio in the US, and create synergies with DuPont-Professional Prod Bus.

5. Syngenta Seeds Inc, a wholly owned unit of Syngenta AG acquired the remaining 50% interest, which it did not already own, in GreenLeaf Genetics LLC, an Omaha-based provider of research and development services, from its joint venture partner, Pioneer Hi-Bred International Inc and a wholly owned unit of El du Pont Nemours & Co. Terms were not disclosed. 11/08/2010 US
- The purposes of the transaction were for Syngenta Seeds Inc to pursue independent licensing strategies for corn and soybean genetics and biotechnology traits ,to enhanced offer for independent seed companies and to expand its portfolio of traits and germplasm.

13. Arkema

1. Arkema SA of France, acquired a 24.9% stake in Ihsedu Agrochem Pvt Ltd, a Mumbai-based producer and wholesaler of castor oil. 04/11/2013 INDIA

- The purpose of the transaction was for Arkema SA to consolidate its position in the castor oil market.

2. Arkema SA acquired an undisclosed majority interest in Adhesifs et Composites Polymer SAS. 04/03/2013 FRANCE

- The purpose of the transaction was for Adhesifs et Composites Polymer SAS to strengthen its operations and expand its presence in foreign markets.

3. Arkema SA acquire specialty alcoxylate industrial business of Societe d'Exploitation de Produits Pour les Industries Chimiques SA. 11/08/2011 FRANCE

- The purpose of the transaction was for Arkema SA to expand its specialty surfactant range intended in particular for niche markets such as warm asphalt mix for road construction, industrial detergency, and the oil and gas business.

4. Arkema SA acquired Cray Valley SNC, a Paris- based manufacturer and wholesaler of gel coats and resins, from Total SA. Concurrently, Arkema acquired Cook Composites & Polymers Co and Sartomer USA LLC. 12/07/2010 FRANCE

- The purpose of the transaction was for Arkema SA to strengthen its downstream acrylics activities.

8.6 Conclusion

It can be concluded from the above analysis that Asia has the highest number of M&A deals and is closely followed by Europe and North America. European chemical companies tend to acquire much more companies from Europe. Over 40 % of the deals of the European chemical companies are with non-chemical related company. In case of large chemical companies, a mixed strategy is noticed. BASF, Air Liquide, Ineos, Evonik and Solvay were more inclined to acquire European companies while Bayer, DSM and Arkema have been making acquisition globally. For most of the large chemical companies, a big percentage of companies acquired did not deal directly with basic chemicals. From the above analysis and specific examples of the deals, we test positive the hypothesis that large chemical companies take M&A as a route to acquire innovation.

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9. Industries, Universities and Research organization collaboration to drive innovation

Contents

9.1 Introduction

When companies and universities work in tandem to push the frontiers of knowledge, they become a powerful engine for innovation and economic growth. Silicon Valley is a dramatic example. For over five decades, a dense web of rich and long-running collaborations in the region have given rise to new technologies at a breakneck pace, and transformed industries while modernizing the role of the university. Similar activities are also observed in chemical industry in Europe. Technologies from different industries are also increasingly being combined to create new products and services. A fundamental challenge for the successful development of these inter-industry innovations is to combine the previously unconnected technologies in entirely new product architecture. The development of the required architectural knowledge is especially challenging in an inter-industry setting. This section covers various research collaborations happening in European chemical industry between industries and Universities or Research center and test the hypothesis if such collaboration is impacting the innovation trend of the companies.

9.2 Industry – University collaboration: A driver toward innovation

For an elite group of world-class research universities, this kind of strategic collaboration is top priority. The most productive collaborations are strategic and long-term, according to the practitioners. They are built around a shared research vision and may continue for a decade or beyond, establishing deep professional ties, trust and shared benefits that work to bridge the sharp cultural divide between academia and industry. Strategic partnerships between companies designed to run for five to ten years delivering greater and often unanticipated benefits to all parties through a virtuous circle of interactions. For the university, they provide a longer stream of secure funding that can bolster academic strength. Creating more strategic industry-university partnerships would substantially improve Europe’s climate for innovation. The modernization of Europe’s higher-education systems is a priority to strengthen the links between higher education, research and business to drive innovation. The European Commission launched a number of initiatives to enhance closer and more effective ties between the three corners of the knowledge triangle, including the European Institute for Innovation and Technology (EIT), the Knowledge Alliances pilot project and the University-Business Forum.

The aim of such initiate is to complement – and add more of a business perspective to – a growing body of academic studies on the state of European industry-university partnerships.

The increased incentives (and pressures) to collaborate with industry have controversial side effects on the production of scientific research itself. Nelson (2004) argues that industry involvement might delay or suppress scientific publication and the dissemination of preliminary results, endangering the “intellectual commons” and the practices of “open science” (Dasgupta and David, 1994). Florida and Cohen (1999) claim that industry collaboration might come at the expense of basic research: growing ties with industry might be affecting the choice of research projects, “skewing” academic research from a basic towards an applied approach.

9.3 Research collaborations

There are specific programme on 'Cooperation' supports covering all types of research activities carried out by different research bodies in trans-national cooperation and aims to gain or consolidate leadership in key scientific and technology areas.

The main types of such cooperation as supported by various government organizations are:

1. European Union Research Funded Projects
    a. FP 7
    b. FP 6
    c. FP 5
    d. Other (FP 4, FP 3, FP 2, FP 1, CIP, EAEC, ECSC, ENG, ENV, JRC etc.)

2. German Government Funded Projects
    a. The Federal Ministry of Education and Research (BMBF)
    b. The Federal Ministry for Economic Affairs and Energy (BMWi)
    c. The Federal Ministry of Food and Agriculture (BMEL),
    d. The Federal Ministry of Health (BMG),

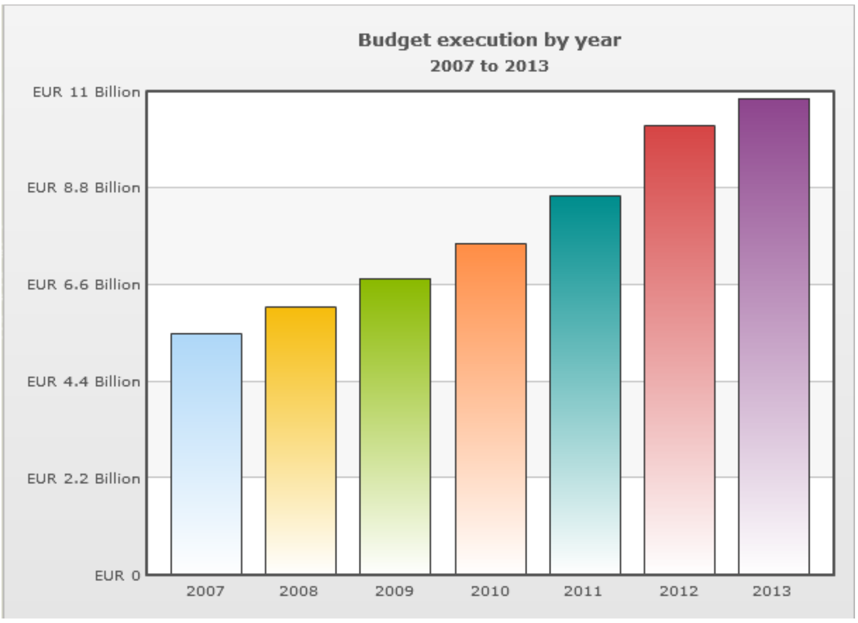
   e. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)
   f. The Federal Ministry of Labour and Social Affairs (BMAS)
3. The French National Research Agency
4. Dutch Government Funded Projects
   a. NWO
   b. The Technology Foundation STW
   c. SenterNovem
5. Spanish Government Funded Projects

For our current study, we will focus on the European Union funded research projects. There are three prime EU funded research projects as stated above: FP7, FP 6, FP 5. Let us now try understanding in details of these funding platforms.

European Union Funded Projects:

The budget of the European Union Research Funding is devoted in supporting cooperation between universities, industry, research centers and public authorities throughout the EU and beyond. The Cooperation programme is sub-divided into ten distinct themes. Each theme is operationally autonomous but aims to maintain coherence within the Cooperation Programme and allowing for joint activities cutting across different themes, through, for example, joint calls. The ten identified themes reflect the most important fields of knowledge and technology where research excellence is particularly important to improve Europe's ability to address its social, economic, public health, environmental and industrial challenges of the future. Important themes identified in the Strategic Research Agendas (SRAs) developed by the ETPs are therefore covered by the Cooperation programme. The last EU funded project, FP7 allocated EUR 32 413 million to the Cooperation programme.

Figure 93. The budgeted execution of EU FP7 research funding



Source: Research and Innovation FP7 (2014)

European Technology Platforms (ETPs) were set up with the aim of defining medium to long-term research and technological objectives and developing roadmaps to achieve them. Their aim was to contribute to increasing synergies between different research actors, ultimately enhancing European competitiveness.

Across all these themes, support to trans-national cooperation between industry and academia is implemented through:

- Collaborative research
- Coordination between national research programmes
- Joint Technology Initiatives
- Technology Platforms

Collaborative research

The bulk of EU research funding in FP7 goes to collaborative research, with the objective of establishing excellent research projects and networks able to attract researchers and investments from Europe and the entire world. The 6th Framework Programme funded European Research and Technological Development from 2002 until 2006.

Coordination between national research programmes

The European Commission showed a strong support for more co-ordination of national research programmes from all categories of contributors.

Joint Technology Initiatives

For a limited number of European Technology Platforms, the scale and scope of their strategic research agendas and the resources involved justified setting up long-term public-private partnerships in the form of Joint Technology Initiatives. These initiatives, combine private sector investment and/or national and European public funding, including grant funding from the Research Framework Programme and loan finance from the European Investment Bank.

Technology Platforms

European Technology Platforms (ETPs) have been set up in a number of areas where Europe's competitiveness, economic growth and welfare depend on important research and technological progress in the medium to long term. They bring together stakeholders, under industrial leadership, to define and implement a Strategic Research Agenda (SRA). The ETPs have contributed to the definition of the themes of the Cooperation programme, in particular in research areas of special industrial relevance (figure 94).

Figure 94. European funded project themes

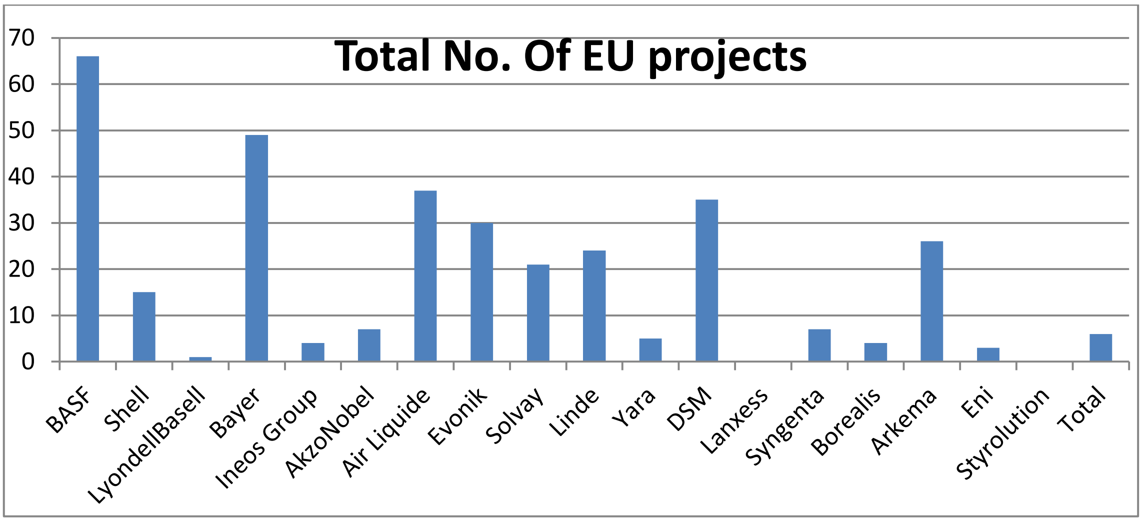
Bio-based economy	Energy	Environment	ICT	Production and processes	Transport
EATIP	Biofuels	WssTP	ARTEMIS	ECTP	ACARE
ETPGAH	EU PV TP		euRobotics	ESTEP	ERRAC
Food for Life	TPWind		ETP4HPC	EuMaT	ERTRAC
Forest-based	RHC		ENIAC	FTC	Logistics
Plants	SmartGrids		EPoSS	SusChem	Waterborne
FABRE TP	SNETP		Networld 2020	Nanomedicine	
TP Organics	ZEP		NEM	ETP-SMR	
			NESSI	Manufuture	

Source: CORDIS (2014)

9.4 Participation of the top European Chemical companies in EU funded projects

From the various data analyzed, it is seen that all the top European chemical companies actively participate in EU funded projects. The data for the last 20 years shows BASF is leader in participating in EU funded project. This is followed by Bayer, Air Liquide and Evonik. Although, there is positive force of EU funding which drives these companies to participate in these projects, but it also shows that they are willing to co-operate not only with research institutes and universities but also work with their competitors in driving research and innovation (figure 95).

Figure 95. Total number of EU projects for last 20 years in which the top European chemical companies participated



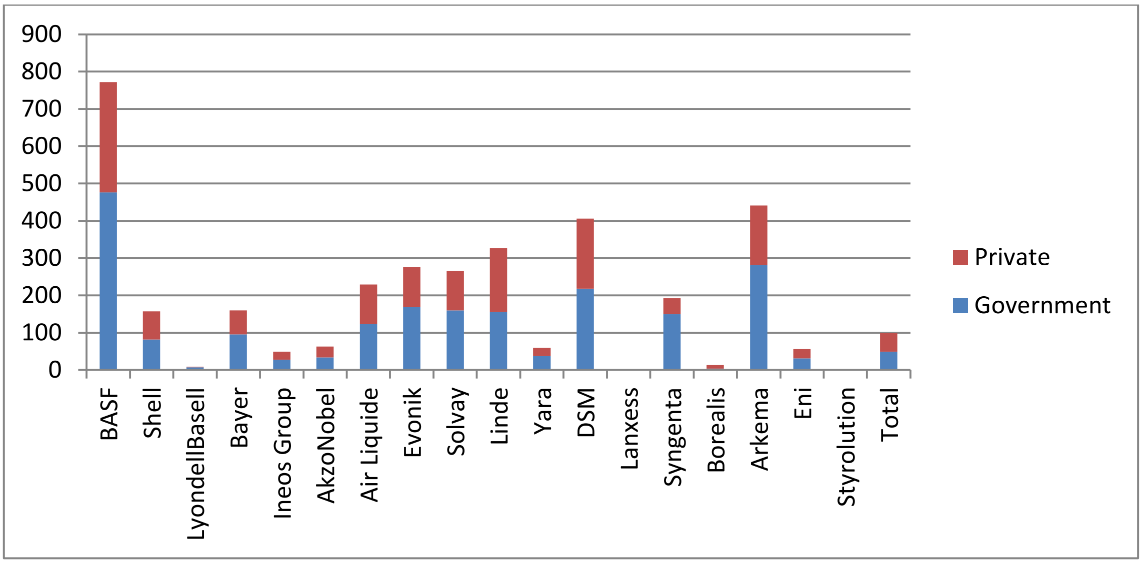
Data Source: CORDIS1 (2014). Author's calculation and graph

Each of the project in which these companies took part was further analyzed in order to get detailed understanding of the type of projects and the partners. Although the type of project theme varies, but in cases where companies are involved, they tend to be more application oriented. Let us take example of an EU funded research project: A common European approach to the regulatory testing of nanomaterials. The project falls under FP7 framework with total cost of 49 Million Euro. It has 63 partners including top chemical companies: BASF, Bayer, Arkema. Over 75 % of the participants are government institute or universities. In terms of private companies involved in this project, they were selected based on their speciality areas such as Veneto Nanotech Spa from Italy who are specialized in Nano-technology. This type of projects drives research and innovation forward but the results are highly unlikely to be patented, given the number of partners and also due to openness of such projects. Another example of BASF´s participation in EU project which involves fundamental research is "Developing the Next Generation of Biocatalysts for Industrial Chemical Synthesis". A collaboration of industrial and academic partners had identified the key technology fields of amine synthesis, polymers from renewable resources, glycoscience and wider oxidase application as four key areas where the next generation of biocatalysts that will lead to improvements in both economic and environmental performance of the chemical manufacturing industries. Most of the partners of this project are universities, but there are some private companies as partners also. Most of the private companies are small, but very specialized in the field of the project.

In some cases, two different entities of the same company can be a partner of a project as seen in the project, “The Plant Cell Wall Training Consortium” where Bayer Bioscience and Bayer Cropscience are two separate partners. It is seen as a common phenomenon that these big chemical companies do not partner in these projects with a single entity, rather they participate either as a individual business or individual location entity.

If we look further into how these companies are participating, we see a distinct trend. Some companies are participating more with government organizations while others are in project which has good distribution of private and government organizations. By government organization, we mean universities, colleges and publicly funded research institutes. The figure 96 shows the distribution of the private and government identities in terms of the total participants.

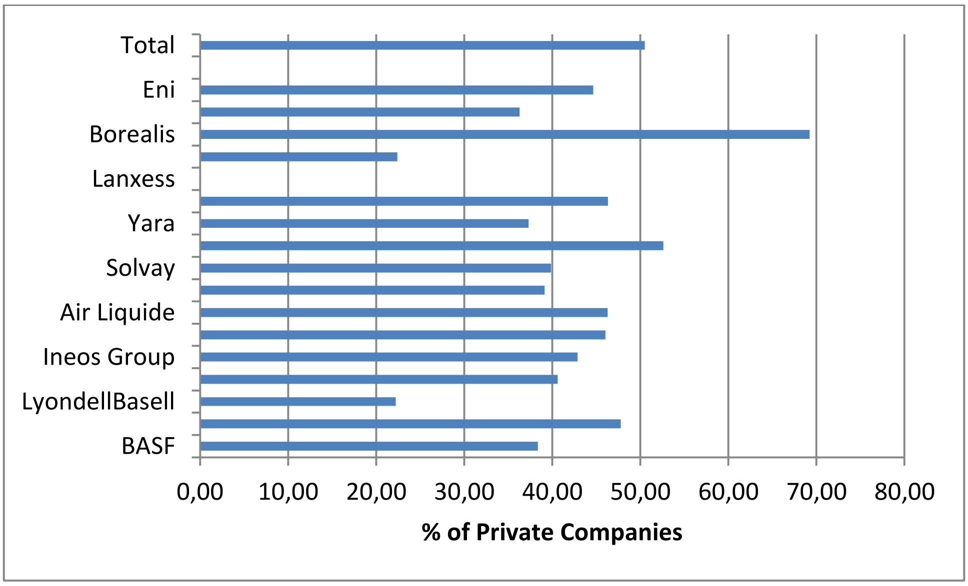
Figure 96. The private company and government partners in the EU projects in which top European chemical companies are involved



Data Source: CORDIS1 (2014). Author's calculation and graph

Figure 97 shows that in these EU project, where one of the partner is the companies under current study, there are 40 -70 % of the participants who are from private sector companies.

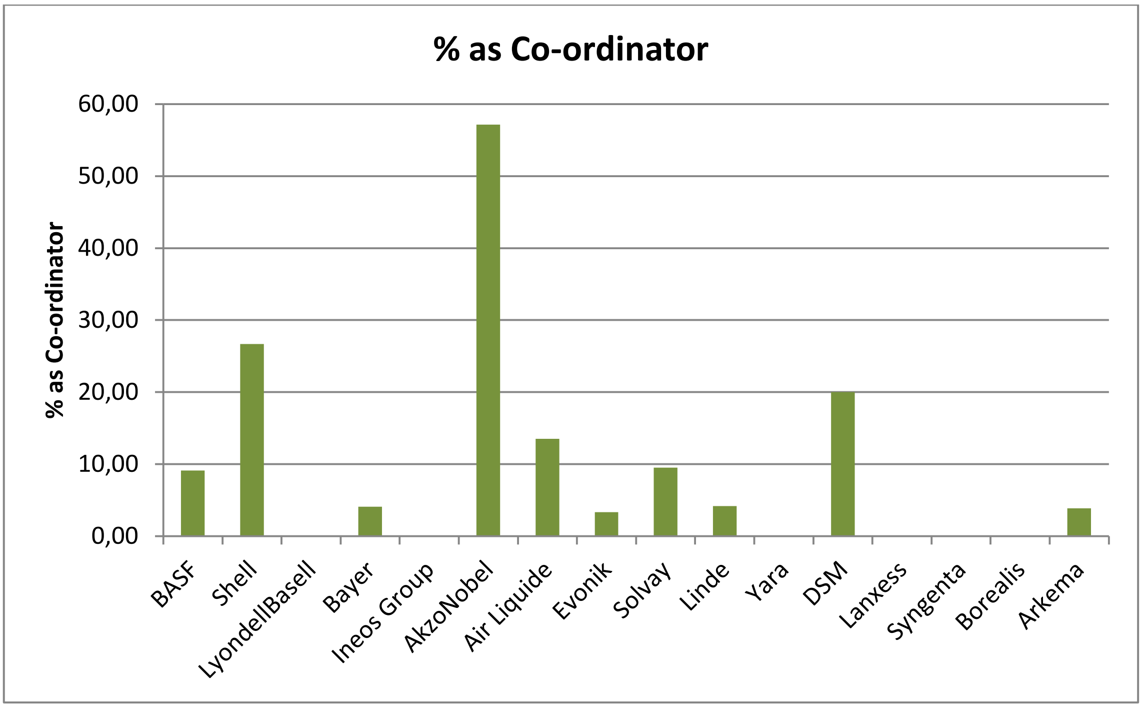
Figure 97. Percentage of private companies in the EU projects



Data Source: CORDIS1 (2014). Author's calculation and graph

Although the top chemical companies participle in a lot of EU funded projects, there is a general tendency that they want to be participant rather than the coordinator. In most cases they are coordinator in less than 20 % of the projects they participate. This may be due to the fact that this involves significant investment in resource to co-ordinate EU projects. The only company which is somewhat out of the box is Akzo Nobel which is co-ordinator in almost 56 % of all projects they participate (figure 98).

Figure 98. Percentage of EU projects in which the top chemical companies participated and in which they are the coordinator of the project



Data Source: CORDIS1 (2014). Author's calculation and graph

We have seen previously that some of the top EU chemical companies are collaborating amount themselves while participating in EU funded projects. Now we will like to evaluate if these companies are jointly filing patents for invention disclosure. For this study we have picked up the top patenting companies as the base companies and then searching the database if they have partnered with the rest of the top 15 companies in filing jointly any patent (figure 99).

Figure 99. Number patents filed jointly by the top 4 base companies with rest of the top European chemical companies

		Base company			
		BASF	Bayer	Air Liquide	Solvay
Comparing Companies	BASF		11	0	0
	LyondellBasell	0	0	0	0
	Bayer	11		0	0
	Ineos Group	0	17	0	23
	AkzoNobel	0	0	0	0
	Air Liquide	0	0		0
	Evonik	0	0	0	0
	Solvay	0	0	0	
	Linde	11	0	0	0
	Yara	0	1	0	0
	DSM	8	0	0	0
	Lanxess	0	0	0	0
	Syngenta	0	1	0	0
	Borealis	0	1	0	0
	Arkema	1	1	0	0

Data source: Thomson innovation. Author's analysis

Assumptions for the above data:

- Assignee/Applicant information is not updated when reassignments are made.
- The Assignee/Applicant-Standardized is the Assignee/Applicant name as it has been standardized by the EPO (via the INPADOC/DocDB data).
- The Assignee/Applicant-Original is the Assignee/Applicant name exactly as provided by the patent issuing authorities; it has not been standardized or normalized.

It is seen that the companies do not collaborate extensively with each other, but some of them partner to some degree to file joint patents. This is seen between BASF and Bayer, Linde and BASF and Solvay and Ineos group.

9.5 Conclusion

Various government agencies in Europe are encouraging research collaboration between the industry and government agencies (universities and research centers). European Union has several funding projects to encourage such collaboration. Top European companies actively participate in the EU funded research projects. In most cases, they want to be collaborator rather than coordinator. In such projects, the members are very even distributed, with private organizations consisting of around 30 to 40 % of total number of participants. There is very little collaboration between these top companies in terms of filing new patents. From the above analysis it is seen that university and research institute collaboration results in various successful R&D projects both in fundamental science and applied research. Such research may necessarily not result in patent application but definitely result in moving forward innovation and R&D. Thus the second part of the third hypothesis that industry and academia has impact on innovation is tested positive in this chapter.

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10. Impact of chemical regulation on innovation of European Company

Contents

10.1 Introduction

Chemical companies designing new or redesigning existing products in Europe today need to consider both regulatory and environmental performance requirements in their strategy development, as well as during their product development processes. Economic aspects are also very important in order for a business to achieve financially sustainable product development. REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. It also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals. In principle, REACH applies to all chemical substances; not only those used in industrial processes but also in our day-to-day lives, for example in cleaning products, paints as well as in articles such as clothes, furniture and electrical appliances. Therefore, the regulation has an impact on most companies across the EU. The aim of this chapter is to describe the impact of the new chemical regulation (REACH) on R&D and innovation activities of the chemical companies of Europe.

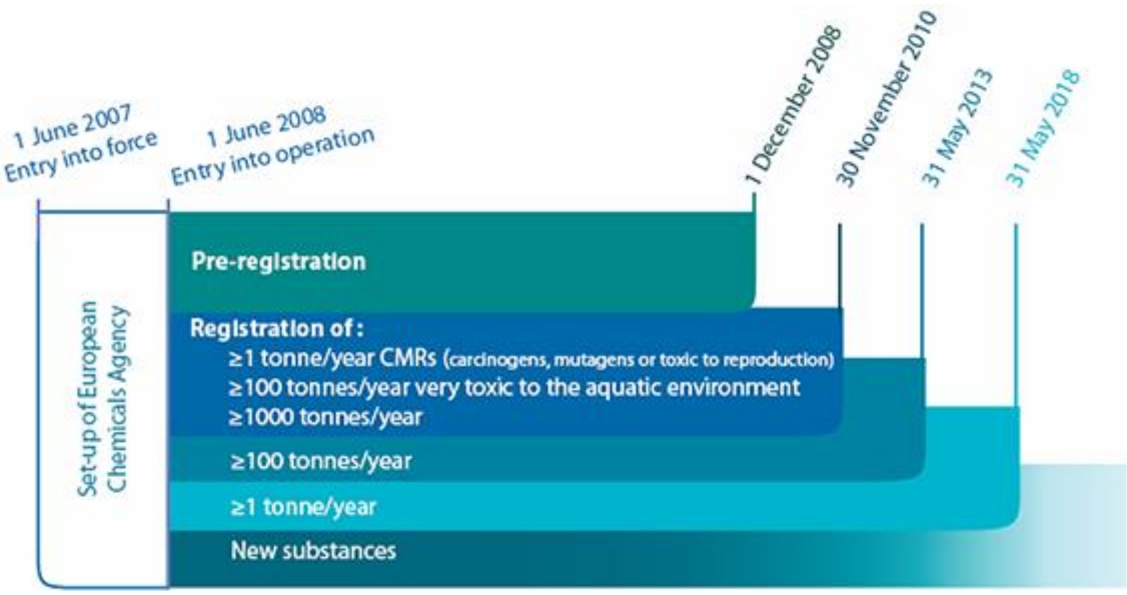
10.2 The new chemical regulation in Europe: REACH

The directive for Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) was adopted by the European Union (EU) in December 2006, and requires companies importing or producing chemicals (>1 tonnes/year) in the EU and EEA regions to register these chemicals with the EU's Chemicals Agency (ECHA). REACH requirements are relevant for both individual substances and substances in mixtures (e.g. paint), although the registration demand is for substances only. Companies manufacturing or importing substances are required to register the substance's identity, classification and labelling, test results and propose further toxicity tests for the substance, exposure potential to humans and different environmental compartments, and recommendations for safe use. The requirements for REACH increase with quantities of chemicals imported, or produced. Quantities greater than 10 tonnes/year/producer or importer mean that a risk assessment ("Chemical Safety Report", CSR) is required for the substance. If a chemicals company does not comply with REACH, it cannot sell its

products in the markets of the European Union or the European Economic Area (Commission of the European Communities, 2007).
Firms have also reported that in recent years they are also often busy implementing a wide range of chemical industry and related initiatives both of EU and industry origin, for example: CLP, revision of the Seveso Directive, RoHS, Responsible Care and the Global Product Strategy, IPPC Directive, etc. in addition to REACH.

REACH places the responsibility on industry to carry out chemical safety assessments and manage the risks that chemicals may pose to health and the environment. REACH entered into force on 1st June 2007 to streamline and improve the EU's former legislative framework on chemicals. The aims of REACH are (ECHA, 2010; van Leeuwen and Vermeire, 2007): to improve the protection of human health and the environment from the risks that can be posed by chemicals; to enhance the competitiveness of the EU chemicals industry; to promote alternative methods for the assessment of hazards of substances; and to ensure the free circulation of substances within the internal market of the EU. The figure 100 below shows the timeline of the REACH implementation. The REACH regulation came into force on 1st of June, 2008. Although the pre-registration need to be finished by 1st of December, 2008 the first stage of registration needed to be completed by 30.11.2010. This was an important date as the companies who could not satisfy the registration process of the product could not sell them any more. There were a subsequent registration date and the final one in May of 2018.

Figure 100. The timeline of the REACH registration process



Source: Clariant (2014)

10.3 Research Survey

As discussed in the methodology, a survey was under taken by Center for Strategy & Evaluation Services (CSES) to study the impact of REACH on innovation of the chemical companies. Although the study covered all size of companies, but the bulk of the respondents were from large chemical companies. According to EU grouping of chemical companies, companies having more than 250 employees are considered as large company. In this study, 57 % of respondent were from large companies. There was no separation made in this study between large and very large companies (table 9).

Table 9. Company size of respondents by category in terms of employees

	Nº	%
<50	126	22
50-249	118	20
250+	327	57
No response	6	1
Total	577	100

Source: CESE Survey (2012)

The following table (table 10) shows that bulks of the responents were either manufacturer of chemical or formulator of chemical substances or mixtures.

They consisted almost 55 % of the total respondents.

Table 10. Response to the question: Please indicate in what role you will be answering this questionnaire

	№	%
Research and Development organisation (including Contract Research Organisations)	26	4.5
Manufacturer of chemical substances	192	33.3
Importer of chemical substances or mixtures	55	9.5
Producer of articles that contain chemical substances	52	9.0
Importer of articles that contain chemical substances	14	2.4
Formulator (mixer) of chemical substances or mixtures	121	21.0
End user of chemical substances or mixtures in professional activities or in industrial activities where substances or mixtures are used as a processing aid and do not form part of the final product	28	4.9
Distributor/ retailer of chemical substances, mixtures or articles that contain chemical substances intended to be released	24	4.2
Other	47	8.1
No response	18	3.1
Total	**577**	**100.0**

Source: CESE Survey (2012)

The characteristics of substances become more transparent as a result of REACH. Some substances will be taken from the market. This increased knowledge and the necessity for substitution will stimulate innovation. In total 18 studies do discuss innovation as a relevant aspect related to the REACH proposal. Most of these studies expect positive aspects for innovation. Some studies also described the negative effects of REACH on innovation.

The following survey question some how shows how innovative the European chemical industry is in terms of developing new chemical substance. Almost 40 % either did not respond or did not think it to be relevant. It is also interesting to see 4.5 % responded that they had placed between 1001 and 10000 new chemical substance. This number corresponds to the percentage of very large chemical companies in Europe (table 11).

Table 11. Respone to the question: How many chemical substances did you place in the market in 2010 (including substances contained in articles)?

Options	***Nº***	***%***
1	*14*	*2.4*
2-10	*72*	*12.5*
11-50	*81*	*14.0*
51-100	*54*	*9.4*
101-1,000	*60*	*10.4*
1,001-10,000	*26*	*4.5*
>10,000	*7*	*1.2*
Don't know	*34*	*5.9*
Not relevant	*118*	*20.5*
No response	*111*	*19.2*
Total	***577***	***100.0***

Source: CESE Survey (2012)

The next question looks into the source of innovation of the companies. It is believed that there can be three general source of innovation: Inside the company, Partnering with another company, other companies or institution. The survey question in the following table 12, addresses this question.

Table 12: Survey question: What would you say the sources of your innovations are in general? If more than one, please rank in importance (1st as most important, 3rd as least important)

Options	**Mainly your enterprise or enterprise group**		**Your enterprise or enterprise group together with other enterprises or institutions**		**Mainly other enterprises or institutions**	
	Nº	**%**	**Nº**	**%**	**Nº**	**%**
1st	205	62.7	98	36.8	59	28.1
2nd	58	17.7	106	39.8	33	15.7
3rd	28	8.6	27	10.2	78	37.1
Don't know	36	11.0	35	13.2	40	19.0
Total	**327**	**100.0**	**266**	**100.0**	**210**	**100.0**

Source: CESE Survey (2012)

10.4 Data Evaluation and analysis

Let us now evaluate the key learning from the survey. The following question is judging if the access to REACH information has acted as a stimulus for innovation. It was obvious from the response that there was no positive impact as 70 to 80 % of the people sayed no (table 13).

Table 13. Survey question: Has the development of, or access to, any of the following sources of information acted as a stimulus to product conception and innovation in your organisation?

Options	Registration dossier with Technical dossier and Chemical Safety Report		Development of the Safety Data Sheets (SDS)/(eSDS)		Substance Information Exchange Forum (SIEFS)	
	Nº	%	Nº	%	Nº	%
Yes	65	17.3	102	25.6	33	9.3
No	293	77.9	284	71.4	296	83.4
Don't know	18	4.8	12	3.0	26	7.3
Total	**376**	**100.0**	**398**	**1.0**	**355**	**100.0**

Source: CESE Survey (2012)

The following question enquired if the additional cost for testing of new substance a dis-incentive to innovation, the answers did not show it to have a negative effect with around 40 % supporting it (table 14).

Table 14. Was the additional cost for testing of new substances (as opposed to the situation for existing substances) a disincentive to innovation for you before the REACH Regulation was implemented?

Options	Nº	%
Yes - a lot	56	17.9
Yes – moderately	90	28.8
No, not at all	120	38.5
Don't know	46	14.7
Total	**312**	**100.0**

Source: CESE Survey (2012)

The next survey question focusses on the substitution of the chemicals which is not in accordance to REACH protocol. This also shows development of new chemical product which in some way is bringing innovation to the company (table 15).

Table 15. What has been the effect of the placing of substances on the authorisation list for your firm?

Options	We launched initiatives to develop new substances to substitute them		We launched initiatives to find alternative formulations of existing substances to substitute them		We withdrew them from our product portfolio		We requested substitution of those substances by our suppliers		We took no special action	
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Yes	57	24.9	116	43.4	105	44.1	105	41.0	89	46.4
No	129	56.3	98	36.7	90	37.8	109	42.6	84	43.8
Don't know	14	6.1	9	3.4	12	5.0	9	3.5	10	5.2
Total	**200**	**87.3**	**223**	**83.5**	**207**	**87.0**	**223**	**87.1**	**183**	**95.3**

Source: CESE Survey (2012)

The table below 8 summarizes the final conclusion of the study. It is seen that 44 % of the respondent were negative or very negative in their views about the impact of REACH on innovation (table 16).

Table 16. Overall, what would you say has been the effect of REACH on innovation at your firm to the present, as compared to the pre-REACH situation?

Options	% All	% SME
Very positive	1	1
Somewhat positive	12	10
Neutral	29	28
Somewhat negative	30	37
Strongly negative	14	21
Don't know	14	3
Total	**100**	**100**

Source: CESE Survey (2012)

The next response also throws negative light on the views the chemical companies have on the future perspective of REACH on innovation and they send out a negative view that according to them, there is no change in scenario with respect to REACH (table 17).

Table 17. Do you see the position changing in the future?

Options	% All	% SME
Yes, it will become more positive	10	3
Yes, it will become more negative	24	38
No change	38	32
Don't know	28	27
Total	**100**	**100**

Source: CESE Survey (2012)

10.5 Discussion based on the survey

An important element, which is often described in studies on REACH, is the effect of the regulation on innovation. The most important factor that has influenced the impact of the REACH Regulation on innovation has been the evolving economic situation. When the Regulation became active at the beginning of 2007 the world was on the verge of what was to become the greatest economic and financial crisis since the 1930's, and at time of writing (2014) slow but sustainable and meaningful recovery has been emerging. As a result company finances have remained highly strained, especially for large companies, and recruitment constraints have also impacted REACH implementation operations. It can be stated that it was not an auspicious environment for the launch of new investments in innovative projects.

As a result of REACH, the characteristics of substances become more transparent and it also resulted in some substances being taken out from the market. REACH profounder believes that this increased knowledge and the necessity for substitution will stimulate innovation. There are studies that expect positive effects, especially from the environmental NGO.s and the European Commission. Based on the survey and the data obtained, in this section it is shown the positive as well as negative effect of REACH regarding innovation.

It is also believed that REACH Regulation will create an information database through gathering, capturing and disseminating data from the chemical industry which will act as a spur to product conception, development and marketing. There is evidence that data has been created through testing, captured and disseminated through the ECHA website. Even if this is not the fully open system for example a university environment, there has been an increased level of openness and scrutiny as a result, and some benefits have been evident, contributing to data generation and creation of IP. In case of large chemical companies, the Material Safety Data Sheet (MSDS) seems to have made the strongest contribution to stimulating new product conception.

Every company has their own IP strategies which depend on the role of IP in their business and costs of protection of IP. Feedback from interviews and the innovation survey so far suggest that whether or not a patent is filed for, the costs of IPP related to REACH can be challenging or even prohibitive.

Many large companies complained that a higher share of turnover was spent on R&D than average due to REACH. Since there is now the compliance aspects that has to be considered by firms, there are grounds to expect that what may be the "normal" time lag for innovation to occur as a result of an external factor such as regulation, may be extended, and it is probably too early to be able to assess the full impact of the Regulation on innovation.

It was observed from the survey that there has been a significant redirection of skilled, sometimes highly skilled, personnel in firms from R&D and innovation-related activities to compliance work as a result of the implementation of the Regulation. It was particularly true for large companies and they think the shift will be permanent. More than half of survey respondents reported that as a result there has been an increase in expenditure on R&D and related innovative activities. Interviews with large firms suggest those that were not financially constrained increased expenditure to maintain R&D activity.

In case of large companies, the evidence from the fieldwork also suggests that links with universities and networks developed tended to focus on the compliance/ regulatory elements of REACH rather than pure research and there is a great deal of activity throughout the EU in this respect. This resulted many firms establishing external relationships, most of which have been with various service providers, especially consultants, but these have not contributed particularly to innovation. Many companies have had to fund the extra cost requirements related to implementing the Regulation from their usual sources, and feedback from interviews suggests that this is easier for larger firms than smaller ones, especially in the current economic environment.

Rate of return from R&D investment was negatively impacted by REACH compliance costs, while uncertainties about actual costs and their timing in the case of innovation projects have not helped financing decision-making in general. REACH regulation generated scope of innovative activities to include more work on new substances, particularly among large firms, who are also responsible for most innovation in the industry, but barriers to R&D and innovation in new substances still remain.

The several steps for substitution mechanisms within REACH: registration, the candidate list, authorisation and restriction, have had various impacts on innovative activities. Registration costs can have an impact on the decision to register a new substance or use, or use of an existing substance in innovative ways and this can in turn also influence the availability of substances within supply chains for future use in innovation. It has also been observed that companies carry out product changes purely with a view to avoiding regulatory burdens of REACH. It seems that the return on investment in new registrations needs to be more certain and possibly higher to compensate for increases in costs, risks and uncertainties.

Due to increased openness and scrutiny driven by the Regulation, it is a concern of the companies over the ability to protect IP. The fieldwork has confirmed that extensive activity in the areas of product, process, marketing and innovation change is occurring as a result of the implementation of the Regulation. Firms also often think that the additional costs placed on requesting IPP are too high, especially when the requests may not be granted. Large firms that use patents to protect IP do not consider REACH patent friendly. There are also widely held views that the protection of CBI within REACH remains insufficient.

In many instances companies have considered the activities to ensure compliance with the Regulation as a distraction from their normal, planned innovation activities (also organizational and marketing innovation) and to be unintended consequences of the Regulation. Increases in time-to-market as a result of the Regulation and increased supply chain rigidities resulting from changes in toll manufacturing arrangements have not been supportive of innovation. Additonally, they thought it would worsen in the future than would improve.

Due to complexity of REACH regulation and cost, it has been argued that some non-EU locations are getting more attractive for undertaking innovative activities. Based on the data provided, it appears that some such delocalisation of innovative activities has occurred, although REACH may not always have been the only or even the main driver.

10.6 Conclusion

The chemical regulation (REACH) has a big impact on R&D activities of the chemical companies in Europe. The chemical products which have not been pre-registered before the due date could not be sold any more until they go through the registration process. The bulk of the respondent of the survey carried out by CSES was from the large chemical companies who are manuafcturer of chemical product. According to the survey, there is a very strong negative effect of REACH on innovation. High amount of R&D resources is being used for REACH compliance need. The compliance cost of REACH has negative effect on further investment for R&D. There is a great concern for IP due to more openness of the Information.

It can be concluded from above survey and following studies that indicated that they had found knowledge generated stimulated product conception and innovation, larger firms were less positive than SMEs. Among survey respondents that indicated a “substantial” shift in resources from R&D and innovative activity to REACH compliance, the share of small firms was high (compared to the overall presence of such firms in the survey), especially in the case of formulators, and also for medium-sized firms, although the increase was not as marked. More SMEs also saw this shift as permanent than large firms, and indicated the response as one of having increasing expenditure on R&D to compensate for this in the long run.

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11. European chemical cluster and geographical distribution: An impact on innovation

Contents

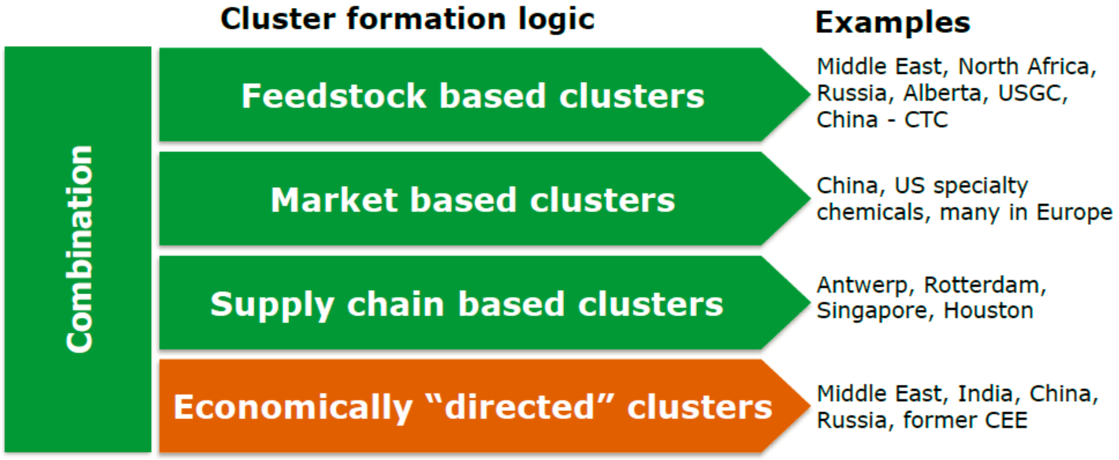
11.1 Introduction

According to Porter (1998), clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. It is geographically limited concentration of mutually related Business units, associations and public or private organizations centering on a specific economic focus (Gordon and McCann, 2003). A high concentration of manufacturing companies and Service providers, but also associations and public or private organization that engage to create an environment for production, innovation and the creation of new business development. Clusters include, for example, suppliers of specialized raw material, suppliers of components, machinery, and services, and providers of specialized infrastructure such as water, electricity or firefighting support. This section explains the structure and geographical distribution of European chemical cluster and its impact on innovation.

11.2 Components of European Chemical Cluster

Clusters normally extend both vertically and horizontally in value chain. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. In such clusters there is outsourcing of related services attracting third party investments in transportation, warehousing, general services, waste treatment, and a wide range of utilities. Finally, many clusters include governmental and other institutions-such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations-that provide specialized training, education, Information, research, and technical Support.

Figure 101. Four main drivers of chemical clusters

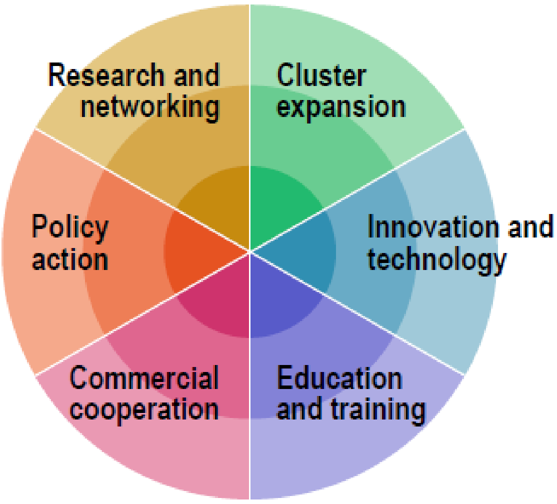


Source: Plessis (2010)

There are four reasons for the formation of chemical clusters (figure 101). Feedstock based clusters are very common reason for chemical clusters around the world. For Europe, supply chain based cluster is the basis for its existence. The interaction and interdependence of companies creates complementary synergies and a combination of skills and incentives which are difficult to reproduce on an isolated basis. This is also a source of innovation to both companies. Unique opportunities in Collaboration across a wide range of activities including capital investment, improved utilization rates and plant occupancies, swap arrangements, shared facilities, cluster carbón footprint reduction etc.

Almost two thirds of Europe´s chemical production is in the cluster. Most of the large chemicals and especially from Europe are located in these clusters. The top chemical clusters are Port of Rotterdam, Antwerp port, Ruhr: chemsite and chemcologne, Tarragona chemical cluster, and Rhine- chemiePark Hoechst and BASF.

Figure 102. Various components of a cluster



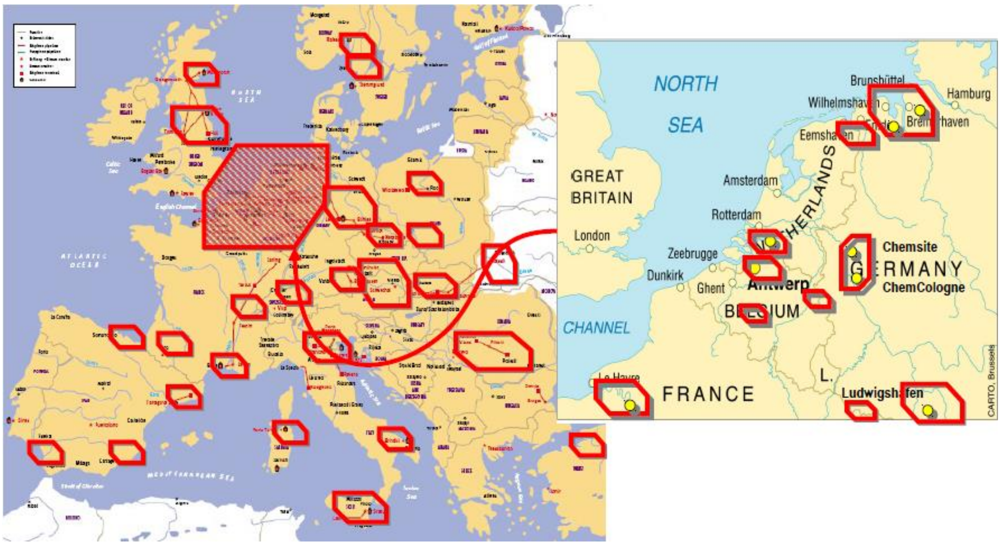
Source: Ketels (2007)

Figure 102 shows how various components play a significant role in the survival and continuation of a chemical cluster.

11.3 Distribution of European chemical cluster

Europe has over 300 chemical production sites, the majority of which are located in clusters. Most of these clusters have evolved historically around either a raw material source, or as a supplier to the downstream industry. As the raw material supply and the downstream industries have evolved, so these clusters have adapted to these changes. There are a few examples of "on-purpose" clusters which have been developed more recently. In general Europe's chemical industry clusters are highly integrated along the product value chains and benefit from competitive infrastructure, utilities and services.

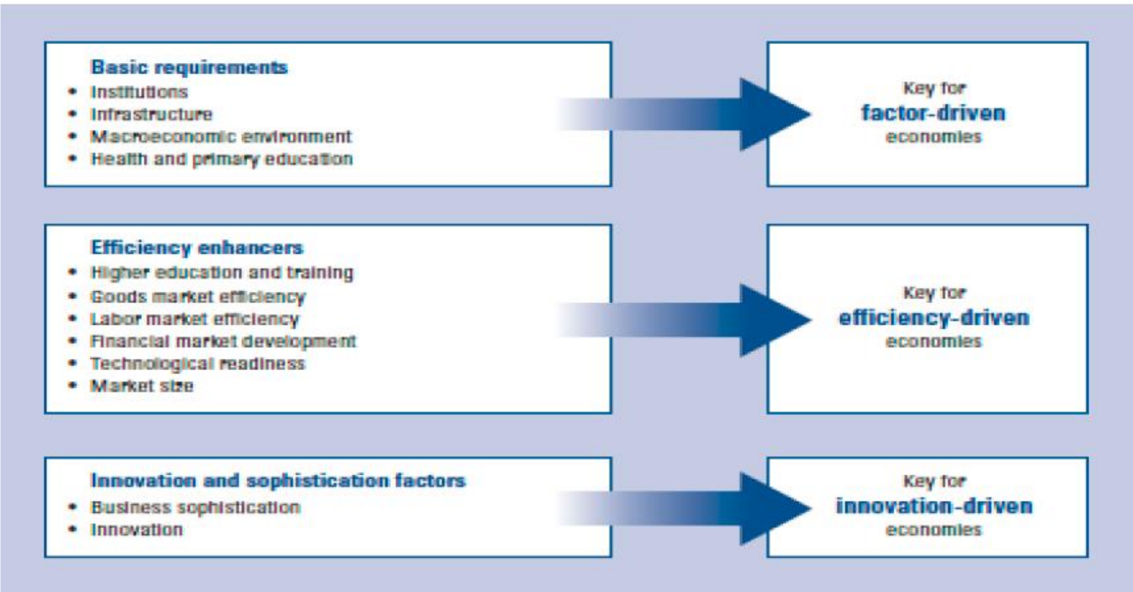
Figure 103. The chemical cluster in Europe



Source: Plessis (2010)

There are four components in order to turn a cluster to a mega cluster. There are few basic requirments such as institution, infrastructure and education. Then comes the factors which act as efficiency enhancers such as market size, labour market, financial market and technology readiness. The ultimate component of a mega-cluster is innovation drive (figure 104).

Figure 104. Key components of a mega-cluster



Source: Plessis (2010)

The mega-clusters: Port of Rotterdam, Antwerp Port, Rhine and the regions around it produces 2/3 of the total productions of all the European clusters.

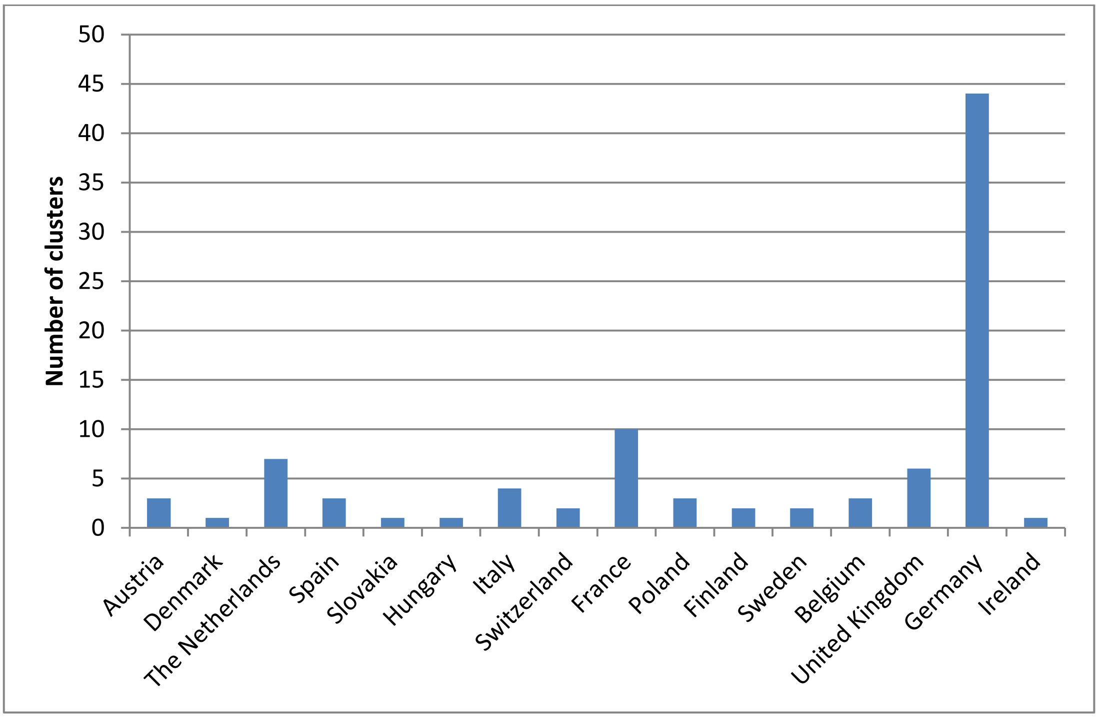
Figure 105. Europe's chemical megaclusters

Source: Plessis (2010)

Advantage of having strong chemical clusters in Europe is improved cost competitiveness from integration along the product value chains. There is synergy benefit from shared utilities, services and infrastructure which also leads to increased investment due to improved cost competitiveness. There is also lower logistics cost due to a competitive offering of services within the cluster. The collaboration mindset of cluster members results in collaborative research and development. This results in cluster innovation. Total cluster performance is better than the sum of the individual cluster members' performance on a stand-alone basis.

Figure 107 shows how various components play a significant role in the survival and continuation of a chemical cluster. The figure 106 shows the number of chemical clusters distributed over various EU countries. Germany have the largest number of 44 chemical clsuters followed by France with ony 10 as distant second while Netherlands with 7 is in the third position.

Figure 106. Number of chemical clusters in each European country



Source: ECSPP (2014)

11.4 Impact of chemical cluster on European Innovation

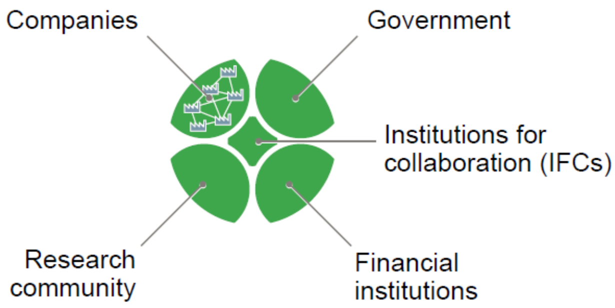
In order to study the chemical cluster´s impact on European Innovation, we will study three chemical clusters. The first one is Tarragona chemical cluster located in Spain and the second one is Axelera chemical cluster located in France while the third one is Port of Antwerp chemical cluster.

11.4.1 Case Study I: Tarragona Chemical Cluster

Chemical cluster in Tarragona consists of the south and north poles, which are linked to the nearby port via road and pipeline. The main raw material –crude oil and natural gas- are all imported. Natural gas is imported in the form of LNG and then processed in several gasification facilities along the coast around Barcelona and Cartagena. Natural gas is also provided via the Trans Pyrenean pipeline link Calahorra from Lacq in France, and from the Maghreb-Europe Gas pipeline from Argelia to Spain. Crude oil is provided by ship from various sources to several terminals. The Tarragona cluster is linked to the Spanish natural gas distribution network.

In addition to enhancing productivity, clusters play a vital role in a company´s ongoing ability to innovate. Some of the same characteristics that enhance productivity have an even more dramatic effect on innovation and productivity growth.

Figure 107. The components of Tarragona Chemical cluster



Source: ECSPP (2014)

Because sophisticated buyers are often part of a cluster, companies inside clusters usually have a better window on the market than isolated competitors do. Chemical companies plug into customer needs and trends with a speed difficult to match by companies located else where. The table 18 below shows the chemical companies that make up the Tarragona chemical cluster.

Table 18. The companies of Tarragona chemical cluster

Tarragona North	Tarragona South
• Asfaltos Españoles, S.A. • Lyondellbasell Poliolefinas Ibérica, S.L. • Basf Española, S.L. • Basf Sonatrach Propanchem, S.A. • Bayer Material Science, S.L. • Celanese Chemicals Ibérica, S.L. • Clariant Ibérica, S.A. • Compania Logistica De Hidrocarburos Clh, S.A. • Dow Chemical Ibérica, S.L. • E.On Generación, S.L. • Ercros Industrial, S.A. • Hércules Quimica, S.A.	• Carburos Metálicos, S.A. • Dow Chemical Ibérica, S.L. • Messer Ibérica De Gases, S.A. Unipersonal • Repsol Petróleo, S.A. • Repsol Química, S.A. • Vinilis, S.A. **Alcover** • Catalana De Tractament D'olis Residuals, S.A. (Cator)

• Industrias Quimicas Asociadas, Lsb, S.L. • Kemira Ibérica, S.A. • Elyx Polimeros, S.L. • Messer Ibérica De Gases, S.A. Unipersonal • Productos Asfálticos, S.A. (Proas) • Repsol Butano, S.A. • Sekisui Speciality Chemicals Europe, S.L. • Tarragona Power, S.L. • Terminales Portuarias, S.L. • Terminales Quimicos, S.A. • Transformadora De Etileno, Aie • Vinilis, S.A.	**Flix** • Ercros Industrial, S.A. • Kemira Ibérica, S.A. **Tortosa** • Ercros Industrial, S.A.

Source: ECSPP (2014)

Some of the chemical companies provide intermediate product which is used as feed stock for other companies in the cluster, while other produce final product which goes for industrial and consumer use. As a result there is a continuous relationship between the supplier and customer in the cluster. The table 19 below shows the list of the raw product, intermediate and final product of the Tarragona chemical cluster. Since the customer and supplier is in the same region it helps them to come together and thus helps in product innovation.

Table 19. Products of the Tarragona chemical cluster

Raw product / feed stock	Intermediate product	Final product
Monomers	Acetaldehyde	Paper Industrial Additives
Ethylene	Ethyl Acetate	Water Industrial Additives
Polypropylene	Vinyl Acetate	Special Products
Benzene	Acetic Acid	Vinyl Derivatives
Octane	Acrylonitrile	Tensoactives
Other Cracking	Butadiene	Polyolefines
C4 Fraction	Styrene	H.D. Polyethylene
Aromatic Component	Methyl Methacrylate	L.D. Polyethylene
FO Pyrolisis	Ethylene Oxide	Lineal Polyethylene
Inorganic	Ethylene Glycol	Polypropylene
Chlorine	Propylene Oxide	Compounds
Sodium Hydroxide	Propylene Glycol	
Chlorhydric Acid	Vinyl Chloride	
Ammonium Sulfate		
Gases		
Nitrogen		
Oxygen		
Hydrogen		
Carbonic Anhydride		
Plastics		
PVC		
ABS Resins		
Styropor Expandable		
Polystyrene		
Polyalcohol		
Isocyanate		

Source: ECSPP (2014)

This ongoing relationship with other entities within the cluster also help companies to learn early about evolving technology, component and machinery availability, service and marketing concepts, and so on. Such learning is facilitated by the ease of making site visits and frequent face-to-face contact.

Clusters do more than make opportunities for innovation more visible. They also provide the capacity and the flexibility to act rapidly. A Company within a cluster often can source what it needs to implement innovations more quickly. Local suppliers and partners can and do get closely involved in the innovation process thus ensuring a better math with customer´s requirements.

Companies within a cluster can experiment at lower cost and can delay large commitments until they are most assured that a given innovation will work out. In contrast, a Company relying on distant suppliers faces greater challenges in every activity it coordinates with other organizations-in contracting, for example, or securing delivery or obtaining associated Technical and Service Support. Innovation can be even harder in vertically integrated companies, especially in those that face difficult trade-offs if the innovation erodes the value of in-house assets of current products or processes must be maintained while new ones are developed. In this cluster, also belong several research institute and the Tarragona university. There is a close cooperation with these reach centers and the university with the chemical companies belonging to the cluster.

- Chemistry Technology Centre (CTQ)
- Institute of Chemical Research of Catalonia (ICIQ)
- Rovira i Virgili University (URV)
- Catalan Government Department of Education (Secondary Schools: Comte de Rius; Pere Martell; Vidal i Barraquer)
- Chambers of Commerce, Industry and Navigation of Reus, Tarragona, Tortosa
- Chamber of Commerce and Industry of Valls

There are also several opportunities of the doctoral research of the Tarragona university at the companies located in the cluster. The university provides analytical and other capabilities which many of these chemical companies might be lacking for research.
Reinforcing the other advantages for innovation is the sheer pressure-competitive pressure, peer pressure, constant comparison-that occurs in a cluster. For all these reasons, Tarragona chemical cluster can remain centers of innovation for decades.

If companies in a cluster are too inward looking, the whole cluster suffers from a collective inertia, making it harder for individual companies to embraces new ideas, much less perceive the need for radical innovation. The government organizations play a critical role in this collaboration for innovation and R&D. The list below lays down the government organization that participate in Tarragona cluster build-up.

- Catalan Government - Tarragona Delegation
- Council of Tarragona
- Spanish Government – Tarragona Delegation
- City Councils: Alcover, La Canonja, Constantí, Flix, El Morell, Perafort, La Pobla de Mafumet, Reus, Tarragona, Tortosa, Salou, Valls, Vila-seca

Collaboration supports provided by Spanish government are: 1. Promote the implementation of large industrial research projects that increase the scientific and technological capacity of firms and research organizations 2. Expand and optimize total use by companies and research organizations, public and private infrastructures existing research in Spain 3. Extend the culture of R & D cooperation between all actors in the science-technology-enterprise system 4. To mobilize the participation of SMEs in industrial research projects of great magnitude 5. Contribute to the participating firms to compete in international markets with innovative products and services and promote a more efficient access to international consortia programs of cooperation in scientific research and technological development and in particular the Framework Programme of the European Union.

More important to ongoing competitiveness is the role of location in innovation. Therefore locational decisions must be based on both total systems cost and innovation potential, not on input cost alone.

Geographic, cultural, and institutional proximity leads to special Access, closer relationships, better Information, powerful incentives, and other advantages in productivity and innovation that are difficult to tap from a distance.

Other components of the cluster are utilities, storage and disposal service provider.

Table 20. Other important components of the Tarragona chemical cluster

Utilities	Storage	Disposal
Power/ Electricity Steam Water (different grades) Natural Gas Effluent Management Industrial Gases	Tanks Caverns Warehouses	Effluent Management (under construction)

Source: ECSPP (2014)

11.4.2 Case Study II: Axelera chemical cluster

This case study focuses on one cluster, Axelera to identify the role it plays in innovation and, in particular in REACH-related innovation. Axelera – a Pôle de compétitivité à vocation mondiale Chimie-Environnement Lyon & Rhône-Alpes, was created in 2005 with the aim to "accelerate the development of sustainable chemistry at national and international levels. With 307 members in 2014, Axelera has demonstrated both its attractiveness and its ability to bring people together. Two third of the network is made up of large sized companies. There are 200 R&D programmes being conducted, for a total budget of over €627 million. Members include private companies (from very small SMEs to some of the largest global multi-nationals), research organisations, training and education organisations and institutional actors. With 126,000 students across the urban area, more than 500 public and private research laboratories, 10,000 researchers and 18 higher education establishments, the Lyon urban area offers world-class training and research potential in a variety of sectors, including chemistry and engineering, life sciences, information sciences, human and social sciences, etc.

The case study starts by looking at the role of chemical clusters in general, identify the difference between clusters in general and the slight variations in the structures of "pôles de compétitivité" before looking at Axelera's activities. It will then go on reviewing some of the projects related to substitution of chemicals. In addition to looking at individual organisms and companies involved in innovation, the case study also looks at the dynamics of the cluster and the impact REACH has had (if any) in its capacity to generate innovative solutions and products.

The pole's main research interests are (Business Greater Lyon, 2014):

•chemistry in the service of the great societal challenges: sustainable building, renewable energy, vehicles, electronics;

•preservation of natural habitat: air, water, soil, agrochemicals;

•total recyclability of materials;

•chemicals from vegetable material;

•the factory of the future and eco-designed processes

<u>The impact of REACH on R&D and innovation in Axelera</u>

At Axelera, some research projects have emerged that are specifically aimed at substitution within the framework of REACH. Rather than having a purely ‘chemical’ approach to the issue surrounding substitution, Axelera has developed a holistic approach to REACH in particular and the regulatory framework in general.
Some of Axelera’s projects are thus not aimed purely at substitution in the way generally understood when talking about the regulation but at a wider reflection on the need of the substance. The current approach has been developed by the synergies created by having chemical engineers working alongside professionals from other sectors with a more intimate knowledge of the issues they face.

The largest number of projects funded in Axelera is funded by the ANR (Agence Nationale de laRecherche), a national organisation proposing calls for research projects in France which launches regular calls of projects in the chemical sector. At first, projects including elements of innovation and substitution relating to the regulation were not branded as “REACH” projects. This is the case, for instance, of a project on solvents. While the results can be used to substitute substances either placed on the candidate list or restricted, it was ‘independent’ of REACH. It is nevertheless likely that the regulation did play a role in the development and thinking behind it. In recent years, projects and calls for projects with a clear ‘REACH-related’ label especially focussed on substitution have emerged.

A final interesting aspect of Axelera with regard to the REACH Regulation is the development of a regional testing platform to conduct toxicological and eco-toxicological testing on substances. This testing platform is expected to play an important role in the innovative capacity of the region and structure the research, development and innovation processes of the pole and the wider region.

Specific project examples

Axelera is typical of the clusters approaching the new regulatory framework REACH as an opportunity to develop new innovative solutions with different types of partners rather than seeing it as a burden. NESOREACH (New “eco-friendly” Solvent for REACH substitution) is a project aiming at substituting existing solvent with alternatives with less hazardous properties. The project’s aim is to develop predicting methods for solvents within the framework of the REACH regulation. The project is specifically related to certain types of enameling varnishes which use large amounts of toxic solvents such as N-methylpyrrolidone, phenol and cresol. In the current process, those solvents are burned during the glazing process and thus release potentially toxic products. The project investigates mechanisms involved in the polymerisation process and carry out polycondensation reactions to evaluate the properties of the new non-toxic solvents for the said applications.

Another interesting project that has taken place at Axelera is the "intensification des procédés". The project's aim was to set up new and innovative tools including environmental efficiency, manufacture performance and adequacy of the processes. The project developed lab tools to optimise energy efficiency, a pilot reactor to gather basic data allowing for a more efficient industrial extrapolation. This allows tests on new substances to be developed in parallel and identify any issues that would prevent the commercialization of substances at an early stage, thus reducing the cost of non-viable substances and increasing the efficiency of research.

The projects taking place in Axelera are interesting and innovative in that they are not only purely chemistry-related but have a wider scope, including studies on the research and innovation processes and therefore approach issues in a global fashion. This approach is embedded in the strategy objectives of the pole.

11.4.3 Case Study III Port of Antwerp Chemical Cluster

The cluster, the Port of Antwerp (table 21), is considered a world-scale refinery and the largest chemical refinery in Europe. The port has historically and organically grown rather than emerged from a direct clustering initiative, therefore it is not considered a typical plug and play environment. The Port of Antwerp functions through an open market concept where companies are not governed or spurred on by associations. There is a high degree of integration between business processes within the port; however each company is ultimately driven individually.

Table 21. Main companies in the port of Antwerp cluster

BASF	Eastman	Total (Refinery)
Styrolution	Evonik	ExxonMobil (Refinery + Petro. Chem.)
Air Liquide	Bayer	Total (Olefins + Polymers)
Erochem	Ashland	Nippon Shokubai
IBR (Refinery)	Monument Chemical	Kuraray
Solvay	Lanxess	Praxair
Ineos	Lubrizol	3 M
Monsanto	Borealis	

Source: Port of Antwerp (2014)

During the current research, the Port Authority was found to be the main governing support system for the chemical and petro-chemical activity. The chemical cluster of Antwerp is found to be substantially more developed than most chemical cluster initiatives identified in other regions. With regard to eco-innovation, the cluster excelled in environmental performance on a European level.

Key Environmental Challenges as identified by the Cluster Organisation

The Port Authority identified various environmental challenges including CO2 recuperation, waste and water treatment. To counter the effects of their industrial activity, the organisation works to preserve and develop nature reserves, bio mass and wind energy. Due to the scale of the cluster's activities, and its high energy consumption and outputs, the cluster Authority has taken a holistic viewpoint toward environmental targets.

The cluster Authority has an internal environmental department consisting of approximately 40 employees who carry out various studies and collaborative research projects with industries to identify and implement eco-innovative solutions for the industry. The incentives which drive eco-innovation differ largely across the value chain. In general, legislation, market incentives and European competitiveness are the primary drivers to eco-innovation uptake.

Eco-Innovation activity undertaken

The Port Authority has been increasing its promotion activity toward eco-innovation constantly. It promotes practices in two core focus areas: calculating the clusters overall carbon footprint (which is also part of its social responsibility targets), and increasing energy diversity to reduce the industry's high dependency on oil. The petrol chemical industry relies heavily on oil prices. As oil is a rather fluctuant and volatile product, it needs to stabilize this overall cost using independent energy source which are more stable by nature (in terms of pricing).

The cluster approaches companies individually to promote such initiatives - since the Port Authority is an independent entity, it is not perceived as a competitor - and they are able to collaborate effectively using a one-on-one approach. Within the European context, the cluster organisation collaborates with other ports on various eco-innovative projects and environmental standard setting. An example of this is a project setup to initiate CO2 recuperation through the European Shipping Index.

The cluster's core targets for the coming five years clearly place emphasis on increasing efficiency and research into optimization, targets include:

1. *Mobility* – Large-scale redevelopment of infrastructural work is planned to gain efficiency and reduce logistics;

2. *Expansion* – The cluster needs to constantly develop itself to remain competitive. Expansion possibilities focus on land procurement or optimization of existing land;

3. *Environment* – The main focus is to tackle the carbon footprint of the industry as a whole by increasing sustainability. This is a generic goal which entails widespread research and a diverse approach toward eco-innovation solutions.

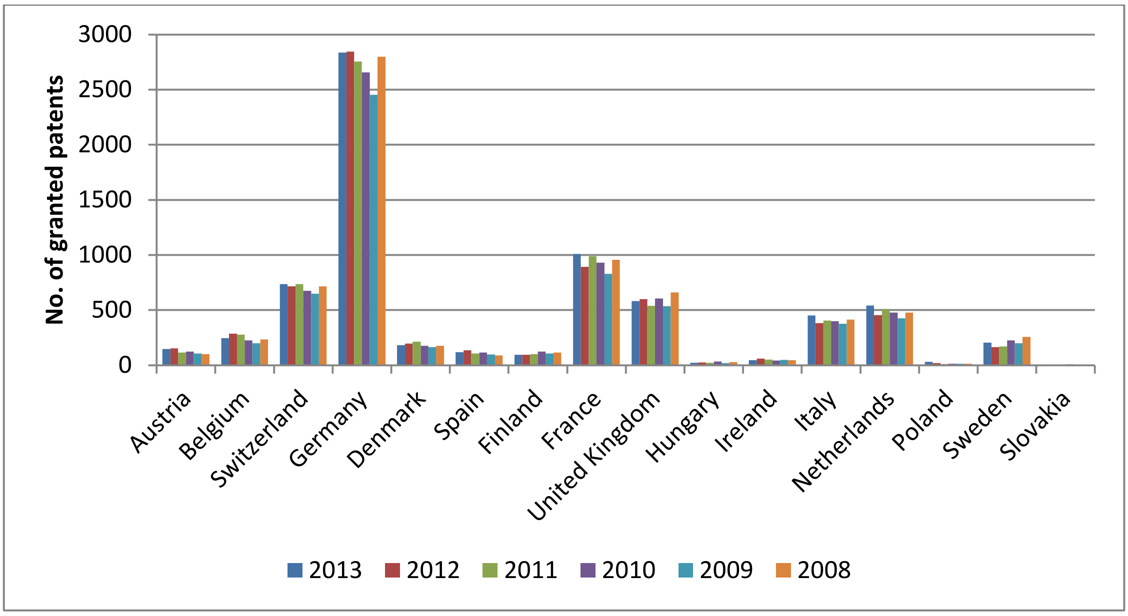
<u>An example of innovation of Antwerp port cluster</u>

The Antwerp Port Authority, in early 2010, in collaboration with the Left Bank Corporation unveiled their plans to develop a large wind farm in the port area in collaboration with private internal and external partners. The port was identified by the Flemish Wind Energy Association (VWEA) and the Flemish Minister of Energy as being a suitable location for wind farming along with a current plan to develop a bio-mass power plant, are concrete steps taken by the Port Authority to maximize on the potential for renewable energy development within the port. These are strong examples as how Antwerp port cluster is driving innovation. In February 2011, the projects was further developed and unveiled to be a 200 million EUR wind farm.

11.4.4 Geographical distribution of chemical cluster and its impact on innovation

The chemical clusters in Europe are concentrated over few specific regions. This can be due to specific government policy or availability of environment for its growth. In any case, it definitely influences the area in which it exists and also has specific character inherent from that region.

Figure 108. Number of granted EU patents in chemistry and chemical engineering for the last five years



Source: European Patent Office (2013). Author's calculation and graph

It is interesting to understand how the innovation in terms of number of granted patent is distributed over various European countries. We saw earlier that Germany host the largest number of 44 clusters which account for 47 % of all European clusters. In terms of granted EU patent in chemistry and chemical engineering, Germany has the largest number of 2835 which is around 40 % of the total EU chemical patent for the year 2013. France holds the second largest number of 11 % of all EU chemical cluster while it has 14 % of all EU granted patents. So there is a direct relation between the number of cluster in a particular country and number of granted EU patents in chemistry and chemical engineering (figure 108).

Table 22. The cluster and granted EU patent for 2013 distribution over different European company

Country	Number of clusters	% of total cluster	Patents granted 2013	% of granted patent
Austria	3	3,23	146	2,02
Denmark	1	1,08	181	2,50
The Netherlands	7	7,53	542	7,49
Spain	3	3,23	118	1,63
Slovakia	1	1,08	1	0,01
Hungary	1	1,08	23	0,32
Italy	4	4,30	450	6,21
Switzerland	2	2,15	735	10,15
France	10	10,75	1008	13,92
Poland	3	3,23	30	0,41
Finland	2	2,15	94	1,30
Sweden	2	2,15	206	2,84
Belgium	3	3,23	245	3,38
United Kingdom	6	6,45	583	8,05
Germany	44	47,31	2835	39,15
Ireland	1	1,08	44	0,61

Source: European Patent Office (2013). Author's calculation

The big exception to the above stated relation is Switzerland. It has 2 chemical clusters but accounts for over 10 % of the granted patent. This can be due to a lot of research done in specialized institutes and university (table 22).

11.4.5 Innovation ranking of the clusters in different region

According to European Cluster Observatory (2014), the amount and quality of knowledge circulating and spilling over between chemical firms located in a cluster is dependent upon the cluster's size, the degree to which it is specialized in chemical products and the extent to which the locality or the region is geared towards and focused upon production in the relevant industries comprising the cluster. These three factors are size, specialization and focus which reflects whether the cluster has reached 'specialised critical mass' to develop positive spill-overs and linkages for innovation.

The European Cluster Observatory (2014) shows the extent to which clusters have achieved innovation by employing measures of these three factors as described below, and assigning each cluster a 'stars' number depending on how many of the below criteria are met.

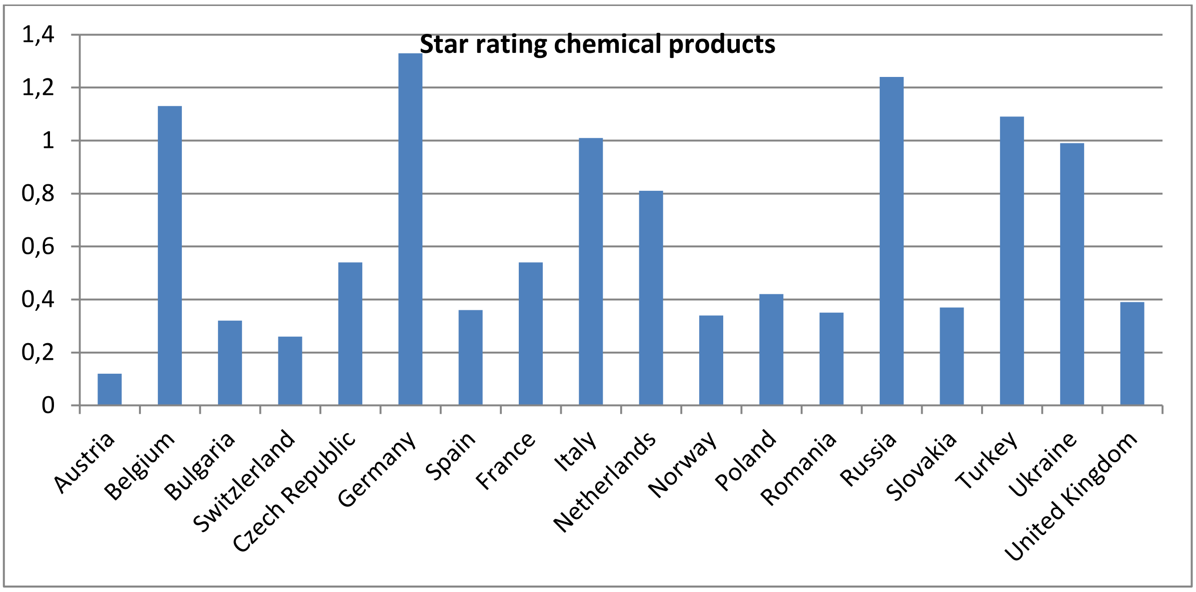
- *Specialisation*: if a region is more technically specialized in a specific cluster category than the overall economy across all regions, this is likely to be an indication that the economic effects of the regional cluster have been strong enough to attract related economic activity from other regions to this location, and that spill-overs and linkages will be stronger. If a cluster category in a region has a specialisation quotient of 2 or more it receives a star.

- *Size*: The 'size' measure shows whether a cluster is in the top 10% of all clusters in Europe within the same cluster category in terms of the number of employees. Those in the top 10% will receive one star. If employment reaches a sufficient share of total European employment, it is more likely that meaningful economic effects of clusters is present.

- *Focus*: The 'focus' measure shows the extent to which the regional economy is focused upon the industries comprising the cluster category. This measure relates employment in the cluster to total employment in the region. The top 10% of clusters which account for the largest proportion of their region's total employment receive a star.

The figure 109 shows the star rating of all the chemical clusters distributed over 27 European countries. Germany leads the race with highest star rating followed by Russia and Belgium. Germany has the largest number of chemical cluster which can impact the innovative collaboration of the chemical firms.

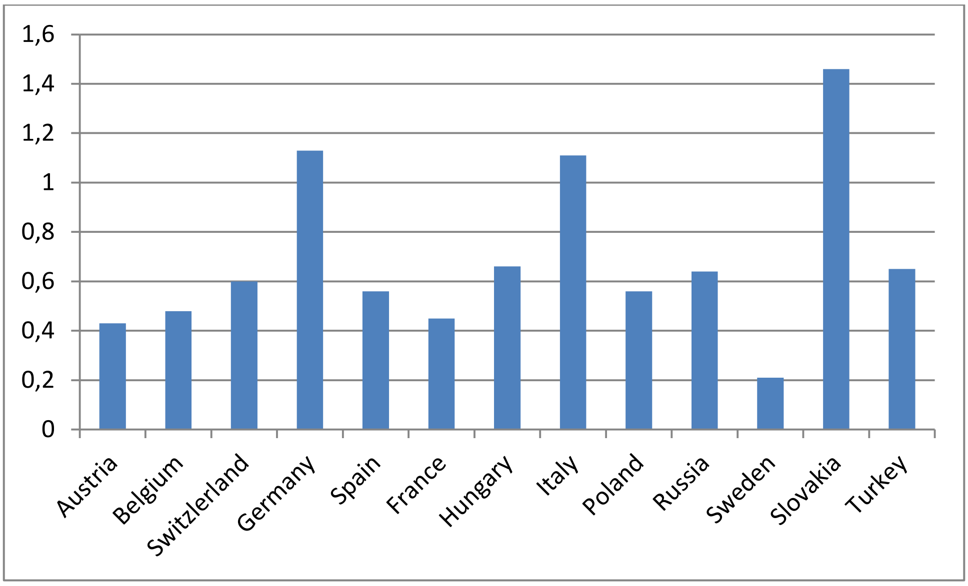
Figure 109. Innovation star rating of various chemical clusters in Europe according to chemical observatory



Data source: Cluster Observatory (2015). Graph: Author

The plastic industry is a key component of chemical industry in Europe and almost all large chemical companies in Europe is involved in production of it. So innovative collaboration of the plastic industry in chemical cluster is significantly important. The figure 110 shows the innovation star rating of the chemical clusters in the field of plastics. It was surprising to see Slovakia leading the race followed by Germany and Italy.

Figure 110. Innovation star rating of plastics producing companies in EU chemical clusters



Data source: Cluster Observatory (2014). Graph: Author

11.5 Conclusion

In Europe, there are over 300 chemical production sites which are located in clusters. Germany has the largest number of chemical cluster followed by France as distant second. Clusters do play a significant role in driving innovation of the European chemical industry. Alexera, Port of Antwerp and Tarragona chemical cluster are good examples of clusters which have been actively playing a role in innovation. It is seen that EU patents in chemistry and chemical engineering are not uniformly distributed over the region. Germany is the home for the largest number of EU patents in chemistry followed by France, UK and Switzerland. It is also seen that there is a strong relationship between the number of chemical clusters in a particular country and the number of granted patent for that country.

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12. Digitalization of the Chemical Industry and marketing innovation

Contents

12.1 Introduction

Economic and business trends are making it crucial for manufacturers to find new method for managing their operations and their business. As an example, chemical manufacturers and oil refiners face complex global supply chains, increased and dynamic regulatory requirements, rising costs of feedstock and energy, and mergers and acquisitions that result in disconnected computer systems. One way to achieve new efficiencies that can help address these business challenges is to leverage new developments and trends in technology to establish a unified set of information technology (IT) architecture principles.

On the other side, the rapid development of new interactive media such as on-line and the World Wide Web has taken most consumer marketers by surprise. Many are struggling to ‘‘guesstimate’’ the likely impact of interactive media on consumer marketing, wondering what they should do and how they should go about doing it. Those who move forward do so with mixed success. A recent analysis (Westerman et al., 2012) of nearly a hundred web sites of Fortune 500 consumer marketing companies shows that most of today’s interactive media marketing applications are very inspiring. There is emerging evidence that new media represent both a tremendous opportunity and a serious threat for marketers today. This section covers few important topics: how is digitalization part of chemical industry, for whom does digital marketing represent an important opportunity, what elements are included in the digital marketing program, and how should the digital marketing organization be designed? At the end we will test the fifth hypothesis of the research, i.e. if the chemical companies are moving toward digitalization and also to digital marketing.

12.2 Digitalization of business

Digitalization is an emerging business model that includes the extension and support of electronic channels, content and transactions. Companies are embracing this strategy to transform their businesses, while balancing electronic capabilities with traditional business practices (hard-copy documents and correspondence, face-to-face interactions, and call center volume).

By the year 2020, an entire generation, Generation C (for "connected"), will have grown up in a primarily digital world. Computers, the Internet, mobile phones, texting, social networking — all are second nature to members of this group. And their familiarity with technology, reliance on mobile communications, and desire to remain in contact with large networks of family members, friends, and business contacts will transform how we work and how we consume. The phenomenon of digitization is reaching an inflection point. The effects of an increasingly digitized world are now reaching into every corner of our lives because three forces are powerfully reinforcing one another:

- **Consumer pull:** Consumers, and particularly Generation C, are already fully adapted to the digital environment. They naturally expect to be always connected, are willing to share personal data, and are more likely to trust referrals from their closest friends than well-known brands.

- **Technology push:** Digital technology continues to expand its influence. The infrastructure backbone of the digital world is bringing affordable broadband to billions of consumers. In parallel, low-cost connected devices are being deployed in every industry, and cloud computing, and the vast information-processing machinery it requires, is developing quickly.

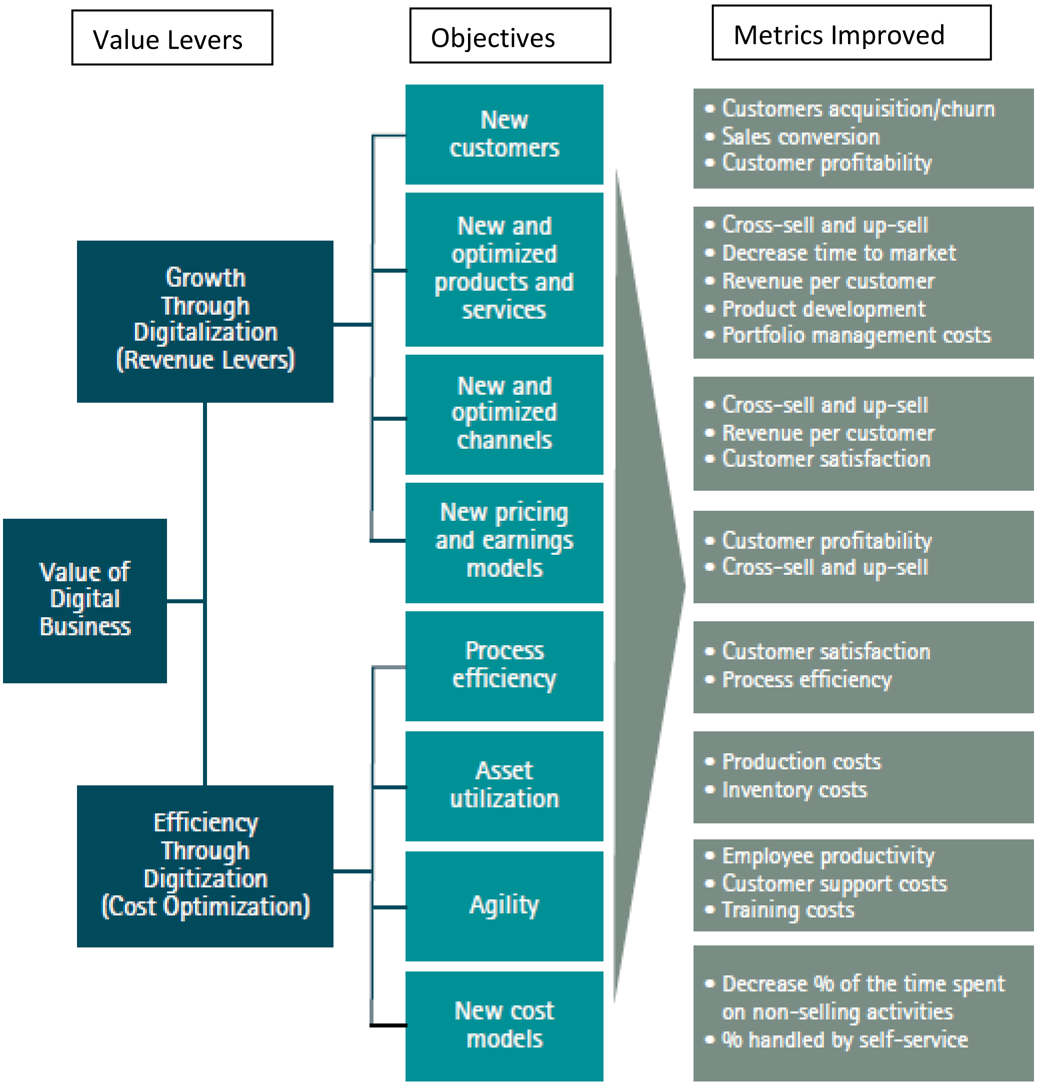
- **Economic benefits:** The economic benefits to be captured through digitization are real. A wave of capital has poured into the new digitization technologies and companies, and the public markets reward early movers with unprecedented valuations.

Digitization is not just the adoption of new technologies, but the resulting transformation of life and work. Today's new technologies, such as the cloud and big data are rapidly being woven into the fabric of business, as other technologies were before them. This is having a more dramatic effect than many people realize — not just on their customers, but on the industry that supplies these tools.

Every business must consider becoming a digital business. Growth requires becoming an innovative digital business, which is different from digitizing the business by substituting new technology for old without changing the way the business works.

When processes are simply digitized, all that happens is that technologies are applied without changing the business model or its growth potential. For instance, mobilizing the sales force by replicating existing processes on new technology may improve efficiency but does not necessarily change growth prospects. The figure 109 shows the objectives of digital business and various metrics to measure it. The chart shows that it is not only to do business in digital way but brings significant values to the business such as creating: new customers, new products, new marketing channels, new pricing models, improved manufacturing and process efficiency. A digital business can create revenue and results by using innovative strategies, products, processes and experiences. Companies may not be able to realize digital ambitions if they continue to be shackled by the cost, complexity and limited capacity of their legacy infrastructures (figure 111).

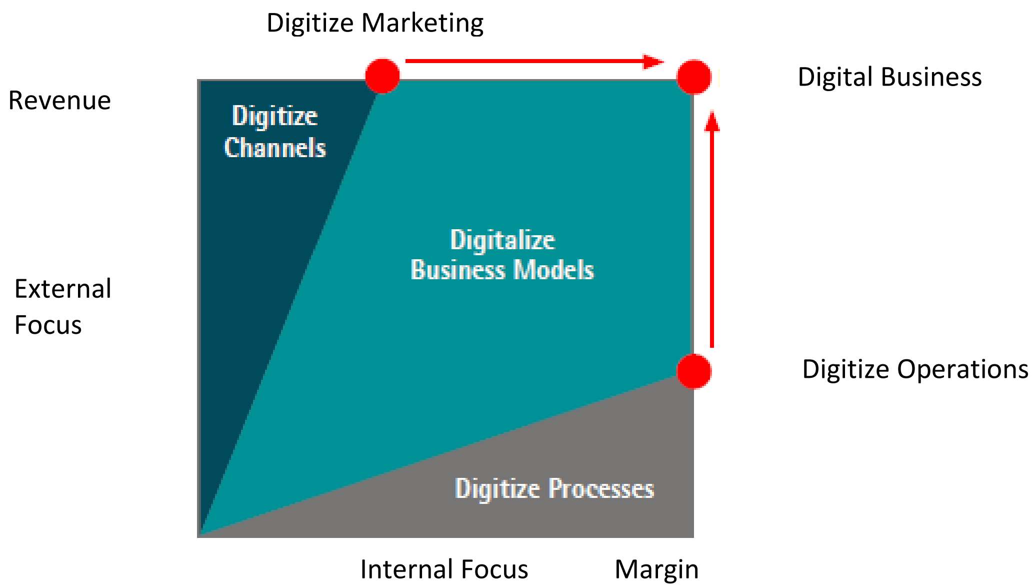
Figure 111. The value and impact of digital



Source: McDonald and Mcmanus (2014)

A digital business platform supports a diverse set of customer and operational requirements with a single set of resources and provides a guide for growth Conventional business strategy is not the best fit for meeting the demands of digital growth and with the given rate and extent of digital change, traditional annual strategy and planning cycles are challenged when required to assess the new needs and appropriately redeploy of resources. According to Accenture's analysis, there are three paths to a single digital business destination (McDonald and Mcmanus 2014). Business leaders can digitize marketing and customer channels, taking an external focus on revenue. Alternatively, they can look to grow margins and earnings by digitizing operations and processes. The third path is to digitalize the business model through combinations of both revenue and margin enhancement. Continued digitizing of either marketing or operations in isolation eventually can create real difficulties such as digital marketing without digital operations can cause companies to rely on old or duplicate operations to support new revenues (figure 112).

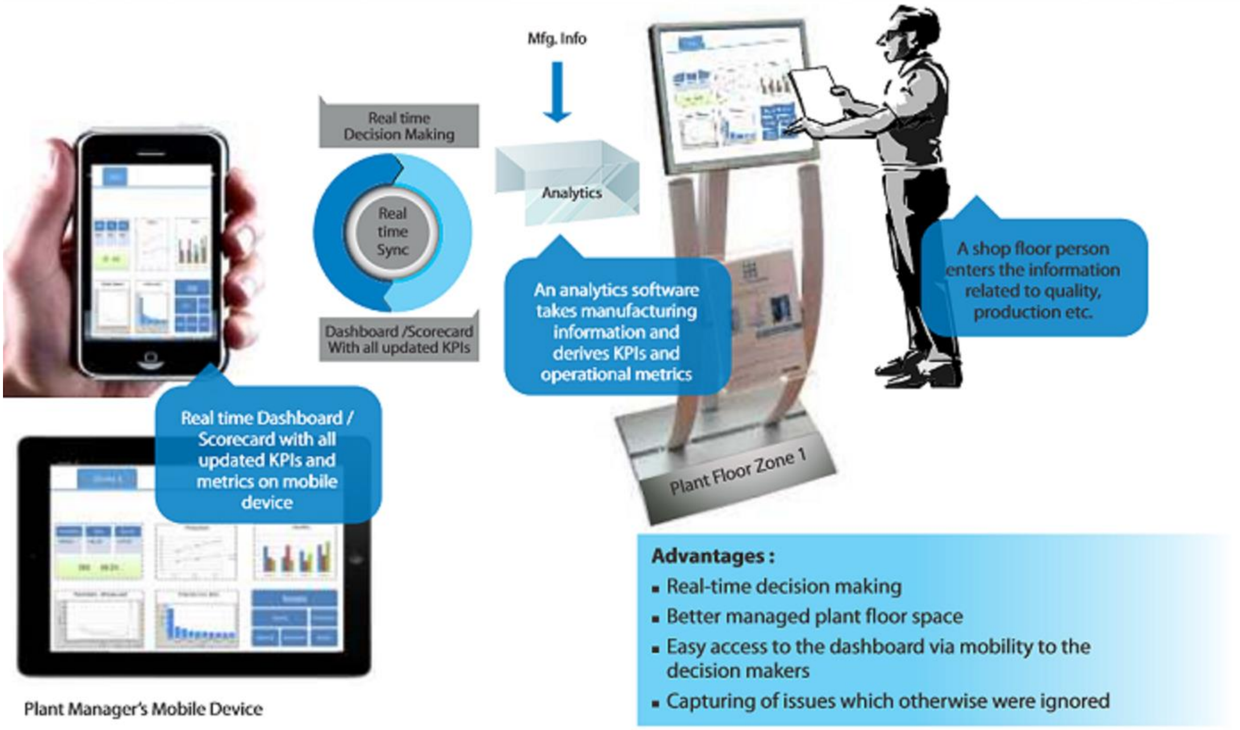
Figure 112. Digital model



Source: McDonald and Mcmanus (2014)

Figure 113 shows various components that typically exist due to digitalization of companies in manufacturing sector. The process starts with a person in shop floor entering the information related to quality and production. The information entered is taken by the analytics tools and send in real-time to various end users who gets a total picture of the manufacturing process at any given point in time. In this way, through digitalization, the top management is updated with the operation on shop floor.

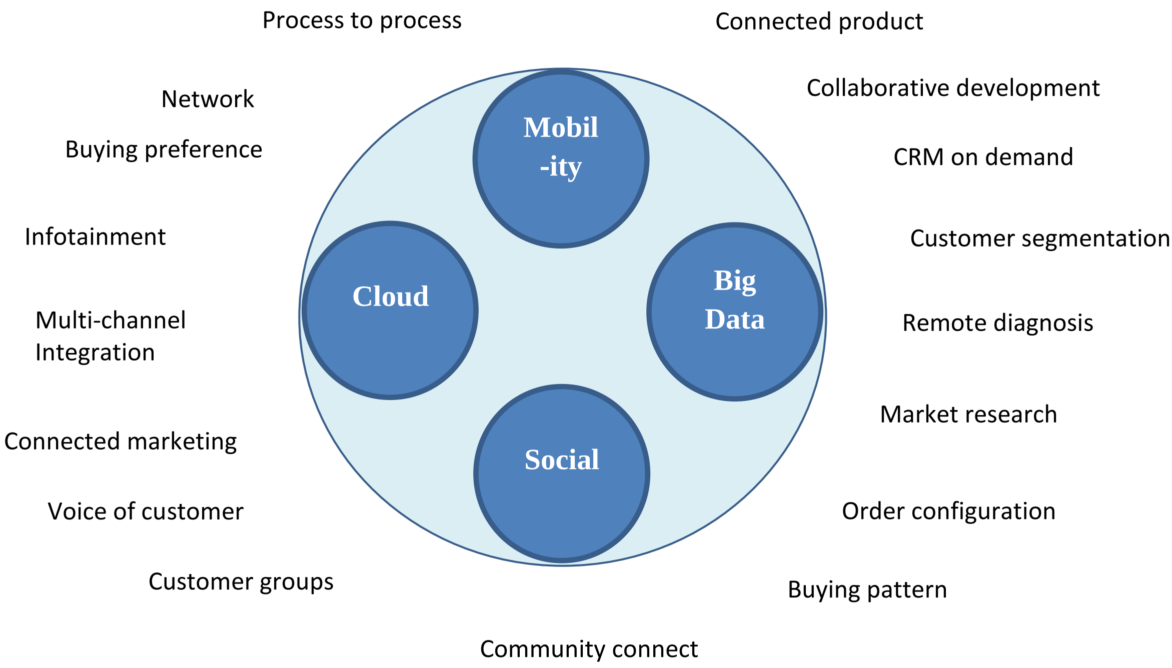
Figure 113. Flow of digital information in a manufacturing



Source: Tata Consultancy Service (2014)

Likewise, digitizing operations without doing the same with marketing can create the potential for higher margins through increased efficiency, but companies need the top-line revenue expansion marketing can deliver to turn that capacity into cash. Without new customers, an emphasis on digital operational efficiency alone will eventually shrink the company when it should be using its efficiency to grow market share.

Figure 114. The various component of digital



Source: Tata Consultancy Service (2014)

The various components of a digital wave in a company can be broadly divided into four parts: Mobility, Cloud, Big Data, Social. This can be divided into several sub-groups as seen in figure 114.

12.3 Digitalization of chemical industry

Shifting business requirements in the chemical manufacturing and oil refining industries are driving new trends and requirements in information technology (IT) architecture. There is an increasing need to manage ever more complex supply chain networks, handle changing demand and customer expectations, comply with regulatory requirements, and a host of other issues, all while still being able to maximize efficiencies in production and resource utilization, and working towards innovative ways to realize new value in industries with notoriously thin margins. Intelligent systems have the potential to transform chemical processing by improving the supply chain and optimizing manufacturing operations. They also provide the technology backbone that enables the capture of process data from industry devices, connectivity for data capture, and business intelligence tools to convert that data into impact.

Chemical and oil refining businesses rely on the ability to process and manage vast amounts of data, extract the needed information from it, and make that information available to those who need it, when they need it. This data includes: dynamic pricing of raw materials, supply chain data, inventory levels, research and product development, weather data, manufacturing operations data, demand data, customer data, and much more. This data flows among multiple systems within an organization and in many cases across different organizations. This vast and complex data flow is further complicated by mergers and acquisitions that require integrating different businesses and the systems they use. Traditionally, such data flows were built as point-to-point integrations, leading to very complex integration architectures that were costly, difficult to maintain, and often returned little value for the investment.

12.4 Digitalization drivers and Trends in chemical industry

Supply chain complexities, changing geopolitical landscape, and natural or man-made disasters can have significant impact on the supply of feedstock or crude oil needed to keep these industries running on schedule. In today's global economy and connected world, organizations must work hard to keep customer loyalty. At the same time, companies want to realize profitable growth, both organic and inorganic, and maintain a high focus on pricing and margin management. One way to achieve the balance between profitable growth and customer loyalty is by providing the best quality products at competitive prices.

12.4.1 Complexity of Supply Chain

Managing demand is crucial to optimizing the supply chain in chemical manufacturing and oil refining, so building a solid demand plan is essential for a successful business. Such planning is the basis for production, inventory, and the overall supply chain costs. Therefore, chemical manufacturers and refining companies have begun investing heavily in this area, moving away from spreadsheets to sophisticated tools, statistical models, and real-time data analyses. This approach helps companies achieve several capabilities, including: more accurate demand forecasts, optimized product mixes, and efficient order processing.

12.4.2 Need to Innovate

Managing innovation requires a culture that nurtures creative ideas and a process that funnels the large pool of ideas down to the viable ones that can evolve into product designs. This type of work requires extensive collaboration, sometimes across different geographies. Some of the major trends in innovation management in chemical company include the need to perform research and development (R&D) work by globally dispersed teams, working with business partners outside the company to collaborate on new ideas, and increased concerns around protecting intellectual property.

These trends make it imperative to have powerful collaborative solutions involving social networks to capture ideas and requests from co-workers, designers, suppliers, and customers, and evolve such ideas in the innovation funnel.

12.4.3 Human Factor

People working in manufacturing, especially in fields like chemicals and oil and gas, accrue a lot of expertise over the years. They know how to handle certain situations intuitively based on experience, for example, when and how to maintain certain pieces of equipment, or when to change the mixture of materials entering production based on certain conditions. However, in the past, with the lack of ways to capture and store people's knowledge and experiences, such knowledge was lost when people left the workforce. Today, new technologies provide ways to gather and share knowledge and experience, but many workers nearing retirement are not comfortable using such technologies. On the other hand, younger workers entering the workforce have grown up with modern technology through consumer products, such as video games, smart phones, and social networks.

12.4.4 Regulatory Requirements

There are strict regulatory requirements for process manufacturing in general, including chemical manufacturing and oil refining. Producing or processing chemicals is inherently dangerous. Mixing the wrong chemicals, or the wrong amounts of chemicals, could lead to explosive reactions, release of toxic fumes, fires, environmental releases, or many other consequences. As a result, the chemical industry is highly regulated at local, state, federal, national, and even international levels, through international treaties.

Regulations in the chemical industry, such as the REACH legislation (Registration, Evaluation, Authorisation and Restriction of Chemical, the European Community's regulations on chemicals and their safe use), are far-reaching in every aspect of manufacturing. They involve rules for plant design, production, maintenance, waste disposal, and proper labeling of finished products, to name a few. Additionally, nearby communities must be informed of the risks associated with a neighboring chemical plant or oil refinery.

12.4.5 Technical Drivers and Trends

New user experience technologies (e.g. HTML5) are being integrated with other end-user technologies, such as portals, communication technologies, analysis tools, and other visualization tools, and are made available for different kinds of screens: PCs and small portable devices, such as smart phones and tablets, bringing new possibilities to end users.

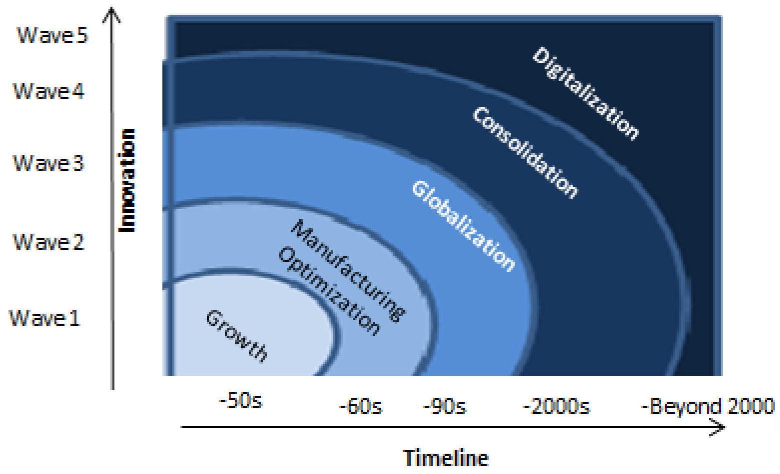
Cloud Computing

Cloud computing is a new development that businesses seem to be embracing for enterprise computing, particularly private clouds, which address many of the security and privacy issues and concerns of manufacturing customers. Private clouds are already used for several applications in the chemical manufacturing environment.

12.4.6 Embrace Innovation

With advanced connectivity between smart assets, products, and devices, technologies such as the IoT and machine-to-machine (M2M) communication are enabling the chemical industry to optimize efficiency and deploy new business models such as precision farming.

Figure 115. The various technological advances as seen by the chemical industry over the years



Source: Author 's graph based on Tata Consultancy Service (2014) concept

To be a digital chemical company is no different. Chemical companies have an opportunity to turn their digital capabilities into a competitive advantage that will create a digital divide in the industry. To get the most from digital systems, chemical companies need to manage the context in which the systems are used; that is, to transform the business to take full advantage of new technologies throughout the value chain (Table 23).

Table 23. Chemicals digital value chain

R&D / Laboratory	**Plant Development and Investment**	**Material Sourcing and Acquisition**	**Product Manufacture**	**Inventory Management and Distribution**	**Sales Management**
Co-innovation	Portfolio management	Collaboration and integration with suppliers	Plant automation	Automated warehouse and route management	Connected consumers
Closed-loop digital product lifecycle	Planning agility	Supply-volatility analytics	Resource optimization	Track and trace	Customer analytics
Product sustainability	Project finance	Commodity risk management	Remote monitoring	Collaboration with thirdparty service providers	Differentiated customer service
Virtual prototyping	Project execution and monitoring	Inventory and demand balancing	Asset performance	Inventory visibility	Dynamic pricing

			Quality automation		Execution compliance
			Track and trace		

Source: Accenture (2014)

Accenture (2014) has identified seven elements fundamental to harnessing digital capabilities for greater business outcomes. By understanding and working through these phases, chemical companies can put themselves in position to take advantage of today's digitally enabled solutions.

Table 24. Digital Landscape in chemical Industry

Digital plant	**Digital sales and marketing**	**Digital supply chain**	**Digital capital projects**	**Digital organization**	**Digital Marketplace presence**
Combines value chain integration with increased digitalization across the value chain for more efficient and profitable operations	Improves planning integration to discover and exploit new revenue and profitability opportunities according to market updated relevant information	Digitalization of stock and fleet management across the value chain	Includes a digital portfolio strategy that simulates financial and operations scenarios, evaluates bottlenecks, interdependencies and digital capital project execution	Leverages digital technologies to improve enterprise function efficiency through better visibility, financial performance and workforce collaboration	Using digital tools and capabilities to maintain an ongoing presence in the digital marketplace to identify and capture opportunities and mitigate risk

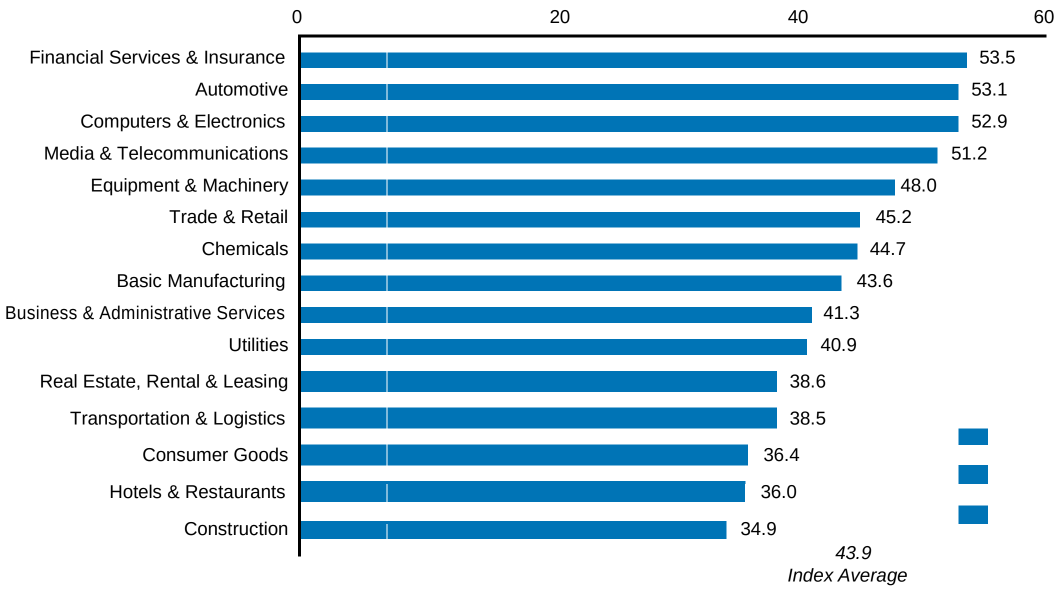
Source: Adapted from Accenture (2014)

12.5 Digitalization of the European chemical industry

In the second Industry Digitization Study done by Booz & Company, which investigates the degree of digitization across 15 industries in Europe, the aim of the study is to better understand which industries in which markets are leading the digitization journey, and which are lagging and also gaining insights into the specific business areas that companies in various industries focus their digitization efforts on.

The industry digitization index is composed of four separate but tightly interconnected dimensions—input (inbound transactions like procurement), processing (internal processes), output (customer-facing activities), and infrastructure (computing and connectivity)—that allow better understanding of what aspects of digitization certain industries and markets focus on. The figure 116 below shows the digitalization index of several industrial sectors in Europe. The average digitalization value is 43.9 while chemical industry has slightly higher value of 44.7. Financial services and insurance lead the race as evident from the extensive digitalization of the banking sector. It is surprising to see the digitalization of the European hotel and restaurant are at the bottom of the chart.

Figure 116. Digitalization Index for several companies

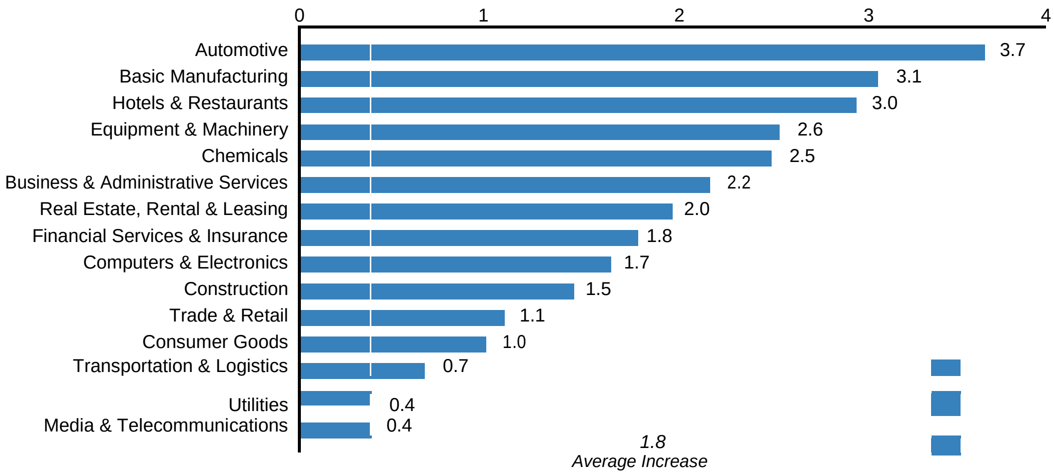


Source: Friedrich et al. (2013)

The next chart shows how rapidly is the above industries moving towards digitalization in Europe. It is seen that European chemical industry is one of the leader in the digitalization movement with an increase of 2.5 units in 2012 compared to 2011.

Although hotel and restaurants industry is having a low digital index, it is rapidly embracing digitalization in their business strategy.

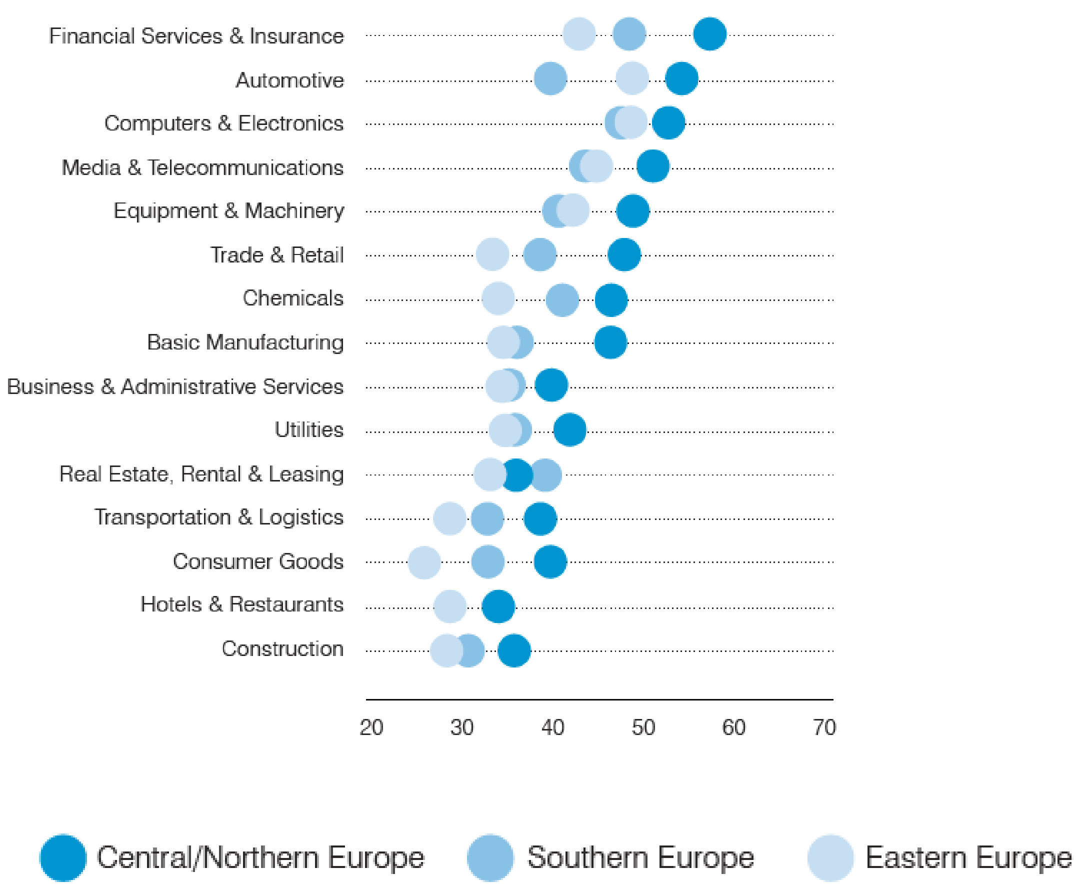
Figure 117. Industry digitization index change 2011–2012



Source: Friedrich et al. (2013)

The figure 118 further divides the European region into three regions: Central/ Northern Europe, Southern Europe and Eastern Europe. It is interesting to see that the digitalization is not equal over three regions. Central and northern Europe are the leader in digitalization followed normally by southern and eastern Europe. In case of chemical industry, the eastern region is way behind in digitalization. This can be attributed to chemical clusters spread over the northern, central and partially over the southern Europe.

Figure 118. Industry digitalization index by European region



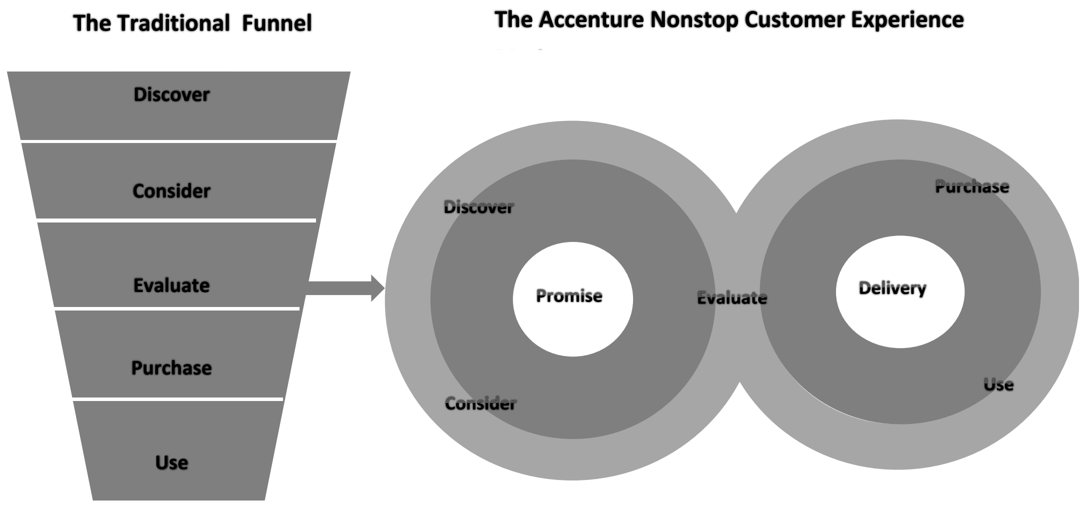
Source: Friedrich et al. (2013)

12.6 Innovation in Marketing in Chemical companies: Digital Marketing

Digital technology is changing all. At the simplest level, we've always known that consumers tend to go through a multistage journey as they make purchasing decisions. Yet most companies still concentrate marketing resources on only two stages: brand marketing up front to woo consumers when they first consider products, and promotions at the final point of sale to sway them as they are about to make a purchase.

The figure 119 shows in the left the traditional path a customer will follow during a purchasing decision. He would come to know a product from the word of mouth as he discovers a new product. He would consider different options and evaluate the various offerings. Based on the evaluation criteria and result he would make purchasing decision and use the product. These steps would follow a linear path one after another and would require significant time. According to Accenture (2014), with the advance of digitalization, the purchasing decision is no more linear as seen from the graph in the right. The activities work parallel in reaching the decision step.

Figure 119. New customer dynamics



Source: Accenture (2014)

According to Oxford Economics, online sales are projected to reach $20.4 trillion in 2013, representing 14 percent of the global economy and growing faster than sales in traditional channels. Of the world's 7 billion people, there are more than 6 billion mobile subscriptions and 3 billion active users of the Internet. Digital technologies drive change from the outside in. Technologies such as mobility, analytics, social media and cloud are intrinsically customer-focused, giving customers the information and connections to change the meaning at every moment of truth. Growth is no longer a matter of creating new products and marketing playbooks that move customers through linear purchasing processes. Growth no longer depends solely on pushing customers through the funnel; increasingly, it is tied to delivery of continuous customer experiences. By coordinating the consumer´s end-to-end experience, companies could enjoy revenue increases of 10 to 20 percent as shown in table 25.

Table 25. Trend in customer engagement to increase sells

Capture Internet Traffic	**Increase Consumer Engagement**	**Capture Qualified Leads**	**Build Consumer Loyalty**	**= Increased online revenue**
Capture 50-100% of fair-market share of traffic	Meet or exceed 50 % of best competitor´s engagement rate	Convert 10-15 % of engaged traffic into qualified leads Convert 20 % of loads into sales	Build 60 % loyalty rate. Achieve 40 % sales coversion rate annually from loyalists	Earn 10-20 % of total incremental revenue from new and loyal customers through online channels

Source: Accenture (2014)

Moving from a one-way, company-driven sales mentality to a two-way relationship with consumers requires core changes in the way marketers do business. While some of them have adjusted effectively, most simply tried everything that came to mind, because they weren't sure what would work. Companies have explored digital-marketing vehicles such as video ads, sponsored content, and online promotions. New forms of targeted online ad delivery have emerged. Web sites have been overhauled, and microsites for specific products or promotions have multiplied. Companies are buying thousands of search terms across their lines of business, and new agencies keep popping up to serve marketers' increasingly keen desire for innovative content, user tools, or social experimentation.

12. 7 Innovation in Marketing: Digital Marketing Strategy

As many other industrial sectors, digital marketing in the chemical sector has the website as the core component of their digital marketing strategy. Website could be textual, visual or aural content that is encountered in a website. I t may include text, images, videos, sounds and animation. It is seen all the top chemical companies have an elaborate website which is the window for information of the company to the outside world. When the website of these companies were analysed in details, seven key components were observed: Search Engine Optimization, Pay per click, Development, Social Media, Content Management, Additional Marketing, Content, Social Media, software. For our current study, we have focused on three digital marketing tools which are being extensively used in chemical industry: Blogging, Article Marketing, E-commerce, social Media Marketing.

Figure 120. Various components of digital marketing strategy of a chemical company

Source: Author

Each of the components of the digital marketing can be sub-divided into several sub components. These sub-components are shown in table 25.

Table 26. Sub-components of the digital marketing relevant to chemical industry

Search Engine Optimization (SEO)	Development	Pay-per-click (PPC)	Social	Software	Additional Marketing	Content
Link Building	CMS	Search	Facebook	Technologies	CRO	PR
Multi-lingual	Mobile	Ad Schedule	Twitter	Reporting	Shopping Feed	Blogs
On Page	Bespoke	Mobile	Linkedin		Cookie / Audit Law	Articles
Mobile	Design	Display	Youtube		EmailMarketing	Content
Local			Google+			
			Other			

Source: Author

Search Engine Optimization (SEO) is a process by which a website or a webpage is ranked as the page is viewed by visitors the number of times. The more the page or website is viewed, the more it is ranked higher in search results by the search engine. There are several acitivies related to SEO in chemical industry website. They can be broadly classified into link building through blogging, article marketing, mobile, local, multi-lingual, mobile and local digital marketing. We have seen that chemical companies are activity involved in link building as seen from the following data.

The search engine optimization is used extensively by the companies in driving to their website. A good example is when we type a key word of a particular product in search engine google, we see that google finds not only the website of the company but also the specific product pages. The product web pages are search built that is indexed very well by top search engines. One way the companies have achieved this is by using the right key words.

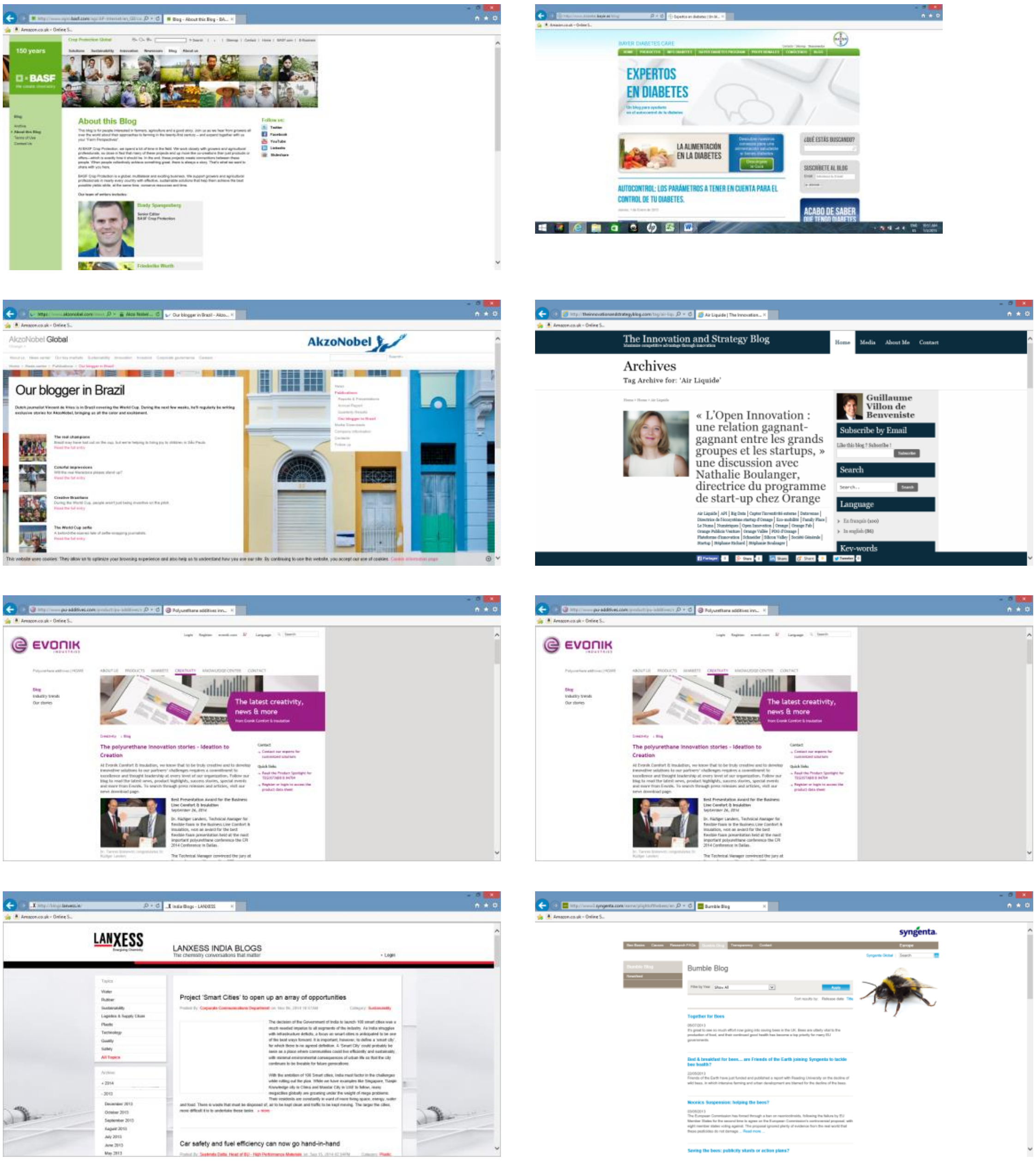
Another way of driving customer to the company website is by putting links in the blogs and other websites. Customers not only read the review of the product but also encouraged to click the links in the discussion blogs to visit the company website.
Blogging is one of the most popular Internet marketing techniques. On the professional side, a blog for marketing can give a company an identity and a "voice," gaining visibility on the Web. It can generate word-of-mouth interest and display current work. It is a way for to write about a product and tell the story behind it. It allows others to get involved with a product by leaving comments. The blog can be noticed by the media bringing the requests for interviews. It is a way of educating clients without being too preachy. The figure 121 shows the steps how blogs can be helpful in building realiability of a product or company.

Figure 121. The steps which the blog undertake to achieve marketing goals

Source: Adapted from I-Sccop (2015)

The figure 122 below show extracts of the blogs of some of the top chemical companies. It is seen that the companies have their own blogs while some of them have blog for specific business and also specific products.

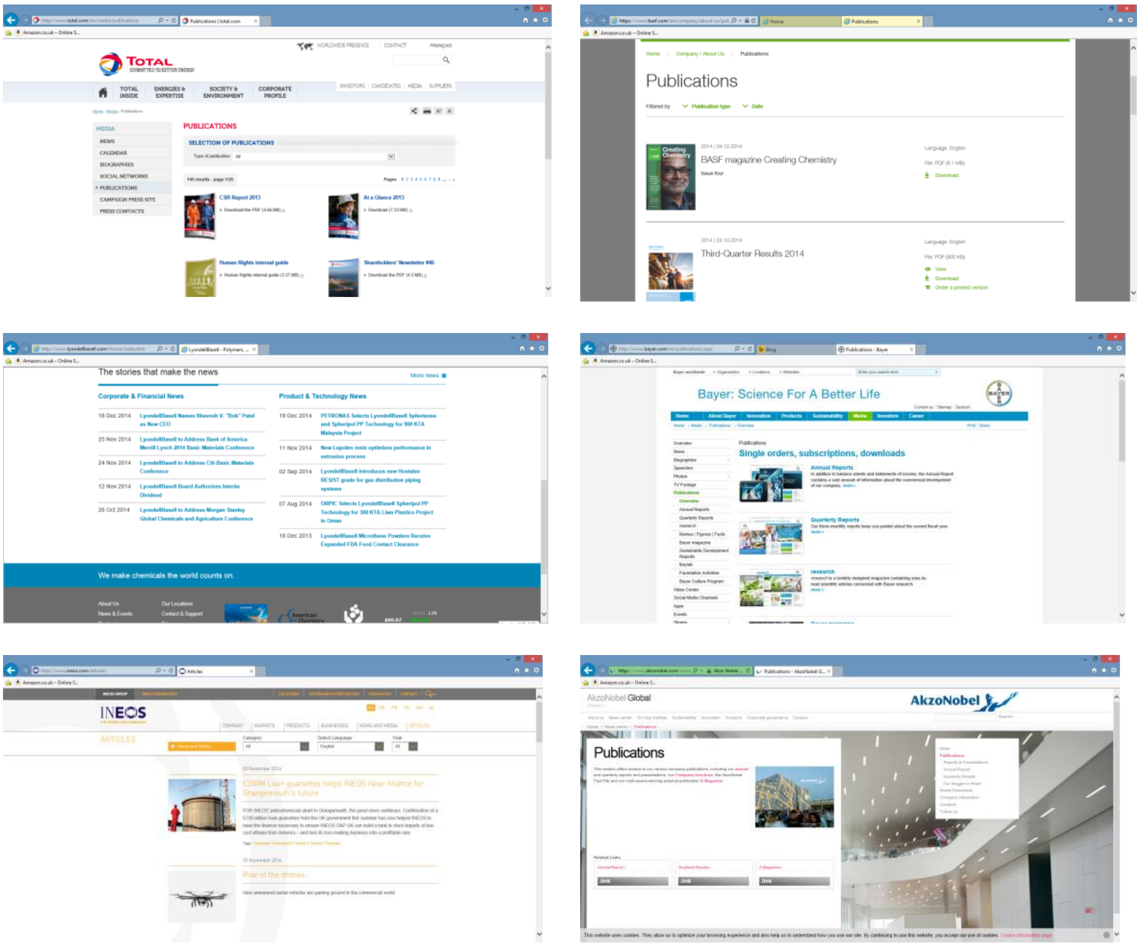
Figure 122. Website with blog web page

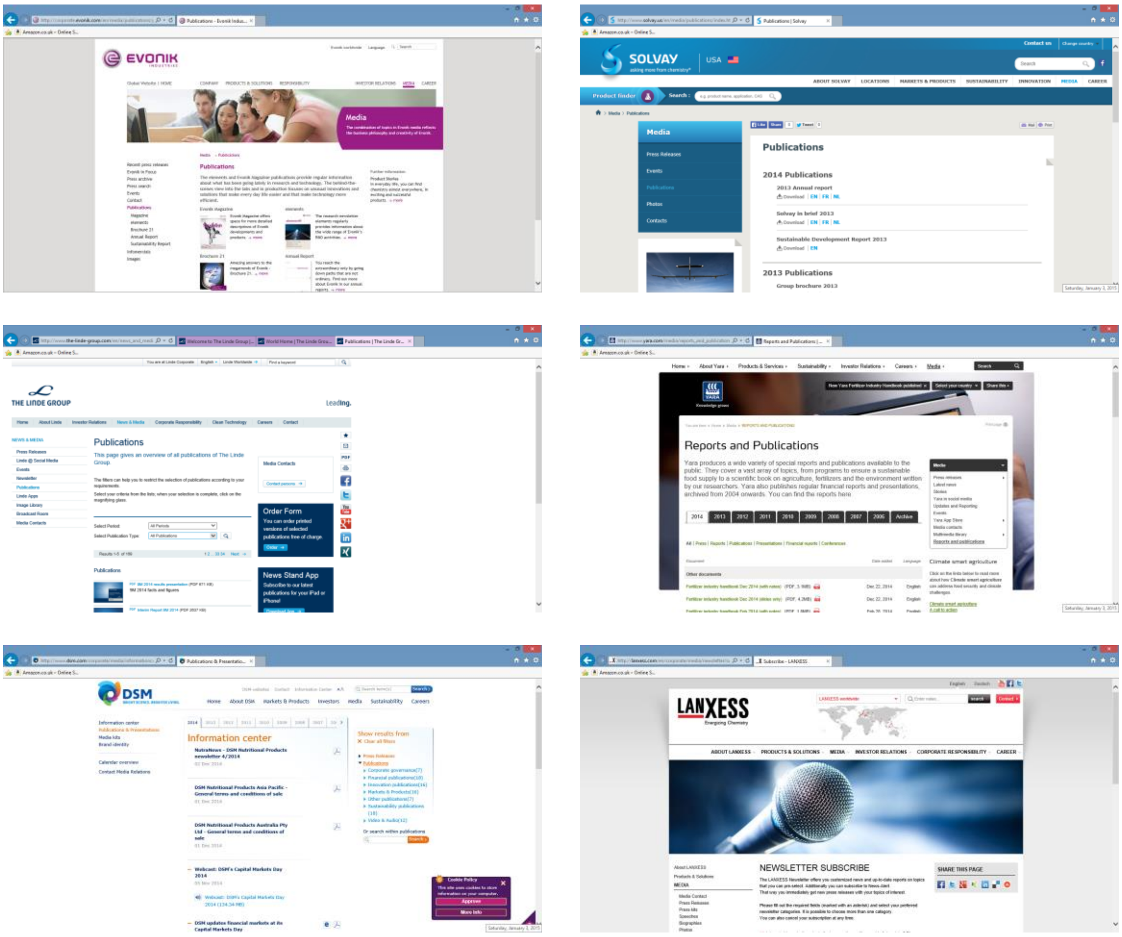


Source: Individual company webpages (2014)

Article marketing is a type of advertising in which businesses write short articles about themselves, their company or their field of expertise as a marketing strategy. Internet article marketing is used to promote the authors expertise of their market, products or services online via article directories. Article directories with good web page ranks receive a lot of site visitors and may be considered authority sites by search engines, leading to high traffic. These directories then give PageRank to the author's website and in addition send traffic from readers. Articles and article directories attract search engines because of their rich content. Business Owners, Marketers and Entrepreneurs attempt to maximize the results of an article advertising campaign by submitting their articles to a number of article directories. However, most of the major search engines filter duplicate content to stop the identical content material from being returned multiple times in a search engine results page. The figure 123 shows screen shot of the article page or publications of the top chemical companies under study.

Figure 123. Article and publication web pages of the top chemical companies

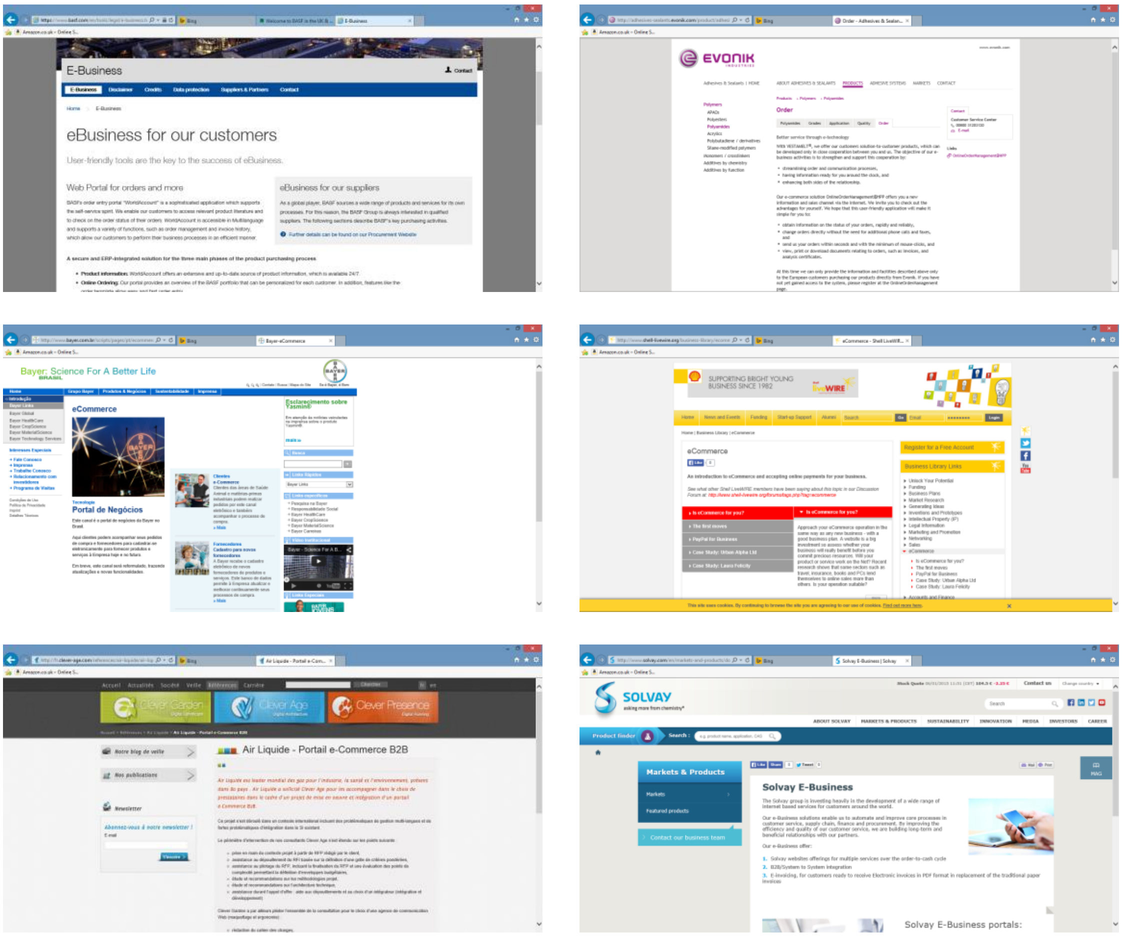




Source: Individual company webpages (2014)

Electronic commerce, commonly known as E-commerce or eCommerce, is trading in products or services using computer networks, such as the Internet. Electronic commerce draws on technologies such as mobile commerce, electronic funds transfer, supply chain management, Internet marketing, online transaction processing, electronic data interchange (EDI), inventory management systems, and automated data collection systems. Modern electronic commerce typically uses the World Wide Web for at least one part of the transaction's life cycle, although it may also use other technologies such as e-mail. It is seen that the top chemical companies in Europe has in most case e-commerce website where they sell some of their products (figure 124).

Figure 124. E-commerce web page of the top chemical companies



Source: Individual company webpages (2014)

Social media marketing refers to the process of gaining traffic or attention through social media sites. Social media often feeds into the discovery of new content such as news stories, and "discovery" is a search activity. Social media can also help build links that in turn support into SEO efforts. Many people also perform searches at social media sites to find social media content. Social connections may also impact the relevancy of some search results, either within a social media network or at a 'mainstream' search engine.

Social media marketing programs usually center on efforts to create content that attracts attention and encourages readers to share it with their social networks. A corporate message spreads from user to user and presumably resonates because it appears to come from a trusted, third-party source, as opposed to the brand or company itself. Hence, this form of marketing is driven by word-of-mouth, meaning it results in earned media rather than paid media.

Social media has become a platform that is easily accessible to anyone with internet access. Increased communication for organizations fosters brand awareness and often, improved customer service. Additionally, social media serves as a relatively inexpensive platform for organizations to implement marketing campaigns.

It is seen that all the top chemical companies are involved strongly in social media marketing. The table 26 shows the study of the top chemical companies websites and the social media link available on their website. All the companies under study is seen to be focussed on social media marketing having involved with top five social media: Facebook, Twitter, Linkedin, Google+, Youtube. Many of them also have a RSS Newsfeed which provides latest updates of the companies (table 27).

Table 27. Active involvement of social media channels by the top European chemical companies

	Face book	Twit ter	Link edin	Goo gle+	Yout ube	Flick r	Slides hare	Insta gram	Xing	Pinte rest	RSS Newfee d
BASF	x	X	X	x	x	x					x
Shell	x	X	X	x	x	x					
LyondellB asell	x	X	X	x	x						
Bayer	x	X	X	x	x						x
Ineos Group	x	X			x						x
Akzo Nobel	x	X		x	x	x	x				
Air Liquide		X	X								x
Evonik	x	X	X	x					x		
Solvay	x	X	X		x						
Linde	x	X	X	x	x				x		
Yara	x	X	X		x		x				x
DSM	x	X	X	x	x						x
Lanxess	x	X			x						
Syngenta	x	X	X		x						x
Arkema	x	X									x
Eni	x	X	X	x	x	x	x	x		x	
Styrolutio		X	X	x	x						

n											
Total	**x**	**X**									**x**

Source: Author

Table 28 shows the activities of top chemical companies in various social media domain. Since all of them have facebook page, "likes" on the facebook was taken as an important statistics for analysis. Shell leads the list with over 5 million likes, followed by Total as distant second and Bayer as the third. In terms of Tweets, Total is the leader followed by Syngenta and DSM. In terms of followers on Twitter, Bayer is the leader with over 101000 followers. Youtube has established itself has a strong social media channel through video. Most of the chemical companies under study have youtube channel and it is seen that shell has highest numbers almost 24000 subscriber followed by BASF with almost 5000 subscriber.

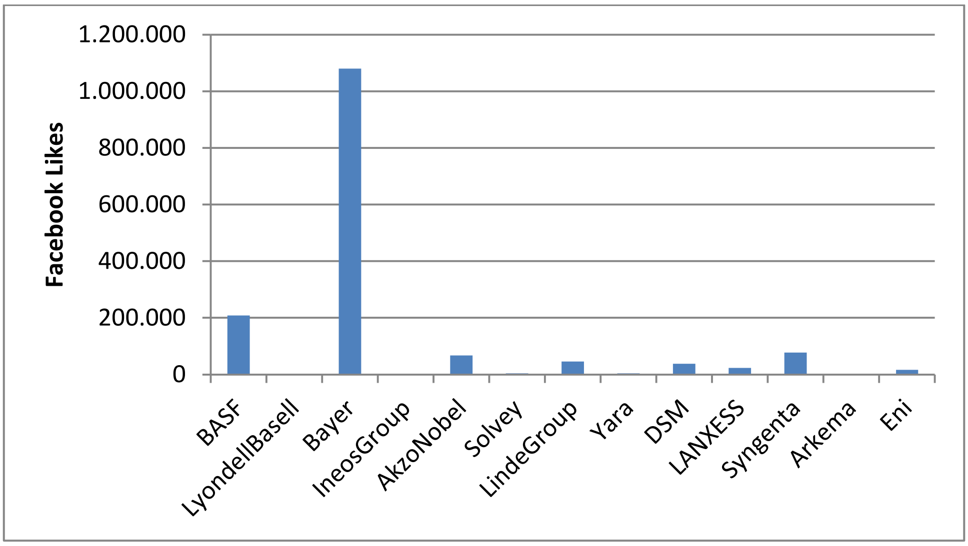
Table 28. Degree of engagement of top chemical companies in various social media channels

	Facebook	Twitter					Linkedin	Google+		Youtube
	likes	Tweets	Following	Followers	Favorites	Lists	Followers	Followers	Views	Subscribe
BASF	208.562	2.590	683	26.4k	364	6	268.993	3.322	1.455.859	4806
Shell	5.375.981	1.632	130	260k	8		1.236.175	229.306	2.241.993	23.941
LyondellBasell	1.312	313	1.964	3.355	18	1	31.762	75	35.270	38
Bayer	1.079.279	1836	1801	101k	1.362		310.454	1958	689.256	910
IneosGroup	609	410	186	3.599	3					183
AkzoNobel	67.016	1.428	682	11.3k	84			608	281.715	776
LindeGroup	45.575	1.395	1.232	5.640	181	6	49.652	544	266.996	705
Yara	4.419	2.398	1.367	3.647	175		49.652			756
DSM	37.337	5.481	437	66.7k		1	55.617		311.772	1.071
LANXESS	23.063	900	95	3.092	305	1				232
Syngenta	76.799	5.920	1.521	33.9k	5.786	4	82.148			
Arkema	1460	546	233	2.409	2	10				
Eni	16.830	2.115	397	14.1k	518	1	178.037	122	85.620	3.847
Styrolution		21	6	52	7		65	17	2.560	18
Total	2.042.088	7.133	371	52.1k	109					

Data Sourec: Individual Websites; Author's calculation

Figure 125 shows a comparative graph as how the facebook page is liked by the visitor. It is seen that Bayer is way ahead than most of the chemical companies and seen to be very active in their facebook website. Distant second is BASF while for most other activity is pretty low. This shows that even though every chemical company has a facebook page, they are not very active there and do not emphasize the importance of facebook marketing. On the other hand the oil companies even though not appearing in this graph are way ahead of chemical companies in terms of activity at the facebook page.

Figure 125. Facebook likes of various chemical companies



Source: Author

12.8 Information technology challenges faced by the Chemical Industry in Europe

Chemical companies have specific concerns relating to cyber security, supply chain and logistics. At the same time, trends like big data, cloud computing and social media have begun to exert an influence on the industry. Chemical companies are moving in and out of markets as their strategy dictates, so portfolio churn is an issue. Margins are tight, so mitigating costs is on the list. Data management and security, especially in new markets, is a concern. Global regulation is another. And while everyone has a basic ERP system, companies are looking upstream and downstream in their value chain, trying to find ways to reduce costs and increase margins.

According to Ray Adams (IBS Chemicals Solution Manager at SAP), IT is helping to integrate groups like R&D to drive down cycle times in the commercialization process.

Some segments like coatings and ink companies introduce hundreds of products each year. They have to commercialize these things quickly. IT provides the tools and mechanisms to make that as seamless as possible, integrating into finance, the regulatory environment, into environmental health and safety databases, and flowing into the manufacturing environment.

12.9 Conclusion

From the above study it can be concluded that chemical industry in Europe is adapting digitalization in a fast pace compared to many other sectors. The digitalization has increased profitability by 10 – 20 %. Digital marketing has become integral part of marketing strategy of the top chemical companies in Europe. Blogging and article marketing is being extensively used to educate the customer and promote their products. The companies under study are extensively involved in social media marketing and video channels.

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13. Conclusions

The chemical industry is one of the European Union's most internationally competitive, innovative and successful industries, embracing a wide field of processing and manufacturing activities while supplier of raw material to almost all industry of European Union. The chemical industry underpins most sectors of the economy, and accounts for over 7% of EU manufacturing output and with a workforce of 1.2 million, 29000 chemical companies and sales of €642 billion, it is one of the biggest industrial sectors and an important source of direct and indirect employment in many regions of the European Union. This is equivalent to 4% of the manufacturing industry's overall workforce. Output from the EU chemical industry covers a wide range of chemical products, supplying virtually all sectors of the economy and providing a significant contribution to EU net exports. Following are the conclusions obtained from the current research:

1. *The European chemical industry is in difficult situation and is facing unprecedented challenges from other regions of the world.*

The manufacture of chemical products is increasingly moving eastward, drawn by the economic growth and market opportunities in Asia, the Middle East and Russia. Production is getting more expensive due to costs of labor and resources. The European chemical industry´s share of world chemical sales declined from 29.8% in 2001 to 19.6% in 2011, which translates into 34% decline over a period of 10 years. The value of the stock over the last ten years shows that the financial crisis of 2007-08 has severely affected the chemical industry and particularly the European chemical industry. Since the European chemical industry supplies all EU industrial sectors, including construction, its strategies impact directly on downstream chemical users.

2. Europe still plays a key role in the global chemical industry

The EU is still the leading world force in the chemical industry: it is home to 19 of the top 50 global chemical companies. Asia is in second place with 16. Data for 2013-14 confirms that the European chemical industry has made a significant recovery. Although China has emerged as the biggest chemical producer, 8 of the top 30 major chemical-producing countries are European, generating chemical sales of EUR 480 billion. In Europe, Germany is the largest producer of chemicals, followed by France, Netherlands and Italy. The European chemical industry is moving towards speciality and consumer chemicals, which in 2011 accounted for 77% of the extra-EU chemical trade surplus. In Europe, even though large companies are only 3% of the total number of chemical companies, they employ 56 % of the work force. BASF is the largest chemical company in terms of sales, almost double those of its nearest European competitor.

3. *The traditional oil companies are now investing in chemical business in Europe while many chemical companies are investing in non chemical businesses*.

Apart from the three oil companies (Shell, Eni, Total), most of the other companies have a very high percentage of chemical sales as a percent of total sales. Although BASF is the largest chemical company in terms of sales, its chemical sales is slightly lower than 80 % of the total sales. Many large chemical companies have diversified into the pharmaceutical and bioscience industry, which brings to them significant profitability as seen in Bayer. BASF is way ahead compared to others in terms of capital asset. It is interesting to see that Bayer’s chemical asset is only around 40 % of the total asset, which can be attributed to a diversified company. Most other companies in this analysis are pure chemical companies with their chemical asset being almost 100 % of their total asset. In case of companies who are almost wholly dedicated to chemical industry, BASF and Linde are the top employers. Although the three oil companies Shell, ENI and TOTAL are large employers, but a significant portion of their work force is engaged in their oil and gas business, since chemical business is not prime business.

4. *Patent as an innovation indicator did not show upward trend for most of the companies*

Chemistry is the leading technical sector in terms of the number of patents granted by the European Patent Office. The areas that have most patents granted are fine organic chemistry, biochemistry and pharmaceuticals. Only five of the top selling European chemical companies feature in the list of the top 25 patent applications for fine organic chemistry in 2013, which suggests that they are moving into speciality chemicals. The number of patents granted to BASF, Bayer and Akzo Nobel has fallen over the last 14 years, which shows that they are not interested in protecting their technology in this market. Over the years BASF and Bayer have had the largest number of patents granted, which clearly shows their strategy of using patenting as a key tool for innovation and the protection of their technology. For most of the companies that were studied, the first patent of a patent family is applied for and granted by the European Patent Office. Some companies had very few patents granted, thus showing that not all companies have the same focus on innovation or patenting. From the trend analysis for the first hypothesis test, it is seen that most companies did not have an upward trend for the last ten years. BASF and Bayer had a downward patenting trend until 2009 and then there was sharp rise in the number of patents granted. This trend was also seen for many other companies analyzed. It can be concluded that the global crisis that hit the economy in 2007–08 had a negative effect on patenting and innovation. So it can be concluded that the first hypothesis of this study is proved false that the companies under study have a positive trend in terms of innovation over the years.

5. *The quality of research in case of most chemical companies is very high.*

The large chemical companies have well-developed research and development departments. In most cases the ratio of patents applied for to patents granted for a particular year is between 0.5 and 1.5, which suggests that patent applications are high quality and are readily granted. Research, then, is of a high level.

6. Although the EU chemical industry is shrinking its R&D spending almost every large chemical companies have been increasing their R&D expenditure.

In the European Union, there has been a decline in R&D spending in terms of both absolute value and percentages of sales but it is still way ahead of other geographical regions. In China there was a threefold increase in R&D investment in 2012 compared to 2006, showing that R&D was being given high priority. For other regions, R&D spending has slightly increased. BASF spends the most on R&D followed by Bayer as a distant second. BASF is the largest chemical company and this high spending on R&D justifies its enormous R&D infrastructure. Bayer invests heavily in research, especially in the pharmaceutical and crop science division. In 2012, Syngenta increased its R&D expenditure compared to 2007 while Arkema and Linde both decreased their R&D expenditure. Yara spent very little on R&D in both the years. Syngenta has the highest R&D intensity followed by Bayer and DSM. In most chemical companies, R&D intensity is around 2% (for example, BASF, AkzoNobal, Air Liquide, Evonik, Solvay, and Arkema). Bayer also shows a high R&D intensity of 5% which can be attributed to their high investment in crop science and pharmaceutical products. LyondellBasell and Yara have very low R&D intensities, which maybe due to a very low level of investment in R&D.

Bayer and BASF have a ratio of R&D spending to patent application of around 2 while some companies have a ratio of below one. Companies whose ratio is low tend to show that their R&D is more efficient at generating patent applications or ideas. BASF has been investing in R&D by increasing the number of people devoted to it. It should be noted that just after the financial crisis that hit in 2008, BASF increased its work force in R&D, thus showing their strategy of R&D expansion. Thus the second hypothesis of this research could proven partially true as all companies understudy did not over the years show upward trend in R&D investment .

7. *All the large chemical companies is using Merger & Acquisition (M&A) to gain access to innovation.*

Most merger and acquisition (M&A) deals were entered into in Asia followed by Europe and North America. Apart from market diversification, the purpose of these deals is to gain R&D knowledge about particular products. This is another way of gaining innovation faster than by internal development. When the acquiring chemical companies are located in Europe, they prefer to acquire companies that are also in Europe. Acquisition in other regions such as Asia and North America stands at a nominal 8 to 9%.Over the last five years, acquisition has largely focused on non-chemical companies, which shows that these companies are trying to diversify and acquire know-how which is not part of their core competencies. Such companies as BASF, Air Liquide, Ineos, Evonik and Solvay are strongly inclined to acquire European companies while others such as Bayer, DSM and Arkema tend to acquire more globally. The companies have considerable expertise in the chemical industry and related sectors, but lack the know-how of the other sectors they wish to enter. So they acquire companies from other sectors to quickly gain technical knowledge and accelerate innovation. Lanxess and Arkema mainly stick to a strategy of acquiring other chemical companies. BASF, however, the largest chemical company in the world, is making 50% of its acquisitions outside the chemical sector. A similar trend has been observed for Bayer: recently the company was granted the highest number of patents for the last ten years. And 50% of the companies they acquired were outside their sector of expertise (chemicals and pharmaceuticals). So it is seen that most of the large chemical companies in Europe are using acquisition as a tool for acquiring the know-how and knowledge from sectors where they did not have core competency and so proves the hypothesis to be true. This proves the third hypothesis true that M&A decisions are influenced by innovation policy of the companies.

8. Industry-academia collaboration is a way to generate innovation in chemical industry in Europe

All the top European chemical companies actively participate in EU-funded projects. The data for the last 20 years shows that BASF is the company that most participates in EU-funded projects followed by Bayer, Air Liquide and Evonik. Although funding acts as a stimulus for companies to take part in EU projects, they are also willing to co-operate not only with research institutes and universities but also with their competitors to drive research and innovation. Over 75% of the participants in EU projects are government institutes or universities. It is common for large chemical companies not to participate in these projects with a single entity; rather they participate either as an individual business or as same company from different region (for example, BASF Agro, BASF SE etc.). Some companies participate more with government organizations while others participate with both private and government organizations such as universities, colleges and publicly funded research institutes. Although the top chemical companies participate in a lot of EU-funded projects, they generally want to be participants rather than the coordinators. In most cases they coordinate less than 20% of the projects they participate in. This may be due to the fact that coordination of EU projects involves a significant investment in resources. The only company which is somewhat the exception is Akzo Nobel, the coordinator of almost 56% of all the projects they participate in. Thus the second part of the third hypothesis is also proven true.

9. *Although the European environmental regulation (REACH) profounder believed that REACH will stimulate innovation, most of the chemical companies believe that REACH is having a negative impact on innovation.*

Initially it was believed that as a result of REACH, the characteristics of substances become more transparent and that this increased knowledge and the necessity for substitution will stimulate innovation. It was also believed that REACH Regulation will create an information database through gathering, capturing and disseminating data from the chemical industry which would act as a motivaion to product development and marketing. Feedback from interviews and the innovation survey suggested that the costs of IPP related to REACH can be challenging or even prohibitive to innovation. Many large companies had a higher share of turnover spent on R&D than average due to REACH. There has been delay in innovation as a result of an external factor such as regulation. In case of large companies, the evidence from the fieldwork also suggested that links with universities and networks developed tended to focus on the compliance and regulatory elements of REACH rather than pure research and there is a great deal of activity throughout the EU in this respect. The several steps for substitution mechanisms within REACH: registration, the candidate list, authorisation and restriction, have had various impacts on innovative activities. It has been observed that companies carry out product changes purely with a view to avoiding regulatory burdens of REACH, or perfectly harmless eco-friendly substances are withdrawn because of registration costs. Registration costs have an impact on the decision to register a new substance or use, or use of an existing substance in innovative ways and this turn also influence the availability of substances within supply chains for future use in innovation. In many instances companies have considered the activities to ensure compliance with the Regulation as a distraction from their normal, planned innovation activities (also organizational and marketing innovation) and to be unintended consequences of the Regulation. Increases in time-to-market as a result of the Regulation and increased supply chain rigidities resulting from changes in toll manufacturing arrangements have not been supportive of innovation. So the last part of the fourth hypothesis that the new environmental regulation is influencing the innovation policy of the chemical companies is proven true.

10. *Chemical clusters and geographical distribution of the chemical companies play a significant role in generating innovation.*

In Europe, there are over 300 chemical production sites which are located in clusters. Germany has the largest number of chemical clusters followed by France in a distant second place. Clusters do play a significant role in driving innovation inthe European chemical industry. Alexera, Port of Antwerp and Tarragona are good examples of clusters which have been actively playing a role in innovation. EU patents in chemistry and chemical engineering are not uniformly distributed over the region. Germany is home tothe largest number of EU patents in chemistry followed by France, UK and Switzerland. There is also a strong relationship between the number of chemical clusters in a particular country and the number of patents granted for that country.

11. *Large chemical companies are adopting digitalization at very high pace.*

The consumer pull, technology push and economic benefit digitalization brings led the larger chemical companies, particularly in Europe to adapt it in their main stream of business. The two pillars of digitalization of a company are digital operation and digital marketing. The drivers for the operational digitalization in larger chemical companies are: very complex supply chain, drive to innovate at very high pace, employee inclined to new technologies, new regulatory requirements such as REACH and very fast information technology growth. The digital value chain in chemical industry has become very complex starting from R&D laboratory and ending in sales management. The digitalization index study from Booz & Co. positioned chemical companies in Europe in seventh position among all growing industry in terms of adapting new digital tool in the business. It also scored higher than the average of the study and was positioned in fifth position in the growth rate. Another significant point came out from the study that the digitalization in chemical industry has not happened smoothly over whole of Europe. Eastern Europe is lagging behind to south and central / Northern Europe. It is worth to mention that most of the large chemical companies studied in research have headquarters or very concentrated in central and south of Europe. This proves true for the fifth hypothesis of this research.

12. The larger chemical companies in Europe have adapted digital marketing as the innovative method of promoting their products and services

The current study shows that digital marketing is playing a key role in chemical industry in influencing purchasing decision both in case of business-to-consumer (B2C) and business-to-business (B2B). The study also showed that the purchasing decision no more follows a vertical stereotype path and follows a more inter-active route until the decision is made. The chemical companies which have been selling through traditional methods are moving to online tools. Several of the large companies we studied have an ecommerce website where they are selling their products. It should be mentioned here that the business to business sell is still done in the conventional method while business to consumer sell is moving more towards online. All the companies we studied have a very detailed website and every effort is being made to capture the internet traffic. Software tool such as search engine optimization (SEO) is used extensively by these companies to drive more traffic to their websites which can eventually lead to increase in consumer engagement, capture qualified leads, build consumer loyalty and ultimately bring in sell. Although being late, the chemical industry is catching up in case of social media marketing. Every company we researched is involved in more than one social media in order to promote their product. Facebook has been the first choice for most of the companies and have on youtube a dedicated video channel which is regularly updated with product or company related promotional video. We also found that these social media channels have a huge fan following, but it was difficult to know if they were employees or dedicated customers or just general public. Another aspect of digital marketing they all are focused on are blogs and article marketing.

14. Recommendation for future work

The current research focused on the European chemical industry. During the study we found that like Europe, North America has been affected by the global financial crisis and its chemical industry is under same pressure as European chemical industry. It would be interesting to study the innovation policy of North America chemical industry as many of the largest and most innovative chemical companies are located in this region.

The rising oil price in the end of last decade has resulted in higher feed stock price for the chemical industry which has resulted negatively their profitability. It would be interesting to study the impact of oil price and performance of the chemical companies in terms of R&D and innovation.

There has been a boom of shale gas in US for last five years which has also impacted the North American chemical industry. It has resulted in new chemical projects starting in NA and rejuvenated the chemical industry of that region. It will be interesting to study the impact of shale gas on the innovation of North American chemical industry.
Although Middle East has cheap source of oil, we do not see too many big chemical companies in this region and the level of innovation is considerably low. It will be also interesting to have a deep drill of the innovation policies of the companies in this region.

The literature research of the current Project even though showed that there has been several work done in the field of innovation, but very little research was available over cross business innovation policy and how learning of one sector is implemented in another sector.