TURKISH CHEMICAL SECTORAL INNOVATION SYSTEM: A CASE STUDY ON R&D CENTERS

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ABSTRACT

TURKISH CHEMICAL SECTORAL INNOVATION SYSTEM: A CASE STUDY ON R&D CENTERS

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This thesis aims to analyze the innovation landscape of the chemical sector in Turkey through face-to-face interviews with six R&D centers operating in the chemical industry. R&D centers are selected for the case study as they are one of the most critical actors conducting R&D and innovation activities in the sector. The sector was investigated within a set of three sub-sectors as follows: basic chemicals, specialty chemicals, and consumer chemicals. In this thesis, the sectoral innovation system (SIS) approach was used as the conceptual framework. The approach provides an overall understanding of the sector in the contexts of three main building blocks, knowledge base and technology, actors and networks, and institutions. The role of human capital in the chemical sector and contribution of qualified labor to chemical innovation system are also examined in this regard. This research uses multiple case study design as a method of inquiry to analyze the current situation of the chemical industry in Turkey in the context of SIS from the R&D centers' point of view and to better understand the similarities and differences between the sub-branches of the chemical industry. Qualitative analysis of semi-structured interviews reveals some areas of improvement in R&D centers as well as the overall sector. Both managerial and policy recommendations that improve the functioning of the chemical sectoral innovation system are proposed accordingly.

Keywords: Chemical Sector, Sectoral Systems of Innovation, Turkish Chemical Industry, R&D Center.

ÖZ

TÜRK KİMYA SEKTÖREL YENİLİK SİSTEMİ: AR-GE MERKEZLERİ DURUM ÇALIŞMASI

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Yüksek Lisans, Bilim ve Teknoloji Politikası Çalışmaları Bölümü

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Bu tez, kimya sektöründe faaliyet gösteren altı Ar-Ge merkezi ile yüz yüze görüşülerek kimya sektörünün yenilik alanını analiz etmeyi amaçlamıştır. İlgili Ar-Ge merkezleri, sektördeki Ar-Ge ve yenilik faaliyetlerini yürüten en kritik aktörler arasında yer aldıklarından ötürü vaka çalışması için seçilmişlerdir. Kimya sektörü üç alt-sektör üzerinden incelenmiştir: temel kimyasallar, özellikli kimyasallar ve tüketici kimyasalları. Bu çalışmada, kavramsal çerçeve olarak sektörel yenilik sistemi yaklaşımı kullanılmıştır. Söz konusu yaklaşım, bilgi altyapısı ve teknoloji, aktörler ve ağ yapıları ile kurumlar olmak üzere sektörün üç ana yapı taşını inceleyerek sektörün genel bir tasvirini yapar. Bu bağlamda, beşeri sermayenin kimya sektöründeki rolü ve nitelikli işgücünün kimya yenilik sistemine katkısı da incelenmiştir. Bu araştırmada, kimya sanayinin mevcut durumunu sektörel yenilik sistemi kapsamında Ar-Ge merkezlerinin bakış açısından görmek ve alt sektörler arasındaki benzerlik ve farklılıkları daha iyi anlamak için araştırma yöntemi olarak çoklu vaka çalışması tasarımı kullanılmıştır. Görüşmelerin nitel analizi, Ar-Ge merkezleri özelinde ve genel olarak sektörde bazı iyileştirme alanlarını ortaya koymaktadır. Buna göre, kimya sektörel yenilik sisteminin işleyişini pekiştirebilecek yönetim ve politika önerileri sunulmuştur.

Anahtar Kelimeler: Kimya Sektörü, Sektörel Yenilik Sistemi, Türk Kimya Sanayi, Ar-Ge Merkezi.

To my aunt Hasibe Aydın and my family

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LIST OF ABBREVIATIONS

CEFIC	The European Chemical Industry Council
ISIC	International Standard Industrial Classification of All Economic Activities
İKMİB	İstanbul Chemicals and Chemical Products Exporters' Association
EPO	European Patent Office
EU	European Union
MoIT	Republic of Turkey Ministry of Industry and Technology
MSc	Master of Science
NACE	European Classification of Economic Activities
NGO	Non-governmental Organizations
OECD	The Organisation for Economic Co-operation and Development
PhD	Doctor of Philosophy
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
R&D	Research and Development
SME	Small and Medium Sized Enterprise
SSI (SIS)	Sectoral Systems of Innovation (Sectoral Innovation System)
TTO	Technology Transfer Office
TURKPATENT	Turkish Patent and Trademark Office
TURKSTAT	Turkish Statistical Institute
TÜBİTAK	The Scientific and Technological Research Council of Turkey
US/USA	United States

CHAPTER 1

INTRODUCTION

Chemical industry is one of the oldest science-based industrial branches in the world. Once a leader in industrial innovation, the chemical industry has changed numerous aspects of modern life. From the clothes that keep us warm, to the plastic in the toothbrush we use every day, to the tires of automobile we drive and the fuel that powers them, chemical innovations have become part of our daily lives (Arora et al., 2011). The chemical industry has also been an integral part of the global economy throughout the modern era, producing both end products for the consumers and also intermediate goods for a wide range of downstream users.

Chemical industry is commonly studied within a set of three sub-categories as follows: basic chemicals, specialty chemicals, and consumer chemicals. Basic chemicals cover the mass-manufactured petrochemicals, their derivatives, and basic inorganics. The outputs of this sub-category are inexpensive and are often delivered in large quantities to the firms in other sectors as intermediate products. Specialty chemicals are produced to fulfill a particular need, and they are comprised of a broad range of products such as adhesives, coatings, surfactants, nanomaterials, and biofuels. Consumer chemicals are the end product that we use in our daily lives, such as soaps, detergents, hair care products, and cosmetics.

Firm size is significant in chemical sector to sustain the big effort of marketing and reaching markets geographically dispersed, and to spread the huge fixed costs of setting a plant or developing a product (Cesaroni et al., 2001). Chemical sector requires large amount of investments on the fixed costs including large production and R&D facilities, and on variable costs such as personnel costs, cost of consumables and cost of maintenance. Therefore, large established firms dominate the chemical sector (Cohen and Levinthal, 1989).

Another important feature of the chemical sector is its long tradition in R&D and innovation. Since its origins in 1850s with the British and German dyestuff manufacturers, the chemical industry is a science-based industry (Cesaroni et al., 2001). Innovations in the chemical sector are deeply rooted in science. Therefore, innovation often remains real critical point of the chemical industry to make substantial contributions to solving societal and environmental challenges. Arvanitis et al. (2000) argued that the chemical sciences and engineering are undergoing significant changes to address future challenges including; new synthesis techniques for combining molecules, new processes that allow for more efficient and eco-friendly products, new materials with better performances and shorter production routes, the introduction of bioprocesses in traditional chemical industries. In recent years, scientific researches conducting about chemicals in the world has been concentrated on the areas of nanotechnology, biochemistry, catalysts, genetics, organic chemistry, and polymer chemistry. The input for innovation in this industry refers to the invention and production of new or improved chemical products and processes. Research and development (R&D) is the most common input for innovation in the chemical industry. All scientific developments increase the stock of technical knowledge as well as the need for skilled labor that can use this knowledge. Therefore, another critical input to successful innovations in the chemical sector is human capital (Ren, 2005). The concept of human capital suggests that individuals possess knowledge and skills that are acquired through education, training, and experience, and these individual competences and attributes facilitate the creation of personal, social and economic well-being (OECD, 2007).

The history of the chemical sector is often characterized by the existence of a series of technological innovations, largely originated from the solid interaction between firms, universities, users and government policies. Empirical studies have shown the significance of linkages between internal R&D capabilities and external sources of technical knowledge for successful innovation. Universities have played a significant role in the generation of scientific knowledge, creating new disciplines (such as environmental sciences, bioengineering which have been crucial for sustaining innovations) and developing human capital. For instance, large chemical companies (such as BASF, DuPont) have collaborated with universities and recruited researchers in the universities for aiming to enhance their R&D capabilities and to develop new chemical products. On the other hand, relationship with users has also been crucial to better specify products' characteristics and to direct the R&D studies according to diversified demand. To achieve a competitive advantage, chemical companies has benefited widely from this type of interaction. In addition, government policies have been momentous throughout evolution of the chemical sector. Patent policies have increased the efficiency of knowledge exchange, while environmental regulations have shaped manufacturing processes of firms to produce environmentally friendly products and to develop less pollutant process technologies (Cesaroni et al., 2001).

The role of the chemical industry is becoming increasingly important for countries, especially for industrialized societies, that want to create a more sustainable future (Landau, 1994). Further, the development of a local chemical industry that has the power to compete globally has become one of the priority issues in shaping the country's economic policies (Ertek, 2014). In this regard, chemical sector is significant for Turkey who wants to develop its economy in a sustainable and competitive way (MoSIT, 2012). Since the implementation of the Industry Plan, there have been many policy documents to improve the chemical industry, such as Turkish Chemical Sector Strategy Document. In addition to those, R&D and innovation capabilities of Turkish chemical firms should be analyzed in-depth to understand better the innovation landscape of the sector. Given this heterogeneity in terms of products, actors, interaction types and knowledge base, attempting to examine every aspect of the chemical industry is difficult. However, it is beneficial to analyze the main activities of the R&D centers, which are one of the most critical actors in innovation system of Turkish chemical sector.

In this regard, it is also advantageous to use sectoral systems of innovation (SSI) approach proposed by Malerba (2002) for the analysis of the innovation landscape of the chemical sector in Turkey. This approach provides an understanding of the main building blocks of the sector, mainly in terms of knowledge base, actors and networks, and institutions. Evolutionary theory and the innovation system approach are the main starting points of this framework (Malerba, 2005). Evolutionary theory implies that innovation processes are characterized by feedback mechanisms and the relations of organizations for knowledge exchange. In other words, cooperation between the various agents and their interactive process are necessary for the generation of new products and processes to be commercialized in the sector. In the literature, an innovation system is examined in different dimensions such as national, regional and technological. Even though each approach focus on assessing innovation within own boundary, in fact all of them complement each other (Edquist, 2001). SSI approach is distinguished from other IS approaches by defining the specific properties of a particular sector in a conceptual framework. SSI framework analyzes each sector according to its knowledge base, demand, market and non-market interactions, agents and institutions. Knowledge base represents ever-changing boundaries of sector with the co-evolution of technology, actors and institutions. Agents include not only firms such as producer, supplier, user, but also non-firm agents such as R&D centers, scientists, bridging organizations and the relationships they are in. Institutions include regulatory, binding and supporting mechanisms affecting innovation activities in the sector (Malerba, 2004).

Primary research question reflecting the focus and aim of this thesis is designed as below:

- What are the main activities of R&D centers in innovation and human capital management within the framework of sectoral innovation system (SIS)?

In this respect, this thesis focuses on the main activities of R&D centers operating in chemical sector in Turkey. Through face to face interviews with six R&D centers, we gathered and compiled information regarding knowledge base, actors and networks, and institutions of Turkish chemical sector. Conducting semi-structured face to face interviews as a methodological tool has allowed to elaborate more on interesting comments of R&D centers and therefore to make more in-depth analysis. Differences and similarities in the R&D and innovation activities of R&D centers operating in different sub-sectors were clarified. Moreover, human capital infrastructure of R&D centers was examined since human capital is an important catalyst of innovation. So this thesis touches upon the significance of human capital for economic growth and the links between human capital and innovation systems approach to understand the role of human capital in chemical sectoral innovation system. By examining main activities of R&D centers in innovation and human capital management, we were able to interpret the sectoral needs to pave the way for a more favorable ecosystem for innovation.

To our knowledge, this study is the first attempt to define and assess the chemical sector in Turkey by using the SSI approach. It contributes empirically to the literature of innovation systems studies by applying this conceptual framework to the chemical sector in a developing country and enlarges the applicability of the SSI framework. R&D centers are significant actors of the innovation ecosystem in Turkey. In line with the literature in the developed countries, the innovation systems perspective is gaining ground in depicting main activities of R&D centers in Turkish chemical industry.

The next chapter will give an overview regarding the chemical industry, summarize the development of the Turkish chemical industry based on statistical data and put forward the SWOT analysis. Chapter 3 will define the theoretical framework for the analysis of the chemical sectoral innovation system in Turkey. Chapter 4 will describe the research methodology, including the definitions for the basic terms used throughout the study and the overall process of the research study. Chapter 5 will analyze the overall findings obtained from interviews and consequently give some managerial and policy recommendations based on the findings. Chapter 6, the conclusion chapter will summarize all findings and recommendations, mention limitations of the study and directives of future work that will enrich and complement this research.

CHAPTER 2

A BRIEF INTRODUCTION TO CHEMICAL INDUSTRY

2.1 Chemical Industry at a Glance

Chemical industry, which is the first science-based industry, is in the medium-high-technology group according to the classification of manufacturing industries based on technology and R&D intensity by the OECD. In this classification, pharmaceuticals are excluded. In general, the sector has capital-intensive structure.

‘Diverse’ can be the word that describes the chemical industry since there is no single product type or single company type (OECD, 2011). Beginning with raw materials such as oil, gas, coal, air, and water, the chemical industry transforms these materials into a large variety of substances for use by other chemical firms, other sectors and consumers. Therefore, one of the most essential features of chemistry is that, as a primary industry, it generates both products that are beneficial for chemical industry and products that play essential roles (inputs) in other industries. Polymers have many primary applications such as coatings, containers, and structural components; on the other hand, they also have secondary uses in the manufacturing process of automobile parts, electronic components, and biomedical devices. As a result of the developments in the chemical industry, the performance and properties of many products used in different sectors have been improved. For example, with the presence of synthetic dyes, the textile sector has been able to provide required dyeing in abundant and economic conditions, and the competitiveness of the producers has increased. Automobiles have become lighter, more durable, and cheaper thanks to new materials developed with the contribution of chemistry science.

About 30% of the products produced from chemical industry are sold directly to end-users, remaining 70% are used as intermediates or raw materials in other industries (textile, metal, construction, electric appliance, automotive, paper, service). Therefore, the chemical sector is of vital importance in our lives and other sectors. Table 1 illustrates the benefits of the chemical industry on our lives, directly and indirectly.

Table 1. Chemical Industry and its Benefits

Chemistry Sub-sector	Direct Benefits	Indirect Benefits
Pesticides	Protection of cereals and plants	Yielding and healthy agricultural products
Fertilizers	Crops with increased yield	Increasing fertility of cultivation area
Detergents	Cleaning	Reduction in fat usage for cleaning and reallocation of fat to nutrition
Synthetic Fibers	Yarn for clothes	New resources of yarn for clothing
Human Medicine Industry	Prevention of diseases	Increasing lifespan of people
Plastic Raw Materials	Articles of daily use	Reduction in chopping trees
Paint	Protection of materials	Providing decorative and protective features to materials
Cosmetics Industry	Personal care products	Making people feel better through personal care
Textile	Characterize the textile products	Long-lasting textile products
Leather	Make the leather processable	Ease of processing, tanning, softening and oiling
Construction	Enabling the use of beton & related products	Safe and fast construction of buildings
Adhesives, fillers and insulating materials	Fulfilling the need of adhesive bonding and insulating in related sectors	Contribution to the latest stage of construction

Source: Adapted from Ulengin et al., 2012

It should be noted that besides the obvious benefits of the chemical industry, there can also be a negative impact on man and the environment. For example, using raw materials such as natural gas and fuel oil as a source of energy and feedstock in the chemical industry can impact on the supply of nonrenewable resources. Since these materials are usually based on hydrocarbons, their combustion may result in emissions of carbon dioxide, volatile organic compounds (VOCs) and nitrogen oxides which bring about the formation of tropospheric ozone or “smog”. The release of pollutants from factories along the production process and the disposal of final products involving hazardous waste are other stages of the lifecycle of a product produced by the chemical industry, and they can affect human health and the environment. Consequently, hazardous waste can be originated from every stage of chemical production and product use (OECD, 2011).

Different classifications are used for the chemical industry. OECD (2001) clarifies the definitions of the sector with respect to different sources (See Table 2). On the other hand, according to NACE Rev. 2 (Statistical classification of economic activities in the European Community) sector classification, the chemical industry involves four main manufacturing industry groups. These are as mentioned below:

C19- Manufacture of coke and refined petroleum products
C20- Manufacture of chemicals and chemical products
C21- Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22- Manufacture of rubber and plastic products

Table 2. Definitions of the "Chemicals Industry" Breakdown by Sector According to Different Sources

CMA & US EPA	CEFIC	CIA	IEA	OECD
-Chemicals and allied products -Industrial organic chemicals -Plastic materials and synthetics -Pharmaceuticals -Soaps, cleaners and toilet goods -Paints and allied products -Industrial organic chemicals -Agricultural chemicals (incl. Fertilisers and pesticides -Miscellaneous chemical products	-Petrochemicals and derivatives -Plastics and polymer-related products -Inorganic chemicals -Specialties, performance and consumer oriented products, including adhesives and paints -Surfactants, oleo chemistry and related products -Agriculture, food chain and protection products (includes biocides)	-Manufacture of industrial chemicals -Basic industrial chemicals, except fertilisers -Fertilisers and pesticides -Synthetic resins, plastic materials and man-made fibres except glass -Manufacture of other chemical products -Paint, varnishes and lacquers -Drugs and medicines -Soap and cleaning preparations, perfumes, cosmetics and other toilet preparations -Chemical products not elsewhere specified	-Manufacture of -Basic chemicals, e.g. Industrial gases, inorganic acids, alkalis, basic organic chemicals -Fertilisers and nitrogen compounds -Plastics in primary forms and of synthetic rubber -Manufacture of other chemical products -Pesticides and other agro-chemicals products -Paints, varnishes and similar coatings, printing ink and mastics -Pharmaceuticals, medicinal chemicals and botanical products -Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations -Other, e.g. Explosives, gelatin and its derivatives, peptones, essential oils, materials used in textile finishing	-Manufacture of basic chemicals, except fertilisers and nitrogen compounds -Manufacture of fertilisers and nitrogen compounds -Manufacture of plastics in primary forms and of synthetic rubber -Manufacture of pesticides and other agrochemical products -Manufacture of paints, varnishes and similar coatings, printing ink and mastics -Manufacture of pharmaceuticals, medicinal chemicals and botanic products -Manufacture of soap and detergents, cleaning and polishing preparations, perfumes, and toilet preparations -Manufacture of other chemical products n.e.c. -Manufacture of man-made fibres -Manufacture of rubber tyres; retreading and rebuilding rubber tyres -Manufacture of other rubber products -Manufacture of plastic products

CMA: US Chemical Manufacturers Association/ **US EPA**: US Environmental Protection Agency/ **IEA:** International Energy Agency/

CEFIC: European Chemical Industry Council/ **CIA:** UK Chemical Industries Association

Source: OECD (2001)

Chemicals are divided into three groups according to their commercial and technological properties (T.C. Kalkınma Bakanlığı, 2015).

- Basic Industrial Chemicals: They cover organic and inorganic chemicals manufactured in large volumes. They are also known as commodity chemicals.
- Special and Specialty Chemicals: They are medium and high value-added chemicals produced on a relatively small scale.
- Consumer Chemicals: They include chemical products being sold directly to final-consumers (end-users). Chemicals in the previous groups are generally used as raw materials in other sectors or in the chemical industry, while chemicals under this group are offered directly to consumers.

Nearly every country has a chemical industry, however almost 80% of the world's total production is produced by only 16 countries: the US, China, Germany, France, the UK, Japan, the Netherlands, Switzerland, Italy, Korea, Brazil, Belgium/Luxembourg, Spain, Taiwan, and Russia (OECD, 2011).

According to Cefic (2018), world chemicals turnover was valued at €3.475 billion in 2017. With €1.293 billion in 2017, China is the largest chemical producer in the world, contributing for 37,2% of global chemical sales in 2017. The EU chemical industry ranks second with 15,6%, along with the United States (13,4%), in total sales. Germany and France are the two largest chemical producers in Europe, followed by Italy and the Netherlands. These four countries together accounted for 61,6% of EU chemical sales in 2017, valued at €334.1 billion. Das and Icart (2015) indicate that Europe plays a key role in the global chemical industry since it is home to 19 of the top 50 global chemical companies. Even though China has emerged as the biggest chemical producer, 8 of the top 30 largest chemical-producing countries are European. BASF is the largest chemical company in the world in terms of sales.

While innovation is more than R&D, the link between research in chemistry and innovation is especially strong in the chemical sector (Das and Icart, 2015).

Investments in research and innovation are critical elements in securing the future of the chemical industry and needed to keep and increase its substantial contribution to solving societal challenges. It may be useful to give current situation of chemicals R&D spending on a global basis and in the EU. Global R&D spending in the chemical sector reached the value of €43.95 billion in 2017, up from €24.43 billion in 2007. On a global basis, R&D expenditure was 80% higher in 2017 compared to ten years ago. During the 11 years from 2007 to 2017, global R&D on chemical industry grew about 6.0% on average. Spending on R&D in the EU increased from €8.1 billion to €9.7 billion within the same period, whereas R&D spending in USA has a higher rate of increase. Notably, Chinese R&D growth during the same period is 19.3%. This means that China is by far outpacing the other economies in the world in terms of R&D growth (Cefic, 2018). Figure 1 clearly shows the R&D spending of different regions in 2007 compared to 2017.

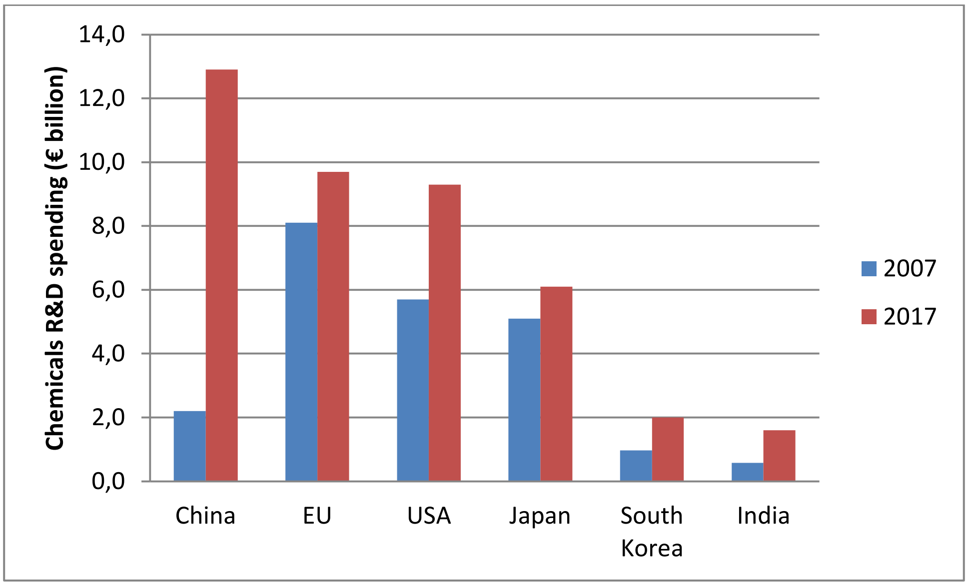

Figure 1. R&D spending of different geographical regions in 2007 compared to 2017
Source: Cefic, 2018

Almost all global chemical companies have been increasing their R&D expenditure in order to provide a global competitive advantage in development-oriented and breakthrough innovations (Das and Icart, 2015). According to the 2017 EU

Industrial R&D Investment Scoreboard, with €1834 million, BASF is the chemical company with the highest R&D expenditure. This high spending on R&D demonstrates enormous R&D infrastructure of BASF. DuPont, Dow Chemical, Monsanto and Syngenta are other chemical companies, with the highest R&D expenditure in the world, respectively (See Table 3).

It is noteworthy that Lubrizol is the chemical company having the highest R&D intensity of 31,1% although R&D spending is about €56 million. After Lubrizol, Monsanto and Syngenta show highest R&D intensity, with 11,2% and 10,9% respectively. In most chemical companies, R&D intensity is around 3% (for instance, BASF, Dow Chemical, Evonik and Solvay). Figure 2 illustrates top fifteen chemical companies in the world in terms of R&D spending and R&D intensity. EU, US and Japan chemical companies are currently world leaders in R&D spending.

Table 3. R&D Ranking of World Top Five Companies in the Chemical Industry

World Rank	Company	Country	R&D Spending (€million)	Net sales (€million)	R&D intensity (%)
1	BASF	Germany	1834,0	57550,0	3,2
2	DUPONT	US	1556,8	23331,8	6,7
3	DOW CHEMICAL	US	1502,7	45686,4	3,3
4	MONSANTO	US	1434,4	12809,0	11,2
5	SYNGENTA	Switzerland	1323,4	12133,6	10,9

Source: EU Industrial R&D Investment Scoreboard, 2017

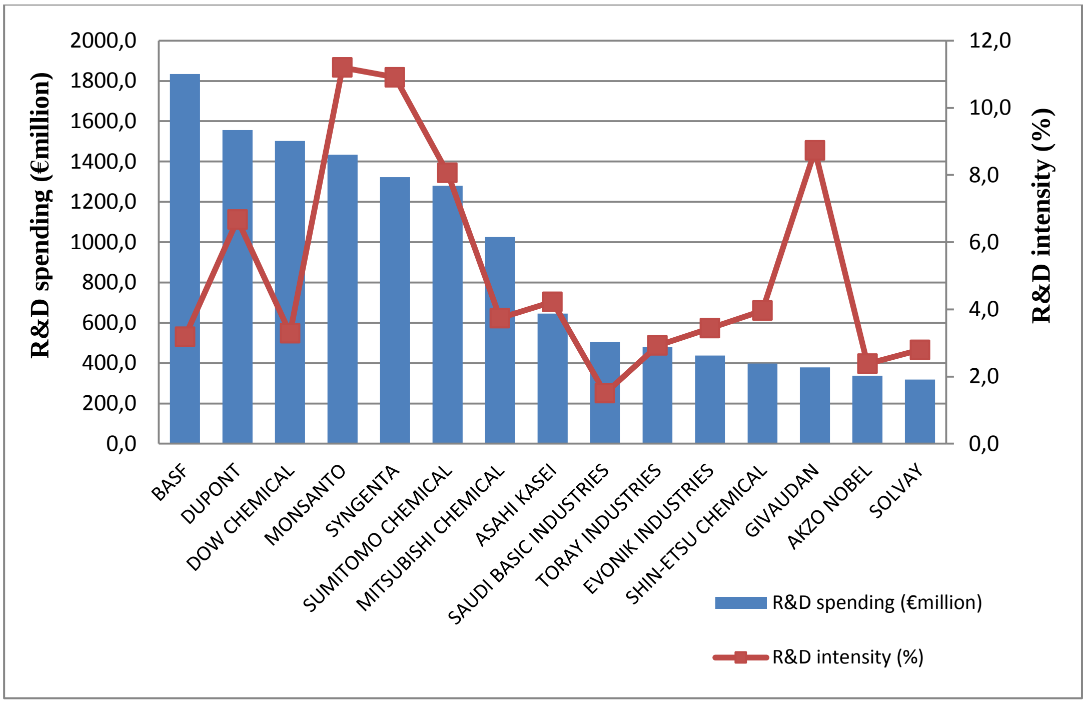

Figure 2. R&D Spending and R&D Intensity of Top Chemical Companies in the World
Source: EU Industrial R&D Investment Scoreboard, 2017

The chemical industry is an enabler of innovation in numerous downstream sectors through its products and technologies. Santagate (2016) states that specialty chemicals is the most robust, versatile and profitable sub-group of the chemical industry. Many large global chemical companies tend to move away from bulk chemicals and focus more on strategies around the specialty chemicals sub-sector. Margins in the specialty chemicals are considerably higher than those in basic chemicals and these chemicals offer a more versatile market because of the cross-industry applications such as agriculture, bioscience, health, coatings and high tech. So research and innovation investments in leading chemical companies are largely based on specialty chemicals. For example, Evonik manufactures specialty chemicals used in wide range of downstream industries like healthcare, automotive, paints and plastics. Further, Monsanto and Syngenta, two of the chemical companies having the highest R&D intensity, are actively conduct research and development studies on crop protection chemicals, seed and biotechnology.

Collaboration activities within the chemical sector are seen as a way to generate innovation. World-class research universities give priority for such kind of strategic collaboration. Das and Icart (2015) mention that leading chemical companies are actively involved in EU-funded projects. Although EU funding acts as a stimulus for companies to participate in projects, it also encourages them to co-operate not only with universities and research institutes but also with their competitors to drive research and innovation. More than 75% of the participants in EU projects regarding chemicals are government organizations such as universities and research institutes. Some chemical companies collaborate more with government agencies while others collaborate with both private and government agencies. According to data for the last 20 years, BASF is the company that most take part in EU-funded projects (Das and Icart, 2015).

2.2 Chemical Industry in Turkey

This section aims to look to Turkish chemical industry from a general perspective and put forward the main characteristics of the chemical sector in Turkey. Firstly, periods regarding Turkish chemical industry and its development will be summarized. Secondly, some statistical information showing the status of chemical sector between 2010 and 2016 will be given. Lastly, SWOT analysis for Turkish chemical sector will be presented.

2.2.1 Turkish Chemical Industry from Early Republican Period to 2000s

Soap, rose oil and gun powder were produced in a small extent at the time prior to the Republic Period in Turkey. Demand for chemicals had increased rapidly with the establishment of manufacturing facilities and beginning of production at the industrial scale in the Republic Period (DPT, 1963). From the foundation of Republic until 1950s, main manufacturing fields regarding chemical industry were agricultural chemicals, explosives, detergents, medicine, printing ink and textile dyes. Moreover, Turkish chemical industry can be traced to the establishment of the first chemistry department at a university in İstanbul in 1918 (Turkay, 2015). After the university reform in 1933, chemistry departments developed quickly with the support of German chemists and assignment of Turkish chemists who studied abroad and completed their doctorate.

The historical development of Turkish chemical sector can be addressed in line with economic policies under three periods. First period started with the implementation of Industry Plan and continued till the beginning of the Planned Development process (1934-1962). Within this period, state investments aimed to establish basic chemicals industry and produce raw materials needed for other sectors, such as inorganic acids, sodium chloride, sodium hydroxide. Private sector investments were particularly directed to consumer chemicals involving small-scale products, such as soap and detergent (Akiş and Çetin, 2016).

Second period includes the time from the beginning of the Planned Development Process to the liberalization of economy, i.e. from 1963 to 1979. Economic policies were based on import substitution and public sector investments were generally oriented towards petrochemicals and fertilizers. The most crucial investment in this period was the establishment of Petkim, which is the first petrochemical complex in Turkey, in 1965. Erk (2015), who was the former president of Turkish Chemical Manufacturers Association, indicates that use of raw materials produced domestically between 1963-1979 had increased from 7,5% to 29%. However, it was impossible to build organic and inorganic chemical complexes planned to be built during this period. Lack of research studies and technical knowledge, and technology problems have been the main factors preventing the development of the chemical industry and its export orientation within this period (DPT, 1979).

Third period have started with the implementation of economy policies aiming outward-oriented and export-led growth after 1980. Customs tariff rates of chemical products were reduced immediately after the enactment of the Customs Law in 1984. In addition, Erk et al. (2016) indicated that Turkish chemical industry greatly benefitted from the export-oriented economic policy changes, and has shown a dramatic increase in exports as well as production capacities and quantities during the last five years (which include the period of 2010-2015). The importance of university-industry relations and new product development studies have been understood after 1990 (DPT, 1989). After 2000, regulations regarding the production, storage, transportation, packaging and labeling of harmful and dangerous chemicals and products have been started to redesign according to new rules introduced by EU. It was understood that R&D activities should be conducted for the chemicals that could be used instead of the ones to be restricted or prohibited according to the new rules. However, the importance given to R&D and innovation in the chemical sector was not sufficient until 2007. The private sector was not willing to R&D and did not allocate resources. Furthermore, there was lack of funding for R&D, and the sector did not have enough qualified labor for R&D (DPT, 2007).

2.2.2 The Status of the Turkish Chemical Industry between 2010 and 2016

ISPAT and Deloitte (2014) reported the distribution of chemical products across various sectors in Turkey in 2012. As can be seen from Figure 3, there is a wide array of users of the chemical industry in Turkey. Chemical outputs are mostly used by final-consumers (end-users) with a share of 29%, followed by the services sector which has a share of 16%, the basic metals, mining, machinery, and electronics industry with 9% and the agriculture sector with 7%.

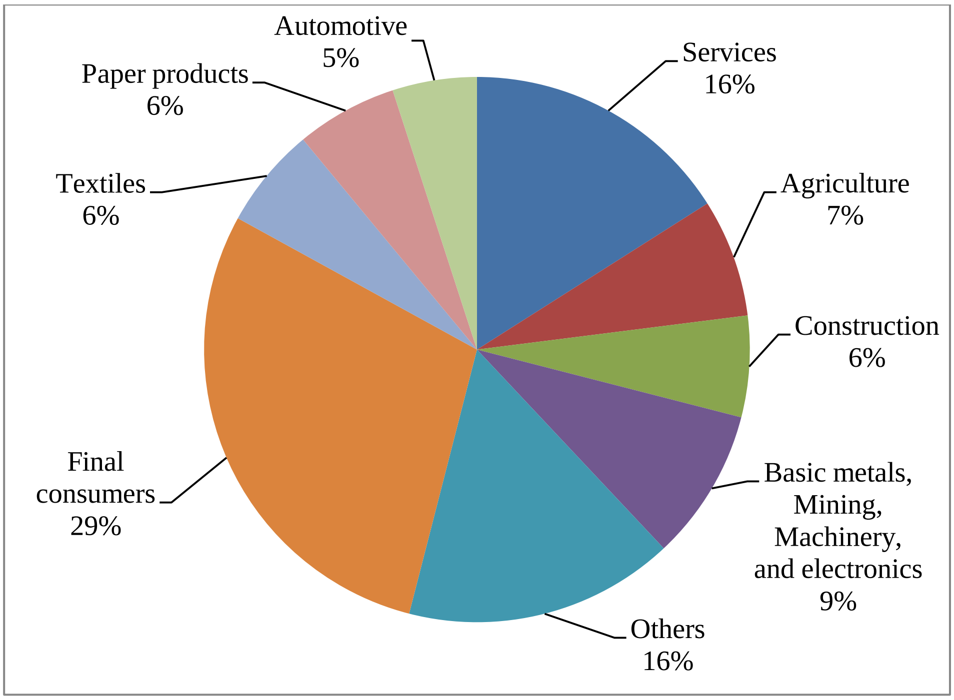

Figure 3. Users of the Turkish Chemical Industry Output, 2012
Source: ISPAT and Deloitte, 2014

As stated previously, the chemical industry comprises four main manufacturing industry categories according to NACE Rev. 2. However, those are not considered as a homogeneous block due to differences in criteria such as capital and technology intensity, labor quality, R&D activities, and value added level (Ertek, 2014). Accordingly, in the remaining part of this chapter, the framework of the chemical sector is limited to economic activities under the industrial division of "manufacture of chemicals and chemical products" (C20). The development of the chemicals and chemical products manufacturing industry in Turkey is evaluated here using fundamental indicators such as the number of enterprises, production, value-added, employment, foreign trade, and science and technology activities. For these indicators, statistical data of official institutions, especially Turkey Statistical Institute (TurkStat), will be used. Only for R&D statistics, the industrial division of "manufacture of coke and refined petroleum products" (C19) will also be covered because TurkStat reports R&D statistics under C19 and C20. The definition of C19 and C20 is specified in Table 4.

Table 4. Detailed Structure of NACE Rev. 2- Section 19-20

n.e.c. : not elsewhere classified			
Division	Group	Class	SECTION C - MANUFACTURING
C19			**Manufacture of coke and refined petroleum products**
	C19.1		Manufacture of coke oven products
		C19.10	Manufacture of coke oven products
	C19.2		Manufacture of refined petroleum products
		C19.20	Manufacture of refined petroleum products
C20			**Manufacture of chemicals and chemical products**
	C20.1		Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms
		C20.11	Manufacture of industrial gases
		C20.12	Manufacture of dyes and pigments
		C20.13	Manufacture of other inorganic basic chemicals
		C20.14	Manufacture of other organic basic chemicals
		C20.15	Manufacture of fertilisers and nitrogen compounds
		C20.16	Manufacture of plastics in primary forms
		C20.17	Manufacture of synthetic rubber in primary forms
	C20.2		Manufacture of pesticides and other agrochemical products
		C20.20	Manufacture of pesticides and other agrochemical products
	C20.3		Manufacture of paints, varnishes and similar coatings, printing ink and mastics
		C20.30	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
	C20.4		Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
		C20.41	Manufacture of soap and detergents, cleaning and polishing preparations
		C20.42	Manufacture of perfumes and toilet preparations
	C20.5		Manufacture of other chemical products
		C20.51	Manufacture of explosives
		C20.52	Manufacture of glues
		C20.53	Manufacture of essential oils
		C20.59	Manufacture of other chemical products n.e.c.
	C20.6		Manufacture of man-made fibres
		C20.60	Manufacture of man-made fibres

Source: Eurostat, 2008

Firm Characteristics: OECD (2018) classifies enterprises according to their size. The number of people employed is the most common used criteria for this categorization. Small and medium-sized enterprises (SMEs) employ fewer than 250 people. SMEs are further subdivided into micro enterprises (fewer than 10 employees), small enterprises (10 to 49 employees), medium-sized enterprises (50 to 249 employees). Large enterprises employ 250 or more people. In Turkey, a substantial part of the chemical products are produced by SMEs. Table 5 reveals that large enterprises account for only 0.9% of total number of enterprises in 2016. It was observed that the share of micro enterprises in total enterprises has declined from 83% to %78 between 2010 and 2016, whereas that of medium-sized enterprises has gradually increased from %2.7 to 4.6% between 2010 and 2016 within the same period.

Multinational companies' operations also exist in Turkish chemical industry. Most of the companies in the chemical industry, specifically private sector companies, are located in Istanbul, Kocaeli, Sakarya, Izmir, Adana, Ankara, and Gaziantep (Social Security Institution, 2017).

Table 5. Number of Enterprises by Size Classes, NACE Rev.2:20, 2010-2016

Size Classes	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
1-9	4 826	4 648	4 326	3 927	3 742	3 855	3 974
10-49	809	876	914	859	866	888	868
50-249	158	173	196	204	217	230	235
250+	31	38	39	42	44	45	46
Total	**5 824**	**5 735**	**5 475**	**5 032**	**4 869**	**5 018**	**5 123**

Source: TurkStat, 2018

According to TurkStat (2018), the number of enterprises comprises the number of all units active in the sectors and in the reference period. As is seen from Table 6, there are 379.894 enterprises in the Turkish manufacturing industry in 2016. With 5.123 thousand enterprises, chemical industry accounts for 1.35% of the total number of enterprises in the manufacturing sector. It is noteworthy that both the number of enterprise in the chemical industry and its share in the manufacturing industry has diminished between 2010 and 2016.

Table 6. Number of Enterprises, 2010-2016

NACE Rev. 2	2010	2011	2012	2013	2014	2015	2016
Turkey	2 678 787	2 737 278	2 800 060	2 847 725	2 888 180	2 941 233	2 981 381
C-Manufacturing	326 925	335 571	354 256	365 723	371 911	375 480	379 894
C20	5 824	5 735	5 475	5 032	4 869	5 018	5 123
Share of C20 in Manufacturing	1,78%	1,71%	1,55%	1,38%	1,31%	1,34%	1,35%

Source: TurkStat, 2018

Employment: According to data obtained from TurkStat, while the number of persons employed in the chemical industry was 67.285 thousand in 2010, it has increased to 83.058 thousand in 2016. On the other hand, the share of C20 in the entire manufacturing industry in Turkey has declined from 2,35% to 2,12% within the same period (See Table 7).

During the period between 2010 and 2016, personnel costs have increased significantly across Turkey and in the manufacturing industry as well. Although personnel costs in the chemical sector have increased from 2010 to 2016, the share of it in the entire manufacturing sector has somewhat decreased. Personnel costs amounted 136,9 billion TL in the Turkish manufacturing sector in 2016. With 4,6 billion TL, the chemical sector accounted for 3,34% of total manufacturing personnel costs (See Table 8).

Table 7. Number of Persons Employed, 2010-2016

NACE Rev. 2	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Turkey	10 929 200	12 078 434	13 141 443	13 889 265	14 615 295	15 222 587	15 401 642
C-Manufacturing	2 865 482	3 150 290	3 436 295	3 642 332	3 826 777	3 908 510	3 922 221
C20	67 285	71 527	75 014	75 781	79 281	81 971	83 058
Share of C20 in Manufacturing	2,35%	2,27%	2,18%	2,08%	2,07%	2,10%	2,12%

Source: TurkStat, 2018

Table 8. Personnel Costs (Billion TL), 2010-2016

NACE Rev. 2	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Turkey	153,7	186,5	225,8	267,0	312,4	364,3	443,7
C-Manufacturing	50,0	59,6	71,2	84,1	98,1	113,7	136,9
C20	1,9	2,2	2,5	2,9	3,4	3,9	4,6
Share of C20 in Manufacturing	3,82%	3,70%	3,55%	3,42%	3,45%	3,44%	3,34%

Source: TurkStat, 2018

Production: As stated previously, products of the chemical industry generally have high added value. However, in Turkey, output of the chemical industry consists of relatively low value-added products. According to TurkStat (2016), with 2,941 billion TL, the manufacture of other inorganic basic chemicals is the highest added value sub-sector group of the chemical industry. Other groups that create high added value are respectively; manufacture of plastics in primary form and manufacture of paints (with 2,449 billion TL) and varnishes and similar coatings, printing ink and mastics (with 2,146 billion TL). Share of chemical industry value-added in that of the entire manufacturing industry in Turkey is about 5% between 2010 and 2016 (See Table 9).

According to the TurkStat (2016), with 12,422 billion TL, manufacture of plastics in primary forms has the highest share in the chemical industry. Other groups having higher production value are respectively; manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations (9,73 billion TL) and manufacture of paints, varnishes and similar coatings, printing ink and mastics (8,697 billion TL). Table 10 shows that share of production value of the chemical industry in that of the total manufacturing industry in Turkey was 5% in 2011. This value decreased by 4,68% in 2016.

Table 9. Value Added at Factor Costs (Billion TL), 2010-2016

NACE Rev. 2	2010	2011	2012	2013	2014	2015	2016
Turkey	305,3	379,3	423,0	509,3	572,9	689,4	806,7
C-Manufacturing	98,9	130,1	135,6	167,3	193,8	235,2	274,4
C20	5,2	7,2	7,2	8,7	10,0	12,3	14,2
Share of C20 in Manufacturing	5,27%	5,50%	5,29%	5,18%	5,14%	5,23%	5,18%

Source: TurkStat, 2018

Table 10. Production (Billion TL), 2010-2016

NACE Rev. 2	2010	2011	2012	2013	2014	2015	2016
Turkey	1230,5	1570,7	1765,7	2047,5	2350,8	2664,7	2958,4
C-Manufacturing	538,8	712,2	771,8	866,2	997,0	1116,8	1220,5
C20	26,3	35,6	38,2	42,4	48,5	53,3	57,1
Share of C20 in Manufacturing	4,89%	5,00%	4,95%	4,89%	4,87%	4,77%	4,68%

Source: TurkStat, 2018

Imports and Exports: Table 11 and Table 12 give exports and imports value of the chemical industry between 2010 and 2016, and compare with manufacturing industry. It is obvious that Turkish chemical industry is one of the major importing sectors among industrial sectors. Figure 4 shows that the gap between exports and imports in the manufacture of chemicals and chemical products has gradually expanded between 2010 and 2016. Ertek (2014) underlines that the chemical sector is one of the main sectors that increase dependence on imports and cause current account deficit problem in Turkish economy in the post-2000 period. The insufficiency of domestic production is the most significant factor driving industrialists to import. Most of the intermediaries imported in the chemical industry are petrochemical products. While 70% of the raw materials used in the chemical industry are imported, 30% is covered by local production (MoSIT, 2015). Therefore, two of the main objectives specified for the development of the sector in the medium term (the years between 2014-2019), was to diminish the foreign dependency in raw material and intermediate products, and to focus on R&D studies for the high value-added chemicals in the product portfolio (Ertek, 2014).

Table 11. Exports (Billion TL), 2010-2016

NACE Rev.2	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Turkey	171	227	275	290	345	391	432
C-Manufacturing	160	214	260	272	325	370	408
C20	8	10	12	13	16	18	18
Share of C20 in Manufacturing	4,8%	4,8%	4,6%	4,8%	4,8%	4,8%	4,5%

Source: TurkStat, 2018

Table 12. Imports (Billion TL), 2010-2016

NACE Rev.2	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Turkey	279	404	426	479	530	562	601
C-Manufacturing	219	309	319	376	412	456	509
C20	34	47	49	55	66	70	74
Share of C20 in Manufacturing	15,3%	15,3%	15,5%	14,7%	16,0%	15,4%	14,6%

Source: TurkStat, 2018

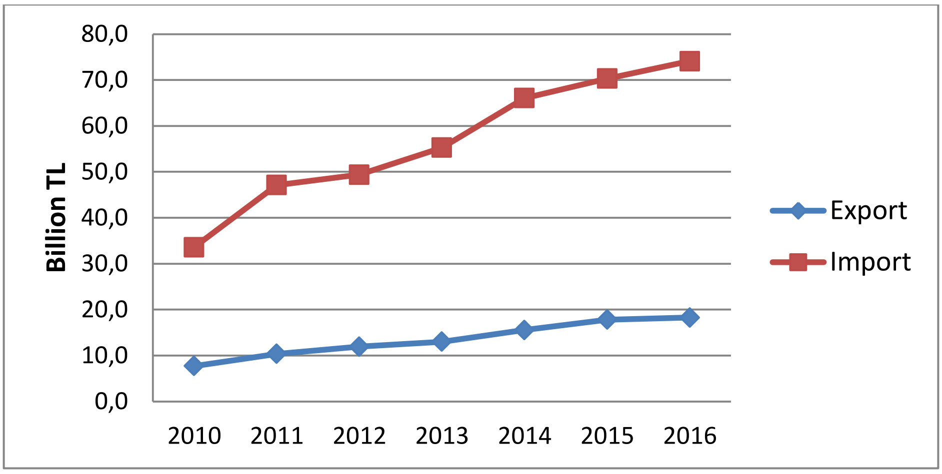

Figure 4. Exports and Imports in the Manufacture of Chemicals and Chemical Products, NACE Rev.2:20, 2010-2016
Source: TurkStat, 2018

R&D, Innovation and Patent: The input for innovation in the chemical industry refers to the invention and generation of new or improved chemical products and processes. Research and development activity (or R&D spending) is the most common input to the innovation in the chemical industry. Other correlated indicators such as the number of publications and industrial chemists, spending on marketing analysis, and training of workforce also have an important role in innovation system (Cefic, 1997, Mahdi et al.2002 in Ren, 2005). In this regard, we will focus on R&D expenditures as it usually comprises over half of the spending in innovation projects in the chemical industry in EU (Cefic, 1997 cited in Ren, 2005).

R&D Expenditure: According to 'Research and Development Activities Survey' conducted by TurkStat, total R&D expenditure in chemical industry (class of C19-C20 according to NACE Rev.2) dramatically increased from 143 million TL in 2010 to 390 million TL in 2013, but this number slightly decreased to 361 million TL in 2016 (See Table 13). This table also depicts that share of chemical industry R&D expenditure in total manufacturing industry is considerably decreasing from 11,1% in 2013 to 4,8% in 2016.

Table 13. R&D Expenditure (Million TL), 2010-2016

NACE Rev. 2	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Turkey	9268	11154	13062	14807	17598	20615	24641
C-Manufacturing	1993	2497	3039	3518	4396	5063	7516
C19-C20	143	196	242	390	358	341	361
Share of C19-C20 in Manufacturing	7,2%	7,9%	8%	11,1%	8,2%	6,7%	4,8%

Source: TurkStat, 2018

R&D Personnel: According to C19-C20 categories of NACE Rev.2, the share of R&D personnel in total employment in the chemical sector was 2,38% in 2010 and increased to 3,15% in 2015. However, this value noteworthily decreased to 2,73% in 2016. On the other hand, Table 14 also illustrates the share of the number of chemical sector R&D personnel in all sectors by years. It is observed that R&D headcount size regularly increases and remarkably decreases from 2015 to 2016. Here, headcount data reflect the total number of persons who are mainly or partially employed on R&D (OECD, 2002). Definitions regarding R&D personnel are given in the Chapter 4.

As is seen from Table 15, with an average of %56, the share of R&D researcher in total headcount has not changed much within six years' period between 2010 and 2016; however, we observe from Table 16 that the share of PhD in total R&D personnel is regularly increasing from 2,99% to 4,84% within the same period.

Table 14. R&D Personnel (Headcount), NACE Rev.2:19-20, 2010-2016

NACE Rev. 2	2010	2011	2012	2013	2014	2015	2016
Turkey	147 417	164 287	184 301	196 321	213 686	224 284	242 213
C-Manufacturing	23 559	27 294	29 870	32 061	33 582	34 893	39 062
C19-C20	1 772	2 051	2 234	2 548	2 643	2 844	2 501
Share of C19-C20 in Manufacturing	7,5%	7,5%	7,5%	7,9%	7,9%	8,2%	6,4%

Source: TurkStat, 2018

Table 15. R&D Personnel (Headcount) by Occupation, NACE Rev.2:19-20, 2010-2016

Occupation	2010	2011	2012	2013	2014	2015	2016
Researcher	963	1215	1266	1464	1507	1523	1338
Technicians/ Equivalent Staff	617	648	760	863	905	1026	892
Other Supporting Staff	192	188	208	221	231	295	271
Share of Researcher in Total R&D Personnel	54%	59%	57%	57%	57%	54%	53%

Source: TurkStat, 2018

Table 16. Number of R&D Personnel by Educational Level, NACE Rev.2:19-20, 2010-2016

Educational Level	2010	2011	2012	2013	2014	2015	2016
Ph.D.	53	82	91	121	107	124	121
Master	289	322	369	465	440	490	496
Bachelor	655	848	898	976	1119	1144	1036
Vocational School	336	347	407	452	428	466	436
High School	371	386	422	475	490	572	358
Others	68	66	47	59	59	48	54
Share of Ph.D. in Total R&D Personnel	2,99%	4,00%	4,07%	4,75%	4,05%	4,36%	4,84%

Source: TurkStat, 2018

Patents: There are various indicators of innovative performance based on the rate of innovation, as given in the Oslo Manual (OECD and Eurostat, 2005). Arora (1997) defines the relation between innovation and patents as "patents are undoubtedly one of the instruments that firms use to capture rents from innovation" (p.391). The output for innovation in the chemical industry is usually attributed to the sales of new or improved chemical products, patenting activities, and licensing of chemical processes (Ren, 2005). In this context, it is of interest to show the performance of Turkey in the chemical industry in terms of granted patents and patent applications.

When we look at the patent and utility model applications made to Turkish Patent and Trademark Authority between 2010 and 2016, it is observed that the number of applications of domestic companies was less than that of foreign firms. Besides, there has been a general increase in the number of applications of domestic and foreign firms, while the share of chemical sector patent and utility model applications in all sectors increased within 2010 and 2013, but declined over time (Table 17).

Table 17. Patent and Utility Model Applications, NACE Rev.2:20, 2010-2016

		2010	2011	2012	2013	2014	2015	2016
All Sectors		10305	12313	13056	13811	10816	15622	19307
C20	Domestic	123	141	126	124	201	234	279
	Foreign	536	653	800	901	346	730	1061
	Total	659	794	926	1025	547	964	1340
Share of C20 in All Sectors		6,4%	6,4%	7,1%	7,4%	5,1%	6,2%	6,9%

Source: TURKPATENT, 2018

Table 18 and 19 reveal that European patent application/granted performance of Turkey in chemicals is quite low. These applications include direct European applications and international (PCT) applications that entered the European phase. Germany, United States, China, Japan, and France have the best scores in this field.

Table 18. European Patent Applications by Field of Technology, 2017

Field of technology	Turkey	Total
Organic fine chemistry	5	6462
Macromolecular chemistry, polymers	5	3773
Basic materials chemistry	8	4535
Surface technology, coating	8	2341
Chemical engineering	10	3456
Environmental technology	6	1833

Source: EPO, 2018

Table 19. European Patents Granted by Field of Technology, 2017

Field of technology	Turkey	Total
Organic fine chemistry	4	4458
Macromolecular chemistry, polymers	3	2613
Basic materials chemistry	5	2714
Surface technology, coating	2	1601
Chemical engineering	7	2254
Environmental technology	1	1530

Source: EPO, 2018

Public Incentives Scheme: R&D centers are seen as one of the most fundamental building blocks of the R&D and innovation ecosystem in Turkey (The Law No.5746, 2008). In recent years, there is a substantial increase in the number of R&D centers. As of January 2018, the number of R&D centers in the chemical sector was 51 while the total number of R&D centers was 779. The chemical sector is the fifth largest sector in Turkey in terms of the number of R&D centers. Other statistical information regarding R&D centers in January 2018 are given in Table 20. According to this table, R&D centers in chemical sector have a remarkable share in all sectors in terms of the number of staff with PhD and Postdoctoral. This shows that the R&D centers in this sector require highly-qualified workforce which will be assigned in considerably large number of projects when compared to that of total sectors. The number of foreign and foreign-partner companies having R&D centers in chemical sector is also significant. On the other hand, the number of patents in R&D centers in chemical sector is pretty low compared to total.

Some of the support programs given from MoSIT to enhance R&D and innovation and data belonging chemical sector are also indicated as below:

Table 20. Statistical Data on R&D Centers (January 2018)

	Chemical Sector	Total	Share of Chemical Sector
Number of R&D Centers	51	779	6,5%
Total Number of Staff (Including Support Staff)	1779	42876	4,1%
PhD and PostDoctoral	64	811	7,9%
Master	274	7755	3,5%
Bachelor	659	22859	2,9%
Number of Projects	1996	25131	7,9%
Completed	1266	14870	8,5%
Ongoing	730	10261	7,1%
Number of Patents	108	9585	1,1%
Granted	44	2404	1,8%
Application	64	7181	0,9%
Number of Foreign and Foreign-Partner Companies having R&D Centers	8	113	7,1%

Source: Ministry of Industry and Technology, 2018

Technological Product Investment Support Program (Teknoyatırım): Applications of Technological Product Investment Support Program started to be received as of July 2014. Within the context of the program, the number of completed projects was 63, and this number was reported as 5 in ‘manufacture of chemicals and chemical products’. Furthermore, the total number of supported projects as of 2015 is 24 in the chemical sector, whereas 204 projects are supported in all areas (MoSIT, 2018).

Technological Product Experience (TÜR) Certificate: TÜR is a certificate given for five years for goods and services resulting from supported R&D projects. By the year 2018, the total number of documents given for all sectors is 521, while this number is 14 for chemicals (MoSIT, 2018).

Techno-Initiative Capital Support: This program was carried out by MoSIT during the years of 2009-2015 in order to establish their firm and encouraged to settle in the technology development zones. Between the years 2009-2014, 1304 enterprises were supported. To date, 121 entrepreneurs who provide business ideas associated with the chemical industry have been granted Techno-Initiative Support (MoSIT, 2015).

Human Capital and Education

Human capital has a paramount effect on the production of the new goods/services and on the R&D in new technologies. The lack of human capital to be employed in research and innovation activities will not only decelerate economic development but will lock it into a no-growth or slow growth path (Edquist, 1997). In other words, a country's ability to conduct research that will promote a nation's knowledge capital is related to having sufficient human capital. Such a nation's capacity to innovate will ultimately determine its competitiveness (Tullao, 2013). In this regard, two fundamental concerns emerge when it comes to the development of human capital in countries:

> The supply of educated workforce should be congruent with the demand for the educated workforce; the country's level of educational development should match its level of technological development. Otherwise, a set of problems may arise, including mismatch of talents and skills, unemployment of the educated, and brain drain (Tullao&Cabuay, 2012 cited in Tullao 2013, p.6).

Universities have played a crucial role in basic research and human capital formation. (Malerba, 2003). Most universities in Turkey provide education in chemistry, chemical engineering, and other related disciplines. At this point, the quality of chemistry education is critical for both university and the industry. Erk (2015) clarifies this issue as follows: The score level required for entering the departments of chemistry and chemical engineering in universities has considerably fallen in recent years. Unfortunately the quality of education in the chemical industry has been declining. In spite of the fact that chemistry education exists in many universities, only 10 of them provide chemical education at the desired level.

Therefore our intellectual capital, that is human capital, well-educated human resources must surely go up.

In the strategy report of chemical industry published by MoSIT (2012), human capital was specified as one of major weaknesses of the sector. Problems regarding human capital were listed as below:

- Lack of qualified, well-equipped labor force
- Incompatibility of education with industry
- Despite the cheap labor force, the lack of efficient labor

İKMİB (2015) also organized a workshop regarding the current structure and the future of chemistry and chemical engineering education with the participation of many representatives from the sector and university. According to the findings of the meeting, the following topics are deemed necessary to increase the quality of chemistry education: increase of laboratory studies and applications; reflection of industrial experience to the education through the trainers who will teach from industry; integration of foreign language education with sectoral content; the introduction of foreign resources into Turkish literature; including the current and technological developments in the education; increase the capacity of trainers. Moreover, application of project-based courses and research methods, increase the quality and duration of the internship, support to the sector-related graduation projects and taking the active role of academicians in the sector in specific periods and transferring their knowledge later to the university were important topics recommended for enhancement of human capital capacity and education-industry practices.

Non-firm Organizations and Accompanying Institutions

The role of government as the primary regulating and standard-setting authority is significant in the chemical industry. The regulatory environment of Turkish chemical sector is primarily framed by supporting organizations: Ministry of

Industry and Technology (MOIT), the Ministry of Commerce, TÜBİTAK, Ministry of Treasury and Finance, Ministry of Health, Ministry of Environment and Urbanization,

Istanbul Chamber of Industry, Istanbul Chemicals, and Chemical Products Exporters' Association and Industrial Development Bank of Turkey are essential contributors to the chemical sector with their sectoral analysis, reports, and recommendations. Turkish Standards Institute also enables the chemical industry to produce products and services in compliance with rules, regulations, and standards applicable in global markets, such as ISO certifications (quality management system standards, environmental management system standards, etc.)

Additionally, it should be noted that developments in regulations propounded by the European Chemicals Agency (ECHA) markedly affect the sector's activities. For example, REACH (Registration, Evaluation and Authorization of Chemicals) is the EU regulation which determines procedures for collecting and evaluating information on the properties and hazards of materials. The REACH Regulation (EC) No. 1907/2006 was published by the European Parliament on 13 December 2006 with the aim of controlling chemical substances throughout Europe. This regulation is so critical that the EU chemical industry is forced to apply this regulation to improve the protection of human health and the environment from the risks that can be caused by chemicals. This regulation concerns manufacturers, importers and downstream users who produce, place on the market or use chemical substances and mixtures. With regulatory obligations, REACH regulation is one of the most advanced chemical regulations in the world (Cefic, 2018).

Manufacturer and exporter firms in Turkey are in "non-EU manufacturer" category according to REACH system because this regulation has not been yet harmonized in Turkey. Within the scope of this category, firms have different procedures while fulfilling their obligations. These procedures are usually too complex and costly. MoSIT (2012) indicated that companies in Turkey may encounter problems in export of relevant substances. Moreover, importing raw materials from suppliers in

Europe may be problematic if relevant materials are not registered by the supplier. This regulatory environment may slow down operations of firms; on the other hand, it may foster innovation by compelling firms to find alternative sustainable solutions.

In the strategy report and action plan of the chemical sector, weak cooperation among public, university and industry, and the lack of data exchange among these organizations are indicated as a threat to the chemical sector. R&D activities are the priority actions for the chemical sector to create a competitive structure that generates and develops its own technology in the production of high value-added products that do not harm the environment. In this respect, the relationship between firms and non-firm organizations such as universities, government agencies and financial organizations is expected to be strong in order to increase R&D and innovation activities in chemical sector. To that end, increasing R&D subsidies regarding university-industry cooperation is considered as an important strategic action (MoSIT, 2012).

On the other hand, bridging organizations try to fill this gap through facilitating interaction and transfer of knowledge among actors. They can also play a crucial role in solving sectoral problems through the provision of expert information and opinion to decision-makers. Major bridging organizations which operate in the chemical industry are indicated as Table 21.

Table 21. Major Bridging Organizations in Turkish Chemical Industry

Name	What They Do
Turkish Chemical Manufacturers Association **Türkiye Kimya Sanayicileri Derneği- TKSD**	TKSD holds discussions and negotiations with government authorities and the representatives of the Turkish chemical industry both nationally and internationally.
Turkish Chemical Society **Türkiye Kimya Derneği**	Main aim of Turkish Chemical Society is to ensure the advancement and development of chemical science and profession; to provide solidarity among colleagues; to enlighten the public and colleagues on all subjects related to chemical science and its applications; to represent our professions and colleagues at home and abroad. In line with this purpose, it organizes training activities such as courses, seminars, conferences and panels; publishes newspapers, magazines and books; cooperates with organizations teaching chemistry.
The Chemist Society **Kimyagerler Derneği- KİMYAGER**	KİMYAGER organizes seminars and panels in universities and within industrial entities to create a highly skilled labor in the industry.
TMMOB Chamber of Chemical Engineers **TMMOB Kimya Mühendisleri Odası- KMO**	KMO conducts different works with 12 representatives in various cities of Turkey in the following issues: protecting natural resources, increasing agricultural and industrial production, protecting the rights of consumer and contributing to the development of chemical engineering.
Turkish Plastics Industry Foundation **Türk Plastik Sanayicileri Araştırma, Geliştirme ve Eğitim Vakfı-PAGEV**	PAGEV is a non-governmental organization following the latest developments in plastics production techniques throughout the world, helping the sector adapt to world standards and contributing to the developments of local plastics production.
The Association of Paint Industry **Boya Sanayicileri Derneği- BOSAD**	Main aim of BOSAD is to contribute to the development of the Turkish paint and coatings industry, to increase national paint consumption, to provide consumers with modern and eco-friendly products, and to contribute to the EU integration process on a sectoral basis.

Table 21. (Cont'd)

Association for Fertilizer Producers and Importers **Gübre Üreticileri ve İthalatçıları Derneği-GÜİD**	GÜİD expands awareness of problems about fertilizer production as well as covering issues respecting import and export by organizing seminars and fairs in Turkey. Furthermore, it supports the sector in the process of adaptation to EU and local regulations.
The Association of Cosmetics and Cleaning Products Industrialists **Temizlik ve Kozmetik Ürünleri Sanayicileri Derneği-KTSD**	KTSD's mission is to support the sector about developments and to provide consumers' access to healthy, reliable and high-quality products by expanding overall awareness.
Turkish Plastics Industrialists' Federation **Plastik Sanayicileri Federasyonu-PLASFED**	Main aim of PLASFED is to inform the industry regarding subjects that involve regulations, taxes, personnel, employment, technology, health and safety. It oversees plastics production therefore it is sustainable and eco-friendly as well as creating public awareness for this process.

Source: ISPAT and Deloitte, 2014

2.2.3 SWOT Analysis

MoSIT (2012) applies SWOT analysis for Turkish chemical sector to identify the strengths of the sector, to take advantage of opportunities, to identify and improve the weaknesses of the sector and to take necessary measures for minimizing the impact of threats. Accordingly, MoSIT develops new strategies to improve the existing situation of chemical sector in Turkey.

Table 22 represents the SWOT analysis regarding chemical sector in Turkey. This table was adapted from sectoral strategy report of MoSIT (2012), combined with statistics presented in previous section.

Table 22. SWOT Analysis of Turkish Chemical Sector

Strengths	**Weaknesses**
1. Private sector acting as a driving force 2. A competitive and strong industrial structure 3. Dynamic labour force 4. Large consumption area in the domestic market 5. Product diversity 6. Logistically, - Being close to the EU market - Availability of marine transportation	1. Inadequate R&D and innovation activities 2. Low number of patent applications 3. Poor cooperation and coordination between industry, university and public sector 4. High production costs due to high cost of energy, water, raw material 5. Production structure; - Limited industrial capacity based on advanced technology - Inadequate evaluation of domestic raw materials - Foreign dependency in raw material use - Inadequate policies to increase production efficiency 6. Human capital; - Lack of qualified, well-equipped labor force - Incompatibility of education with industry - Despite the cheap labor force, the lack of efficient labor
Opportunities	**Threats**
1. National strategy reports towards chemical industry 2. Production planning of chemicals with high added value 3. Bridging organizations in the sector 4. Increase in the number of R&D personnel with high education level 5. Increase in support programs provided by MoSIT	1. Lack of effective education system 2. Failure to build trust-based collaboration between stakeholders 3. Lack of data exchange among the stakeholders 4. REACH regulation and accompanying export problems

Source: Adapted from MoSIT (2012)

CHAPTER 3

THEORETICAL FRAMEWORK

3.1 Systems of Innovation

The difference between invention and innovation is a significant issue as pointed out in the studies regarding innovation. While invention refers to the creation of an idea with regards to a product or process, innovation can be defined as the introduction of this idea to the market. Fagerberg (2005) points out that a single innovation is generally the result of a lengthy process, including many interrelated inventions/innovations.

In the Oslo Manual (OECD and Eurostat, 2005), the concept of innovation is linked with the introduction of a new or considerably improved product on the market, implementation of a process, marketing method, or organizational method in business practices, workplace organization or external relations.

In the rich literature on innovation, the systems of innovation (IS) approach has a central place. Here the term of ‘systems’ is crucial. Its definition may change concerning different approaches, but one way of expressing ‘system’ is “to include in it all-important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations” (Edquist, 1997, p.14). According to Edquist (1997), all IS approaches complement each other, and the difference among the approaches is the boundaries of the system.

IS approach examines all of the influencing factors and dynamics of the innovation processes (Edquist, 1997). Innovation processes are shaped by feedback mechanisms and the relations of organizations to exchange knowledge. Edquist

(1997) argues that “these organizations might be other firms (suppliers, customers, competitors) but also universities, research institutes, investment banks, schools, government ministries, etc.” (p.2). In summary, according to the IS approach, innovation is a context-specific and path-dependent activity and is the consequence of the interactive learning processes of the actors within the boundaries of the system.

The concept of IS has evolved through the inclusion of new building blocks or new boundaries. The first occurrence of the IS approach dates back to the late 1980s with the seminal work by Freeman (1987), Lundvall (1992) and Nelson (1993). The learning processes are emphasized within the scope of IS, and in this scope, interactions and interdependencies among players/actors come into the forefront. Lundvall (1992) mentions that these learning processes comprise learning-by-doing, improving the efficiency of production operations, learning-by-using, improving the efficiency of use of complex systems, and learning-by-interacting, engaging users and producers in an interaction that lead to product innovations. Profit-oriented organizations interact with non-profit organizations, and such interactions set the stage for further innovations or learning processes. Through these interactions, organizations exchange information regarding legal conditions, rules, and norms, which are classified as ‘institutions.’ The interactions make the sector undergo an evolutionary process through technological change. In time, the innovation generator introduces new outputs such as producing new products and adding new technological features to the existing products.

There are various definitions of IS. In the beginning, the main emphasis was on National Systems of Innovation (NSI). Non-firm organizations and institutions, as well as national boundaries, were the critical points of NSI. According to Lundvall (1992), NSI includes all parts and aspects of the economic structure and the institutional set-up that affects learning, searching and exploring (the production system, the marketing system and the system of finance) present themselves as subsystems where learning takes place. NSI includes all parts mentioned above, placing a significant emphasis on the role of nation-states. Related studies focus on the actors within a national boundary, that share a common societal culture, history, language, socioeconomic, and political institutions. The drawback of NSI is that the approach cannot be used in the comparison of various sectors or various technological improvements (Edquist, 1997).

Further, Nelson (1993) stated that agents from various technological fields within a particular geography might contribute to technical innovation, so regional/local and technological types of innovation systems came into the forefront. The geographical boundaries have become significant for Regional Systems of Innovation (RSI), as such in NSI. Geographical boundaries of RIS involve regions within countries as well as parts of different countries. RSI approach focuses on assessing innovation within regional boundaries since institutional set-ups, organizations and linkages within local and regional structures may differ from the national levels (Edquist, 2001).

The NSI and RSI approaches do not analyze particular technological innovation processes in detail. The increase of internationalization has led to the increase of networks between the agents from different countries and different technological fields. This enforced the focus on the formation, expansion and utilization of technologies and innovation in Technological Innovation Systems (TIS) (Edquist, 1997). Unlike the spatial dimension, TIS focuses on a particular industrial branch which brings more explanations to the transformation of the specific technology fields. TIS can be national, regional, or international; depending on market requirements and innovative capabilities of actors. As TIS concentrates on the rate of technological change, it is most often conducted to analyze the development of newly emerging technological fields rather than the established ones (Carlsson et al., 1995).

According to Malerba (2005), innovation varies widely across sectors in terms of features, sources, relevant actors, process boundaries, and the organization of innovative activities. Such difference across sectors leads to the need for another IS approach to bring a clearer understanding of particular sectors. Malerba and his colleagues introduced the concept of Sectoral Innovation Systems (SIS) in which different product and technology areas are investigated within a sectoral perspective (Breschi and Malerba 1997). In a sectoral system perspective, national and regional boundaries are considered to be necessary to varying degrees depending on the particular sector in question (Malerba, 2003).

3.2 Sectoral Systems of Innovation

Within the development of the sectoral system analysis, Pavitt (1984) took the first step to categorize industries according to the sources of technology. Pavitt investigated approximately 2000 significant innovations which took place between 1945 and 1979 in UK and asserted that “most technological knowledge turns out not to be ‘information’ that is generally applicable and easily reproducible, but specific to firms and applications, cumulative in development and varied amongst sectors in source and direction” (p.343).

In 1997, Malerba and his colleagues were the first to define a Sectoral System of Innovation (SSI):

> System (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies; such a system of firms is related in two different ways: through processes of interaction and cooperation in artefact-technology development and through processes of competition and selection in innovative and market activities (Breschi and Malerba 1997, p.131).

Evolutionary theory and the innovation system approaches are the backbones of this framework (Malerba, 2005). SSI concept has originated from the evolutionary theory in which fundamental concepts such as learning, knowledge, competencies, and significant focus on dynamics, process, and transformation are present. It has also been inspired by the innovation system literature that places a key emphasis on relationships and networks in the innovation and production processes (Malerba, 2002).

Malerba (2005) defines a sector as a set of activities which are performed with the intent of producing an output on a particular demand. The output may be a particular product or process to be marketed in the sector. Through these activities, know-how is spread within the sector. The concept of sectoral systems of innovation is centered on elements such as knowledge base, technologies, inputs, and demand. Each agent has a certain level of relationship with each other and has distinctive organizational and operational characteristics and capabilities such as specific learning processes, competencies, organizational structure, beliefs, goals, and behaviors. Malerba states that "a sectoral system undergoes processes of change and transformation through the co-evolution of its various "elements" which are 'knowledge and technology', 'actors and networks' and 'institutions' (Malerba, 2002).

An innovation system describes innovation as an interactive process which necessitates cooperation between the agents in the system. Furthermore, the sectoral system of innovation articulates a system comprising a wide variety of actors having the market and non-market interactions and activities which are performed with the intent of the creation of new products or processes to be commercialized in the sector (Malerba, 2005). Malerba defines institutions as one of the critical building blocks of the SSI. Agents interact at various levels, and through the exchange, cooperation, competition or command and these interactions are shaped and regulated by institutions which include norms, routines, common habits, established practices, rules, laws, and standards (Malerba, 2005).

As previously mentioned, a sector is composed of a set of activities for the intent of producing a product or process. These activities are aimed to fulfill a given or emerging demand and also are centered around a shared knowledge base (Malerba, 2005). Furthermore, these activities result in the spread of know-how within the sector and lead to know-how spillovers.

3.2.1 Building Blocks of Sectoral Innovation Systems

The concept of sectoral innovation systems is centered on three building blocks: ‘knowledge and technology’, ‘actors and networks’ and ‘institutions’. Firstly, we will describe knowledge base which is characterized by its differences in terms of accessibility, cumulativeness and technological opportunities. Later, actors and their interaction types will be elaborated. Demand is also mentioned in this section. Finally, institutions which shape direction of sector will be described.

Knowledge Base and Technology: The first building block of sectoral innovation systems comprises knowledge base and technology, which characterizes the sector. Knowledge is not automatically spread among firms (Nelson and Winter, 1982), but absorbed by firms through their absorptive capacity (Cohen and Levinthal, 1990). Cohen and Levinthal (1990) define absorptive capacity as firms’ “ability to recognize the value of new information, assimilate it, and apply it to commercial ends” (p.128). The knowledge base represents the sectoral boundaries, which continuously change as the sectoral system transforms through co-evolution of its various elements involving technology, actors, and institutions. There are two main drivers of such a continuous change: links among agents, knowledge, products, and technologies; complementarities in knowledge capabilities and specializations.

Learning and knowledge are the two major factors that may trigger drastic changes in an economic system. Prior learning and experience have a massive impact on beliefs, objectives, and expectations of the agents acting in the environment (Nelson, 1995; Dosi, 1997; Metcalfe, 1998). Learning capabilities may differ among sectors with respect to the way of getting knowledge. Internal activities of firms (i.e., developing new products, modifying production processes, searching for technological information, collaborating with other agents) and external factors (i.e., educational level of population, institutional environment) are important components that determine the learning capabilities of sectors (Arvanitis et al., 2000).

Accessibility of knowledge is another phenomenon which differs between sectors. Knowledge has different degrees of accessibility. It involves opportunities of obtaining knowledge that are external to companies and that may be internal or external to the sector. In both cases, accessibility of knowledge is inversely proportional to industrial concentration. As internal accessibility to knowledge in a sector become greater, appropriability of knowledge decreases. This means that firms may gain appropriate knowledge related to new products and processes which they can imitate. If knowledge is external to a firm or a sector, accessibility may be associated to scientific and technological opportunities. Here, the external environment may influence firms through scientific and technological knowledge developed in other firms or non-firms like universities. Human capital is also critical in triggering the spread of knowledge in the sector. Human capital is defined by the OECD (2007) as the knowledge, competencies and skills embodied in individuals that enable the creation of personal, social and economic well-being. Human capital receives scientific and technological knowledge from firms or non-firm organizations and leads the absorption and accumulation of that knowledge in other firms. This issue will be elaborated in following sections.

The sources of technological opportunities may also differ from sector to sector (Malerba, 2002). In some sectors, opportunity conditions are associated with scientific breakthroughs in universities (i.e., pharmaceuticals sector). In other sectors, opportunities to innovate may originate from advancements in scientific knowledge, R&D, instrumentation and equipment. For instance, scientific developments in many chemical disciplines and the progress in the instrumentation have led to chemical research to steer from trial-and-error methods to science-based approach to industrial research (Cesaroni et al., 2001). On the other hand, external sources of knowledge in terms of users or suppliers may also create an opportunity for some sectors to innovate. In order to stimulate innovative activities, know-how should be easily transformable and accessible. “If external knowledge is easily accessible, transformable into new artifacts and exposed to a number of actors (such as customers or suppliers), then innovative entry may take place” (Winter, 1984 cited in Malerba, 2002, p.252). For instance, advances in polymer chemistry and chemical engineering brought codifiable knowledge, and it eased the diffusion of knowledge among agents. As a consequence, codificability of knowledge is an obvious example of leveraging the transformation of the sector (Malerba, 2004).

Cumulativeness of knowledge, which is “the degree by which the generation of new knowledge builds upon current knowledge” (Malerba, 2002, p.252) also creates the difference between sectors by constituting a basis for new knowledge. Malerba (2002) states that there are three different sources of cumulativeness: learning processes, firm’s organizational capabilities, and feedback from the market. Learning processes, which set the stage for new questions and new knowledge although it constrains current research, are linked with cognitive dimensions such as beliefs, objectives, and expectations which are emphasized explicitly by the evolutionary theory. Organizational capabilities are firm-specific and can be developed over time. They define learning capabilities that a firm possesses now and possible achievements that a firm hopes in the future. Feedback from the market is the third aspect of cumulativeness. When R&D efforts yield profits, it creates an opportunity for reinvestment, which also increases the probability of further R&D investments. Malerba (2002) calls this loop “success-breeds-success”. Cumulativeness is graded as “high” and “low”; high cumulativeness of the sector indicates the high appropriability of innovations (Malerba, 2002). Cumulativeness of knowledge is high in the chemical industry, and therefore, it provides a suitable environment for knowledge spillovers within the industry.

Actors and Networks: In the context of sectoral innovation systems, the key actors in the system are the firms since they conduct vital activities such as commercial operations and R&D activities. In the system, firms may operate as producers, users or suppliers. Other types of actors in sectoral systems are non-firm organizations (e.g. government agencies, universities, bridging organizations, or financial organizations), individuals (e.g. scientists, entrepreneur or consumers), sub-units of larger organizations (e.g. R&D, production, and business development departments) and groups of organizations (e.g. industry consortia).

One of the most significant aspects in sectoral systems is the agent heterogeneity. Different agents carry out different studies in different ways. Differences in learning processes, knowledge base and behavior cause agents' heterogeneity in competencies, experience, and organization. Furthermore, firm heterogeneity may stem from differences in firms' specific interactions with demand, firms' histories, and differential rates and trajectories of innovation (Malerba, 2002). The extent of agent heterogeneity affects the interactions among actors in the sector. Agents interact through various processes such as communication, exchange, cooperation and competition. These interactions take place through the market and non-market relations. Such interactions among a wide array of actors affect innovation processes and drive the evolution of the sector through expanding knowledge boundaries (Malerba, 2005).

Demand is another crucial phenomenon to be focused within the scope of a sectoral system of innovation approach. Alongside other actors, demand not only contributes to ideas and ensures feedback for innovation, but also improves innovative solutions (Adams et al., 2012). The sources of demand are heterogeneous agents like end-consumers, intermediate user firms (industrial clients), and public agencies. Each agent has its knowledge base, behavior, competencies, and goals. These agents are affected by the societal culture of their environment and also institutions.

In addition, links and complementarities among artifacts and activities have a critical role in defining the real boundaries of a sectoral system. Dynamic complementarities consider interdependencies and feed-backs both at the demand and production levels. Linkages and complementarities may alter over time and differ from sectoral systems to sectoral systems. They influence firms' organization, strategies and performance, the rate and direction of technological change, the type of competition among actors (Malerba, 2002).

All in all, the type and structure of relations and networks differ among sectoral systems as a result of the knowledge base, basic technologies, characteristics of demand, the key links and dynamic complementarities. For instance, in pharmaceuticals, knowledge base has switched from “random screening” (natural and chemically derived compounds are randomly screened in test tube experiment for therapeutic purpose from 1945 to the early 1980s) to “modern biotechnology” (drug discovery by design has been implemented with the advent of molecular biology in the early 1980s). This change has generated new types of relationships and networks between firms (large pharmaceutical companies and new biotech firms), and among firms, non-firms (i.e. universities) and institutions (i.e. regulations) (Malerba, 2002).

Institutions: Sectoral systems may vary greatly with respect to their typical institutions, which comprise common habits, norms, established practices, regulations, laws, rules, and standards. As we have already mentioned, actions of agents and interactions among agents are shaped by institutions. Institutions may be formal (such as patent laws, government regulations of bank conduct) or informal (such as traditions, work norms, conventions). Whereas formal institutions are codified, informal ones are observed through the behavior of individuals and organizations. This distinction is significant since the balance between formal and informal institutions may vary between countries, between sectors within countries, or between small and large companies within sectors (Edquist, 1997).

In addition, Malerba (2005) states that “a lot of institutions are national (such as the patent system), while others may be specific to sectoral systems, such as sectoral labour markets or sector-specific financial institutions” (p.67). In this context, it is essential to consider the relationships between national institutions and sectoral systems. Malerba (2005) focuses on this issue, as presented below:

- Each national institution has a particular effect on innovation at the sectoral level. To illustrate, institutions such as property rights or antitrust regulations have different effects on innovation in different sectors.
- Impact of an institution on innovation differs according to the country. For example, in the chemical industry; the impact of property rights in an

underdeveloped country strictly differs from that of a developed country, according to the extent of the knowledge base.

- National institutions are most likely to favor some sectors that fit better with their specificities. Malerba (2002) explains this through following: “In certain cases, some sectoral systems become predominant in a country because the existing institutions of that country provide an environment more suitable for certain types of sectors and not for others” (p.257). On the other hand, national institutions may restrict innovation in specific sectors, or there exist mismatches between national and sectoral institutions.
- Relationship between national institutions and sectoral systems should be studied at the country level.

3.3 An Outlook on the Chemical Sectoral Innovation System

Chemical industry is one of the oldest industries in the world. The chemical sector consists of different subsectors, ranging from bulk chemicals- or basic or commodity chemicals- to specialty chemicals. Basic chemicals refer to high volume and low value-added products characterized by low differentiation whereas specialty chemicals like dyes and paints, food additives stand for more differentiated and complex products which are produced in low quantity and sold for high prices. Each subsector is characterized by a set of specific knowledge, technological base, and inputs. Its large market size, agent heterogeneity, and linkages with many other industries are the foremost characteristics of the chemical sector (Cesaroni et al., 2001).

The chemical sector generates transferrable knowledge and technology, which provides support to innovation activities in other sectors. As a result of this, new downstream markets emerge and contribute to world economy continuously. After a new product or process is commercialized, a particular percentage of its revenue is reinvested on new R&D activities (Malerba, 2002). These continuous improvements create a virtuous circle which accelerates both innovation activities and widens the boundaries of the sector through the extension of the knowledge base. The chemical sector is in a continuous evolutionary cycle through gaining new features in different countries, and at different times. With the extension of the knowledge base, firms' behaviors are re-shaped, so that they become more eager to interact with other agents (Malerba, 2005). The transformation of the sector from *synthetic-dyestuff model* to the *era of polymer chemistry* would be a good example depicting the evolutionary cycle (See below).

Large chemical firms are considered as the backbone of the chemical industry. One may explain the reason of this phenomenon: "Large R&D expenditures, economies of scale and scope, cumulativeness of technical advance and commercialization capabilities have given these firms major innovative and commercial advantages" (Malerba, 2004, p.11).

In the chemical sector, the learning process has been set up on formal search processes with the *synthetic-dyestuff model* in which firms have developed a knowledge base on organic chemistry to form complex molecules. Cesaroni (2001) explains the importance of this model as that this knowledge was the introduction of the development of a 'general purpose technology' based on the idea that different chemical composites could be designed through using the scientific background on the features related with atoms and bonds among atoms. This model is also considered as a milestone for capitalizing on the advancement in universities for innovative activities. Furthermore, in parallel with the development of organic chemistry, firms scaled-up their R&D departments in order to get benefit from the economies of scope through the discovery of new molecules. This has shaped the interaction of large firms with universities and other scientific organizations. Firms also increased their interaction with users. Their knowledge base and learning processes have evolved through this period and in parallel with such advancements, new agents, and organizations emerged.

Later, the *era of polymer chemistry* has begun. This concept was initiated by Herman Staudinger in the 1920s to identify the synthesis, structure, and properties of macromolecules – i.e., polymers – linked together by chemical bonds. The scientific understanding of the presence and configuration of these long chemical macromolecules led to the principle of ‘materials by design’ (Arora and Gambardella, 1998). According to this principle, there is a relationship between the properties of the macromolecular structures and material characteristics. This means that the scientific understanding of chemical composites is the basis for different product applications (Cesaroni, 2001). Through this period, firms started to conduct research such as polymer design and synthesis for the development of different products. This has led to the development of knowledge base and characteristics of sub-sectors such as plastics, fibers, surface coatings, and adhesives. In this period, knowledge about downstream markets and interactions with agents in downstream sectors became important (Malerba, 2005).

The development of chemical engineering and the concept of ‘unit operation’ in 1915 led to the development of product lines and this technology evolution developed two distinct categories of innovation: process innovation and product innovation. This concept involves “the breaking down of chemical processes into a limited number of basic components or distinctive processes that are common to many product lines” (Wright, 1998 cited in Cesaroni et al., 2001, p.7) and “provided the unifying base for more contextualized and problem-solving innovations at the plant level” (Rosenberg, 1998 cited in Cesaroni et al., 2001, p.7). Before the concept of the product line, the chemical processes were not clustered as a continuous production flow. After the development of process technology, design and engineering know-how increased. In this period, process innovation has started to be considered as a commodity which could be traded. This has built-up solid networks between specialized engineering firms (SEF) and chemical companies. These networks resolved into partnering relationships for the aim of developing or buying new technologies.

The previous developments are considered as milestones that transformed radically the learning processes of firms in the chemical industry and evolved these processes into science-based methodologies. In that sense, Malerba (2005) states that “The advances in chemical disciplines such as polymer chemistry and chemical engineering have created the base for greater codificability of knowledge" (p.71). Codifiable knowledge is also transferrable and having such knowledge resulted in the diffusion of knowledge to other sectors. This has led to the emergence of new markets for process design services. Transferrable knowledge can be internal or external. This knowledge has started to be complementary to the internal R&D efforts, so firms' interaction with external resources of scientific & technological knowledge became critical (Malerba, 2005). Besides, Malerba (2003) explains the re-shaped interactions among agents through the following:

> The increasing reliance on external links for complementary scientific and technological knowledge has led to the emergence of networks of three types: inter-firms, university-industry, and user–producers in specialty segments. However, the relevant networks have changed in relation to the type of knowledge base (p.345).

The role of institutions in the chemical industry has been critical throughout evolution of the sector. Initially, intellectual property rights protection, especially patents, was critical as it stimulated innovation and diffusion of technologies. In the chemical industry, patents were mostly used in conjunction with other instruments, such as first mover advantage and secrecy. The limited understanding of the chemistry underlying the development and production of dyestuffs restricted the useful scope of patents, and encouraged secrecy. Especially German companies expertly combined secrecy and patents to exclude competitors, both at home and abroad (Arora and Fosfuri, 2000). On the other hand, the development of chemical engineering increased process innovations, and encouraged patenting of processes. Therefore, patents were also be used to purchase or to sell technology through license contracts. Licensing and antitrust rulings have created broader competition and accelerated the diffusion of technologies. Although patents were useful for hampering straight imitation, rivals could develop competing types of patented chemical processes. These processes vary in terms of starting materials, yields, operating procedures, and characteristics of end substance. This has shaped firms' behavior and led to vigorous competition in the market. Chemical firms heavily licensed their process technology so that new technologies were rapidly diffused.

Furthermore, antitrust regulations have decreased the concentration of technology ownership and increased competition in the market (Arora and Gamberdalla, 1998).

Environmental issues have also shaped the behavior of consumers as well as governmental organizations vis-a-vis the chemical industry. End-users wanted to use environmentally safe and fewer pollutant products due to the detrimental effects of chemicals. In order to meet consumers’ demand, the government has paid more attention to pollution related issues and has started to impose regulations in order to control the manufacturers’ production processes (Cesaroni et al., 2001).

3.4 The Role of Human Capital in Economic Growth

Human capital is a broad concept involving many different types of investment in people. Andrijević-Matovac et al. (2010) define it “the abilities, knowledge, and skills embodied in people and acquired through education, training, and experience” (p.361). They also underline that both developing and developed countries had recognized the significance of human capital in the era of globalization and intense competition. Human capital is also seen as a critical input for the new technological developments (Andrijević-Matovac et al., 2010).

When it comes to the role of human capital in economic growth, one must investigate it from the evolution of growth theory, beginning from the neo-classical model of Solow, then shifting to Denison’s explanation of the Solow residuals, to Becker’s findings on the role of education, and lastly, to Romer’s model of endogenous growth (Tullao et al., 2013).

Solow’s neo-classical model suggests that technical change is the most significant determinant of growth. Solow (1957) defines the technical change as “any kind of shift in the production function” (p. 312). The theory led to growth accounting and demonstrates that technological progress is a critical factor for the growth of labor productivity, or output per worker (Tullao et al., 2013). From a broader perspective, growth is also linked with capital accumulation, which depends on the savings rate, marginal productivity of capital, the growth rate of population, technological progress and depreciation (Romer, 2001).

Furthermore, growth in the economy is linked with the Solow Residuals which measures factor productivity growth and technical progress (Tullao et al., 2013). In that point of view, Denison (1962) suggested a significant approach for accounting for the residual. He offered that education is linked with the contribution of labor quality (Crafts, 2008). This has led to the development of further studies on Total Factor Productivity (TFP). TFP is the ratio of aggregate output to aggregate inputs and is also an essential component of economic growth. TFP is associated with technological progress, human resource development and management, institutional restructuring, and socio-demographic factors (Jajri, 2007). Jajri (2007) lists the determinants of TFP as below:

- Education and training of the workforce to upgrade skill and knowledge
- Economic restructuring into sectors with higher productivity
- Capital structure related to the investment in productive capital inputs
- Technical progress related to the effective and efficient utilization of technology, capital, work attitudes, and management effectiveness
- Demand intensity that reflects the extent of the economy’s productive capacity (Tullao et al., 2013).

Becker (1964) and Mincer (1974) suggest that human capital is one of the drivers of economic growth. They have proved that investment in human capital leads to an increase in the earnings of the individual (Tullao et al., 2013). This is also known as the human capital theory which explains that education and training raise the productivity of the worker and leads to the increase of the earnings of the individual in the future (Xiao, 2001; Mincer, 1974; Becker, 1964).

Becker and Mincer’s studies gave rise to many studies trying to explain how education enhances productivity. Spence (1973) states that education is an indicator for an employer to qualify the productivity of the worker; Shultz (1975) claims that education brings to workers the competency to cope with disequilibria in the economy; Hall and Jones (1998) further links this equilibrium with the differences in social infrastructure. According to them, social infrastructure is associated with the government policies and institutions which facilitate the economic environment. These institutions can be good governance, trade openness, and facilities for technology transfer, and enforcement of intellectual property rights. The social infrastructure is also linked with physical and human capital accumulation, productivity, and output per worker (Hall and Jones, 1998).

Differences in earnings are associated with several factors, including the differences in training, talents, family background, education, and gender (Tullao et al., 2013). Mincer (1981) suggests that human capital investments shall be categorized into life-cycle chronology: childcare and development, formal school education, labor market mobility, job choice, job training, work effort, healthcare, and other maintenance activities.

Lately, Romer (1986) developed ‘Endogenous Growth Theory’, which acts as an alternative model to the neo-classical growth theories, expanding the definition of capital to include human capital or knowledge capital and eliminating the hypothesis of decreasing returns to capital. It is essential to point out that human capital is different from knowledge capital. Human capital is a rival good comprising health, education and training and whose use is unavailable for others. On the other hand, knowledge capital is a non-rival good which is available for all stakeholders to get benefit. Put differently; knowledge capital is likely a public good, whereas human capital is not (Romer, 1990). Romer’s model assumes that the stock of capital in the economy affects the level of per-capita output positively at the level of the industry. This possibly leads to produce increasing returns at the industry level. Consequently, this theory defends that in the long term, forward-looking and profit-maximizing agents drive their growth through the accumulation of knowledge and the more massive total stock of human capital (Romer, 1986).

3.5 Human Capital in Innovation Systems

Policymakers and academics have emphasized that human capital is one of the critical components of competitiveness and economic growth. Nelson and Phelps (1966) underlined that the crucial role of human capital for growth is presumably its capability to adopt and generate innovations. That is, human capital is fuel for the R&D sector (Cadil et al.,2014).

According to Oslo Manual, much knowledge of innovation is embodied in people and their skills, and there is a need for proper skills to make intelligent use of external sources or codified knowledge. The role of human capital in innovation systems is significant at both the firm and the aggregate level. In this respect, the Oslo Manual defines some critical issues as follows:

> The quality of the education system and how well it matches the needs of innovative firms and other organisations; what efforts firms make to invest in the human capital of their employees; whether innovation activity is hampered by shortages of qualified personnel; whether there are sufficient opportunities for worker training; and how adaptive the workforce is in terms of the structure of the labour market and mobility across regions and sectors (OECD and Eurostat, 2005, p.43).

In the rich literature on innovation, studies have also laid weight on the role of knowledge production in the innovation process. Nevertheless, in the same literature, there is a collective agreement that the mere presence of advanced scientific and technical knowledge does not automatically create innovation, including commercialization of products and processes. Some of the critical elements that translate knowledge into innovation are the ways in which skills and expertise are advanced and used by individuals and organizations. Integration of knowledge, skills, and expertise is generally named as ‘competences’ (Borras et al.,2014). In this respect, it is said that the creation of human capital is linked with ‘individual learning’ or ‘individual competence building’. According to Edquist (2001), education is associated with ‘individual learning’ because human capital is generated in this process. Education can be in two forms: ‘formal’ (for instance, in educational institutes) and informal (for instance, competence building ('learning-by-doing') in the workplace). In line with individual competence building, the stock of human capital is increased (Borras et al.,2014).

All in all, the usually assumed causality from education, training and experience to human capital and skilled labor force, and from qualified human capital to R&D and innovation, finally economic growth can be summarized as following: formal or informal education enables individuals to acquire specific competences; individual learning brings about individual competence building; individual competences enhance human capital infrastructure, in other words, create a highly-skilled grouped in the labor force; qualified human capital increases accumulation of knowledge; accumulated knowledge and experiences boost R&D and innovation; R&D and innovation have massive impact on economic growth and development of nations (Tullao et al., 2013).

3.6 The Importance of Human Capital in Chemical Industry

The history of the chemical industry can be characterized by the existence of a series of significant changes (Cesaroni et al., 2001). From the Schumpeterian point of view, these changes can also be named as waves in technological innovations (Swift, 1999). All technological innovations in the chemical industry have concomitantly increased the stock of chemical knowledge as well as the need for qualified human capital.

To better understand this process, a closer look at these waves is needed: The first generation of chemical process and product innovations began around 1850 and lasted about sixty years (Swift, 1999). As mentioned previously, the synthetic-dyestuff model is a significant example of the new approach to innovation since it implies the use of scientific knowledge for developing new products and processes. It is possible to say that with the introduction of the first synthetic dye in 1856, the discoveries of other synthetic dyes intensified especially in Britain, Germany, and France, and the importance of human capital in the chemical industry began to be understood (Forster et al., 2013). According to Bijker et al. (2012), the era of synthetic dye chemistry in 19th century was the emergence of heuristics due to successive discoveries of aniline purple, or mauve, and aniline red, or fuchsine, then elucidation of the chemical constitution of derivatives such as rosaniline. It is noteworthy that the invention of new compounds in this science-based model precisely depended on developments in the scientific understanding of the chemical structure of molecules and the researchers who discover them. In this period, the role of universities and other scientific research institutes in R&D and innovation has been revived. Therefore, the largest and most innovative chemical companies made active contact with the university, started to recruit researchers in the universities and enhanced research collaborations aspired to invent new compounds (Cesaroni et al., 2001).

In the 1920s-1930s innovation in chemicals took place majorly in four countries: Germany, Switzerland, the U.S.A. and the U.K. The excellence of chemical education and academic research in Germany and Switzerland and significant steps took by British and American universities were a significant factor for those innovations (Achilladelis, 1990).

A second wave of innovation in chemicals began with polymer chemistry and petrochemicals in the 1930s. The scientific understanding of the presence and configuration of these polymers, which mean long chemical macromolecules, resulted in the principle of ‘materials by design’ which is defined in detail in Section 2.3. In this period, there was an upsurge of skilled labor in the chemical industry, particularly chemical engineering (Cesaroni et al., 2001). The concept of ‘unit operation’ in 1915 and the development of chemical engineering made it easier to separate the process design in chemical plants from the details of chemical compounds being produced in the laboratory. Furthermore, questions like “how” macromolecular structures are produced and “how” to innovate were answered, but afterwards, the question shifted to “what” to produce due to lack of knowledge regarding the characteristics of market segments. This shift created competition among chemical companies and encouraged extensive investments in R&D and human resource to develop new product variants.

All the fundamental technological innovations between the years 1920 and 1940 - such as polyethylene, polystyrene, PVC, nylon, synthetic rubbers and other artificial fibers - were developed in the laboratories of large chemical companies, where scientists have a critical role and most of those firms still exist today (e.g., BASF, Bayer and DuPont) (Cesaroni et al., 2001). At this point, it may be useful to give place to Penrose's (1959) explanation, which claims that the growth of firms depended on their human resources. In his study, Han (2017) also enucleates this issue as flows: "those companies that can hire and keep this qualified human capital will have a sustained advantage over those who do not" (p.8).

During all above mentioned periods, the interaction between profit-oriented organizations and scientists was critical and had a massive impact on the evolution of chemistry and chemical engineering disciplines. Cesaroni et al. (2001) commentate this relationship as follows:

> Threatened by the possibility of going to the academy as a potential employment option, firms often had to adapt their employment conditions to match those typically found at the university. In so doing they allowed a certain degree of freedom and flexibility to chemical scientists and engineers, and gave the possibility to publish their research achievements (p.8).

Scientific discoveries and technological developments have been leading to the third wave of chemical product and process innovation. This period has begun in 1980s-1990s in conjunction with the growing significance of biosciences and green technologies. In this new era, consumers' demand and government regulations have come to the forefront so that firms' behavior in the market has changed. Pharmaceuticals, agrochemicals, electronic chemicals, high-performance materials, and bioengineering are defined as the promising sectors, where firms spend large amounts of money on R&D in anticipation of the new radical innovations and market success as well (Achilladelis, 1990). There has been a shift toward biological raw materials and processes since biological-based technology is less energy-intensive and produces less pollution (Swift, 1999). In this respect, environmental technologies or “green” processes were mentioned as critical coevolutionary processes in chemicals (Malerba, 2003). In this regard, new terms such as green economy, green jobs, and green human capital have become prominent. According to UNESCO-UNEVOC (2017), the green economy is an economic system in which natural resources are efficiently used with limited polluting activities and environmentally friendly business practices. Moving towards a green economy has brought about changes in employment, both quantitatively and qualitatively. Various sectors starting with chemistry and the energy need to adapt to green jobs which aim to preserve environmental quality. Such need result in increases in demand for some jobs and declines for others (for instance a petrochemist turning to vegetal-based chemistry). Evolution of skills and job qualifications has created the concept of green human capital, which comprises the set of skills appropriate to the needs of the green economy shown by a society’s labor force. It is recommended for every country that public and economic actors should act together to form a roadmap for adapting skills to the demands of the green economy (UNESCO-UNEVOC, 2017).

As a result, it is seen that from the first wave of technological innovations until today, firms’ as well as governments’ approach to research and the human capital has influenced the development of the chemical sector and is becoming increasingly important.

CHAPTER 4

METHODOLOGY

This chapter presents the research methodology used in the thesis.

4.1 Definitions

The main concepts which have been used in previous chapters and which will be used in the subsequent chapters of the thesis are as below.

Innovation: According to Oslo Manual, "innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational in business practices, workplace organization or external relations" (OECD and Eurostat, 2005, p.46). The minimum requirement for an innovation is indicated as that the product, process, marketing, or organizational method must be new (or significantly improved) to the firm. Oslo Manual (OECD and Eurostat, 2005, p.47) categorizes and defines the types innovation as below:

> **Product innovation** is the introduction of a good or service that is new or significantly improved concerning its characteristics or intended uses. This includes significant improvements in technical specifications, components, and materials, incorporated software, user-friendliness, or other functional characteristics.
>
> **Process innovation** is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment, and software.
>
> **Marketing innovation** is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion, or pricing.

> **Organizational innovation** is the implementation of a new organizational method in the firm’s business practices, workplace organization, or external relations.

By considering the Oslo Manual’s definitions for innovation, product innovation, and process innovation used in this study can be adapted for the chemical products and processes as follows. Product innovation is the introduction of a product to the market (i.e., chemical goods or service) and involves changes in both processes and products. For instance, product innovation could be using a new feedstock (chemical raw material) and a new process to produce a new non-basic chemical. On the other hand, the result of process innovation must have a significant effect on the level of chemical manufacturing, product quality, and manufacturing and distribution costs. Process innovation could be using a new feedstock and a new process to obtain the existing basic chemical as before (Ren, 2005).

Research and Development (R&D)*:* According to Frascati Manual, R&D includes creative work conducted systematically in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to develop new applications. Frascati Manual (OECD, 2002, p.30) distinguishes the types of R&D as basic research, applied research and experimental development and defines them as below:

> **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
>
> **Applied research** is also an original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.
>
> **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience that is directed to producing new materials, products, and devices; to installing new processes, systems, and services; or to improving substantially those already produced or installed.

R&D and technological innovation: Frascati Manual gives information about which activities can be classified as technological innovation. These activities are

> All of the scientific, technological, organizational, financial, commercial steps, including investments in new knowledge, which actually, or are intended to lead to the implementation of technologically new or improved products and processes. R&D is only one of these activities and may be carried out at different phases of the innovation process (OECD, 2002, p.18).

R&D Center: MoIT defines R&D centers as units of legal equity companies located in Turkey, which are exclusively engaged in R&D activities, those that employ at least fifteen full-time equivalent R&D staff and have sufficient R&D accumulation and capability. Private sector R&D centers are established and operating under the Law No. 5746 which is prepared with the understanding that investments in R&D, technology and human resources will turn into technological development, high competitiveness and high level of prosperity.

R&D Project: It specifies the project conducted by the researcher and carries out within the framework of scientific principles that will determine each phase of R&D activities. The purpose, scope, general and technical description, duration, budget, special conditions, the amounts of real and/or cash support to be provided by other institutions, organizations, real and legal persons, and the principles of sharing of intellectual property rights that will emerge of the project are determined (The Law No.5746, 2008).

R&D Personnel: It mentions researchers and technicians directly in charge of R&D activities

Researcher: Experts having at least an undergraduate degree, who participates in R&D activities and projects under the definition of innovation, in the designing and building up of new knowledge, products, processes, methods and systems and in the management processes of the related projects

Technician: People who are graduated from designing, technical, science and health departments of vocational high schools or higher vocational schools, who own technical knowledge and experience

Support Staff: It mentions manager, technical staff, laboratorian, secretary, worker, and staff as such participating in or directly relevant to R&D activities (The Law No.5746, 2008).

The brief sketch of the applied methodology is indicated in Figure 5, and explanations are given below.

4.2 Theoretical background

As a theoretical framework, the sectoral system of innovation approach is used in this study. Malerba (2002) suggests this approach as a beneficial tool in various respects;

> For descriptive analysis of the differences and similarities in the structure, organization, and boundaries of sectors; for a full understanding of the differences and similarities in the working dynamics and transformation of sectors; for the identification of the factors affecting innovation, commercial performance and international competitiveness of firms and countries in the different sectors; for the development of new public policy indications (p.332).

So the SSI concept is used in this thesis in order to obtain an integrated view of what the essential dimensions of Turkish chemical sector are, and what the determinants of innovation in chemical industry are. In addition, when any research-intensive sector is studied for innovation, the role of the qualified human capital needs to be explored. Therefore, in compliance with the research questions, literature associated with human capital in the innovation system and the importance of skilled labor infrastructure in the chemical industry were also reviewed (See chapter 3).

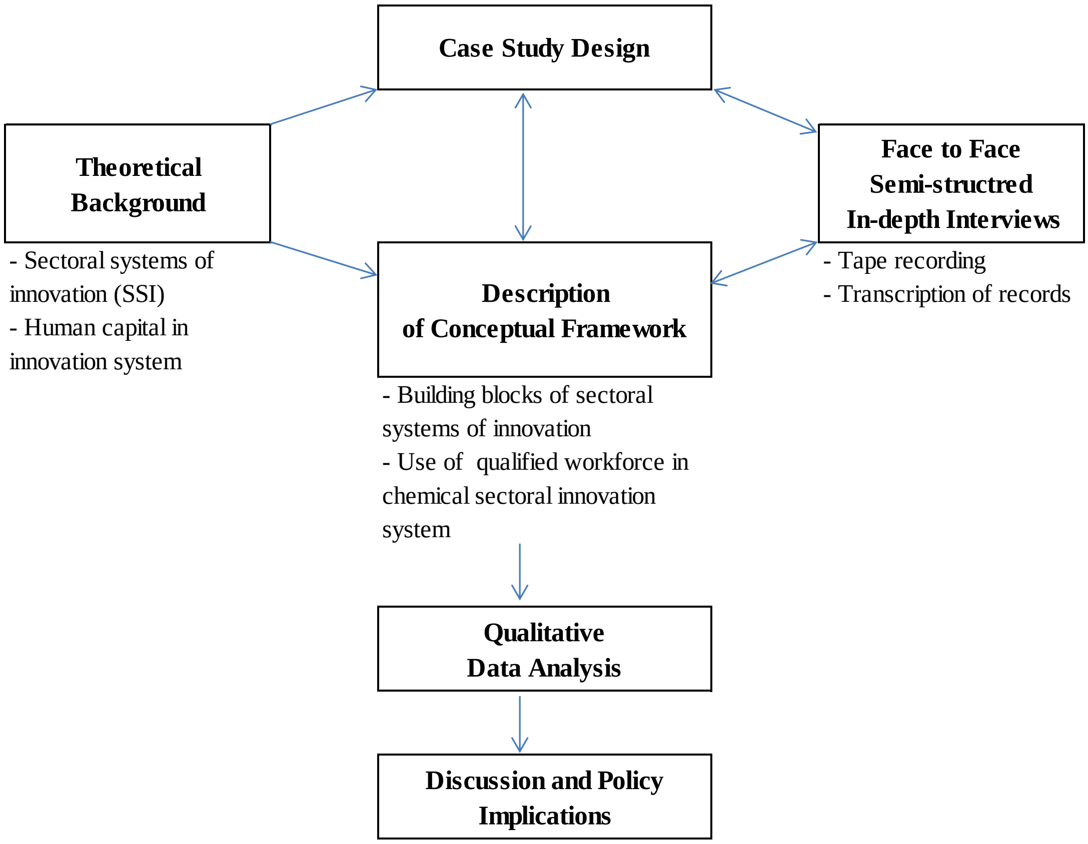

Figure 5. Brief Sketch of Applied Methodology

4.3 Case Study Design

This research study was built on qualitative techniques. Qualitative research methods allow analyzing social phenomena in a more detailed and profound manner (Vedovello, 1997). Among the various techniques in qualitative research, case studies are preferred to examine complex social phenomena (Yin, 2003). For this thesis, multiple case study design (Yin, 2003) was applied as a method of inquiry in order to identify the current situation of the chemical industry in the context of SSI from the employers' point of view and to understand better the similarities and differences between the sub-branches of the chemical industry. This type of study was also used to confirm convergent or contrasting evidence between the cases and to obtain a more robust study, although it is incredibly time-consuming (Yin, 2003). This research design with multiple case studies has been conducted as below.

Selection of Cases (Sampling)

The most common sampling strategy used in qualitative research can be described as *purposeful sampling* (Creswell, 1998, cited in Elliot et al., 2005). Patton (1990) emphasizes that the logic of purposeful sampling lies in choosing information-rich cases for study in depth. According to him, information-rich cases involve a great deal about the importance and aim of the research and studying such cases yields insights and in-depth understanding rather than empirical generalizations.

The aim of qualitative research is typically trying to sample broadly enough and to do an in-depth interview so that all the significant aspects and variations of the studied issue are captured in the sample (Elliot et al., 2005). Therefore, sampling in qualitative research seeks to capture the range of views/experiences rather than quantitative representativeness.

Since the author of this thesis works in the R&D center and can easily do an interview, 'convenience sampling' was also used in the study. This is one of the most common sampling strategy, but also the least recommended one since selecting cases are easy to access and inexpensive to study (Patton,1990).

For this study, R&D centers are the units of analysis. The author of this thesis specified some criteria with the help of her supervisor. In this regard, selected cases had to meet the below criteria:

1. *Firms having R&D centers operating in the chemical industry*: It was assumed if the chemical company has an R&D Center, it conducts many scientific and innovative projects. According to the sectoral classification of R&D centers determined by MoSIT (2018), R&D centers are operating in totally 42 different sectors. It was assumed that the 'chemistry' category would be more representative since there are lots of downstream users of chemical industry ranging from cosmetics to textile, construction, etc. (See Chapter 3).

2. *Firms having R&D center for at least two years*: R&D centers are audited by the Ministry of Industry and Technology every year within the scope of various performance indices such as employment of R&D personnel, R&D expenditure, project capacity, cooperation and interaction, commercialization. So it was assumed that the firms would assimilate the responsibilities given by the R&D center and have the capacity to evaluate the contribution of the R&D center to the sector in 2 years and would answer interview questions more accurately.

3. *Firms located in İstanbul, Kocaeli, and Yalova*: Most of the chemical firms having R&D centers are located in Istanbul, Kocaeli, Yalova, Sakarya, Izmir, Adana, Tekirdağ, Bursa. Geographical proximity to the participants was significant for the researcher. In order not to waste time, firms located in İstanbul, Kocaeli and Yalova, were selected.

4. *Firms active in at least one of the sub-sectors which are basic, specialty, and consumer chemicals*: Since chemical industry consists of different sub-sectors, firms were selected from at least one sub-branch of the chemical industry. Therefore, each sub-sector case was taken into consideration, and the information that can be obtained from the chemical sector was maximized.

Identifying Cases and Reaching Participants

According to the January 2018 statistical data published by the Ministry of Industry and Technology, 51 R&D Centers were operating in the chemical sector. Most of them were established in 2017. Therefore, when we filtered the ones which met the above criteria except for sub-sector, there were *nine firms* identified at first glance.

The main field of manufacturing and research areas of these nine firms have been searched from their official websites. So it was possible to categorize the firms concerning sub-branches of the chemical sector. By using this data together with

R&D center statistics, it was seen that these firms mostly operate in specialty chemicals. There existed two firms active in basic and consumer chemicals, while this number reached about 7 in specialty chemicals. Furthermore, two firms operate in the same field of manufacturing among specialty chemicals. Since the researcher has been working in the R&D center of one of them, the rival company was eliminated ethically.

In line with this information, it has been planned to conduct research with eight firms. The researcher tried to contact the manager or director of R&D centers via phone calls, e-mail, or some platforms. However, reaching the firms was the bottleneck within the overall research process. Although the majority of potential participants were interested in participating in such a research on R&D centers in the chemical industry, some of them kept away from giving information regarding their processes or unavailable to spare the specified duration for interview. Therefore, the acquisition of cases and getting appointments for some interviews took several weeks. Eventually, *six firms in total* have been interviewed since two firms did not make a positive return.

Data Collection Process

There are several methods of getting information for qualitative research. Interviews are the most common general approach, with semi-structured and unstructured interview formats predominating. In these forms of interview, participants are asked to provide detailed accounts concerning particular experiences (Elliot et al., 2005). In this study, data has been collected via a semi-structured interview guide designed by the researcher in collaboration with her supervisor.

Analyzing a chemical sector from an innovation system perspective requires a theoretical background and description of the conceptual framework; knowledge base and learning processes of firms; actors and their interactions; soft institutions such as values, trust, attitudes of actors; the importance of human capital from the firms’ point of view, etc. Analysis of these subjects requests deeper and richer data that could be generated by qualitative inquiry methods. In this regard, face-to-face semi-structured interviews are useful tools since they allow flexibility for the interviewer and interviewee to negotiate and elaborate more on interesting comments, hence to have more in-depth interviews. Additionally, through the interview, participants are forced to think of their processes, interactions, and expectations which cannot be elucidated by direct questions. Especially, face-to-face interactions with the manager or director of R&D departments allow observing comprehensive knowledge of experts who have experience in the sector both technically and socially.

For this aim, a question set was prepared based on the research question and conceptual framework. This semi-structured interview guide has four main sections (see Appendix B and C). The first section aims to obtain general information about the firm and its main manufacturing field. The second section consists of 3 sub-sections, where the field of activity of the firm is examined with the approach of the sectoral innovation system. Put differently; these questions are sorted by main building blocks of the SIS approach, which are “knowledge base and technology”, “actors ad networks” and “institutions”. The third section aims to examine what sort of R&D and innovation activities are carried out by firms. The last section is designed to investigate the qualified labor force infrastructure in R&D centers.

The researcher collected qualitative data through the following phases and conducted all interviews by herself.

1- Pilot interview: In the initial phase, a pilot interview was carried out with a chemistry professor offering consultancy service to the private chemical sector about R&D activities as well as being the founder of a start-up company. The aim of applying this phase was to check which interview questions are meaningful and applicable, to eliminate the questions which would not work and determine the question hierarchy. This pilot study was done with a person staying out of sampling in order to see the comment of an expert who could be unbiased as well as well-informed about the sector.

After the pilot interview, the researcher made some modifications such as the removal of irrelevant questions and the addition of some questions to be more explanatory and acquire precise answers.

2- Interviews: In the second phase, semi-structured interviews were conducted with the manager or director of R&D centers selected through purposeful sampling. Contacting the participants and conducting a total of 6 in-depth interviews were realized between the mids of March 2018 and beginning of June 2018.

All of the interview sessions were recorded using voice recorders with permissions of participants. The researcher has particularly noted issues that need attention during the interview, and some statistical data was obtained from the participant by e-mail after the interview. The names of participants and their interviews were kept secret. The lengths of the interviews changed between 50 minutes and 90 minutes. The transcriptions of records were initially made verbatim and then refined several times in order to prepare them for the analysis where any of significant points should not be missed.

4.4 Description of Conceptual Framework

When the case and its boundaries have been decided, it is significant to take into consideration the additional components necessary for designing and implementing a rigorous case study (Baxter et al., 2008). These include: (a) propositions (which may or may not be present) (Yin, 2003, Miles & Huberman, 1994); (b) the application of a conceptual framework (Miles & Huberman, 1994); (c) development of the research questions (generally ‘how’ and/or ‘why’ questions); (d) the logic linking data to propositions; and (e) the criteria for interpreting findings.

In this research, the conceptual framework was preferred to manage the processes of data collection and data analysis. Miles and Huberman (1994) indicate that the conceptual framework serves several purposes: “(a) identifying who will and will not be included in the study; (b) describing what relationships may be present based on logic, theory and/or experience; and (c) providing the researcher with the opportunity to gather general constructs into intellectual bins"(p. 18).

In this study, initially SSI was used for creating a conceptual framework. By considering the definition of primary building blocks of SSI, the following components affecting R&D and innovation processes of chemical firms have been identified: characteristics of knowledge base and technological trajectories, nature of learning processes, competencies, organization, and behavior of firms; actors and networks, vertical/horizontal inter-relations and complementarities; institutions. Secondly, human resources in R&D, employers' assessment parameters of researcher quality, etc. have also been extracted from the literature. According to cases and semi-structured interviews with an organic structure, the conceptual framework was fully formed and so useful at the stage of data interpretation (See Table 23).

Table 23. Description of Conceptual Framework

Knowledge Base and Technology	Sources of knowledge
	Types/objectives/outputs of R&D projects
	Types/objectives/outputs of innovation projects
	Trends for the future
Actors and Networks	Primary actors
	The role of firms
	The role of universities
	The role of government organizations
	Interactions and Collaboration Projects
Institutions	Primary regulations and their effects
Human Capital Infrastructure	Criteria in positioning in R&D department
	Expectations from researchers/technicians
	Extent of difficulties in recruiting
	Impact of Being an R&D Center and the Number and Qualification of Researchers
	Contribution of researchers to innovation process
	Encouraging researcher to do master/doctorate

4.5 Data Analysis

In this research, data obtained by interviews were analyzed according to the predetermined conceptual framework. In the literature, this type of analysis is defined as ‘descriptive analysis’ as it includes summarizing and interpreting data concerning predesigned themes. In this type of analysis, the researcher can provide direct quotations in order to reflect the views of the participants. The primary purpose of this analysis type is to present the findings obtained to the reader in a summarized and interpreted form (Yıldırım and Şimşek, 2003).

The descriptive analysis consists of four stages. The initial step for analysis is *to create a conceptual framework*. In this research, this stage was elaborated in the preceding section. According to this framework, it was determined which data would be arranged and presented under which topic. Subsequently, the researcher read and organized the data based on the framework she had already created. This second stage is called *processing data according to thematic framework*. In this process, it was critical to combine the data in a meaningful and logical manner. For this study, since the data was obtained via tape recordings, they were first transcribed verbatim. Reading of whole data set and writing down understandings as memos were worthwhile in order to see the whole picture of study in question. After this initial reading, the initial editing of the data like omitting redundancies, repetitions, and insignificant digressions took place. The following step includes *identification of findings* in which the organized data is identified and supported by direct quotations where necessary. Eventually, the researcher explains, associates, and makes sense of the findings. This final process of analysis is called *interpretation of findings*. At this stage, the researcher also expresses the cause and effect relationship between the findings to strengthen her comments further and compare the different cases if needed (Yıldırım ve Şimşek, 2003).

In this study, since the researcher conducted multiple cases, she treated each case as a separate study. Moreover, cases were categorized as basic, specialty, and consumer chemicals according to firms’ active production areas. Doing this categorization enables the researcher to understand similarities and dissimilarities across cases. So in this study, in addition to descriptive analysis, cross-case synthesis (Yin, 2003) was applied at the same time. Yin (2003) emphasizes that the creation of word tables that show the data from the individual cases according to some uniform framework is an alternative tactic for the synthesis of a modest number of case studies. In this regard, the researcher used MS Excel in order to categorize the cases, to process data according to the thematic framework, and to generate word tables. All in all, interview data have been reported by using methods of descriptive analysis as well as cross-case synthesis. Moreover, figures and diagrams were formed to picture the relationships among cases and sub-sectors.

4.6 Methodological Limitations and Ethics

The first limitation of this research study is related to sample size. The researcher interviewed with fewer R&D centers than planned. While one reason for this limitation was that two firms did not make a positive return, the other one was to ethically eliminate one firm as it was the competitor of the R&D center where the researcher has been working. Six participants were selected by using purposive sampling which lacks generalizability. As mentioned previously, there are 51 R&D centers operating in chemical sector in Turkey. These R&D centers may have different experiences in terms of R&D and innovation activities than interviewed ones. So interviewing with R&D centers of six large companies may not permit generalization to whole Turkish chemical sector. Furthermore, ‘convenience sampling’ was applied in this study since the researcher works in the R&D department of one of the chosen cases. A sample of convenience is biased because the units that are easiest to choose are usually not representative of the harder-to-select or non-responding units (Lohr, 2010). However, only one of the sources was convenient so that limitations could be minimized. Apart from these, time was also a limitation of this research because data about R&D centers and their strategies could be subjected to change over time. In this study, a snapshot of the current situation of R&D centers in the data sample was reached despite the dynamic approach of sectoral systems. The participants gave the information, and their experiences might also be limited in the sense that they do not represent the whole population of chemical firms. Additionally, the description of the conceptual framework for the stages of data collection and data analysis may limit the inductive approach when exploring a phenomenon (Baxter et al., 2008). In order to safeguard against becoming deductive, the researcher shared her thoughts and decisions with other researchers to determine if her thinking has become too driven by the framework.

In this study, all field research instruments were submitted to the Human Research Committee of Applied Ethics Research Centre (UEAM) of Middle East Technical University (METU) for approval. Interviews were carried out after the ethical compliance of the research had been confirmed (see Appendix A). Before starting the interview, all the participants were compelled to sign a Voluntary Participation Form, which includes all necessary information about the research and confidentiality of firm and participant. The participants signed and gave back the document to the researcher during the interview. Only one of the participants wanted to take transcription of the recording after the interview in terms of confidentiality purposes. In order to make the participant feel relieved and comfortable, the transcription of recording was sent for review; the participant reorganized the information, and the researcher used this final transcript for data analysis. In order to preserve confidentiality, we used following codes instead of the firm names: “CHEM A”, “CHEM B”, “CHEM C”, “CHEM D”, “CHEM E” and “CHEM F”. Therefore, the research process was conducted by meeting the ethical requirements.

CHAPTER 5

ANALYSIS OF FINDINGS AND RECOMMENDATIONS

In this chapter, I will put forward and analyze, in light of the results obtained from the face-to-face interviews, the main findings of this thesis in terms of primary building blocks of R&D centers in the chemical sector (CHEMs) within the concept of SIS. Based on the findings, I define the areas of improvement in CHEMs as well as the chemical sector. Moreover, I present managerial recommendations (MR) and policy recommendations (PR) in order to ease the functioning of the chemical sectoral innovation system.

Table 24. CHEMs at a Glance

	CHEM A	CHEM B	CHEM C	CHEM D	CHEM E	CHEM F
Date of Establishment of the Company	1977	1949	1965	1976	1964	1987
Line of Business	Basic and specialty chemicals	Basic and consumer chemicals	Specialty chemicals	Specialty chemicals	Specialty chemicals	Consumer chemicals
Number of Personnel	850	1600	500	350	550	8000
Foreign Shareholder Status	None	None	None	Special partnership in different products	Equal partnership	None
Share of Export in Total Sales Revenue	25%	30%	70%	29%	5%	35%
Date of Establishment of the R&D Center	October 2013	December 2015	August 2009	January 2012	June 2014	January 2013
R&D Intensity	2%	1%	3%	1,5%	1,6%	0,2%

Source: Interviews with CHEMs

Some essential features of the six CHEMs who have been interviewed are given in Table 24.

In the remaining part of this chapter, I will first elaborate the knowledge base and technology of CHEMs, especially by focusing on their R&D and innovation projects. Actors and networks, as well as institutions, will be examined respectively in Section 5.2 and Section 5.3. The human capital infrastructure of CHEMs will be finally elaborated in Section 5.4. Interviews will be analyzed from a qualitative point of view.

5.1 Knowledge Base and Technology

As specified by the interviewed CHEMs, innovation in basic chemicals sub-sector necessitates know-how on organic and inorganic chemistry. Specialty and consumer chemicals sub-sectors have a more diversified product portfolio than basic chemicals. Specialty chemicals mostly need polymer chemistry as a scientific base, which shapes firms' know-how needs accordingly. In consumer chemicals, firms conduct interdisciplinary research in the fields of chemistry, chemical engineering, material engineering, bioengineering, and mechanical engineering. Scientific disciplines which are relevant to each subsector are shown in Table 25.

Table 25. Scientific Background in CHEMs by Sub-Sectors

Sub-sectors	**Relevant Scientific Disciplines**
Basic Chemicals	organic & inorganic & polymer chemistry
Specialty Chemicals	organic & polymer chemistry & materials science
Consumer Chemicals	interdisciplinary research such as chemistry, chemical engineering, material engineering, bioengineering

Source: Interviews with CHEMs

In specialty and consumer chemicals, heterogeneous demands of consumers prompt firms to expand their networks to reach external sources of knowledge. That is, consumers with heterogeneous demand necessitate the use of new technological know-how from various disciplines. Hence, the exchange of know-how between firms becomes critical. Firms strive for building-up networks with various agents such as the firms that operate in the fields of materials science and biotechnology and they expand their knowledge base through collaboration or know-how exchange with these firms. Expanding network and interacting with new firms that own newly required technologies are the two essential characteristics of firms in specialty and consumer chemicals. In order to implement new technologies, firms update the appropriate learning processes such as recruiting candidates from the new scientific fields mentioned above, participating to international congresses, exchange of know-how or collaboration with the firms in these fields. Further, firms continue to follow-up with the consumer expectations in order to recognize if there is a change in the market demand. Therefore, the heterogeneity in terms of the scientific base (polymer chemistry, materials science, biotechnology) of both sub-sectors also has implications for firms' learning processes and the needed scientific base, especially for product innovation.

5.1.1 Sources of Knowledge

A common statement issued by the CHEMs is that they use technical information from relevant literature, including publications, articles, books, etc. Therefore, technical literature has primary importance as a source of knowledge. Moreover, the majority of CHEMs interviewed underlined the significance of knowledge provided by raw material suppliers. Guilhon (2001) has mentioned that suppliers have technological know-how on the production function, and they use it for responding to immediate demands of customers. From the CHEMs' point of view, this situation is as follows: When a new chemical raw material with different specifications is present in the market, the relevant supplier provides technical information and firms need these suppliers' guidance in their decision to use that raw material in new product developments.

Customers were also mentioned as another noteworthy source for specialty chemicals, while consumer trends are critical for consumer chemicals. Customer demand may change in time, and it may require new product development activities, so especially firms in specialty chemicals need information from their customers.

National and international fairs, which bring together many actors in the sector, were also mentioned by especially basic and specialty chemical firms as a source of knowledge since it provides interactive ways of communication and creates a knowledge-sharing environment. For consumer chemicals, CHEM F stated the need for interaction through processes of communication, exchange, and cooperation through international research clusters, and conferences.

Networks (interactions) established with universities are not as important as other sources of knowledge for the majority of R&D centers interviewed. CHEM A claimed that there exists communication with universities, but it does not give concrete output. According to CHEM A, one of the most important benefits of the university was having access to libraries for journals and articles, while CHEM B ranked universities third as a source of knowledge since they provide consultancy services. From the consumer chemicals point of view, collaboration with universities in product development projects is not convenient because of disputes in commercial rights. In this respect, CHEM F stated that their interaction with universities was mostly in the form of consultancy and that the analytical approach of an academician was vital for them in TÜBİTAK or EU projects.

Guilhon (2001) has remarked that knowledge can be embedded in a product, and firms can conduct reverse engineering if there is an unpatented innovation in the market. R&D centers operating in specialty and consumer chemicals make use of reverse engineering as one of the channels of knowledge transfer. In this regard, CHEM F stated that examining competitor firms’ products was critical for them in order to compete with world giants like P&G, Unilever, Henkel, etc.

Only CHEM C mentioned the importance of internal sources within the enterprise as a source of knowledge. She expressed her case by saying:

> *We have an innovation academy designed for creating a favorable atmosphere for the exchange of ideas and brainstorming activities. We organize events and generally host external speakers from different disciplines. We particularly prefer to invite non-technical speakers because our employees have already got the required technical background. The academy is open for all of our employees to exchange their ideas and also to expand their creativity and vision.*

Table 26. Ranking of the Sources of Technical Knowledge by CHEMs

CHEMs	Position 1	Position 2	Position 3
CHEM A (Basic & Specialty Chemicals)	Literature: Publications, articles, books & patent disclosures	Raw Material Suppliers	Fairs/exhibitions
CHEM B (Basic & Consumer Chemicals)	Literature: Publications, articles, books & patent disclosures	Raw Material Suppliers	Universities
CHEM C (Specialty Chemicals)	Literature: Publications, articles, books & patent disclosures	Customers & Suppliers	Internal sources: within the enterprise
CHEM D (Specialty Chemicals)	Literature: Publications, articles, books & patent disclosures	Universities	Raw Material Suppliers
CHEM E (Specialty Chemicals)	Raw Material Suppliers	Literature: Publications, articles, books & patent disclosures	Universities
CHEM F (Consumer Chemicals)	Literature: Publications, articles, books & patent disclosures	International conferences, meetings	Reverse-engineering, competitors in the same line of business

Source: Interviews with CHEMs

Table 26 shows the three most used knowledge sources for R&D centers interviewed.

Turkey remains weak in terms of patenting of technology when compared to developed countries such as the US, China, Japan, and European countries. Patent grants by technology and origins are presented in Appendix D to compare Turkey with developed countries. In line with this fact, a common argument repeated by all CHEMs was that they are behind their multinational competitors in terms of publications, patents, and other literature outputs. "*In Turkey, the number of patent applications and patents granted are minute amount. When we do literature search for patents, obviously we do not look at Turkey-originated ones*," said CHEM F in support of this argument.

According to Meyer-Krahmer et al. (1998), university-industry collaboration with an emphasis on more open interaction types since the 19th century and considerable focus on basic research at universities for chemical industry ended up with a high number of university-based patents in chemistry. In this sense, CHEM E commented that collaboration between the chemical industry and university is weak, and it can be one of the main reasons why Turkey is underdeveloped in patenting in chemicals.

In the scope of consumer chemicals, CHEM F went on: "*We mostly observe patents that belong to individuals*", and in the scope of basic chemicals, CHEM B stated that "*There may be a limited number of publications from theses in Turkey. This may be due to weak interactions between the academic environment and chemical industry."* In line with these comments, the subsequent sections will explain why interactions and collaboration with universities are weak.

5.1.1.1 Managerial Recommendations for Diversifying Knowledge Sources and Dissemination of Knowledge

MR 1: Firms should attend conferences to be informed about recent developments in scientific field and to expand their knowledge

Chemicals sector by its nature has a science-based ecosystem; therefore, scientific literature is the primary source of knowledge for innovation, as expected. The findings from the interviews show that CHEMs often access existing codified knowledge in the scientific literature. Yet, it is seen that they do not attend conferences enough. Conference attendance is another way to acquire the knowledge needed to produce the innovation (Guilhon, 2001). Firms need to be informed about recent developments both in their field of operations and beyond their interests. New techniques, new types of equipment or unpublished data presented in conferences can expand firms' knowledge and give the opportunity to find new solutions to problems. For example, by attending national chemistry conferences or related international conferences, firms can hear about the multidisciplinary projects and different ideas can be a great inspiration for their own research.

MR 2: Consumer and specialty chemicals firms should expand their international networks to create opportunities for know-how exchange

According to interviews, specialty and consumer chemicals firms need heterogeneous know-how from various sources. In this sense, it is essential to build up networks with various agents that operate in chemistry or related sectors. These sub-disciplines may include biotechnology, nanotechnology, materials science, and so on. Cooperation with a wide variety of agents and exchange of know-how seems crucial as these both consumer and specialty chemicals require interdisciplinary research capabilities. Firms in both sub-sectors should put continuous efforts in building-up networks within international conferences for know-how exchange.

Also, such networks may lead to further cooperative initiatives of the firms that communicate through international research clusters.

5.1.2 R&D and Innovation

In the interviews, R&D centers were asked about the main subject of their projects. All of them indicated that R&D projects comprised product or process development projects within the firm’s field of activity. Table 27 shows the main activities of CHEMs and their products for which they conduct R&D projects.

Table 27. R&D Activities of CHEMs

CHEMs	Field of Activity and Products	Types of R&D
CHEM A	Organic and inorganic basic chemicals: chlorine alkali and derivatives, peroxides, methylamines... Performance chemicals: textile auxiliaries, pulp&paper chemicals, construction chemicals... Life sciences: a small-sized research team is conducting a few projects	Applied research & Experimental development
CHEM B	Inorganic basic chemicals & pesticides: marketed in bulk form Cleaning products: marketed as end products for consumers	Applied research & Experimental development
CHEM C	Raw materials: Polymer emulsions, construction chemicals, textile auxiliaries, industrial adhesive solutions	Applied research & Experimental development
CHEM D	Wood coatings, architectural and industrial paints	Applied research & Experimental development
CHEM E	Water based decorative and industrial paints	Applied research & Experimental development
CHEM F	Fast-moving consumer goods Home care:Laxatives, cleaners... Hygienie: diapers, feminine hygiene products... Tissues: paper towels, toilet papers and napkins	Applied research & Experimental development

Source: Interviews with CHEMs

All CHEMs conduct mostly applied research and experimental development studies with the intent of an output which can be introduced into the market. The objective of product commercialization leads to a situation where consumer demand shapes the research projects in firms' R&D laboratories. So it can be said that basic research studies are not conducted very often in the industry. "*In the field of basic chemicals, basic research is rarely conducted within universities. However, I think that in the industry, nobody does science for science!"* claimed CHEM B.

<u>Objectives of R&D Projects:</u> The main objective of CHEMs' R&D projects is to develop new products/processes or an alternative to an existing one in the sector or to improve an existing output. For specialty chemicals, CHEM C stated:

> *The first aim is to meet customer demand. We need to increase the performance and quality. The second one is the product cost. Our business needs financial sustainability. The third one is compliance with regulations; we modify our processes for the benefit of the environment, human health, occupational health, and safety.*

All CHEMs mentioned that their main aim was to develop new products. New product development projects range between 40-90% of their R&D efforts. In basic chemicals, new product development projects are in the foreground. The primary purpose is to develop chemicals that are not produced locally. For that reason, firms in basic chemicals allocate nearly 90% of their R&D efforts and resources to new product development studies.

In specialty chemicals, firms that produce intermediate product allocate 60% of their R&D efforts for new product development; on the other hand, firms producing end products such as paint devote their 60-80% of their R&D studies to improve existing products and find alternatives to existing raw materials. That is, these firms aim to find alternative raw materials with higher performance or lower cost and they perform compatibility analysis in order to confirm if the alternative ones can be used within current processes.

In consumer chemicals, R&D projects are intended to develop new products. So, CHEM F claims that 70% of their R&D studies are related to the development of end products. To this end, firms strive for incremental development or development from scratch. CHEM F elaborates such developments through following:

> *The studies vary in terms of timewise and budget. In budgetary scope, 90% is allocated to a new product; in terms of duration and the full-time equivalent of R&D projects, 50% is allocated for new product development (new to sector), and the other 50% is allocated for product improvement.*

Outputs of R&D Projects: The main output of R&D projects in all interviewed CHEMs is commercialized products in the form of the sales of new or improved chemical products. These products can be intermediary or end products which are expected to contribute to total revenue. Profitability is also appreciated, so cost efficiency is also a key outcome. "*Our firm's aim is profitability. Top management expects from R&D center that new products and new plants come into operation*" says CHEM B. A new product necessitates new production line through a solid production planning. Building a new plant also necessitates a new production capacity for the product of interest. Nonetheless, implementing the production processes for a new plant is another critical milestone. As a consequence, new products, newly implemented production and test processes, newly created production capacity are the outcomes of successful product and process design projects for basic chemicals sub-sector.

Patent applications or granted patents are also significant outputs of R&D projects. Table 28 illustrates the number of patent applications done by CHEMs and their granted patents. Although the number of granted patents is scarce, all CHEMs indicate that they work on patent applications and aim to increase their number. Being an R&D center and pressures made by the Ministry of Industry and Technology have a significant impact on this increase. "*After becoming an R&D center, we had about five patent applications. We have not applied for a single patent before that. Being an R&D center led us forward in this regard*," says CHEM E.

CHEM F makes an additional comment on patent applications and highlights the importance of managers' viewpoint on this issue:

> *In the last two years, we have had nearly 25 patent applications. This is mostly related to a management change; our new manager perceives patent application as a strategy. Besides, government incentives such as 1602 Tübitak patent support program have also increased the number of patents.*

Table 28. The Number of Patent Applications and Patents Granted in CHEMs

	CHEM A	**CHEM B**	**CHEM C**	**CHEM D**	**CHEM E**	**CHEM F**
Patent (application)	3	2	4	-	3	34
Patent (granted)	-	1	2	-	2	1

Source: Interviews with CHEMs

In the relevant literature, licensing on chemical processes and licensing revenues are regarded as the output from process innovation (Ren, 2005). However, none of the CHEMs mentioned licensing activities or licensing agreements as an output of their projects. "*Patenting, licensing, and publishing activities are very limited. We generally prepare posters for conferences and technical writings regarding our products for sectoral journals*" expressed CHEM C. CHEM E and CHEM F also stated that they started to prepare presentations and posters for sectoral congresses after becoming R&D center.

"Market-pull" and "technology-push" concepts are significant sources of innovation. The former implies innovations developed as a response to customer demand, whereas the latter shows exploitation of a research-based technology whose market value was not yet established in the area in which innovation was being considered (Ashford et al., 1983). Empirical researches indicate that both are critical in order to innovate in chemistry. To illustrate, the study by Freeman et al. (1968) of 810 innovative chemical processes demonstrated that the user was the source of information for 70 percent of these innovations, while merely 30 percent of the ideas came from the innovating firm. According to Von Hippel (1988), the likelihood for the success of innovation increases when there is an interaction with customers.

Table 29. Ranking of Driving Forces for R&D Center Projects by Sub-Sectors

Sub-Sectors	Position 1	Position 2	Position 3
Basic Chemicals	creating first-mover advantage in the market	meeting customer need	providing cost advantage
Specialty Chemicals	meeting customer need	becoming the leader	providing cost advantage / improving product quality
Consumer Chemicals	becoming the leader	meeting customer need (consumer trends)	competing with other companies

Source: Interviews with CHEMs

Table 29 indicates the factors that lead CHEMs to conduct innovative projects according to priority ranking in the sub-sectors. In the interviews, it was mentioned that firms are keen on conducting customer-centric projects, and that is why they conduct experimental development projects. These projects are mostly shaped by market demand; all firms maintained that needs of customers shape the innovation and CHEM A said:

> *Sales and marketing departments have assessments regarding customer demand and our SWOT analysis. When starting a new product, we certainly ask them. After persuasion of all decision-makers, we start the new product design process.*

Both of the CHEMs in basic chemicals mentioned the importance of the first-mover advantage. Nevertheless, CHEM A expressed that when a competitor launches a new product, they assess the accessible market size of the product segment and decide whether or not to launch a similar one, but this is a rare case.

Moreover, CHEM A indicated the following innovation pillars for the firms in basic chemicals such as “creating a competitive advantage”, “increasing cost efficiency”, “being more eco-friendly”, “reduction of energy consumption”. At this point, it is noteworthy that reducing energy consumption is of particular significance for the production of basic chemicals because an essential percentage of their costs is associated with energy usage (Albach et al., 1996).

Being the market leader is also as important as fulfilling consumer demand, and CHEM B went on stating that "*both market demand and being the market leader are important, the top management knows the market dynamics*". When deciding to start a new product development project, market demand is the most critical factor to consider. Firms calculate the return of investment through anticipating high sales volumes with affordable price. In that sense, we can conclude that firm's understanding of market dynamics shapes the innovation in the basic chemicals sub-sector. Indeed, it also applies to specialty and consumer chemicals.

Likewise, meeting customer need is indicated as the triggering factor that stimulates R&D projects in specialty chemicals. In this subsector, innovative activities of CHEMs are always centered on demand, so that this sub-sector is considered customer-centric and demand always shapes firms' innovation strategies. Enhancing quality performance and providing cost advantage are essential components of R&D projects in the specialty chemicals since they affect customer choice. At this point, CHEM E clarifies: "*If you are in a more appropriate position in terms of both quality and price, you are preferred.*"

R&D and innovation projects in the field of consumer chemicals are mostly shaped according to "trends in the world" and "consumer habits or preferences". Herein status of competitors is also critical. In general, the target of becoming the leader or being the first stimulates innovation and increases R&D activities. CHEM F also noted:

> *If an improvement in a product is greater than 30% (in terms of performance and cost), we call it an innovation. Other projects are considered kaizen (continuous improvement), rather than innovation. In this respect, I would say that process improvement takes place, but not process innovation.*

The types of innovation mentioned by CHEMs and their main objectives are summarized in Table 30.

Table 30. Types of Innovation by Sub-Sectors and Related Objectives

Sub-Sectors	Product innovations	Process innovations
Basic Chemicals	New product development (new to Turkey and new to firm innovations)	Improvements in manufacturing process and existing product (using new feedstock, reducing product design costs, reducing environmental damage, reducing energy consumption)
Specialty Chemicals	New product development (new to firm innovation)	Improvements in manufacturing process and existing product (enhancing quality, using new feedstock, reducing product design costs, reducing environmental damage)
Consumer Chemicals	New product development (new to Turkey and new to firm innovations)	Improvements in manufacturing process and existing product (enhancing quality, using new feedstock, reducing product design costs, reducing environmental damage)

Source: Interviews with CHEMs

Radical and Incremental Innovation: In Schumpeter's view, "radical" innovations are related to the concept of "creative destruction" which implies innovation through a dynamic process in which new technologies replace the old. While radical innovations generate significant disruptive changes, "incremental" innovations continuously develop the process of change (OECD and Eurostat, 2005). The question of whether scientific development triggers innovation or vice versa has been controversial in the history of science and innovation literature. Achilladelis (1990) showed that in the chemical industry, they occur simultaneously. He also stated that "*The spark that set the motion was in most cases a radical innovation which was introduced when the scientific knowledge on which it relied was only partially available and market demand was neither gauged nor firmly established" (p.25).*

All CHEMs have a consensus that the majority of studies performed in R&D centers are composed of applied research and experimental development studies which result in incremental innovation.

In basic chemicals, firms mostly conduct incremental innovation activities through process development. R&D directors in basic chemicals expressed that innovation is most likely to be “the very first” for the sector in Turkey. This is well reflected in the director’s explanation from CHEM B:

> *In Turkey, it occurs seldom for a firm operating in basic chemical sub-sector to replicate a locally produced product. For example, in case the firm does not have the product of interest in its portfolio, and another local firm is producing it, the firm does not consider entering such a saturated market. Rather the firm focuses on the incremental innovation studies on their existing products. Mainly, there are R&D studies conducted to develop a new product, which has not been locally produced in Turkey. Namely, this is an innovative initiative for both firm and Turkey.*

Basic chemical firms state that they always assess potential market size for related product segments and shape their R&D strategy according to the market needs. Additionally, the studies for innovation are not aimed to bring new processes, but new products into the market. Existing process development studies are conducted to implement incremental innovations.

Moreover, in specialty and consumer chemicals, mostly incremental innovation through product development is conducted. CHEM C states, “*There are not many innovative products in the sector. Products are most likely to be developed in order to solve a particular problem such as mechanical stability or material durability*”. In addition to that, R&D centers in specialty chemicals have the objective to conduct research studies for drastic innovation, but this effort comprises a small percentage of their overall effort, and CHEM D went on: “*Even if we want to make a radical innovation, most of the time, the domestic market does not seem to be ready for this, so that drastic innovation is not possible*”. CHEM E made a similar comment about this phenomenon:

> *We have a research study on a self-healing product. The product will be valuable, but costly, and the future demand is unclear. Moreover, we launched a new product a few years ago, we claimed that 'first in the world', so the product* was innovative, but the sales results were too low. In fact, market failure might result not only from high product cost but also from ineffective product promotion. So introducing a new product into the market requires a robust collaboration with the marketing department.

From the specialty chemicals viewpoint, CHEM E stated that there were times when excellent products were not sold, and this caused discomfort. CHEM C also stated that almost %7 of total R&D studies resulted in breakthrough innovation and went on: "*it is hard to convince both internal and external stakeholders for radical innovation.*"

CHEM F claims that there are limited new product development studies and are composed of 2-3% of total R&D activities because such activities are costly. That is why both local and global firms in consumer chemicals spend all R&D efforts for imitative or 'me too' studies. CHEM F further elaborates the issue with an example from the pharmaceutical industry:

> *New molecule development costs 5 billion dollars, and that is why local firms do not intend to develop one. The firm must sell the product to 100 countries in order to compensate the cost, not to mention the fact that it requires regulatory and sales network. Firms rather prefer to produce generic products, and it also reduces dependence on other countries. This example also applies to the chemical sector, and Turkish firms are good at conducting incremental innovations and adapting it to their business. Conducting drastic innovation brings together technical and commercial difficulties.*

According to all CHEMs, the system in Turkey does not favor breakthrough innovations. In all sub-segments, the return of investment is a crucial fact in considering R&D investments. There is a high likelihood that the return of investment would not compensate for the R&D costs of a high-end product in both sub-sectors.

Organizational Structure Affecting Innovation: Ogbonna and Harris (2003) state that several challenges in business environment force firms to review and adapt their organizational structure in order to cope with the difficulties, to keep a competitive advantage within the sector, or to improve efficiency. In line with this information, the Oslo Manual (OECD and Eurostat, 2005) describes organizational innovation with various examples. Some of them are as follows: The implementation of new practices to develop learning and knowledge sharing within the organization; the implementation of new practices for employee development and improving employee retention; the implementation of new methods in a firm's external relations.

In the chemical industry, market needs and regulations may shape firm structure (Ashford et al., 1983). According to interviews with CHEMs, the most common organizational innovations in R&D centers are creating new job descriptions and the establishment of new types of collaborations. It has been seen in all CHEMs that new positions have been opened to manage the R&D center process and this position did not exist before.

According to CHEM A, it is almost impossible for firms to have the same levels of technical knowledge and laboratory infrastructure with that of universities. In this context, they have collaborated with a particular university and built up a joint research and application center in order to implement co-development projects and to utilize university facilities (laboratories, equipment, services) that did not exist within the firm.

CHEM E also underlined the effect of having a partnership with a foreign firm on their R&D projects:

> *In collaboration with our foreign partner firm, we are building up our own technology transfer office, and this office will contribute to assessing new projects. For example, we may conduct R&D studies for new products that have no market demand currently. Through such TTOs, we will be able to commercialize such products in other countries.*

It was concluded from the interviews that the human resources department mainly manages organizational structure, and the organizational structure of the R&D center usually changes with corporate strategy. To be more precise, external relations and the importance given to the number and quality of employees in the R&D center changes when the top management changes; the firm collaborates with other firms or research centers; and especially family firms (such as CHEM A) undergo cultural change such as reducing closeness and warmth of the family businesses during the transition to corporate structure.

Trends for the Future: CHEMs were asked about which innovations would gain more significance in the future. Common argument repeated by all CHEMs interviewed was that bio-based, water-based products or environmentally friendly products would come into prominence shortly. From that point of view, such transformation will require new regulations and policy changes as well.

> *While 30 years ago there was no packaged food, many of us today have those routinely. Soon, there will be a huge packaging sector for foods to be consumed by heating in the microwave. The packaging industry will grow a lot, so we think that the plastic additives we work with will grow as well. In the sector, there is a tendency towards green chemistry. Bio-based and biodegradable products are the new trend in the market. Year over year, water becomes more important; the products that are developed for water will be trendy. As life conditions change, new products will be demanded, and countries will place more importance on chemistry R&D shortly (CHEM A).*

CHEM D also made a similar comment by saying that water-based, nature-friendly, waste-reducing, environmental, and organic products would gain importance. "*Examples include developing a variety of renewable products, such as developing a varnish using eggs. It will be costly at first, but its cost can be reduced over time by joint efforts of R&D and marketing,*" she explains.

From the consumer chemicals point of view, CHEM F also stated his foresight:

> *When we look at the sector roadmap, the issues that will gain importance vary according to the country and products. In terms of general trends, comfort and ease of use in diapers, zero chemical technology with only cellulose in paper, original content in detergent and the use of raw materials that degrade quickly in nature will be the innovations of the next 5-10 years.*

CHEM C also touched on the importance of the agents in downstream markets such as the firms which are operating in the business to customer (B2C) commerce. “As per we are the producer of raw materials, our customers’ innovative activities and preferences are more important,” she states.

If relevant regulations are identified and the market is ready, it is seen that CHEMs can carry out R&D and innovation studies according to new trends. Demand is critical for conducting such projects. Because of its high cost and inadequate demand, developing such products is not currently priority of CHEMs.

5.1.2.1 Managerial Recommendations for the Enhancement of R&D and Innovation Infrastructure

PR 1: Incentives for localization of basic chemical products should be increased

Product development studies dominate the projects in CHEMs. All of the CHEMs, without any exception, allocate all of their resources to applied research and experimental development studies. Basic chemicals firms focus on the innovation of products which do not have an alternative in Turkey. The goal of their R&D projects is to produce a new chemical and to build a new plant for the production, therefore they give prioritization for the development of products which do not have an alternative in Turkey.

Imported basic chemicals products create external dependence and economic burden for Turkey. In order to overcome such a situation, the government should encourage especially basic chemicals firms in localizing these products through innovation and technology transfer activities. In order to localize currently imported basic chemicals products, the government should offer attractive incentives. That might accelerate R&D projects, thereby reducing foreign dependency. The government should follow-up with the local firms which have the potential to produce novel products for Turkey, and should also follow-up with the multinationals which already produce such products. Furthermore, the government should encourage local firms to collaborate with these multinationals for the technology transfer and to increase the allocated budget for the R&D projects aiming to develop high-demand products.

MR 3: Firms should invest in the market research studies to better follow up with the market demand

Some R&D activities are intended to fulfill customer demand in terms of performance, quality, and introduction of new product features. Customer centricity is one of the most significant objectives which shape the R&D strategy of the CHEMs. In Turkish chemical industry, R&D projects are largely shaped by market demand, so we can conclude that firms follow a market-pull strategy rather than technology push.

As consumer chemicals firms produce end products, end-user demand is one of the most critical factors that shape R&D projects. Consumer demand changes over time, consumer chemicals firms need to invest in the market intelligence through allocating personnel or forming new departments dedicated to this task. Such departments may put effort on following-up the consumer demand and focus on strengthening internal feedback mechanisms through cross-collaboration between R&D, procurement, marketing, sales, business excellence departments as well as top management as the strategy owner. Practical usage of internal resources and a feedback mechanism centered around these departments would lead to maximizing the potential of the firm in recognizing and improving the know-how. Such organization may also be beneficial for basic and specialty chemical firms that give importance on customer behavior.

MR 4: Firms should do customer segmentation and set up its innovation strategy based on the dominant segment

The firm should classify users in terms of behaviors. There are three main customer types related to the innovation context (Malerba, 2006):

- Standard customers
- Experimental customers
- Customers in new demand segment

Standard customers focus on the established products, and their specifications are performance and price. If this customer segment dominates the customer mass in the market, the firm should focus on decreasing the product margin costs through optimization studies on the production processes. Such innovation will increase the profit margin of the product, which enables the marketing department to set a competitive price for the product to outrun the competition.

Experimental customers look for new technological features on existing products. If this is the dominant segment in the market, the firm should set the R&D strategy on incremental innovation projects on the development of existing products.

Customers in new demands segment focus on new products. If the dominant segment is the ones who look for new products, the firm should allocate R&D budget for drastic innovation projects, and also should initiate collaboration with multinationals for technology transfer activities.

MR 5: Firms should implement robust project evaluation methodologies to receive early-signals for possible failure in their drastic innovation projects

Other objectives of CHEMs' projects are the reduction of the product cost and compliance with regulations through a change of process. Profitability is a significant measure of success, and the top management seeks for opportunities to increase the profit margin of the portfolio. Return on investment should compensate for the R&D costs so that the cost of goods sold increases and reflects the product price. The increased price would result in a low number of sales, and in consequence, the R&D project fails to contribute to company growth. In general, that is the reason that firms avoid to conduct drastic improvement.

In that sense, companies should not stop seeking opportunities for drastic improvements, but rather should implement a robust project evaluation methodology to assess the project success over time (For instance, implementing stage gate approach including multiple project milestones acting as checkpoints*)*. In case a change in the project status, which gives early-signals that the project will not bring the expected sales numbers, the project group shall decide between the change of project direction or early exist. By doing so, firms may avoid unnecessary R&D expenditures and use their R&D budget more efficiently. Further, such process streamlines the innovation process.

MR 6: Firms should open alliance management department

Raw material suppliers are one of the essential sources of knowledge since they provide technical information on the recent updates of their product portfolio. Conducting joint projects with suppliers will increase the dissemination of knowledge.

R&D centers cooperate with local and multinational suppliers, and apparently, most of them have stronger relationships with the local ones than multinationals, due to the communication advantage. Such a relationship has some implications for building-up commercial networks. For example, firms in basic chemicals sell intermediaries to the specialty chemicals firm, and this would create a chance for conducting collaborative projects. This would generate an in-market interaction between two essential actors in the market. Further to that, we suggest firms to build-up specific departments to undertake the alliance management and project management roles through such collaborative initiatives. By doing so, firms might trigger the exchange of know-how through particular point-of-contacts. Such an exchange of know-how might expand the firms' vision, and it seems like a very natural and organic way of increasing the knowledge base.

MR 7: Firms should create a research consortium to collaborate for radical innovation and know-how exchange

Majority of the projects comprise of applied research or experimental development studies with the intent of incremental development of the products in the portfolio. In order to conduct projects aiming radical innovation, firms should always increase their knowledge base. A favorable innovative landscape is the one in which all the actors are intended to exchange their know-how. This must be a common habit of firms in all sub-sectors. Mostly, drastic innovations are the ones with the highest risk of failure that require high R&D spending. In this sense, firms that have a typical specialty might develop a consortium in order to fund and conduct a joint project. Through such collaborative initiatives, firms will gain the power to take risks with pooled budgets.

Two of the CHEMs interviewed applied building up internal organizations to strengthen the cooperation between stakeholders and also the exchange of know-how. Inspired by these initiatives, we suggest that firms can build up product-specific innovation project groups from various departments to induce cross-collaboration inside the organization. These groups can also be included in the strategy development sessions in order to be in line with the priorities of the top management. Another initiative can be building up a technology transfer office, which mostly operates internally to strengthen the exchange of information between the subsidiaries and headquarters in large companies. Accordingly, TTO can be externalized to enable the exchange of know-how with other international companies. Building-up a joint R&D organization with a university may also bring greater future success, depending on the knowledge base and future potential of the university. Such collaboration creates an opportunity for academicians to understand the sectoral needs and also to increase their business acumen. With all these initiatives, firms may follow up with new market trends and technological trajectories.

PR 2: Green-related jobs and skills should be identified and standardized; stakeholder awareness and knowledge base regarding bio-based, greener technologies should be increased

PR 3: Universities and faculty members should also be encouraged for conducting applied research studies related to this issue through incentive mechanisms.

CHEMs stated that bio-based, water-based, i.e., environmentally friendly products will be among the highest priorities of R&D centers and will require the transformation of production and R&D processes. Developments in the EU and among leading multinational chemical companies are driving interest in cleaner technologies, including green chemistry. It is becoming clear that eco-friendly technologies will play an increasingly important role in R&D and innovation activities in the chemical industry. This will require new regulations and policy changes so that firms and decisive bodies shall increase their knowledge base on bio-based and water-based technologies in order to produce, innovate, and regulate. A broad array of stakeholders should handle the co-evolution of the sector into a greener environment: public representatives, economic, social and environmental experts, employers, NGOs, and career guidance institutions. Actors operating in downstream markets should also adapt to this transformation.

According to green policy objectives and the economic findings on evolutions in employment and skills requirements in Turkey, the government should identify the needs and priorities for developing green-relevant jobs and skills through working cooperatively with other stakeholders. The government shall provide incentives to the companies which set up their strategies on bio-based, eco-friendly products or processes.

Both governmental and non-governmental organizations should put an effort to increase the knowledge base and the number of research studies on eco-friendly technologies. If knowledge base on the greener-technologies increases, local producers as well as universities will become more competitive in the global market. When an output of state-funded project turns to a product for commercialization, the inventor should be rewarded through royalty payments and the lower limit of the percentile of royalty payment in the total product sales revenue should be clearly stated in the relevant law.

5.2 Actors and Networks

5.2.1 Primary Actors

Producer and supplier firms in the private sector, as well as government and the universities, are considered as the main actors of the chemical sectoral innovation system. Users and customers are also influential on the demand side; however, their role and significance vary depending upon sub-sectors.

All CHEMs also consider their employees as an actor within the firm. Researchers in R&D centers have a vital role in the R&D and innovation strategies of firms since they turn an idea into a product. Production, purchasing, marketing, and sales departments are other components in the process of innovation. Customers are also essential, especially for B2C firms.

The Role of Firms: In specialty and consumer chemicals, firms in the private sector are considered as the main actors in innovation. Mainly, inter-firm competition, which was previously explained as one of the main interaction types of firms, drives the development of the sector.

It is worth mentioning that there are competitors in all three sub-sectors, but the intensity of competition differs according to the particular product segment. CHEM B claimed that there were few competitors in their product segments in basic chemicals. Moreover, CHEM A explained the competition landscape through the following; "*There are tens of competitors in some of the product segments; however, there are a few in other segments. Segments which have low technology barrier such as paper include a large number of competitors; on the other hand, other segments include few numbers of multinational producers*".

Basic chemicals are an oligopolistic sub-sector in Turkey, with a limited number of large producer firms and low competition intensity. When a large firm introduces a product into the market, other firms assess the future potential of the market size and do not enter the same segment. With this respect, CHEM B stated that it was a rare condition for a large firm to produce a product which was already marketed by another firm.

The situation is different in consumer chemicals in Turkey since there is intense competition, and large multinational companies compete with each other. Exporting firms also compete in the global market and shape their R&D strategy based on global demand.

The Role of Universities: Universities mostly provide consultancy services or test analysis for the chemical sector. Priorities of universities are different from that of firms. CHEM B claimed that unlike universities in Turkey, universities abroad conduct R&D activities in chemistry. He said there were a small number of faculty members who have a sector-oriented mindset In Turkey, and made an additional comment on that point: *"When faculty members do not have an interaction with the industry, their graduates also become distanced to the industry".*

Universities have a critical role in training qualified human resource needed by the sector. However, CHEM B complained about a fall in the quality of newcomers.

This situation affects negatively the knowledge base of the sector. CHEM B explained:

> *We observe that the quality of the new graduates is decreasing year by year. In case these graduates become academicians in the near future, the quality of academicians may also decrease. It is not nice to say, but that is the truth.*

According to CHEM C, universities in Turkey are mostly introvert; they need to be extrovert and international. She explained well her experience and opinion:

> *Last year, we made a speech in the National Chemistry Conference hosted by METU. It was a deplorable experience since there were very few participants. This might be due to the fact that it was not international. Secondly, September might not be the right time for organizing a conference. Such conferences should also be thought of as networking. Universities need to think like the private sector. I certainly agree that they aim to produce knowledge and provide with an education; on the other hand, they have to consider that their graduates will work in the private sector. It is a rare condition that research studies in the universities turn into patents. Academicians mostly publish notice and articles, but they do not focus on the applicability. Theoretical studies are a must, but as I said, it should contribute to the private sector as well. There are plenty of chemicals produced in the world, so why can't we?*

CHEM F complained about the lack of innovative approach in the university as below:

> *The main problem of the university is that they act with the approach like 'explain your problem', but R&D centers like us – having 100 employees with 40 PhD degrees- can solve their problem. I think universities must be keen on conducting the basic research for the development of disruptive technology, such as 'I have a new molecule study with super-absorbent potential, I did the lab-scale studies and I want to improve it for you'. Unfortunately, it does not work that way in Turkey and universities generally want to give consultancy services.*

The Role of Governmental Organizations: The role of government varies depending upon sub-sectors in the chemical industry and the business units of each sector. In this regard, CHEM A told his experience of basic chemicals:

> *Government is the most critical actor in tender-type-of business like concrete additives. In basic chemicals, international trade laws, quota, tax, import regulations come into the forefront. While foreign multinational firms like Croda and BASF are the biggest actor for some products, Chinese firms can be a major actor for others. Therefore, the role of government and private firms changes from product to product.*

In all sub-sectors in the chemical industry, the Ministry of Industry and Technology is positioned as a leading policy-maker, and its subsidiary TUBITAK encourages R&D activities through funding R&D projects and plays a crucial role in determining the innovation policies. Ministries of Economy and Development also play a supporter role through stimulus packages. Nevertheless, such support has a minimal impact on the firms in consumer chemicals because they compete with large firms with considerably high R&D budgets. Increased R&D budget creates an advantage because it accelerates the R&D processes and leads to an earlier time to market opportunities for the end products. Therefore, competing with large multinational firms is very difficult with limited financial support. In such circumstance, CHEMs often use their budget, and they are not much in expectation from governmental organizations.

CHEM B described government organizations in the chemical sector in Turkey through following example from the cinema industry: "*Ministries shall be considered as not a headliner like a firm in the private market, but a director.*"

Public Health Directorate of Turkey plays an essential role in the context of the regulation on biocidal products and also the registration of these products. In addition, when building a chemical production facility, Ministry of Environment and Urbanization comes into forefront, especially in basic chemicals sub-sector. The ministry plays a vital role in the implementation of the REACH regulation.

This regulation imposes the obligation of registration for both locally produced and imported chemicals. Such an obligation expands the role of the Ministry of Environment and Urbanization on avoiding chemicals' adverse effects on the environment. In this regard, KKDİK (Kimyasalların Kaydı, Değerlendirmesi, İzni ve Kısıtlanması Hakkında Yönetmelik), also known as Turkish REACH in the sector, is being designed by this Ministry. REACH regulation will be elaborated in section regarding institutions.

5.2.2 Interactions and Collaboration Projects

Formal or informal interactions between actors can take place in a market or non-market-related context, and such interactions and collaborative networks play an essential role in the development of industries. In general, such networks enable firms to get benefit from others' competencies, know-how, and expertise (Edquist, 1997). Furthermore, the collaboration between firms, universities, and research institutes are considered as one of the most important sources of innovation (Nelson, 1993). According to findings obtained from interviews, collaborative research studies exist in all three sub-sectors, but firms complain about the limited collaboration between firms and universities: The difference between the priorities of the university and that of the firms is a crucial factor. In the same way, CHEM C has an explanation for the differences in terms of goals between industry and university: "*In our joint-project, the university ended the project on its own after conducting lab-scale studies. For university, publishing an article is usually more important than developing an end product in an industrial scale*". Paint industry differs on this point since firms in this sub-sector are conservative, intending to preserve their trade secrets so that they are not keen on such collaborations. Specialty and consumer chemicals firms also have collaboration with suppliers. Some CHEMs do not tend to partner with universities due to disputes in royalty payments.

As mentioned before, collaboration with universities is essential for increasing firms' knowledge base in the chemical sector. All CHEMs are aware of the importance of university-industry collaboration; however, it is evident that there are some communication problems. In this respect, CHEM A envisaged a transition model in which firms and universities collaboratively develop and produce a product, and share its revenues. As previously mentioned, they actualized this idea by establishing joint research and development center with a university.

According to CHEM F, university-industry interactions are enhanced with the support of technology transfer offices (TTOs), but CHEM C does not find it sufficient and emphasizes weak interactions with universities as well as TTOs:

> *I value universities-industry collaboration; however, I do not know the way of such collaboration. TTOs seem to be interested, but they position themselves with only limited contribution like 'support on patenting'; they do not have sufficient knowledge and experience. Currently, TTOs act as an accounting department of universities. They need to act like a consultancy or head-hunter firm; it would be better to proceed with a similar mind-set.*

Collaboration between producer firms and user firms is critical in chemical industry. Raw material producers in basic chemicals or specialty chemicals focus on customer experience when manufacturing their innovative products. On the other hand, user firms in specialty or consumer chemicals want to collaborate with raw material suppliers (producers) while reducing product design cost or developing new product. "*Collaboration with local firms brings value and government support is significant in this sense*", CHEM D claims.

For the firms in consumer chemicals, it is essential to maintain close interactions with end-users and follow up consumer trends. In light of this information, consumers can be considered as critical actors in innovation for this sub-sector.

5.2.2.1 Managerial and Policy Recommendations for the Network of Collaborative Relations Among Actors

PR 4: The public representatives should change their authoritative image; be more supportive and listener.

We may conclude that the government-industry network is weak. According to the interviews, CHEMs do not see the government as an actor, but as a director, because these bodies look like “authoritative” to the firms. This may be one of the most important reasons for the lack of communication in public-industrial relations. The public representatives should change their authoritative image and be more supportive and listener. In that point, decisive bodies need to recruit public representatives with background from the chemical industry.

PR 5: Universities should re-consider research, education, and training functions of chemistry faculties in order to enhance university–private sector partnership initiatives

Universities in Turkey do not play the leading role in terms of conducting R&D and innovation activities for the chemical sector, as they do in the developed countries. Universities contribute to the dissemination of knowledge through providing consultancy services or test analysis, but in fact, they have the potential to do more. An important measure of success in the university is, in general, number of publication and high H-index scores of the academicians whereas stakeholders from the industry seek for output for commercialization such as new product or process development. Difference between priorities is one of the main reasons for the weak interaction between industry and university. Although the primary purpose of universities is research, education, and training, they should also position themselves to collaborate with private companies to drive innovation.

Based on a review of CHEMs, the students coming from undergraduate/graduate programs are not well prepared to contribute within an industrial setting.

Universities seem to be introvert and one of the more resistant agents in Turkey to include diversity. In this regard, faculty members need to provide students more competent to be able to perform well in various career options. Universities should strengthen their interactions through workshops inviting stakeholders from industry and decisive bodies. Stakeholders from the sector may contribute to developing the syllabus of the relevant lectures, or these stakeholders may give a couple of lectures in some of the reputable universities. Academicians' being active in the sector in certain periods and transferring their knowledge later to the university might also stimulate further industry-university collaboration. Moreover, an increased number of consultancy services through new projects may also increase the academicians' familiarity with the industry.

PR 6: Universities should be encouraged to create university-originated start-ups

Chemistry sector is based on mass production of the intermediaries or end products, and the firms with high production capacity have a massive advantage in this regards. In all sub-sectors, large firms (local or multinational) dominate the market, and they place entry barriers, which makes it difficult for another actor to enter the market. These barriers include high fixed costs, high variable costs, extensive regulatory requirements, etc. In such a situation, innovation is driven by these large firms, in collaboration with the university. In this situation, the knowledge base expands depending on the innovation strategies of the large firms. This is called "creative accumulation" and it clearly describes the situation in the chemistry sub-sectors. (Marsili and Verspagen, 2002). In this sense, universities should be encouraged to generate university-originated start-ups to bring the new technological advancements to the sector, since it will drastically accelerate the expansion of the knowledge base. For this aim, faculty members shall have the freedom to operate on a particular time of the week, and this right must be protected by law. Such encouragement will stimulate the increase in the number of new entrepreneurs and in that of university-based start-ups to emerge soon. In this way, the innovative landscape will include new players who use their advanced technological know-how for the ease of market entry. Such innovative landscape is named “creative destruction”, in which innovation is accelerated by entrepreneurs and start-ups (Marsili and Verspagen, 2002).

MR 8: Large firms should seek for new alliances with start-ups

Moreover, new start-ups and large firms shall follow-up with partnership opportunities with each other. This has a win-win approach since start-ups would capitalize on the sales channels of these large firms, and the large firms would benefit from the advanced R&D know-how along with offering drastically improved novel products of the start-ups. Also, large chemical firms should invest in improving entrepreneurship skills and experience.

DuPont’s chief technology officer has expressed that innovation is not certainly about invention; instead, it is mostly about combining existing technologies in new ways that create value. Large chemical firms have broad access to customers and a low cost of capital. As both are significant elements in the development of new product/technology and the management of current product/technology, there is an opportunity for them to participate as partners with SME or start-up companies for new product development. The “not invented here” mentality within these large companies should be left aside via any means necessary to enable partnerships stimulating disruptive innovation (ACS, 2011).

PR 7: Role and responsibilities of TTOs in universities should be re-defined

All CHEMs are aware of the significance of university-industry collaboration, but they state that there are some communication problems. TTOs act as a bridge between university and industry, but according to some CHEMs, TTOs do not have enough knowledge and experience, and they seem to run the university's accounting rather than providing consultancy. In this case, we may suggest TTOs that they should:

- Investigate the areas of activity of the R&D centers in the chemical sector and contact them on this issue and be able to identify sector needs and present it to the academy
- Be able to, build-up network with the academy, recognize the latest updates on their research studies and inform their colleagues in R&D centers about what they have learned
- Organize platforms to bring stakeholders together
- Follow-up with the technological trajectories of the sector
- Follow-up the opportunities for collaboration with the universities
- Be able to follow-up the legislations which are relevant to the R&D activities and be able to offer the policy efforts which would improve the R&D power of their organizations

5.3 Institutions

Institutions set ‘the rules of the game’ (North, 1990 cited in Edquist, 1997). The behavior of firms is shaped by institutions that form constraints or incentives for innovation, such as laws, health regulations, property rights, common habits, cultural norms and social rules (Edquist, 1997). In this sense, CHEMs were asked about institutions that promote or impede their R&D activities.

According to all CHEMs, being an R&D center has an impact on conducting subsidized R&D projects because MoIT audits R&D centers annually and gives several missions such as conducting different projects, increasing collaboration activities, applying for patents. CHEM A added that sharing the financial risk with the State rendered them more confident.

CHEMs underlined that Law numbered 5746 has played a vital role in creating an R&D culture. “*Requirements of this legislation reinforce the project management*” CHEM A explains. CHEM F echoes this claim through the following:

> *This legislation provided the switch to an R&D center structure, and firm's top management started to invest more in both physical and human capital infrastructure as they realized the significance of this structure.*

Reportedly, the R&D center structure enhanced the project management competencies of the firms, which supported firms to manage their projects. In that sense, the workforce is a critical factor for increasing the knowledge base and network; CHEM D went on:

> *We proceed systematically; and as employees get experienced, their mindset gets widened, and we build up domestic and overseas networks", on the other hand, she/he complained about insufficient labor force in terms of qualifications and efficacy.*

Furthermore, CHEM A touched on the significance of support needed during the period of introduction of the innovative product into the market and went on:

> *TÜBİTAK's incentives and the Law numbered 5746 work well; however, the stage after R&D is critical. It is important to support the commercialization of local products; at least these products may be supported during the introduction cycle. A local producer may be supported with different mechanisms such as customs legislation, general protection rules, and restrictions on importation.*

CHEM C mentions the lack of harmony between organizations as follows:

> *Ministry of Industry and Technology supervises legislation 5746, but it has several pillars including Ministry of Economy, Ministry of Labor and Social Security, Ministry of Customs and Trade; but these do not act in harmony.*

Governmental organizations may slow down firms during the investment stages through regulations, and chemical firms complain about the long duration of procedures. Firms mention that TEYDEB projects, especially 1501 and 1509, are the critical national R&D funding which firms mostly apply to. However, CHEMs complained that the procedures of application and evaluation had been slowed down, and this situation influenced their studies negatively.

The primary purpose of regulation is to protect public health, safety, and the environment (Ashford et al., 1983). All firms agree that regulations have a significant role in shaping the chemicals industry; however, the drastic changes are difficult to adapt, and the time needed for implementation of the regulation is an issue. CHEM E echoes this idea with the following: *"Regulation on the Biocidal products is an example to show its hindering effect on the studies, which results in the waste of time and effort."*

Regulation of biocidal products was adapted from that of Europe and the adaptation period of Turkey was difficult, and it also reflected in R&D studies. In this respect, CHEM E also stated:

> *Because of the regulations, the product registration process took 4-5 years. During this period, there have been some uncertainties in practice: initially, it was not clear which universities are authorized to test and analyze the biocidal products. Such clarification took a long time, and it affected the R&D timelines and innovation projects regarding products under this regulation.*

In specialty and consumer chemicals, R&D activities of firms are also affected by "REACH" legislation. Since it is mostly related to the operations of supplier firms, firms operating in consumer chemicals are indirectly influenced by this legislation, especially in the procurement of intermediates. CHEM F epitomized this situation:

> *An intermediate product necessary for the production process cannot be procured for a year and a half and cannot be dispatched, and consequently, the final innovative product cannot be placed on the market.*

For consumer chemicals, regulations made by Advertising Self-regulatory Board and Ministry of Customs and Trade are also considered as influential institutions.

CHEM D touched on the dilemma that patenting and the associated patent documents create a disadvantage for the patent owner:

> *Patents do not remain at the forefront of the paint industry. We need to publish patents. When you publish a patent, you strengthen your competitor's hand! The government should set regulations.*

CHEM D emphasized the regulations on patent protection in order to protect the rights of the patent owner. He also explained that he had started to pay attention to patent applications after becoming an R&D center because it was an obligation.

5.3.1 Managerial and Policy Recommendations for Legislative Landscape

PR 8: Decisive bodies should come together with firms in the sector and make a preparatory work before bringing a new regulation
MR 9: Firms should try to find a competitive advantage of new regulations

Law no. 5746 plays a critical role in developing a project management discipline. The legislation prompted the switch to R&D center structure, and seemingly, firms are aware of its benefits. The switch to R&D center structure was a milestone increasing firms' affinity on improving project management skills through participation in project management seminars. Also, firms gave priority to the project management skills of the candidates during the recruitment of researchers. As firms increased their project management competencies, they started to be more efficient in FTE allocation and the use of budget.

CHEMs stated that long duration of application and evaluation procedures of various TEYDEB projects slowed down their projects. Therefore, TUBITAK should shorten the duration of procedures in question so that firms do not postpone their projects due to procedural reasons.

Especially for basic chemicals sub-sector, firms need further legislation to support local products through customs legislation, general protection rules, and importation cap. By doing so, firms will get motivated on the localization of the imported chemicals. In this scope, other decisive bodies such as the Ministries of Economy, Labor and Social Security, and Customs and Trade should work in harmony with MoIT.

Decisive bodies should also concentrate on the duration of familiarization and adaptation of legislations within the framework of EU harmonization studies. Regulations on biocidal products and REACH are the two most emphasized legislations within this context. In developing or implementing new legislation, it is crucial for the decisive bodies to align with all of these actors, including suppliers and producers in different segments.

REACH legislation has different roles in chemical sector. It imposes the obligation of registration for both domestically produced and imported chemicals, and can adversely affect the operations of suppliers/producers; on the other hand, it gives better information of hazards and risks of substances. Although regulatory pressure might be compelling for companies, it can be considered as an initial driver for research and developing greener alternatives to hazardous chemicals. In this regard, companies should understand the significance of gaining competitive advantages by producing safer products, saving chemical management costs, and benefiting from eco-friendly innovative products and services. In this sense, conducting market research for identifying the need for greener products and services is very significant, and this is a likely aspect where public authorities offer most of the support and funds. If there are initiatives focusing on providing assistance to the chemical firms in exploring the possibility of substituting hazardous chemicals in products, the adaptation of firms to this transition can be easier. Collaborating with university for developing greener products is indeed always a viable option within this scope.

PR 9: Awareness regarding patent applications should be increased through informative training sessions for senior management groups in chemical companies

As mentioned in preceding chapters, the number of patent applications and grants by local firms is very low in Turkish chemical sector. There are three main reasons for this:

- Weak interactions and network between industry and university
- University inventors’ desire to publish rather than a patent application
- Firms’ being overprotective on their know-how

The awareness of R&D centers to increase patent applications should be turned into action. The company which has the highest number of patent application among the CHEMs has the highest number of PhD personnel. We may conclude that the incentives that are offered to increase the number of doctoral personnel should be expanded. Moreover, the same CHEM emphasized that the manager considers the patent application as a strategy. At this point, especially the awareness of the top management will increase the patent output in the R&D centers and thus in the sector. It may be useful to increase awareness by providing informative training sessions to the senior management team. TTOs might be appointed as the coordinator in accordance with this purpose. To follow up the number of applicable patents issued by MSc and PhD researchers and to establish incentive mechanisms for cooperation with the industrialists, both for the university inventor and the company contributing to the commercialization of the invention, can be beneficial. According to CHEMs operating in specialty chemicals, publishing a patent does not preserve the rights of the patent owner since the other firms are able to copy, modify, and commercialize the product within the current legal landscape. Based on this, the government should review and if necessary, redesign regulations about intellectual property rights.

5.4 Human Capital Infrastructure

As mentioned in previously, much knowledge of innovation is embodied in people and their abilities. In the literature, the concept of human capital is often used to define the knowledge and skills possessed by people and acquired through education, training and experience. Human capital is one of critical inputs for the technological innovations in the chemical sector.

Researchers in R&D centers are part of the skilled workforce in the chemical sector. The number of R&D personnel, their educational level, skills and qualifications are some of essential indicators in understanding the human capital infrastructure of the sector. In this section, we will examine how R&D centers build-up their human capital.

Table 31. R&D Personnel in CHEMs According to the Law No. 5746 (2018, June)

Firms	Researcher				Technician	R&D Personnel	Support Staff	Researcher Ratio
	PhD	Master	Bachelor	Total				
CHEM A	3	14	9	26	5	31	-	84%
CHEM B	2	5	3	10	22	32	-	31%
CHEM C	4	30	24	58	22	80	-	73%
CHEM D	2	4	14	20	21	41	-	49%
CHEM E	3	13	5	21	43	64	-	33%
CHEM F	17	22	17	56	34	90	-	62%
TOTAL	**31**	**88**	**72**	**191**	**147**	**338**	**-**	**57%**

Source: Based on the data obtained from interviews

Table 31 shows the number and education level of R&D personnel in CHEMs interviewed. Based on this data, we observe that researcher ratio among R&D personnel fluctuates depending on the firm, and we conclude that it is a result of the difference in the firm’s strategy. The sub-sector of firms is also a determining factor, such that CHEM D and CHEM E are in the paint sector. It appears that R&D

departments in this sector need higher numbers of technicians; therefore, the proportion of the researchers in total R&D personnel is lower than the average of CHEMs. Among all CHEMs, 62% of the researchers include employees with masters or PhD degrees. We may conclude that the firms –except CHEM D- consider an advanced degree in the recruitment of researchers. CHEM D has the least number of employees with advanced degree among all CHEMs.

On the other hand, two-third of the researchers in CHEM F is comprised of employees with an advanced degree. This shows that R&D projects in consumer chemicals require in-depth knowledge. This does not imply to all consumer chemicals sub-sector and is strictly related to CHEM F's strategy. This firm needs substantial human capital with advanced academic knowledge since it competes with the multinational firms and moreover, the firm has set up a new strategy which is reaching to the maximum number of patent applications.

5.4.1 Criteria in positioning in R&D Department

Profession Choice: In basic chemicals, firms are keen to recruit both chemists and chemical engineers, whereas specialty and consumer chemicals firms prioritize the recruitment of chemists.

In basic chemicals, chemical engineers are needed in process innovation projects. On the other hand, chemists are mostly used during incremental product innovation projects. These professions are not separated by a precise line according to firms in specialty chemicals; instead, a chemical engineer or a chemist may be allocated to the same job. This is well reflected in the explanation from CHEM D:

> *There is a significant difference between a chemist and a chemical engineer. Chemistry is a major branch of science like physics, maths, and medicine. Due to the education system or vast technical information, students from chemistry departments are overwhelmed with chemical education, and they graduate with a low level of technical knowledge in recent years. The situation is different for chemical engineers; they predominantly take engineering classes so*

> *that they compensate for their lack of chemistry knowledge with their engineering background.*

In parallel with recent developments in nanotechnology and biotechnology, material engineers and bioengineers are also recruited in consumer chemicals, and it is expected to be a need for chemicals firms in order to expand the scope of the existing knowledge base in the firms. Firms always develop incrementally modified specifications of existing products or new products with drastically improved specifications. Both nanotechnology and biotechnology are the new sources of knowledge that are used for such innovative activities. Shortly, firms will benefit more from know-how in these fields through interdisciplinary research projects. By doing so, they will be expanding the existing knowledge base through applied research studies.

<u>University Choice:</u> In the recruitment of a researcher, R&D centers mostly consider candidate's traits (analytical thinking, problem-solving, technical skills, soft skills, etc.) and interest in the job role (eager to learn and dedication) and the company. Most of the firms have a consensus that they do not give primacy to leading universities, and CHEM F went on: "*First of all, we do not focus on a particular university, rather we would like to consider his/her background and interest about what we do. Second, we consider the candidate's place of residence*" and made an additional comment stating that recruiting the top-level graduate from a university with a lower reputation would be more efficient than recruiting an average graduate from a highly reputable university. He also underlined that this preference might be up to the situation and manager; they did not have a general strategy on this.

Only CHEM E emphasizes the importance of recruiting graduates from universities with high reputation. Director from CHEM E explained how he got benefit from the excellent education from a highly reputable university:

> *I am an ODTU alumnus, and my educational background has provided extensive guidance to me through my whole career. I also observed the same for the other ODTU alumni whom we recruited.*

> *Colleagues from top universities are fast-learners, and they start their careers with an advantage.*

Experienced/New Graduate Choice: Firms' preference in recruiting new graduates or rather experienced candidates differ according to their needs. The general view obtained from interviews that it is less costly to recruit a new graduate but also time-consuming to train. Firms state that it is not easy to find and attract an experienced employee: "*We shape the newcomers, their graduation is not a satisfactory point for our business; in other words, we format the newcomers!*" CHEM C explained. CHEM E has commented within corporate culture and went on: *"It is easier to adapt the new graduates to firm corporate identity; however, the time needed for such adaptation is still an issue."*

In the scope of R&D operations in consumer chemicals, CHEM F stated that:

> *Our multinational competitors conduct the overall R&D study in headquarters and allocate local affiliate R&D departments to only conduct experimental development studies, and these studies require limited technical competencies. The R&D department in the local affiliate does not have the right to make decisions on the product development strategy; rather, they apply what is asked from the headquarters. They receive guidance and know-how from headquarters, and the employees in local R&D follows up with his/her particular tasks. He/she lacks taking the initiative; and for this reason, we do not prefer to transfer an employee from our competitors, rather we prefer to recruit new graduates and train them in our facilities.*

We can conclude that CHEMs generally recruit new graduates from chemistry and chemical engineering departments.

5.4.2 Expectations from Researchers/Technicians

CHEMs stated that their researchers needed to have some competencies. The ranking of required competencies differs according to the company. These competencies are as below;

- Curiosity about the field of the job
- Eager to learn
- Analytical thinking
- Problem-solving
- Dedication to his/her job
- Hard (technical) skills and know-how
- Quick decision-making ability
- Time management ability

The competencies which are known to be compulsory for nearly all CHEMs are listed below:

- Teamwork
- Soft skills (i.e. communication)
- English proficiency

CHEM F explained the importance of an advanced degree through the following:

> *People with a doctorate mostly possess aforementioned competencies; however, it is hard to find new graduates having these same competencies. For new graduates, we have a special internship program; and we give priority to candidates who have done an internship in our company before.*

CHEM D pointed out that there was a huge difference between recent graduates and those of two decades ago and continued:

> *Nowadays, we are looking for candidates who hold masters or PhD degrees. We keep the expectations low for the new graduates having a bachelor's degree and allocate them to simple tasks along with R&D studies. We also keep the expectations even lower for the new graduates from technical high schools.*

CHEMs' expectations from technicians in terms of competencies were also indicated as follows:

- Curiosity
- Soft skills (i.e. communication)
- Compliance to safety rules
- Coordination

5.4.3 Extent of Difficulties in Recruiting

All CHEMs stated that it is not easy for companies to find the researchers for R&D in the chemical sector. Finding a candidate having the desired profile is a complicated process. After the human resources department conducts preliminary eliminations in the recruitment of personnel, R&D center makes its evaluation. Main challenges are listed below:

- Candidate's place of residence
- Candidate's interest in the job (role) / position
- The salary expectation which is higher than the salary range for the job (role) / position

Candidates prefer the center of big cities for residence; and when they search for companies to work, they prioritize these companies in terms of their location. For the companies which are located out of cities, it is hard to convince the candidate to work in the upstate. "In general, candidates mainly prefer to work in Istanbul or Ankara, and such preference complicates the recruitment of the desired candidate." CHEM F explains. CHEM C gave another argument about recruitment in the chemical industry:

> *Apart from our desire, the candidate's interest is critical. A new graduate may realize that he/she is not interested in laboratory work. There are such examples in our company that a new graduate switched to the sales department. In this respect, we have such an*

> *approach that a newcomer explores different job roles in the first year and if he/she decides to move to another department, we direct him/her to the technical sales department. There are many examples of such transfer.*

CHEM D’s following comment states the current situation in recruitments in the R&D department: “There are lots of applications with the CV’s which are not strong enough.”

CHEM A elaborates the importance of candidate’s self-motivation and the difficulties in recruiting as below:

> *The important thing is motivation for your job, to create an added value, and to self-development. Nowadays, the system is centered on self-success, egocentricity and money. I can say that 60-70% of the candidates are looking for new jobs to double their salaries even though they are satisfied with the current job and the workplace. That is why recruitment is a difficult process that takes a long time. When we find a candidate who has the desired vision, we make an offer.*

5.4.4 Impact of Being an R&D Center and the Number and Qualification of Researchers

According to CHEMs, following the switch to R&D center structure, the number of people with masters and doctorate degrees has increased, with an influence on the knowledge base of the firms. After the switch, the number of researchers also increased, especially in the firms in specialty and consumer chemicals, although the minimum number of full-time equivalent (FTE) R&D personnel had been decreased from 50 to 15. FTE is defined as the ratio of working hours actually spent on R&D during a specific period (such as quarterly) divided by the total number of hours worked in the same period by an employee.

In basic chemicals, even the number of researchers has decreased, the effectiveness of the R&D research studies has increased with the increase of the postgraduates.

CHEM A stated that reduction in the number of the researcher was mainly due to the firm's change of its strategy.

CHEM C explains the qualitative changes of the researchers as below:

> *Firstly, R&D centers are enforced by the state to recruit the researchers with the desired qualifications. Secondly, in previous years, the number of graduates from masters or PhD programs was quite low. Due to unemployment, new graduates choose to start such a program. Therefore the supply is currently higher than the demand. By nature, the employer considers the level of education in making a selection from several candidates. This is the overall situation in the sector.*

In other words, as the supply exceeds the demand in postgraduates, firms start recruiting candidates with higher levels of education. Postgraduates have more in-depth knowledge and technical competencies, and it increases the effectiveness of their employers' R&D centers. CHEM F explained that after they had the R&D center status, their employees -that are master students-, did not have to go to university except for the courses; they can perform their tasks in R&D center laboratory under the control of supervisor.

CHEM E made the following comment on the hiring employees with a PhD degree: *"It is not easy to find a candidate with a PhD degree, whose thesis is related with our field."*

Soon, the number of researchers in R&D centers is expected to be in a steady-state. The number is dependent on the workforce need for upcoming projects and R&D capacity increase. CHEM C and CHEM F state that they reached the maximum level of their workforce capacity, and therefore, it was not possible for those firms to increase the number of researchers. On the other hand, other CHEMs anticipate such an increase in the number of researchers in parallel with the needs of headcount for the new projects. This also works for the demand for masters and doctorate graduates. "*We focus on competencies rather than the number. We aim to recruit new candidates who are expected to gain a competitive advantage for our* *firm*", CHEM A stated. Various product demands and accompanied scientific know-how requirements lead to the new needs related to new personnel and infrastructural needs.

CHEMs gave a negative answer to the question, "*Would the demand for qualified labor be at the same level if the R&D Center had not been established?*" In this respect, CHEM A mentioned that being an R&D center provided a different status and created different needs, which led to an increase in the number and the diversity of personnel. Also, CHEM B enthusiastically said:

> *The aim of R&D centers is not only to get benefit from the government's incentives but to conduct genuine R&D projects. It is important to build up a systematical R&D project. There has been the product or process projects that have been conducted before becoming an R&D center, but the number of these projects was low, and the methodology was not systematical.*

All CHEMs agree that a systematical methodology is essential for the effectiveness of R&D projects, and after the switch to R&D center; firms concentrated more on the project management competencies. CHEMs began to participate in project management seminars, to recruit candidates with project management skills and also to receive consultancy service from the relevant experts.

5.4.5 Contribution of Researchers to Innovation Process

Although mainly applied research and incremental innovation projects are conducted in the sector, qualified labor force, especially doctorate graduates, taking place in R&D centers increases the research capability of companies. CHEM F put it well by saying:

> *Graduates do not experience failure because their job is to fulfill straightforward tasks. In that sense, there is no challenge, so there is no risk to encounter. For example, the tasks they operate may not lead to sufficient output, in other words, it may not bring sufficient cost advantage, or the product may not sell too much; this does not count as the failure of any graduate himself/herself. This failure is*

> *mainly attributed to the marketing department. On the other hand, it is unlikely that someone who holds a doctorate has not tasted the failure. He/she knows how it feels and how failure motivates himself/herself. In cases of failure, he/she realizes that he/she has to put more effort or take more risks. That is a learning process which we expect our employees to experience throughout the educational life, and such experiences lead them to build-up their research approach.*

As specified by CHEMs interviewed, significant contributions of qualified researchers to R&D center are as below:

- Building-up R&D culture
- Participation to projects
- Literature research
- Building up network
- Contribute through laboratory experience
- Effective presentations in both Turkish and English
- Task planning and disciplined approach

5.4.6 Encouraging Researcher to Do Master/Doctorate

All CHEMs support their researchers for doctorate education, but they also leave the choice to the researcher. The motivation of the employee is to climb up the corporate ladder in the R&D department, and this does not seem possible without a PhD degree for the case of CHEM F. He explained this situation:

> *We do not specifically direct our researchers to hold a PhD degree, but they see that a bright future would come true with such degree. They know that a managerial position requires this degree. We directly arbitrate this kind of a requirement for an R&D career. On the other hand, R&D acts as a school for some colleagues who develop themselves in R&D and then move to other departments.*

CHEM B's motivation about doing master or doctorate of employees is to build up a network with the university and get its employee to develop himself/herself. The employee is guided to pursue his/her doctorate education within a relevant department or through a relevant thesis topic. Besides permission, all R&D centers also let the employee use infrastructure and the resources of the firm through his/her doctorate project.

5.4.6.1 Managerial and Policy Recommendations for the Enhancement of Human Capital Infrastructure

MR 10: Firms should give a particular role to new graduates in collaborative projects and assign them challenging tasks

Firms mostly prefer new graduates due to the cost of attracting an experienced candidate. Firms allocate money and time to improve the technical capabilities of the new graduates and their quick adaptation to the firm’s corporate culture. During that period, firms shall appreciate a proactive approach and allocate them specific tasks on which the newcomers would face new challenges. Considering that the theoretical knowledge of the new graduates is fresh, the recruitment of such dynamic candidates and assigning them a role in university-industry cooperation projects makes it easier for them to adapt to the industry. Also, it increases the number of people who have experience in such cooperation initiatives.

PR 10: Universities should restructure the curriculum of chemistry faculties and other related science/engineering faculties in order that they support multidisciplinary studies and variety of skills development

As mentioned by many sectoral representatives (CHEMs, NGOs), the quality of new graduates from chemical sciences in Turkey has been declining in terms of technical knowledge. This may arise from the educational system that does not keep up with the developments in the knowledge base of the chemical sector. This reflects the slow-down in the growth of the knowledge base. It has been stated by CHEMs interviews that new graduates do not meet most of the expectations; on the other hand, employees with an advanced degree do so. These competencies include both hard skills, including technical know-how, analytical thinking, and problem-solving, etc., and soft skills such as teamwork and communication. Although graduates from universities with high reputation are usually fast-learners, according to CHEMs, being a top-level university graduate is not a necessary inclusion criterion during the recruitment process. Firms rather focus on the personal traits and research interests of the candidates. Indeed, firms stated that project management skills have come into the forefront after the switch to the R&D center structure.

This approach has been already included in the agenda on the developed countries. Graduates in the chemical sciences need to move beyond the technical aspects of their education to achieve greater development of allied knowledge and skills (ACS, 2011). Tullao et al. (2013) stated that students and universities should shift their learning emphasis from mere transmission of information to comprehension of abstract concepts. This is an essential tool for students to attain analytical thinking and the ability to solve problems, gather appropriate information, and make intelligent decisions. The ability to work in teams is also necessary for innovation because most innovation comes from interdisciplinary ventures and solutions are more easily found when one works in teams and cooperates for the benefit of each other's expertise. This develops communication, negotiation, persuasion, organization, and eventually, management skills.

As mentioned previously, the culture of entrepreneurship is essential for developing a "creative destruction" set-up, which enables the actors to concentrate more on the drastic innovation projects. To this aim, universities should guide their students to gain entrepreneurship skills for transforming ideas into business. Elective courses providing students to gain a rudimentary grasp of the economics of technical business, including the establishment of robust business plans, can be given in this regard.

Research performance of universities providing education on chemistry and chemical education should be analyzed, and quota of those departments should be redesigned according to need. New departments relevant to sub-branch of chemistry (such as bioengineering, materials science, semiconductor) should be increased. Allocating greater budgets to the projects within these scopes will increase the motivation of universities to conduct more projects in these fields. Therefore more students will pursue their academic careers within these branches, and it will result in an increased number of faculty members in these branches soon.

MR 11: Firms should establish a solid organizational structure in human capital management to attract newcomers and to reach desired headcount retention

Main difficulties in recruiting were stated as follows: the place of residence, job interest, and salary expectation. City centers of Istanbul and Ankara are seen as the center of attraction, and convincing a candidate to live in another location is the biggest challenge for most of the CHEMs. Newcomers sometimes realize that they do not have an intention to pursue an R&D career, and at that time, some firms look for cross-departmental moves. Salary is also one of the main challenges, but it may be very important in recruiting experienced candidates.

Chemical companies should find the way of attracting candidates with high potential because they are trying to persuade these candidates to be exposed to chemicals during their career and to continue their career in the facilities that are not preferred in terms of location. In this sense, it seems that they have a great disadvantage compared to other companies or sectors.

While evaluating a company to work, employees consider company culture, technical infrastructure, and reward systems. Reward systems include promotions within career ladder, bonus payments, rewards for suggestions, rewards, or royalties for patents. The technical infrastructure is important because it most often determines the limits of R&D capabilities. In that point, cross-collaboration between firms is important to use the missing tools/machines which are necessary for particular research studies. Establishing a standardized rewarding system is important at this point since it is important to show that all employees are treated equally. Promotion seems to be one of the most critical rewards, and we suggest firms to implement a fair grading system for all positions. Moreover, salary ranges should be set up based on grades and seniority. Besides, international technical meetings and sabbatical leave for education are also tools to attractive, qualified researchers to chemical firms.

Rotational programs would be beneficial for newcomers to understand their motivation to different types of roles in various departments. This has a remarkable effect on the motivation of the employees since they still have diverse options in managing their career path.

MR 12: Firms should benefit from different support programs in recruiting qualified labor

Switching to an R&D center structure reflected an increase in the number of postgraduates, thereby expanding the knowledge base of the firm. The number of postgraduates is increasing year-over-year, and it means the supply of qualified human capital is expected to meet the demand from CHEMs in upcoming years. In addition, R&D centers' opening their facilities for their employees' academic research projects eased the maintenance of academic studies of their R&D researchers. By doing so, CHEMs render their personnel to observe both academic and industrial innovative landscape, thereby strengthening the relations between industry and academy. Furthermore, CHEMs state that they get benefits from the rearrangement of Law No. 5746, which provides additional support and income tax exemption for R&D personnel graduated from basic sciences (such as chemistry and biology). In parallel with this, we suggest firms to also get benefit from the law 1601 (Support Program for Increasing Capacity in Innovation and Entrepreneurship) which provides an incentive for recruitment of employees with a doctorate degree.

MR 13: Firms should allocate additional time for researchers to work on their own authentic projects

One of the advantages of being an R&D center has been the increased awareness of companies to give more importance to personnel having an advanced degree. In addition, firms should encourage and support their employees to improve their creativity and authenticity in order to design or contribute to radical innovation projects. To do this, companies should allow their employees to allocate part of their working hours to their authentic projects. Furthermore, employees should follow up with recent publications in literature and use what they learned for particular projects. Assigning R&D centers on this subject during the annual audits would be a stimulating activity to adopt such an approach.

CHAPTER 6

CONCLUSION

6.1 Summary

The main objective of this thesis was to examine the R&D centers in the chemical sector in Turkey (CHEMs), providing the compilation of relevant information regarding the main building blocks of the SSI. In the context of SSI framework, this thesis investigated the main activities and strategies of CHEMs in innovation management and human capital management. In terms of knowledge base, we clarified the sources of technical knowledge and how effectively these sources are used by CHEMs. Types of R&D and innovation activities conducted by CHEMs were identified and suggestions were developed to customize their R&D efforts through better defined market information. We further questioned the interactions between various actors and elaborated on the relationship of university-industry and the reason why this relationship needs to be strengthened. We mentioned institutions that influence innovation activities, concentrating more on the collective preparedness of multiple actors prior to design of a regulation, giving importance to the better use of regulations for creating competitive advantage as well as increasing awareness for intellectual property management. Lastly, we focused on the effect of educational level and labor quality on CHEMs' innovation activities as well as the human capital management activities of CHEMs to better use existing talents and build-up a broader high-qualified talent pool in the sector.

In Turkey, R&D expenditures of local chemical companies has recently increased, however, it is still far behind when compared to the leading multinationals. Turkey is still a foreign-dependent country in supplying raw materials. Along with it, high cost of materials and high risk of failure in drastic innovation projects prompt firms to set up their innovation strategies around incremental innovation projects to fulfill the customer demand. Large chemical firms follow market-pull strategies and strive for slight improvements in manufacturing process or existing products. Most of the time, local firms do not prefer to invest in basic research activities and radical innovation. This may be the cause of a small number of patent applications and grants in the sector. There exists another explanation for the low number of patenting: strategically, CHEMs are overprotective on their know-how. On the other hand, universities most likely tend to concentrate on publishing their research rather than a commercialization of a technology or a product. In addition to that, the coordination between industry, university and state is not strong enough to prompt faculty members to work on a radical product innovation or patentable technology.

Qualified labor recognizes and expands the existing knowledge base in the sector. The switch to R&D center structure is one of the critical milestones which prompt firms to increase the number of people with masters and doctorate, and to concentrate on their project management competencies. However, the chemical sector in Turkey still lacks qualified labor and it is difficult for CHEMs to find researchers of the desired quality to fulfill the job requirements. CHEMs are aware of the importance of bio-based, green products and eco-friendly technologies, but their R&D activities still lack in these technological fields. CHEMs do not have the motivation to initiate relevant projects on account of its high cost and insufficient demand. According to CHEMs, such innovations will gain importance in the future, whereas the research and policies on this subject have already started in the countries where the chemical industry has developed.

All findings and recommendations to improve functioning of the chemical sectoral innovation system in Turkey are summarized in Table 32.

Table 32. Wrap-up of findings and recommendations

Building Blocks	**Findings**	**Managerial and Policy Recommendations**
Knowledge Base and Technology	• Firms use following knowledge sources: literature, raw material suppliers, customers, universities • Firms lack participation to international conferences	MR 1: Firms should attend conferences to be informed about recent developments in scientific field and to expand their knowledge MR 2: Consumer and specialty chemicals firms should expand their international networks to create opportunities for know-how exchange
	• CHEMs in basic chemicals develop products new to Turkey • Imported products with high added-value are the top priority for localization	PR 1: Incentives for localization of basic chemical products should be increased
	• R&D studies are intended to fulfill customer demand, especially for specialty and consumer chemicals	MR 3: Firms should invest in the market research studies to better follow up with the market demand
	• Different customer segments concentrate on a particular product preference in terms of performance, quality and new product features	MR 4: Firms should do customer segmentation and set up its innovation strategy based on the dominant segment
	• Firms avoid to conduct radical innovation projects due to: - High project costs - High risk of project failure - Low sales performance of the new product	MR 5: Firms should implement robust project evaluation methodologies to receive early-signals for possible failure in their drastic innovation projects MR 6: Firms should open alliance management department MR 7: Firms should create a research consortium to collaborate for radical innovation and know-how exchange
	• Environmentally friendly products will be among the highest priorities of CHEMs • Eco-friendly technologies will require expanded knowledge base for further innovation activities	PR 2: Green-related jobs and skills should be identified and standardized; stakeholder awareness and knowledge base regarding greener technologies should be increased PR 3: Universities and faculty members should also be encouraged for conducting applied research studies related to this issue through incentive mechanisms

Table 32. (Cont'd)

Actors and Networks	• Lack of communication in public-industrial relations	PR 4: The public representatives should change their authoritative image; be more supportive and listener
	• In the scope of chemical sector, interaction between industry and university is weak	PR 5: Universities should re-consider research, education, and training functions of chemistry faculties in order to enhance university–private sector partnership initiatives
	• Large firms dominate the sector • Start-ups may bring new technological advancements thereby accelerating the expansion of existing knowledge base	PR 6: Universities should be encouraged to create university-originated start-ups MR 8: Large firms should seek for new alliances with start-ups
	• TTOs lack experience • TTOs seem to run the university's accounting rather than providing consultancy.	PR 7: Role and responsibilities of TTOs in universities should be re-defined
Institutions	• Duration of familiarization and adaptation of legislations within the framework of EU harmonization studies is problematic (such as REACH)	PR 8: Decisive bodies should come together with firms in the sector and make a preparatory work before bringing a new regulation MR 9: Firms should try to find a competitive advantage of new regulations
	• Reasons for low number of patent applications and grants: - Weak interactions and network between industry and university - University inventors' desire to publish rather than a patent application - Firms' being overprotective on their know-how	PR 9: Awareness regarding patent applications should be increased through informative training sessions for senior management groups in chemical companies

Table 32. (Cont'd)

Human Capital Infrastructure	• Firms strive for quick adaptation of newcomers	MR 10: Firms should give a particular role to new graduates in collaborative projects and assign them challenging tasks
	• Chemistry education in universities does not keep up with the developments in the chemical sector • Expectations from researchers in CHEMs to innovate: interest in the job role, hard skills, soft skills	PR 10: Universities should restructure the curriculum of chemistry faculties and other related science/engineering faculties in order that they support multidisciplinary studies and variety of skills development
	• Main challenges in recruiting researchers: the place of residence, job interest, and salary expectation	MR 11: Firms should establish a solid organizational structure in human capital management to attract newcomers and to reach desired headcount retention
	After the switch to R&D center; • The number of people with masters and doctorate degrees has increased • Firms get benefit from the Law No. 5746 which provides income tax exemption for R&D personnel graduated from basic sciences • Firms concentrated more on the project management competencies • Employees holding PhD are enforced to use their creativity skills during the education period. This is a critical skill which enables employees to find creative solutions to troubleshoot problems	MR 12: Firms should benefit from different support programs in recruiting qualified labor MR 13: Firms should allocate additional time for researchers to work on their own authentic projects

6.2 Concluding Remarks

This study makes several contributions to the chemical sector in Turkey by its different aspects. First of all, to our knowledge, this is the first research which uses an SSI approach to understand the current situation of the chemical sector from the viewpoint of R&D centers operating in the chemical industry. Behind this case study, many analyzes are depicting the current situation of the chemical industry and barriers for its development. Especially sectoral reports and action plans published by MoIT regarding chemical industry are one of the primary sources in this context. However, existing reports do not touch on the sector from the innovation system viewpoint. So this thesis analyzes the chemical sector from a more different approach than existing ones and it offers both managerial and policy recommendation by applying to the methodology of SSI.

The chemical industry is comprised of several sub-sectors and therefore, assessing chemical sector through SSI approach brings both advantages and disadvantages. The primary advantage is that the approach enables the readers to have an overall understanding of the sector, through the eyes of R&D centers. The disadvantage is that since we did not apply a technology-based or regional-based IS approach, we do not have the in-depth understanding in the technological areas which need improvement in sub-sectors; and we do not have the extensive information on the status of the sector on a regional scale.

Limitations of the thesis are related to the sample size and geographical restrictions which reveal the problem of generalization over other chemical firms. Concentration on a limited number of large firms located in the Marmara region inevitably brings the concern of whether these findings would be different in SMEs and other regions of Turkey. For example, if we used a regional IS approach rather than SSI, we would concentrate on clustering chemical firms in different regions and compare the clusters in terms of their technological advancements, common habits, learning processes and so on. If we have used the technological IS approach, in case, we would concentrate on a group of firms which focus on the green technology-based R&D activities, and by doing so, we would have a deeper understanding of the status of the local R&D centers in terms of the technological advancements in this scientific field. Another approach is to do a sampling of firms from other higher or lower technology sectors would show different areas of improvement as well as barriers in front of these areas within the scope of the innovation system.

Further studies should complement our study with an in-depth assessment of a specific sub-sector through interviewing with diverse departments. Also, further studies should assess sub-sectors by making the benchmark analyzes with other developed/developing countries. This thesis conducts an examination only on the R&D centers, which are assumed to have the highest R&D and innovation activities in the chemical sector. The position of R&D centers in the chemical sectoral innovation system is critical because this sector provides opportunities for commercialization of technical knowledge, high investment return opportunities, a large number of qualified personnel, and cooperation with universities to increase knowledge base. However, the R&D department is just one of the actors in this system. Interviewing with other actors, including the representatives of other departments, decisive bodies, bridging organizations and university would be essential for understanding the sectoral dynamics in all perspectives. Interviewing from people having different grades in their organization would be another idea to enrich the study scope. Therefore in further studies, we suggest to do interviews with managers in SMEs, researchers working both in industry and university, students and faculty members in chemistry and chemical engineering departments. As a consequence, further quantitative and qualitative studies should support this thesis in defining the innovation system in Turkish chemical sector.

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APPENDICES

APPENDIX A: APPROVAL OF METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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05 NİSAN 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Mehmet Teoman PAMUKÇU

Danışmanlığını yaptığınız yüksek lisans öğrencisi Aslı BOYACI'nın ***"Kimya Sektörel Yenilik Sistemi Kapsamında Araştırmacı Kullanımı: Türk Kimya Sanayi Ar-Ge Merkezleri Üzerine Durum Çalışması"*** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-SOS-046** protokol numarası ile **06.04.2018 - 30.09.2018** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Doç. Dr. Emre SELÇUK
Üye

Dr. Öğr. Üyesi Pınar KAYGAN
Üye

APPENDIX B: INTERVIEW QUESTIONNAIRE (TURKISH)

Bölüm 1: Firma Hakkında Temel Bilgiler

Bu bölümde firmanın faaliyet gösterdiği alan/sektör ve genel firma yapısı incelenecektir.

1. Firmanızın faaliyet gösterdiği alan/sektör nedir?
2. Başlıca ürünleriniz nelerdir?
3. Yabancı sermaye ortaklığınız var mı?
4. Ürünlerinizin kullanıcısı, müşterileriniz iç pazar mı? İhracat da yapıyor musunuz?
5. Ar-Ge yatırım/ciro yüzdesi (2017 yılı) nedir?
6. Firma toplam çalışan sayısı nedir?

Bölüm 2: Firmanın Faaliyet Gösterdiği Alan/Sektör Hakkında Bilgiler

Her sektörün yapısı, organizasyon şekli, üretim girdileri ve yenilik dinamikleri farklılık gösterir. Bu bağlamda Malerba, "sektörel yenilik sistemi" kavramını üç temel yapıtaşı altında incelemektedir. Burada firmanın faaliyet gösterdiği alan, sektörel yenilik sistemi yaklaşımıyla irdelenecektir.

Bilgi altyapısı ve teknoloji

7. Bulunduğunuz alanda hangi bilim dalı ya da disiplinin çatısı altında araştırma yürütülüyor?
8. Bulunduğunuz alanda Ar-Ge yapılırken kullanılan bilgi kaynakları nelerdir/ kimlerdir?
9. Diğer ülkelere kıyasla, Türkiye'de faaliyet gösterdiğiniz alanda patent, lisans ve yayın performansı ne düzeydedir?
10. Türkiye'de bulunduğunuz alanda daha çok ne tür Ar-Ge çalışmaları yürütülüyor?
11. Türkiye'de bulunduğunuz alanda daha çok ne tür inovasyon yapılmakta?

Aktörler ve ağ yapıları

12. Bulunduğunuz alanda Ar-Ge, üretim ve inovasyon süreçlerindeki aktörler kimlerdir?
13. Faaliyet alanınızda, rakibiniz çok mu yoksa az sayıda mı firma var?
14. Hangi devlet kurumları bulunduğunuz sektöre ait politikaları belirliyor?
15. Üniversitelerin faaliyet gösterdiğiniz alanda özel bir işlevi, rolü var mı?
16. Sizce hangi eğitim kurumları bu alana işgücü yetiştiriyor?
17. Faaliyet gösterdiğiniz alanda ne tür işbirlikleri önemlidir ve gelecek vaat eder?

Kurumlar

18. Bilgi transferi ve gelişimi için çalışmalarınızı destekleyen ya da sorun yarattığını düşündüğünüz kurumlar hangileridir?
19. Pazarı etkileyen başlıca düzenlemeler/yönetmelikler ve en önemli etkileri nelerdir?

Bölüm 3: Firmanın Ar-Ge ve İnovasyon Faaliyetleri Hakkında Bilgiler

Bu bölümde, firmaların faaliyet gösterdiği alanda ne gibi Ar-Ge ve yenilik faaliyetleri yürüttüğü incelenecektir.

20. Ar-Ge projelerinizin ana konusu nedir?
21. Ar-Ge projelerinizin ağırlıklı hedefi nedir?

22. Projelerinizi tetikleyen unsurlar nelerdir?
23. Ar-Ge ve yenilik faaliyetlerinizi nasıl sınıflandırırsınız?
24. Organizasyon yenilikleri yapıyor musunuz?
25. İşbirliği projeleriniz var mı?
26. Ulusal ya da uluslararası ortaklı destek programları kapsamında Ar-Ge projeleri yürütüyor musunuz?
27. Ar-Ge bilgi kaynaklarınız nelerdir?
28. Projelerinizin çıktıları nelerdir? Proje çıktılarınız ticari faaliyetlerinizi ne derece destekliyor?

Bölüm 4. Ar-Ge Merkezi Nitelikli İşgücü Kullanımı

Bu bölüm, Ar-Ge merkezlerindeki işgücü profilini, nitelikli personele yönelik arz-talep ilişkisini ve bunların projeler üzerindeki etkisini incelemek adına kurgulanmıştır.

29. Ar-Ge merkezinde toplam kaç personel var?
30. Ar-Ge merkezinde kaç araştırmacı var?
31. Araştırmacı istihdamında meslek (kimyager/kimya mühendisi/diğer) tercihiniz nedir? Nedenini açıklayınız.
32. Araştırmacı istihdamında üniversite tercihiniz var mı? Varsa hangi üniversiteleri, neden tercih ediyorsunuz?
33. Araştırmacı istihdamında deneyimli/yeni mezun tercihiniz nedir?
34. Araştırmacılardan başlıca beklentileriniz nelerdir? Önem derecesine göre ilk beşi sıralayabilir misiniz?
35. Diğer personelden (teknisyen) beklentileriniz nelerdir?
36. İhtiyacınıza yönelik araştırmacıları ne derece kolay buluyorsunuz?
37. Ar-Ge merkezi kuruluşundan bu yana, işe aldığınız mezun profilinde/niteliğinde bir değişim gözlemlediniz mi?
38. Ar-Ge merkezi kuruluşundan bu yana, araştırmacı (özellikle MSc ve PhD) sayısında nasıl bir değişim oldu? Nedenini açıklayınız. Ar-Ge Merkezi kurulmasaydı nitelikli işgücü talebiniz aynı düzeyde olur muydu?
39. Önümüzdeki yıllarda personel sayısı ve niteliğinde bir değişim öngörüyor musunuz? Neden?
40. Nitelikli araştırmacıların Ar-Ge Merkezi'ne başlıca katkıları nelerdir?
41. Araştırmacıların beklentilerini karşıladığınızı düşünüyor musunuz?
42. Araştırmacılarınızı yüksek lisans / doktora yapmaları için teşvik ediyor musunuz? Neden? Teşvik ediyorsanız, hangi alanda yüksek lisans/doktora yapmalarını tercih ediyorsunuz? Neden?

APPENDIX C: INTERVIEW QUESTIONNAIRE (ENGLISH)

Section 1: The Basics about Company

In this section, an overview of the firm will be questioned.

1. What is the area/sector in which your company operates?
2. What are your main products?
3. Does the firm have a foreign capital partnership?
4. Are the firm's customers in the domestic market? Does the firm export as well?
5. For 2017, what is the percentage of the firm's R&D investment to its turnover?
6. What is the total number of employees in the company?

Section 2: Field of Activity

Sectors differ on the structure, organization, production inputs, and innovation dynamics. In this context, Malerba examines the concept of "sectoral innovation system altında under three basic building blocks. In this section, the field in which the company operates will be examined with the sectoral innovation system approach.

Knowledge base and technology

7. In which scientific discipline does the firm conduct research?
8. What are the sources of information that is used in R&D projects?
9. In the area the firm operates; compared to other countries, what is the performance level of the local companies in terms of patents, licensing, and publishing?
10. In Turkey, what kinds of R&D activities are carried out in the field that the firm operates?
11. In Turkey, what kind of innovation is being made in the field that the firm operates?

Actors and networks

12. Who are the actors in R&D, production, and innovation processes in your field?
13. Does the firm have many or few competitors in the field that it operates?
14. Which governmental agencies set the policies of the sector?
15. Do universities have a specific function or role in the field that the firm operates?
16. Which educational organizations do you think are training labor force in this field
17. What kind of collaborative studies is talented and promising in the field that the firm operates?

Institutions

18. Which institutions support or hamper knowledge transfer and development?
19. What are the principal regulations affecting the market; and what are their most significant effects on the market?

Section 3: Information on the Company's R&D and Innovation Activities

In this section, R&D and innovation activities carried out by firms in their field of activity will be examined.

20. What is the primary research topic of the firm's R & D projects?
21. What is the main objective of the firm's R & D projects?

22. What are the main factors that trigger the firm's projects?
23. How do you classify the firm's R&D and innovation activities?
24. Does the firm conduct organizational changes?
25. Does the firm conduct projects in collaboration with another organization?
26. Does the firm conduct out R&D projects within the scope of national or international support programs?
27. What are the sources of R&D know-how?
28. What are the outputs of the firm's projects? To what extent do the firm's project outputs support the firm's business activities?

Section 4: Use of Qualified Workforce in R&D Center

This section is designed to examine labor force profile in R&D centers, the supply-demand relationship of qualified personnel, and the impact of those two on R&D projects.

29. What is the number of personnel in R&D center?
30. What is the number of researchers in R&D center?
31. Which professions does the firm prefer for the recruitment of researchers? Please explain the reason.
32. Does the firm have a university preference for researcher recruitment? If yes, which universities does the firm prefer and what is the reason?
33. What is the firm's preference between experienced candidates and new graduates in researcher recruitment?
34. What are your main expectations from researchers? Please rank the top five by severity.
35. What does the firm expect from other staff (technician)?
36. Is the firm having difficulty recruiting researchers for the firm's needs?
37. Have you observed a change in the profile/qualification of the graduates since the establishment of the R & D center?
38. Since the establishment of the R & D center, how has the number of researchers (especially MSc and Ph.D.) changed? Please explain the reason. If the R&D Center was not established, would the firm's demand for qualified labor be at the same level?
39. Do you anticipate a change in the number or quality of staff in the coming years? Why?
40. What are the significant contributions of qualified researchers to the R&D Center?
41. Do you think the firm meets the expectations of researchers?
42. Does the firm encourage the firm's researchers to pursue a Master's or Ph.D.? Why? If yes, in which field do the firm prefer the firm's researchers to pursue a Master's or Ph.D.? Why?

APPENDIX D: PATENT GRANTS BY TECHNOLOGY AND ORIGINS, (RESIDENT & ABROAD OFFICE TOTAL), 2010-2017

Field of technology	Origin	2010	2011	2012	2013	2014	2015	2016	2017
14- Organic fine chemistry	China	2133	3219	4627	5389	6164	8336	8929	7631
	Germany	2980	2766	2996	3459	3593	3201	3599	3197
	Japan	4420	5020	5723	5738	5905	5093	5021	4529
	Republic of Korea	863	1277	1538	1605	1697	1577	1755	2214
	Turkey	7	1	3	5	7	16	13	12
	US	5887	6326	7210	7838	8349	7806	8533	7976
17- Macromolecular chemistry, polymers	China	1515	2792	3616	3799	3891	5329	7420	6259
	Germany	1560	1708	1820	1978	2196	1901	2048	2086
	Japan	4931	5796	6711	7731	7780	6077	6464	6089
	Republic of Korea	724	800	1245	1355	1412	1234	1545	1918
	Turkey	9	3	3	2	2	1	5	8
	US	2825	3099	3511	3794	3834	3364	3867	3772
19- Basic materials chemistry	China	2301	3319	5710	9418	9142	10420	11997	9460
	Germany	2417	2313	2605	2887	3140	2880	3262	2939
	Japan	4842	5607	6316	7112	7908	6153	6550	6008
	Republic of Korea	1149	1358	1771	2058	2081	1783	1843	2323
	Turkey	1	0	1	10	5	2	19	15
	US	4009	4368	5057	5913	6717	6489	7114	7036
21- Surface technology, coating	China	1698	2130	2697	2385	2882	4978	6298	5950
	Germany	1296	1320	1476	1563	1549	1470	1701	1488
	Japan	6307	7457	8024	8073	8099	6494	7234	6564
	Republic of Korea	1081	1341	1781	2086	2083	1737	1954	2019
	Turkey	3	5	3	9	1	5	16	14
	US	3267	3507	3980	4245	3921	3420	3669	3733
23- Chemical engineering	China	2108	3032	4526	4753	5497	8947	10595	10743
	Germany	2049	2118	2305	2423	2520	2409	2843	2637
	Japan	4584	4961	5350	4902	4775	4040	4524	4187
	Republic of Korea	1547	1951	2560	2937	2945	2463	2737	3200
	Turkey	5	12	14	5	20	8	11	20
	US	3951	4159	4648	4737	4962	4889	5429	5503
24- Environmental technology	China	1496	2790	3780	4221	4436	6315	7711	7002
	Germany	1056	983	1169	1224	1251	1387	1537	1444
	Japan	3820	4205	4326	4137	3910	3479	3801	3760
	Republic of Korea	1547	1737	2087	2447	2250	1716	1932	2212
	Turkey	2	0	1	2	4	1	4	5
	US	1865	1851	2262	2356	2388	2555	2938	2752

Source: WIPO statistics database, 2018

APPENDIX E: TURKISH SUMMARY / TÜRKÇE ÖZET

Kimya sanayi, dünyadaki en eski bilim temelli sanayi dallarından biridir. Bir zamanlar endüstriyel yeniliklerde lider olan kimya sanayi, modern yaşamın birçok yönünü değiştirmiştir. Sıcak tutan giysilerden, her gün kullanılan diş fırçasındaki plastiğe, otomobil lastiklerinden onları besleyen yakıta kadar kimyasal yenilikler günlük hayatımızın bir parçası olmuştur (Arora ve arkadaşları, 2011). Kimya sanayi, modern çağ boyunca küresel ekonominin ayrılmaz bir parçası olmuş, hem nihai tüketiciler için son ürünler hem de çok çeşitli alt sanayi kullanıcıları için ara ürünler üretmiştir.

Kimyasalların ticari ve teknolojik özellikleri dikkate alındığında, kimya endüstrisi üç ana kategoride incelenebilir.

- *Temel kimyasallar*, yüksek miktarlarda üretilen petrokimyasal ürün türevlerini ve temel inorganik kimyasalları kapsar. Aynı zamanda emtia kimyasalları olarak da bilinir. Görece düşük katma değere sahip olan temel kimyasallar, hem kimya sanayinde hem de diğer imalat sanayi üretimlerinde geniş bir kullanım alanına sahiptir.

- *Özellikli kimyasallar*, nispeten küçük ölçekte üretilen orta ve yüksek katma değerli kimyasallardır. Birçok farklı sektörde ürün performansına katkı sağlamak için özel olarak üretilir. Bunlar yapıştırıcılar, kaplamalar, yüzey aktif maddeler ve nano malzemeler gibi çok çeşitli ürünlerden oluşur.

- *Tüketici kimyasalları*, doğrudan son tüketicinin kullanımı için üretilen kimyasalları içerir. Sabun, deterjan, saç bakım ürünü ve kozmetik gibi günlük yaşamda kullanılan ürünlerdir.

Kimya sektöründe firma büyüklüğü, coğrafi olarak dağınık pazarlara ulaşma çabasını sürdürmek ve bir tesis kurmanın ya da bir ürün geliştirmenin büyük sabit maliyetlerini karşılamak için önemlidir (Cesaroni ve arkadaşları, 2001). Kimya sektörü, büyük üretim ve Ar-Ge tesisleri dâhil sabit maliyetler, personel maliyetleri, sarf malzemesi maliyetleri ve bakım maliyetleri gibi değişken maliyetlere büyük miktarda yatırım yapılmasını gerektirir. Bu sebeple, büyük firmalar kimya sektörüne hâkimdir (Cohen ve Levinthal, 1989).

Kimya sektörünün bir diğer önemli özelliği de Ar-Ge ve yenilik konusundaki köklü geleneğidir. 1850'lerde İngiliz ve Alman boyarmadde üreticileri ile başlayan bu gelenek, günümüzde çok çeşitli bilimsel ve teknolojik çalışmalar ile devam etmektedir. Kimya sektöründeki yeniliklerin çoğu bilim temellidir. Kimya sektöründe yenilik, toplumsal ve çevresel zorlukların çözümünde önemli rol oynamaktadır. Arvanitis ve arkadaşları (2000) kimya biliminin ve mühendisliğin günümüz koşullarına uyum sağlamak ve gelecekteki zorlukları ele almak için önemli değişiklikler geçirdiğini iddia etmektedir. Yeni sentez teknikleri, daha verimli ve çevre dostu ürünler sağlayan yeni süreçler, daha iyi performansa sahip yeni malzemeler, daha kısa üretim yöntemleri ve geleneksel kimya sanayine biyoproses işlemlerinin tanıtılması bunlardan bazılarıdır. Son yıllarda, kimyasallarla ilgili bilimsel araştırmalar nanoteknoloji, biyokimya, katalizörler, genetik, organik kimya ve polimer kimyası alanlarında yoğunlaşmıştır.

Kimya sektöründe yenilik, yeni veya iyileştirilmiş kimyasal ürün ve süreçlerin icat edilmesi ve üretilmesi anlamına gelir. Araştırma ve geliştirme (Ar-Ge), kimya sanayindeki yeniliklerin en yaygın girdisidir. Tüm bilimsel gelişmeler teknik bilginin yanı sıra bu bilgiyi kullanabilecek nitelikli işgücüne olan ihtiyacı da arttırmıştır. Bu nedenle, kimya sektöründeki başarılı yeniliklere bir diğer önemli girdi, beşeri sermayedir (Ren, 2005). Beşeri sermaye kavramı, bireylerin eğitim, öğretim ve deneyim yoluyla bilgi ve beceri kazandığını ve bu bireysel yeterliliklerin ve niteliklerin kişisel, sosyal ve ekonomik refahın yaratılmasını kolaylaştırdığını göstermektedir (OECD, 2007).

Kimya sektörünün tarihi genellikle firmalar, üniversiteler, kullanıcılar ve devlet politikaları arasındaki sağlam etkileşimden kaynaklanan bir dizi teknolojik yeniliklerin varlığı ile karakterize edilir. Ampirik çalışmalar, başarılı bir yenilik için iç Ar-Ge olanakları ile dış teknik bilgi kaynakları arasındaki bağlantıların önemini göstermiştir. Üniversiteler bilimsel bilginin oluşmasında, yeni disiplinler (çevre bilimleri, biyomühendislik ve malzeme mühendisliği gibi) yaratmada ve nitelikli işgücü geliştirmede önemli rol oynamıştır. Örneğin, büyük kimya şirketleri (BASF, DuPont gibi) Ar-Ge yeteneklerini geliştirmek ve yeni kimyasal ürünler geliştirmek amacıyla üniversitelerle işbirliği yapmış ve üniversitelerdeki araştırmacıları işe almıştır. Öte yandan, kullanıcıların (müşterilerin) özellikleri, ürünlerin özelliklerini daha iyi belirlemek ve Ar-Ge çalışmalarını çeşitlendirilmiş talebe göre yönlendirmek için büyük önem taşımaktadır. Kimya şirketleri rekabet avantajı elde etmek için bu tür etkileşimden geniş ölçüde yararlanmıştır. Ayrıca, devlet politikaları kimya sektörünün evrimi boyunca son derece önemli olmuştur. Patent politikaları bilgi alışverişinin verimliliğini arttırırken, çevre regülasyonları çevre dostu ürünler üretmek ve daha az kirletici proses teknolojileri geliştirmek için firmaların üretim süreçlerini şekillendirmiştir (Cesaroni ve arkadaşları, 2001).

Kimya sanayinin rolü, daha sürdürülebilir bir gelecek yaratmak isteyen ülkeler, özellikle sanayileşmiş toplumlar için giderek önem kazanmaktadır (Landau, 1994). Ayrıca, küresel ölçekte rekabet etme gücüne sahip yerel bir kimya sanayinin geliştirilmesi, ülke ekonomik politikalarının şekillendirilmesinde öncelikli konulardan biri haline gelmiştir (Ertek, 2014). Bu bakımdan, ekonomisini sürdürülebilir ve rekabetçi bir şekilde geliştirmek isteyen Türkiye için kimya sektörü önemlidir (MoSIT, 2012). Sanayi Planı’nın uygulanmasından bu yana, “Türkiye Kimya Sektörü Strateji Belgesi” gibi kimya endüstrisini iyileştirmek için birçok politika dokümanı oluşturulmuştur. Bunlara ek olarak, sektörün yenilik sistemini daha iyi anlamak için Türk kimya firmalarının Ar-Ge ve yenilik yeteneklerinin derinlemesine analiz edilmesi gerektiği görülmüştür. Ürünler, aktörler, etkileşim türleri ve bilgi tabanı açısından heterojen bir yapıya sahip olan kimya endüstrisinin her yönünü incelemeye çalışmak zordur. Ancak, Türk kimya sektörünün yenilik sistemindeki en kritik aktörlerinden biri olan Ar-Ge merkezlerinin faaliyetlerini analiz etmek mümkündür.

Bu bağlamda, Türkiye'de kimya sektörünün yenilik faaliyetlerini analiz etmek için Malerba (2002) tarafından önerilen sektörel yenilik sistemi (SIS) yaklaşımının kullanılması faydalıdır. Söz konusu yaklaşım, sektörün temel yapı taşlarının, özellikle bilgi altyapısı ve teknolojisi, aktörler ve ağ yapıları, ve kurumlar açısından anlaşılmasını sağlar. Evrimsel iktisat teorisi ve yenilik sistemi yaklaşımı bu çerçevenin ana başlangıç noktalarıdır (Malerba, 2005). Schumpeterci yaklaşım olarak da bilinen evrimsel iktisat teorisi, öğrenme, bilgi, yeterlilik gibi temel kavramlar üzerinde durur ve farklı dinamiklere, süreçlere, dönüşümlere odaklanır. Ayrıca yenilik süreçlerinin geri bildirim mekanizmaları ve kurumların ilişkileri ile nitelendirildiğini ima eder. Başka bir deyişle, sektörde ticarileşecek yeni ürün ve süreçler, tek başına bir firmanın yürüttüğü yalıtılmış bir süreç olmayıp, çeşitli aktörlerin etkileşim içerisinde beraber öğrenmeleri ve işbirliği yapmaları sonucunda üretilmektedir. Literatürde yenilik sistemi ulusal, bölgesel ve teknolojik gibi farklı boyutlarda incelenmektedir. Her yaklaşım, yeniliği kendi sınırları içinde değerlendirmeye odaklansa da, aslında hepsi birbirini tamamlar (Edquist, 2001). SIS yaklaşımı, belirli bir sektörün kendine has özelliklerini kavramsal bir çerçevede tanımlayarak diğer yenilik sistemi yaklaşımlarından ayrılmaktadır. SIS kavramsal çerçevesi, her sektörü kendi bilgi tabanı, talebi, pazar ve pazar dışı etkileşimleri, aktörleri ve kurumlarına göre analiz eder. Bilgi tabanı olarak adlandırılan kavram, teknolojinin, aktörlerin ve kurumların birlikte evrimleşmesiyle sektörün sürekli değişen sınırlarını temsil etmektedir. Aktörler yalnızca üretici, tedarikçi, kullanıcı gibi özel sektör firmalarını değil, aynı zamanda üniversiteler, bilim insanları, sivil toplum kuruluşları gibi farklı oyuncuları da içerir. Aktörler arasındaki ilişkiler de bu çerçevede çok önemlidir. Kurumlar ise sektördeki yenilik faaliyetlerini etkileyen kanun, düzenleme, yönetmelik gibi yazılı olan düzenleyici ve destekleyici mekanizmaların yanı sıra güven, gelenekler, alışkanlıklar gibi yazılı olmayan davranışları kapsar (Malerba, 2004).

Bu tezin odağını ve amacını yansıtan temel araştırma sorusu aşağıdaki gibi tasarlanmıştır:

- Sektörel yenilik sistemi (SIS) çerçevesinde Ar-Ge merkezlerinin yenilik ve beşeri sermaye yönetimindeki temel faaliyetleri nelerdir?

Bu bağlamda bu tez, Türkiye'de kimya sektöründe faaliyet gösteren Ar-Ge merkezlerinin temel Ar-Ge ve yenilik faaliyetlerine odaklanmaktadır. Bu araştırma çalışması nitel teknikler üzerine inşa edilmiştir. SIS kapsamında kimya sektörünün mevcut durumunu işveren bakış açısıyla belirlemek ve kimya alt-sektörleri arasındaki benzerlik ve farklılıkları daha iyi anlamak için araştırma yöntemi olarak çoklu vaka çalışması uygulanmıştır. Bu tezde “amaçlı örnekleme” kullanılmış ve böylelikle, derinlemesine çalışma için bilgi bakımından zengin vakaların seçilmesi planlanmıştır. Ayrıca bu tezin yazarı, bir Ar-Ge merkezinde çalıştığı ve o Ar-Ge merkezi ile kolayca görüşme yapabileceği için araştırmada “uygun örnekleme” kullanılmıştır. Her ne kadar bu yöntem, sonuçlarına en az güvenilen ve araştırmacılar tarafından önerilmeyen bir yöntem olsa da, sadece bir vakanın bu türden olduğunu belirtmekte fayda var. Bu çalışmanın analiz birimi Ar-Ge merkezleridir. Vakaların seçilmesinde rol oynayan başlıca kriterler aşağıdaki gibi belirlenmiştir:

- Kimya sanayinde Ar-Ge merkezine sahip firmalar
- En az iki yıldır Ar-Ge merkezi olan firmalar
- İstanbul, Kocaeli ve Yalova’da bulunan firmalar
- Temel kimyasallar, özellikli kimyasallar ya da tüketici kimyasalları alt-sektörlerinden en birinde faaliyet gösteren firmalar

Amaçlı ve uygun örnekleme yöntemleri ile seçilen Ar-Ge merkezlerinin müdürü veya yöneticisi ile yarı yapılandırılmış görüşmeler yapılmıştır. Bu tezde yarı-yapılandırılmış görüşme formu ile veri toplanmıştır. İki firma olumlu geri dönüş yapmadığından, toplamda altı Ar-Ge merkezi ile görüşülmüştür. Yüz yüze yapılan görüşmelerden elde edilen bilgiler önceden belirlenmiş kavramsal çerçeveye göre analiz edilmiştir. Bu bağlamda, Türk kimya sektörünün bilgi tabanı, aktörleri ve ilişkileri ile başlıca kurumları hakkında bilgiler toplanmış ve derlenmiştir. Yarı yapılandırılmış yüz yüze görüşmeleri metodolojik bir araç olarak kullanmak, görüşme yapılan Ar-Ge merkezi temsilcilerinin ilginç yorumları üzerinde daha fazla bilgi sahibi olmayı ve bu nedenle daha derinlemesine bir analiz yapmayı mümkün kılmıştır. Bu tür analizler önceden tanımlanmış temalarla ilgili verileri özetlemeyi ve yorumlamayı içerdiğinden literatürde “betimsel analiz” olarak tanımlanmaktadır. Betimsel analiz yönteminde, araştırmacı katılımcıların görüşlerini yansıtmak için doğrudan alıntılar yapabilir. Bu analiz türünün temel amacı, okuyucuya elde edilen bulguları özetlenmiş ve yorumlanmış bir biçimde sunmaktır (Yıldırım ve Şimşek, 2003).

Bu tezde, kimya sanayinin farklı alt-sektörlerinde faaliyet gösteren Ar-Ge merkezlerinin, Ar-Ge ve yenilik faaliyetleri incelenmiş, alt-sektörler arasındaki farklılıklar ve benzerlikler açıklığa kavuşturulmuştur. Ayrıca beşeri sermaye, yeniliğin önemli bir katalizörü olduğu için Ar-Ge merkezlerinin beşeri sermaye altyapısı incelenmiştir. Beşeri sermayenin kimya sektörel yenilik sistemindeki önemini anlamak için öncelikle beşeri sermaye kavramının ekonomik büyümedeki rolü ve beşeri sermaye ile yenilik sistemleri arasındaki bağlantılara değinilmiştir. Bu tezde, Ar-Ge merkezlerinin yenilik ve beşeri sermaye yönetimindeki temel faaliyetleri incelenerek, yenilik için daha uygun bir ekosistemin yaratılmasını sağlayacak sektörel ihtiyaçların analizi yapılmıştır.

Bildiğim kadarıyla, bu çalışma Türk kimya sektörünü SIS yaklaşımını kullanarak inceleyen ilk çalışmadır. Bu kavramsal çerçeveyi gelişmekte olan bir ülkede kimya sektörüne uygulayarak yenilik sistemleri çalışmaları literatürüne ampirik olarak katkıda bulunulmakta ve SIS çerçevesinin uygulanabilirliği arttırılmaktadır. Ar-Ge merkezleri, Türkiye'deki yenilik ekosisteminin önemli aktörlerinden biridir. Dolayısıyla kimya sektörünü Ar-Ge merkezleri açısından incelemek, Türkiye’de kimya sektörünü analiz eden mevcut dokümanlara ek bir katkı sağlamış, aynı zamanda genel politika önerilerinin yanı sıra firmalar için yönetim önerileri sunmayı da mümkün kılmıştır.

Bilgi tabanı açısından, farklı alt-sektörlerde faaliyet gösteren Ar-Ge merkezlerinde en fazla kullanılan teknik bilgi kaynakları ve bu kaynakların ne derece etkili kullanıldığı belirlenmiştir. Yürütülen Ar-Ge projeleri ve yenilik faaliyetleri sınıflandırılmış ve Ar-Ge çalışmalarını daha iyi tanımlanmış piyasa bilgileri ile özelleştirmek için öneriler geliştirilmiştir. Sektörde yer alan aktörler ve aralarındaki iletişim türleri ve yapıları incelenmiş, üniversite-sanayi arasındaki ilişki ve bu ilişkinin güçlendirilmesinin nedenleri açıklanmıştır. Kurumlar başlığı altında, yenilik faaliyetlerini etkileyen bir regülasyonun tasarlanması ya da uyumlaştırılması sürecinde birden fazla aktörün rol oynaması gerektiği, fikri mülkiyet yönetimi konusunda farkındalığın arttırılmasının getireceği faydalar ile yeni düzenlemelerin sektörde rekabeti arttıracağı tespit edilmiştir. Son olarak, kimya sektöründeki mevcut yeteneklerin daha verimli kullanılması ve sektörde daha yüksek nitelikli bir yetenek havuzu oluşturulması için Ar-Ge merkezlerindeki personelin eğitim seviyesi, yürütülen Ar-Ge projeleri ve yenilik faaliyetleri arasındaki ilişki incelenmiştir. Ar-Ge merkezi olmanın beşeri sermaye yönetimi üzerindeki etkilerine de değinilmiştir.

Türkiye'deki kimya firmalarının Ar-Ge harcamalarının son zamanlarda arttığı, ancak önde gelen çokuluslu şirketlere kıyasla hala çok geride olduğu görülmektedir. Türkiye hammadde tedarikinde halen dışa bağımlı bir ülkedir. Buna bağlı olarak, malzeme maliyetinin ve başarısızlık riskinin yüksek olmasından dolayı firmalar radikal yenilik projeleri yapmak yerine müşteri talebini karşılamak için artımsal yenilik projeleri yapmaktadır. Büyük ölçekli kimya firmaları pazar çekme stratejileri izlemekte ve üretim sürecini veya mevcut ürün performansını iyileştirecek projelere odaklanmaktadır. Yerel firmalar çoğu zaman temel araştırma faaliyetlerine ve radikal yeniliklere yatırım yapmayı tercih etmemektedir. Bu durum aslında patent başvuru ve tescil sayısının düşük olmasının bir sebebi olabilir. Az sayıda patent başvurusu olmasının diğer sebepleri de, Ar-Ge merkezlerinin sahip oldukları bilgiyi koruma içgüdüsüdür. Öte yandan, üniversiteler büyük olasılıkla bir teknolojinin veya bir ürünün ticarileştirilmesinden ziyade araştırmalarını yayınlamaya odaklanmaktadır. Buna ek olarak, sanayi, üniversite ve devlet arasındaki iletişim ve koordinasyon, öğretim üyelerini radikal bir ürün inovasyonu veya patentlenebilir bir teknoloji üzerinde çalışmaya zorlayacak kadar güçlü değildir. Ar-Ge merkezleri biyobazlı, yeşil ürünlerin ve çevre dostu teknolojilerin öneminin farkındadır, ancak Ar-Ge çalışmalarının bu teknolojik alanlarda hala eksik olduğu anlaşılmaktadır. Yüksek proje maliyeti ve yetersiz talep nedeniyle ilgili projeleri başlatma motivasyonuna sahip değillerdir. Oysa ki, kimya sanayisi gelişmiş ülkeler ve sürdürülebilir teknolojilere önem veren firmaların bu konudaki Ar-Ge faaliyetlerini ileri düzeye taşıdığı yapılan patent araştırmalarından görülmektedir.

Nitelikli işgücü sektördeki mevcut bilgi düzeyinin geliştirilmesinde kritik bir role sahiptir. Ar-Ge merkezi yapısına geçiş, firmaların yüksek lisans ve doktora derecesine sahip personel sayısını artırmalarını ve proje yönetimi yetkinliklerine odaklanmalarını sağlayan önemli kilometre taşlarından biridir. Fakat Ar-Ge merkezlerinin iş gereksinimlerini yerine getirmek için istenen nitelikte ve deneyimde araştırmacıları bulması da bir hayli zorlu bir süreç olduğu görülmektedir.

Türkiye'de kimya sektörel yenilik sisteminin mevcut durumunu tespit eden temel bulgular ve sistemin işleyişini iyileştirmeye yönelik sunulan yönetim önerileri (YÖ) ve politika önerileri (PÖ) Tablo 1’de özetlenmiştir.

Tablo 1. Bulgular ve Öneriler Özeti

	Bulgular	**Yönetim ve Politika Önerileri**
Bilgi Tabanı ve Teknoloji	• Firmaların sıklıkla kullandığı bilgi kaynakları: literatür, hammadde tedarikçileri, müşteriler ve üniversiteler • Firmaların uluslararası konferanslara katılımı yok denecek kadar az	YÖ 1: Firmalar bilimsel alandaki son gelişmelerden haberdar olmak ve bilgilerini artırmak için konferanslara katılmalıdır YÖ 2: Tüketici ve özellikli kimyasallar alanında faaliyet gösteren firmalar, bilgi paylaşımı yapmak için uluslararası ağlarını genişletmelidir
	• Temel kimyasallar alanında faaliyet gösteren Ar-Ge merkezleri "Türkiye'de ilk" olan yeni ürünler geliştirmekte • İthal edilen ürünlerden katma değeri yüksek olanların yerelleştirilmesi yüksek önceliğe sahiptir.	PÖ 1: Temel kimyasal ürünlerin ithal ikamesi için teşvikler arttırılmalıdır
	• Özellikli ve tüketici kimyasalları alanındaki Ar-Ge çalışmaları, müşteri talebini karşılamayı amaçlamaktadır	YÖ 3: Firmalar pazar talebini daha iyi takip edebilmek için pazar araştırması çalışmalarına yatırım yapmalıdır
	• Müşteriler, performans, kalite ve yeni ürün özellikleri bakımından belirli bir ürün tercihine odaklanırlar	YÖ 4: Firmalar müşterilerini belirli segmentlere ayırmalı ve yenilik stratejisini daha çok hâkim olduğu segmente göre oluşturmalıdır
	• Firmalar radikal inovasyon projeleri yürütmekten kaçınırlar. Başlıca nedenleri: - Proje maliyetlerinin yüksek olması - Proje başarısızlığı riskinin yüksek olması - Yeni ürünün düşük satış performansının olması	YÖ 5: Firmalar, radikal inovasyon projeleri yürütürken muhtemel başarısızlığın erken sinyallerini almak için proje değerlendirme metodolojileri uygulamalıdır YÖ 6: Firmalar ortaklık yönetimi bölümü açmalıdır YÖ 7: Firmalar, radikal inovasyon ve bilgi alışverişi için işbirliği yapacakları bir araştırma konsorsiyumu oluşturmalıdır
	• Çevre dostu ürünlerin geliştirilmesi, kimya sektörü Ar-Ge merkezlerinin en yüksek öncelikli projeleri arasında olacak • Çevre dostu teknolojilere ilişkin inovatif faaliyetlerin yürütülmesi, daha fazla bilgi birikimi gerektirecektir	PÖ 2: Çevre dostu teknolojilerin geliştirilmesine yönelik işler ve beceriler tanımlanmalı ve standartlaştırılmalıdır; Daha yeşil teknolojilere ilişkin paydaş farkındalığı ve bilgi tabanı artırılmalıdır PÖ 3: Üniversitelerin ve öğretim üyelerinin çevre dostu ürün ve teknolojilere ilişkin uygulamalı araştırma yürütmeleri teşvik edilmelidir

Tablo 1. (Devamı)

Aktörler ve Ağ Yapıları	• Kamu-sanayi arasında iletişim eksikliği vardır	PÖ 4: Kamu temsilcileri, otoriter imajını değiştirmeli; daha destekleyici ve dinleyici olmalıdır
	• Üniversite ve sanayi arasındaki iletişim zayıftır	PÖ 5: Üniversite-özel sektör ortaklık girişimlerini geliştirmek için kimya fakülteleri, araştırma, eğitim ve öğretim işlevlerini gözden geçirmelidir
	• Kimya sektörüne büyük firmalar hâkimdir • Yeni girişimler yeni teknolojik ilerlemeler getirebilir, böylece mevcut bilgi tabanının genişlemesini hızlandırabilir	PÖ 6: Üniversiteler, üniversite kökenli girişimler kurma konusunda teşvik edilmelidir YÖ 8: Büyük firmalar, girişim şirketleri ile yeni ortaklık fırsatları aramalıdır
	• TTO'lar yeterli deneyime sahip değiller • TTO'lar danışmanlık yapmak yerine üniversitenin muhasebesini yönetiyor gibi görünmekte	PÖ 7: TTO'ların üniversitelerdeki rolü ve sorumlulukları yeniden tanımlanmalıdır
Kurumlar	• AB uyum çalışmaları çerçevesinde, ilgili yasaların tanımlanma ve Türkiye'ye uyarlanma süreleri problemlidir (Örneğin, REACH yasası)	PÖ 8: Karar verici organlar sektördeki firmalarla bir araya gelmeli ve yeni bir düzenleme getirmeden önce beraber hazırlık çalışmaları yapmalıdır YÖ 9: Firmalar yeni düzenlemelerin/ yasaların rekabet avantajını bulmaya çalışmalıdır
	• Türkiye'de kimya sektöründe patent başvuru ve tescil sayısı çok azdır. Başlıca nedenleri: - Üniversite ve sanayi arasındaki zayıf etkileşim - Üniversitedeki buluşçunun patent başvurusu yerine yayın yapma isteği - Firmaların kendi bilgi ve deneyimlerini aşırı koruma isteği	PÖ 9: Kimya firmalarında üst düzey yönetim grupları için bilgilendirici eğitim oturumları düzenlenerek, patent başvurularına yönelik farkındalık arttırılmalıdır

Tablo 1. (Devamı)

Beşeri Sermaye Altyapısı	• Ar-Ge merkezleri yeni başlayan personelin hızlı adaptasyonunu sağlamakta	YÖ 10: Ar-Ge merkezleri, yeni mezunlara işbirliği projelerinde özel bir rol ve zorlu görevler vermelidir
	• Üniversitelerdeki kimya eğitimi, kimya sektöründeki gelişmelere ayak uyduramamakta • Ar-Ge merkezlerinin araştırmacılardan inovatif olmak için bekledikleri özellikler: iş rolüne ilgi, teknik beceri ve sosyal beceri	PÖ 10: Üniversiteler, multidisipliner çalışmaları ve çeşitli teknik ve sosyal becerilerin geliştirilmesini desteklemek için kimya fakülteleri ve diğer ilgili fen / mühendislik fakülteleri müfredatlarını yeniden yapılandırmalıdır
	• Araştırmacıları işe alırken karşılaşılan temel zorluklar: ikamet yeri, iş (pozisyon) ilgisi ve maaş beklentisi	YÖ 11: Firmalar, yeni başlayan personeli cezbetmek ve mevcut personel sayısını elde tutmak için insan kaynakları yönetiminde sağlam bir örgütsel yapı oluşturmalıdır
	Ar-Ge merkezi olduktan sonra; • Yüksek lisans ve doktora dereceli personel sayısı artmıştır • Firmalar, temel bilimlerden mezun olan Ar-Ge personeli için gelir vergisi muafiyeti sağlayan 5746 sayılı Kanun'dan yararlanmaktadır. • Firmalar proje yönetimine daha fazla odaklanmıştır • Doktoralı çalışanlar, yaratıcılık becerilerini doktora eğitimi sürecinde kullanırlar. Bu durum, iş yerindeki sorunları gidermek için yaratıcı çözümler bulmalarını sağlayan kritik bir beceridir.	YÖ 12: Firmalar nitelikli işgücü alımı konusunda farklı destek programlarından faydalanmalıdır YÖ 13: Firmalar, araştırmacıların kendi özgün projeleri üzerinde çalışması için ek süre ayırmalıdır

Kimya sanayi birkaç alt sektörden oluşmaktadır ve bu nedenle, kimyasal sektörünü SIS yaklaşımı ile değerlendirmenin hem avantajları hem de dezavantajları vardır. Bu analitik yaklaşımın en önemli avantajı, Ar-Ge merkezlerinin bakış açısından sektör hakkında genel bir görüşe sahip olmayı sağlamasıdır. Dezavantajı ise teknoloji-tabanlı ya da bölgesel-tabanlı bir yenilik sistemi yaklaşımı uygulanmadığı için, alt sektörlerde iyileştirilmesi gereken teknolojik alanlar derinlemesine incelenememekte ve bölgesel ölçekte sektörün durumu hakkında kapsamlı bilgiye sahip olunamamaktadır.

Örneklem büyüklüğünün yetersiz oluşu ve sadece belirli coğrafi bölgedeki kimya firmaları Ar-Ge merkezlerinin incelenmesi bu tezi kısıtlayan başlıca faktörlerdir. Sadece altı büyük firmanın Ar-Ge merkezleriyle görüşme yapılması, Türk kimya sektörüne genelleme yapılmasını kısıtlamaktadır. Marmara bölgesinde yer alan sınırlı sayıda büyük firmanın incelenmesi, bulguların KOBİ'lerde ve Türkiye'nin diğer bölgelerinde farklı olup olmayacağı endişesini de beraberinde getirmektedir. Örneğin, SIS yaklaşımı yerine bölgesel yenilik sistemi yaklaşımı kullanılsaydı, farklı bölgelerdeki kimya firmalarının faaliyetlerine odaklanılabilir ve bu firmalar teknolojik ilerleme, ortak alışkanlıklar, öğrenme süreçleri gibi farklı açılardan karşılaştırılabilirdi. Teknolojik yenilik sistemi yaklaşımı kullanılmış olsaydı, çevre dostu teknoloji alanı gibi belirli bir teknoloji alanında Ar-Ge faaliyetleri yürüten bir grup firmaya odaklanılarak, bu bilimsel alandaki teknolojik gelişmelerin durumu daha iyi anlaşılabilirdi.

Gelecekte kimya sektörüne ilişkin yapılacak çalışmalar, belirli bir alt-sektörde yer alan firmaların farklı bölümlerini derinlemesine inceleyerek daha kapsamlı bir analiz yapmayı amaçlayabilir. Ayrıca, kimya alt-sektörlerini gelişmiş veya gelişmekte olan ülkelerle kıyaslama yaparak analiz edebilir. Bu tez sadece kimya sektöründe en fazla Ar-Ge ve yenilik faaliyeti yürüten aktörlerden biri olan Ar-Ge merkezleri üzerine bir inceleme yapmaktadır. Ar-Ge merkezlerinin kimya sektörel yenilik sistemindeki yeri önemlidir çünkü sektörün bilgi tabanını genişleten aktörlerden biridir. Teknik bilginin ticarileştirilmesi, yüksek yatırım getirisi fırsatları, nitelikli personel sayısının arttırılması, üniversitelerle işbirliği yapılması gibi konularda kritik rol oynamaktadır. Ancak, Ar-Ge bölümü bu sistemdeki aktörlerden sadece bir tanesidir. Dolayısıyla firma içindeki diğer bölümlerin temsilcileri, sektördeki karar verici kuruluşlar, kamu-sanayi arasında köprü görevi yapan organizasyonlar ve üniversiteler dâhil olmak üzere diğer aktörlerle görüşme yapmak, sektörel dinamikleri daha iyi anlamayı sağlayabilir. Firmalarda farklı pozisyonlarda görev alan kişiler ile görüşmek, çalışma kapsamını zenginleştirebilir. Bu nedenle gelecek çalışmalarda KOBİ'lerle, hem sanayide hem de üniversitede çalışan araştırmacılarla, kimya ve kimya mühendisliği bölümlerindeki öğrenciler ve öğretim üyeleri ile görüşmeler yapmayı ya da anket uygulamayı önerebilirim. Sonuç olarak, Türk kimya sektörel yenilik sistemi farklı boyuttaki nicel ve nitel yöntemler ile incelenerek bu tezin bulguları desteklenebilir ve analizin kapsamı genişletilebilir.

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