Inspect the Effects of Research and Development on Performance of Industries in OECD Countries Data Envelopment Analysis - Malmquist Productivity Index Approach

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ABSTRACT

The competition among companies and industrial firms is getting more and more tense in the recent years, and one way for these firms to gain advantage over one another is by using Research and Development (R&D) sections. R&D is assumed to be a pathway for businesses to gather some knowledge for the purpose of creating new product, finding or even building new paths towards improvement of their former goods or services. Investments on R&D sections of companies is attracting more and more attention each year and so, a lot of researches has been done towards this matter. Some companies, dedicate more resources for this purpose in hope of getting more in return, but in this way, some resources may be falsely used as the effective ones; and this is what we focus on in this thesis by measuring the amount they have invested in different areas and the amount they receive in return. the group chosen for the intent of this evaluation is a group of 19 countries from OECD countries for the time period of 2013 to 2019. For this mentioned purpose, Introduction of "Malmquist Index" (MI), has attracted a lot of attention and it has grown as a standard method for evaluation of productivity over time. And also, cost efficiency which was introduced by Farrell, made Data Envelopment Analysis (DEA) a powerful tool for quantifying performances of different data sets; this fact, makes it perfect for process of evaluation of the countries which we are trying to compare. This DEA-Based MPI explains the productivity change of Decision-Making Units (DMUs) over the time period that is specified.

Keywords: DEA, Malmquist, R&D, Research and Development

ÖZ

Şirketler ve sanayi firmaları arasındaki rekabet son yıllarda giderek gerginleşmekte ve bu firmaların birbirlerine üstünlük sağlamalarının bir yolu da Araştırma ve Geliştirme (Ar-Ge) bölümlerini kullanmaktır. Ar-Ge, işletmelerin yeni ürün yaratmak, eski mal veya hizmetlerini geliştirmeye yönelik yeni yollar bulmak ve hatta inşa etmek amacıyla bir miktar bilgi toplaması için bir yol olarak varsayılmaktadır. Firmaların Ar-Ge bölümlerine yaptığı yatırımlar her geçen yıl daha fazla ilgi görmekte ve bu konuda birçok araştırma yapılmaktadır. Bazı şirketler, karşılığında daha fazlasını elde etme umuduyla bu amaca daha fazla kaynak ayırıyor, ancak bu şekilde bazı kaynaklar yanlış bir şekilde etkin kaynaklar olarak kullanılabiliyor; ve farklı alanlara yatırdıkları miktarı ve karşılığında aldıkları tutarı ölçerek bu tezde odaklandığımız şey budur. Bu değerlendirme için seçilen grup, 2013-2019 dönemi için OECD ülkelerinden 19 ülkeden oluşan bir gruptur. Bu amaçla, "Malmquist İndeksi"nin (MI) Tanıtımı büyük ilgi görmüş ve zaman içinde üretkenliğin değerlendirilmesi için standart bir yöntem olarak büyümüştür. Ayrıca, Farrell tarafından tanıtılan maliyet verimliliği, Veri Zarflama Analizini (DEA) farklı veri kümelerinin performanslarını ölçmek için güçlü bir araç haline getirdi; bu gerçek, karşılaştırmaya çalıştığımız ülkelerin değerlendirme sürecini mükemmel kılıyor. Bu VZA-Tabanlı ÇBYE, Karar Verme Birimlerinin (KVB'ler) belirtilen zaman periyodu boyunca üretkenlik değişimini açıklar.

Anahtar Kelimeler: DEA, Malmquist, Ar-Ge, Araştırma ve Geliştirme

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BCC	Banker, Charnes and Cooper
BSC	Balance Scoreboard
CCD	Caves, Christensen and Diewert
CCR	Charnes, Cooper and Rhodes
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EC	Efficiency Change
FORD	Fields of Research and Development
GDP	Grand Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
R&D	Research and Development
ICT	Information and Communications Technology
IEDS	Industrial Enterprises above Designated Size
LP	Linear Programming
MI	Malmquist Index
MPI	Malmquist Productivity Index
OEC	Optimistic Efficiency Change
OECD	The Organization for Economic Cooperation and Development
OTC	Optimistic Technical Change
PPF	Production Possibility Frontier

PPS	Production Possibility Set
PTE	Pure Technical Efficiency
SE	Scale Efficiency
SQ	Staff Quality
TC	Technical Change
TE	Technical Efficiency
TFP	Total Factor Productivity
VRS	Variable Returns to Scale

Chapter 1

INTRODUCTION

1.1 R&D Definition and Measurement

The benefits of R&D expense on the corporate performance have been widely studied during the past decade, as R&D activities of countries play a crucial role in developing and sustaining the growth of their national economy and corporate business as well as value added to their industries. The economic success has been based on the effective utilization of intangible assets such as knowledge, skills and innovative potential in order to achieve a competitive advantage. (Karadayia & Ekinci, 2018) These advantages surely have a direct or indirect impact on the results shown by regular measurements. Also, one vital indicator of measuring countries' technological improvements is their patents. While patenting has a long history, it has been recently considered as a factor to measure technological improvements with.

Moreover, the economic performance of Europe has lagged behind due to inadequate R&D investments. Academic studies have widely discussed that R&D is the dominant factor of productivity growth. Technological development is one of the most important components of economic growth. The efficiency of R&D activities is vital for all countries since it leads to economic growth. This point motivates us to conduct an R&D analysis of countries. (Karadayia & Ekinci, 2018) However, economic is not the only aspect in which R&D's success in different countries should be measure in. Of course, it has its huge impact on it; however, there are some other factors to keep track of like the number of professional personnel who is considered for R&D projects, etc.

The main purpose of this thesis is to discuss methods and the factors which should be considered in our evaluations. We are going to expand all the information and investigate how much each of them influence the outcome of R&Ds.

1.2 Background

The current studies that measure the R&D efficiency can be grouped into two. One group measures the R&D efficiencies of the companies, and the second group measures the efficiencies of countries. This study is in the second group and aims to provide valuable insights for the policy makers of OECD countries about their R&D activities. It is crucial to select comparable DMUs since the DEA gives relative efficiency scores. (Karadayia & Ekinci, 2018)

Many studies have investigated the determinants of economic growth. The survey of Petrakos and Arvanitidis in 2008 identified a number of important determinants of economic dynamism at the global scale. Among others, it was found that the determinants of economic dynamism do not have the same influence in advanced and less advanced countries. (Szarowská, 2018)

An important finding resulting from research (Szarowská, 2018) is that the dynamic panel analysis conclusively confirms a positive and statistically significant impact of R&D expenditure on economic growth.

There is another paper written by Liu et al. in 2020, which utilizes the data envelopment analysis (DEA) as the main tool to measure the R&D performance of

Chinese IEDSs (industrial enterprises above designated size). (Guo-Liang, Hui-Hui, Xiao-Xiao, & Yao-Yao, 2020)

The paper written by Mahendhiran et al. in 2020 claims that, while there is ample empirical evidence to show the close linkages between R&D and ICT infrastructure development and their impact on economic growth, other studies in the literature examine the causal linkages between R&D investments and ICT infrastructure development separately on economic growth. Studies do not typically treat the inter-linkages between R&D investments, ICT development and economic growth. (Mahendhiran , P. Pradhan, & Mak , 2020)

Also, R&D productivity is measured at the national level in order to provide R&D policy implications by a paper written by Hak-Yeon Lee and Yong-Tae Park, particularly for Asian countries, by identifying the characteristics of Asian countries with respect to R&D productivity. In terms of the measurement method, total factor productivity (TFP) has been mainly employed as a measure of overall productivity in the previous studies. (Lee & Park, 2005)

1.3 Provided Suggestion

Data Envelopment Analysis is a method which helps the evaluation of Relative Efficiency of Decision-Making Units (DMUs). It certainly uses programming based on mathematical equations. Since then, numerous numbers of papers and researches has been focusing on this methodology to this day. (Wang & Lan, 2011)

An important research subject in the area of DEA is Productivity evaluation. In this subject, the method that comes very handful is the Malmquist Productivity Index

(MPI). It is used in various time spans for computing the relative performance and it utilizes the technology of the base period. (Wang & Lan, 2011)

The purpose of this study is to apply DEA-based Malmquist Productivity Index to measure the productivity growth in 19 Countries in OECD sector over a 6-year period (2013–2019). Thanks to the application of the Malmquist index, our investigation goes one step further in assessing the productivity by identifying the main components of changes in productivity.

1.4 Advantages and Disadvantages

Malmquist index which has been introduced by Malmquist (1953) in a expenditure context and it is used as a Productivity Index. There are two major privileges and which are: First, there are no need for information about price or assumptions of equilibrium for comparison of prices and marginal products. But, Malmquist is unable to evaluate a sole country and it needs to make comparisons between multiple datasets with their related inputs and outputs. These data is available in the OECD website related to R&D. The second advantage of using Malmquist Productivity Index is that the Total Factor Productivity can be broken down into two different factors of Productivity efficiency and Technological change and that is a huge help; we will talk about these terms later in this thesis.

1.5 Thesis Structure

The remainder of this article is organised as follows. The next section outlines a review of R&D Literatures as well as investigation of previous literature done for DEA and other methods used in this thesis; also the last couple of research with almost the same subject as this one "*Impacts of R&D on productivity of countries*". In Section 3, DEA with categorical data is considered for both Methodology and Data collection for evaluating R&D performance of chosen countries. In Methodology we will define the methods used in this thesis and their extensions and we will explain the choosing process of the factors in which will be used as inputs and outputs in the evaluation process. The calculations towards available data and their analysis are given in Section 4 and this includes providing graphs and numbers regarding the technical and efficiency changes in DEA methodology. In Section 5, research hypotheses and their results are reported and discussed more.

Chapter 2

LITERATURE REVIEW

In this chapter which is dedicated to reviewing literature, we discuss and inspect the previous works done in the subjects related to this thesis. First, we discuss the previous researches done about Research & Development (R&D), as well as checking the definition, different ways of R&D classifications, as well as its vital factors and the firms' measurements. Then the Data Envelopment Analysis is mentioned and the first thing to inspect about it is its history and background; after that the standard DEA model is added and the economic point of view is considered, then Production Possibility Set and DEA's models, CCR and BCC are mentions. Malmquist is also is defined in this chapter. At couple of paragraphs, some of the important previous works which has used DEA as a tool for measuring R&D is reviewed and a summery is provided for their better understanding.

2.1 Research and Development (R&D)

It is undeniable that the pace which technologies are developing in the past decades is staggering. The way different companies and institutions found to get more involved in this competitive environment is throughout their Research and Development sections; of course, they expect things in return to their involvements. An article published by (Bronwyn, 2002) named "The financing of research and development" focuses on financial reasons for investments on R&D. Also, the book section under the subject of "Appropriating the Results from Industrial research and Development" by (Levin, et al., 1987), explains that a firm must have a suitable return sufficient in order to make the investments reasonable, to encourage firms to do participate through research and development. Another article published by (Griliches, 1979) , gives out the layout of the production functions approach for forecasting return to R&D by either measuring output in R&D intensive industries, or/and by measuring the stock of R&D "capital". There are a lot more publications and books such as "Two Decades of Research and Development in Transformational Leadership" by (Bass, 1999) and "*Research for development: A practical guide*" by (Laws, Harper, Jones, & Marcus, 2013) in which a lot of information can be extracted from.

2.1.1 Definition

Research and Development (R&D) can be explained as a set of creative and systematic activities in which different companies undertake to produce services and products yet unknown. It is considered to be the first step in the development process. The purpose of these actions is mostly to take these new products and services to related markets and to add to company's value. R&D is believed to have a positive impact on companies in case of staying ahead of their competitors. Without a suitable R&D program, companies will not be able to stay competitive and so, probably will have to rely on other ways in order to stay innovative and productive. It is through R&D that they can make improvements and meet their consumer's needs. (Frascati, 2015)

Every R&D project has either general or specific goals to achieve. They are for sure aimed to explore new findings, based on related concepts or hypothesis. Usually, R&D projects are believed to be dubious about their final outcome or the time or the resources needed to achieve this outcome; it should be planned and mostly some budget should be allocated to them, and they are mostly aimed to produce result that could either be freely transferable or has the value to be transferred for a cost in the marketplace. (Frascati, 2015)

R&D communities are in close relevance with other parts in their organization. the main purpose is to import scientific and technological information, make practical and convenient inventions based on them, create processes based on this information, or even use them to produce new ideas, and then send out these products to the other parts of their organizations. There are a lot that should be done for this outcome to be useful in a profitable manner to the customers of the firm (Vieira, Dias , Santos , Pereira , & Oliveira, 2018), such as business planning, but our focus in this paper is the R&D part.

2.1.2 Classification

There are four enterprises which R&D can be used in: Business enterprise, Higher education, Government, and Private non-profit. Now there are three types of R&D itself:

- Basic Research
- Applied Research
- Experimental Research

Basic research is empirical or theoretical activity done for the purpose of gaining new knowledge, without any particular application or use in view.

Applied research is research which has been set a specific practical aim or objective, and it is defined as the original analysis for grasping new data and gaining new knowledge.

Experimental research is the research which is systematic, and is based on information taken from experiments for adding to existed knowledge in a specific field, in order to introduce new products and optimized processes or to improve already existing ones. (Frascati, 2015)

An important and practical way to distinguish these classifications from each other is by the expected use of the results. Also, the time the project is expected to reach a certain goal can be vital in this classification, as well as the broadness of the fields which are affected by the result of this research. (Frascati, 2015)

There is also another way to classify R&Ds and that is through Fields of Research and Development (FORD). Reasonably, R&D preforming units are divided according to the knowledge domain they are related to. Although the R&D subjects are closely related, these subjects are grouped into plenty of so called broad and narrower classifications. (Frascati, 2015)

Table 1 : Field of Research Classification

Broad classification	Second-level classification
1. Natural sciences	1.1 Mathematics 1.2 Computer and information sciences 1.3 Physical sciences 1.4 Chemical sciences 1.5 Earth and related environmental sciences 1.6 Biological sciences 1.7 Other natural sciences
2. Engineering and technology	2.1 Civil engineering 2.2 Electrical engineering, electronic engineering, information engineering 2.3 Mechanical engineering 2.4 Chemical engineering 2.5 Materials engineering 2.6 Medical engineering 2.7 Environmental engineering 2.8 Environmental biotechnology 2.9 Industrial biotechnology 2.10 Nano-technology 2.11 Other engineering and technologies
3. Medical and health sciences	3.1 Basic medicine 3.2 Clinical medicine 3.3 Health sciences 3.4 Medical biotechnology 3.5 Other medical science
4. Agricultural and veterinary sciences	4.1 Agriculture, forestry, and fisheries 4.2 Animal and dairy science 4.3 Veterinary science 4.4 Agricultural biotechnology 4.5 Other agricultural sciences
5. Social sciences	5.1 Psychology and cognitive sciences 5.2 Economics and business 5.3 Education 5.4 Sociology 5.5 Law 5.6 Political science 5.7 Social and economic geography 5.8 Media and communications 5.9 Other social sciences
6. Humanities and the arts	6.1 History and archaeology 6.2 Languages and literature 6.3 Philosophy, ethics and religion 6.4 Arts (arts, history of arts, performing arts, music) 6.5 Other humanities

2.1.3 Important Factors

The basis of R&D can be grasped by the human being's scientific and technological activities. Technological innovation theory discusses that net worthy knowledge and professional competency are advantageous for improving R&D staff's learning capabilities, their comprehension, advancements and their overall performance during their research and developments, as well as their industrial transformation performance. Therefore, any improvements in **staff quality** (SQ) are considered helpful for RDEs (R&D efficiency). Human capital theory is considered as a proper approach to boost SQ by investing in education. (Sung & Nam Choi, 2013)

Regarding SQ, It is believed that using formal education can have an effect throughout providing appropriate knowledge for individuals (Ødegaard & Roos, 2014); however, the SQ is improved more efficiently by technological innovation abilities, and they are proved to be more reasonable and rational than formal education investment; because In such high pace of updating knowledge, SQ needs some time to adapt to new information in order to perform effectively and practically. (Nazarov & Akhmedjonov, 2014) R&Ds are believed to be practical, meaning that they are hard to be grasped throughout formal education, and they are most being taught by on-job trainings, as the complexity of R&D projects requires lot of participation and collaboration from staff at the same time of these on-the-job education. Also, R&D is considered to be a 'link-loop' process and therefore it is dependent on previous researches and findings and needs its own past data as a source of information and it is accumulating knowledge. (Song, Wang, & Sun, 2018)

It should not be unsaid that, although comparing R&D expenditures to other capital investments may seem reasonable, they have some differentiates in several aspects.

One of these aspects is that, the results of findings by these R&D researches, not only benefit the ones invested in them but also the competitors, suppliers and also it helps development of firms. Therefore, R&D must not be considered as an asset held by a specific owner. The knowledge produced by R&D is influential in productivity growth of the whole market. (Sveikauskas, 2007)

Output of R&Ds should be investigated differently from other areas. Using market-sensitive measures such as profitability and return to investment do not seem thoughtful for R&D context because of sporadic and nonmarket nature. For instance, new ideas and inventions may take years to turn into new producible assets. Some additional time is needed for these newly introduced products to be allocated to the marketing, and manufacturing. Therefore, evaluation of R&D cannot be easily and specifically measured. (Elkins & T Keller, 2003) Therefore, it is vital to find a connection between R&D and total effect of R&D on economic growth, which can show both the asset returns and the spill-overs throughout similar companies. (Sveikauskas, 2007)

To show the importance of taking R&D researches to a practical and broader level, imagine a big change in the pharmaceutical firm. Statins are a kind of anti-cholesterol drug which has contributed enormously to decline of hearth diseases. First company which introduced it was a major pharmaceutical firm that took its production to a commercial level in 1987 and declared that they are safe, and it actually did decrease number of deaths from heart disease. Since 1987, numerous firms in different countries have introduced improved version of stains. Some different firms now produced stains that could lower cholesterol more efficiently than the first ones, and thus, became the market leader at that time. (Sveikauskas, 2007)

Another example that is worth mentioning is the leading firms which have been successful in producing micro-processors. When one of them introduces a newly built chip, the second firm soon matches, and as a result, the prices fall immediately. Most of the benefit is dedicated to the consumers through lower price. (Sveikauskas, 2007)

But generally, most of the times the worth of an R&D is known by various factors which are directly or indirectly related to it. These indicators and their exercises can be performed at different types of aggregation, from various kinds of businesses and governments, to different regions, and also industrial organizations. (Adam & Hall, 2018) The most important factors cand be found in the ones related to the subjects mentioned below:

- Investments (not only financial) which are being dedicated to creation of new knowledge. It is mostly directly related to R&D, but it includes other related fields. For instance, the business marketing related to the newly built product.
- The investment in new capital equipment that is related to introduction of new processes or products themselves.
- The capital dedicated for training and educating new engineers or scientists.
- The pace in which the degrees in Science and Engineering is being received
- The pace in which knowledge is being accomplished, mostly measured in number of patents or publications
- The pace of transferring of knowledge between or among different organizations or regions, sometimes measure by citations.
- The pace at which these newly found or invented methods are being incorporated into production of goods or services. (Adam & Hall, 2018)

2.1.4 Measurements

Generally, R&D projects are like seed and soil, as all the other projects. Sprout quality depends on the quality of seed, quality of soil and the caretakers. Project can be resembled as seed, organization and its surrounding environment as the soil, and caretakers are the managers of the project and the research group. Also, may need some collaboration and extra resource during the process of any given project. (Nagesh & Thomas, 2015)

There is no doubt that projects are being created in hope of accomplishing their objectives; however, few are successful in the real world. And this question has been asked a dozen times: why does this happen? The answers to this question vary in a large scale, as they could be originated from internal reasons to external factors. (Nagesh & Thomas, 2015) The way to the way to know the efficient attempts from inefficient ones, it is necessary to find a proper way of evaluation for these firms.

For more than 30 years, R&D research managers tried to measure the success rate of R&Ds. Sadly, there are no proper way to measure R&Ds which universally accepted. For example, in 1982, Alfred H. Schainblatt, after surveying 34 companies wrote "There are no currently used systems for measuring the productivity of scientific and engineering groups without substantial flaws. Nor does the literature on productivity measurement offer encouragement that suitable systems will soon be available". Four years after that, Jeffrey K. Liker and Walton K. Hancock came to a similar conclusion and wrote "Despite decades of research on the organization of engineers, no widely used measurement systems have been developed to guide productivity improvement". (Szakonyi, 2016)

Despite the generally accepted fact of R&Ds' effectiveness being heavily dependent on wellness of its harmony with other parts of the organization, from year 1960, there has been no effort made towards this fact. All of the measurements insist on the importance of focusing on R&D output instead of their collaboration with system as a team. (Szakonyi, 2016)

Considering counting patents, publications or citations, they have not been totally acceptable methods for checking R&D output quality yet in 1971, E. C. Galloway wrote: *"None of the normal criteria of productivity like (patents and publications, products developed in the last five years, project success ratio, etc) give the profit all industry managers would like to see"*. Yet, lots of literatures about measuring R&D output are focused on their publications and citations. As Schainblatt wrote, although the researchers are aware of shortcomings related to these indicators, *"the countability of publications and citations, and the relative lack of alternative things to count, apparently makes them too hard to resist"*. (Szakonyi, 2016)

Knowing all this, R&D generally is considered to be concentrated in few entities, specifically in business sector. However, the shape of the indicators for measurements changes over time, even with this highly concentrated nature; objectives of R&D statistical programs are multi-dimensional, in addition to these indicators. Some of them are:

- Aggregate indicators supporting science policies
- Expenditures allocated directly and indirectly to the R&D programs
- Micro-level data to support unit-level analysis (units regarded business enterprises, government, higher education and non-profit sectors)

It should be mentioned that, these aspects sometimes have conflictions and the strategies for sampling and processing would definitely be affected. (Szakonyi, 2016)

2.2 Data Envelopment Analysis (DEA)

2.2.1 Background and History

In the initiative article representing DEA, Farrell in 1957 was motivated to find a more suitable method for evaluating productivity. He argued that this was only achievable by producing careful measurements, and why this was impossible to do so is because of the lack of a method in which they can combine analysis of numerous inputs into any adequate overall measuring method of their efficiencies. He claimed that formal measurements of separate indices of labour productivity, capital productivity, etc. were not usable, and he offered an activity analysis approach which is concerned with the problem more adequately. His measurement was tried to be appropriate to all productive organizations. He claims "... from a workshop to a whole economy." In this process, he deepened the idea of "productivity" to a more generally understandable concept called "efficiency". (Cooper, et al., 2011)

The initial DEA model was presented by Charnes, Cooper, and Rhodes which is called CCR and it was based on the formal woks done by Farrell. It was originated in 1970s in answer to the thesis efforts of Edwardo Rhodes at Carnegie Mellon University's School of Urban & Public Affairs. This thesis was under supervision of W.W. Cooper and its purpose was to evaluate educational programs for disadvantaged students (mostly black or Hispanic) in series of massive researches in public schools in US with aid of Federal government. The studies finally were centred on program follow through – a splendid try by United States office of Education to apply regulations from statistical designs of experiment for a set of matched schools in an inter-state study.

Rhodes secured access to the data which were being used for this experiment by Abt Associates, a consulting firm based in Boston that was in connection with the United States Office of Education. Because they wanted the degree of freedom to be as easy as possible to work with (Cooper, et al., 2011), the database was selected in a sufficiently large scale; therefore, despite the numerous numbers of inputs and outputs, it will not make any difficulties. Also, unsuitable and absurd results were secured from the statistical-econometric approaches that were tried by Rhodes.

While trying to solve these issues, Rhodes seeks Cooper's attention to Farrell's primitive article. Therefore, Ferrell (Cooper, et al., 2011) used "Activity Analysis Concepts" in order to determine what he presumed to be deficiencies in regularly used index number methods for measuring the productivity related.

Cooper had collaboration with A. Charnes to give computationally frasible form to Tjalling Koopmans' "Activity Analysis Concepts". By assuming Farrell's statement (Cooper, et al., 2011) as a face value, Cooper and Rhodes could formalize the definition given previously in this paper. These definitions were given for the purpose of providing guidance for the further research.

Name of Pareto were given to the first definition among these two because of his Manual of Politic Economy (1906). In this Manual (Cooper, et al., 2011), he settled the foundation of modern "welfare economics", i.e., the part of economics that were dedicated to analysing public policies, which a social policy is worth mentioning if it can benefit some individuals without harming other ones in any way. In this manner, complexity of comparing the value of gains to some and losses to others will be avoided. This avoids the urgency of verifying the "utility functions" for each individual who were affected, or/and by "weight" of their relative importance for each one's achievements and failures.

It is known as "Pareto criterion" in welfare economics. It also were mentioned and adapted by a book written by Koopmans in 1951. In this book, "the final goods" were applied to this property, so that no eventual goods were allowed to develop further if its improvement would cost one or more other goods to be worsened. Amount of the final goods (=output) were conditional, while the amount of inputs were to be chosen in the most optimal way in return to the prices and external environmental situation (=final good). Then the phrase "efficiency prices" were defined by Koopmans (Cooper, et al., 2011) to define prices associated with efficient allocation of resources (=inputs) to justify the demands for the final goods (=outputs).

Pareto and Koopmans were implicated with analysing the entire economies. In this case it seems reasonable to allow input prices and quantities be defined by reference to their capability of satisfying the final demands and goals. However, Farrell (Cooper, et al., 2011) has expended this property to be used on inputs as well as outputs and avoided using any prices of "exchange mechanism" or the ones related. And more importantly, he utilized the performance of all other DMUs to analyse the performance of each DMU in comparison to the inputs and outputs of all the other ones.

The term "Farrell measure of efficiency" was dedicated to Farrell defined as "technical efficiency" or the volume of "waste" which is unnecessary in out process and we can eliminate them without harming or worsening any input or output. After that, Farrell (Cooper, et al., 2011) tried to categorize them as "allocative" and "scale" efficiencies which is extracted from literature of economies. "Farrell measure", assumes that all the DMUs have the same access to the inputs. This does not necessarily mean that they all have access to same amount of input material, however, part of their rating is as much dependent on the input amount used by each DMU, as it is dependent on the amount of output they produce.

As far as data availability is concerned, this “equal access assumption” is a mild one. It is easier to work with, in comparison to the data and other qualifications linked with performance such as “allocative” or “scope” or “scale efficiencies”. Plus, this assumption can now be more flexible. For example, terms like “nondiscretionary variables and constraints” is an option which can be used to work with conditions that is not controllable of managements of DMUs – in the shapes of “exogenously” resources that are fixed somehow (such as weather), which might vary for every DMU. Also, “categorical variables” can be introduced to ensure that these comparisons and analysis are affected by reference to the DMUs which has some similarities. (Cooper, et al., 2011) These extensions and more of them can help the flexibility of this method.

Data which Rhodes worked with in his thesis used “increased self-esteem in a disadvantaged child” as “input” and “time spent by a mother in reading with her child” as “output”, which were measured with by suggestion of psychological sources, as well as their record keeping and reporting practices. The fact that Farrell eliminated any need for prices in some of his researches, seemed pleasant for working with inputs and outputs such as these - as it was introduced for the schools included in the Program Follow Through experiment.

This experimental work of Farrell was limited to one-output cases and his plan for extensions with more than one outputs did not provide the requirements needed for applications of large datasets like those concerned with Program Follow Through. To reach to the point that we need in computationally achievable form, Charnes, Cooper and Rhodes (Cooper, et al., 2011) defined the dual type of the linear programming problems. Then, it turned out that Farrell's module was unable to consider nonzero slacks, which is where the changes in the ratios are connected with mixture of inefficiencies (for both inputs and outputs). The possibility of taking one of these nonzero slacks as an origin of these mixed efficiencies, also requires consideration even when it is limited to "technical efficiency".

2.2.2 Sandard Model

In the first original paper published in this matter, Charnes, Cooper and Rhodes (Cooper, et al., 2011) define DEA as *"mathematical programming model applied to observational data [that] provides a new way of obtaining empirical estimates of relations that are cornerstones of modern economics."*

DEA has not fundamentally changed since 1978; and so, numerous numbers of researches and investigations in this field has proven that it is a magnificent and easy-to-use methodology for modelling operational processes for evaluating different entities performance. (Zhu, 2020) Because DEA is a factual approach to solve the problems, and it does not require numerous assumptions, unlike other approaches which have to be accompanied with various numbers of assumptions, this methodology is being utilized by many of studies involving efficient frontier estimation in the governmental and non-profit sector, regulated sector, and in the private sector. (Cooper, et al., 2011)

Provisionally, DEA has been considered as a method more based on the input groups in comparison to fundamental tendencies. Because of this, DEA has been able to uncover dependencies that are hidden to other approaches and methodologies. For instance, imagine trying to find out the meaning of "efficiency", or more generally, trying to find out which DMU is more efficient among some number of DMUs. This can be surely accomplished by DEA easier than any other approache, without any requirement for explicitly formulated assumptions and variations; this is completely more efficient than other models like linear and nonlinear regression models. (Zhu, 2020)

Moreover, DEA is more concerned with efficiency of each of the groups under investigation individually. The chosen one works as a central unit for analysis that specifies the sample for analysing and is called a Decision-Making Unit. (DMU) (Charnes, Cooper, & Rhodes, 1978)

Full efficiency of a DMU is defined by a situation in which none of the inputs or output could be improved without any other input or output (Feng, Fangqing, Yongjun, Ying, & Yao, 2018) compared to the other ones. In most cases, in management and social science applications, using empirically available limits for efficiency are more reasonable than the theoretically possible levels of efficiency. (Cooper, et al., 2011)

Efficiency is an important feature in the areas related to economics and is mentioned in numerous papers and textbooks. The core approach is simply related to the economically efficient use of resources that are considered as inputs for the production. The fact that the resources are finite and they are not going to last forever, makes studying efficiency undeniable. Leibenstein in 1966 in his influential paper, claims that *"At the core of economics is the concept of efficiency"*. (Leibenstein, 1966)

Relative efficiency is defined by a situation when based on available evidence, none of the other DMUs show an improvement in inputs or outputs, unless there are some worsening in their other inputs or outputs. (Cooper, et al., 2011) Relative efficiency in DEA agrees with the assumption of all the inputs and outputs as equal in case of priori measures of relative importance. And that is considered as a huge advantage for this approach. (Cooper, et al., 2011)

The measurement of relative efficiency for multiple inputs and outputs is defined by Farrell and Fieldhouse, focusing on building a theoretically efficient unit, as a weighted average of efficient units, to makes the process of comparing more facilitated. (Farrell & Fieldhouse, 1962)

The first step to reach this measure of efficiency is to assign simple common set of weight to all the units. And so, we have to define all these agreed common sets of weights which we can properly assign to these units. There might be two different difficulties for evaluation of these sets of weights. On one hand, the matter is how difficult it may be to assign values to inputs and outputs. For instance, for designation of weights for outputs, we probably should consider their values and costs of producing, however this may not be as easy as it seems. On the other hand, different depots may have different measurement methods, so that their relative values cannot be compared with each other. This probably gets clearer if we were to compare schools' relative efficiencies, we would have considered achievements in music or sport as outputs. In this case, different schools may value the achievements in music or sports differently, and in general, they may treat their inputs and outputs different than other firms. Knowing this, assigning a common set of weights may seem unsatisfactory. (Farrell & Fieldhouse, 1962)

The fundamental information grasped from the DEA models, is dependent on the capability of a firm in case of improving its performance compared to other firms. Different sets of firms will result in different efficiency outcomes and the reason lies in ways possible in which the production frontier can move around. (Lu & Wang, 2017)

Because CCR model provides a comparison for all its DMUs based on a scale of 1, it does not have the flexibility to establish any further distinction among the DMUs that has been known as efficient. Therefore, Anderson and Peterson represented a new DEA model called "DEA-Super Efficiency" model. The way this model works is through removing one of the efficient DMUs and estimating the production frontier one more time; this enables us to have a fresh efficiency value for the DMU which has been eliminated temporarily. Unlike the first model, a number more than 1 can be assigned to the fresh value. However, if we exclude one of the inefficient DMUs, the original production frontier will remain untouched in DEA-Super Efficiency model. (Lu & Wang, 2017)

In other words, these two different DEA models both provide values for self-appraisal of their operations' performance, but DEA-Super Efficiency model is used to take this distinction to another level; it compares the efficient DMUs to each other, since they all have the value of 1 in the CCR model. Therefore, if we want to make a more complete explanation of the performance evaluation, we have to use all three of them. (Lu & Wang, 2017)

The following table provides a summery a some of the publications relating DEA which came in handy specially in this thesis:

Table 2 : Literature Review Regarding DEA

Column1	publication year	topic	author	summery
1	1978	Measuring the efficiency of decision making units.	Charnes, Abraham, William W. Cooper, and Edwardo Rhodes.	Extensions of the Farrell Efficiency Measure', and 'Measuring the Efficiency of Decision Making Units With Some New Production Functions and Estimation Methods'
2	2001	Data envelopment analysis	Quanling WEI	The review of DEA research and its models, its past and present (in 2001).Management, economics and mathematics are the main sources of power of DEA development (Wei, 2001).
3	2005	DATA Envelopment Analysis and its application to the measurement of efficiency in higher education	Jill Johnes	Presentation of the advantages and the drawbacks of the methods used in the measurement of the efficiency in the higher education, as well as the extended approaches developed to deal with these drawbacks. As a result of DEA, technical and scale efficiency in the English higher education sector are high on average
4	2007	A survey of data envelopment analysis in energy and environmental studies	P. Zhou , B.W. Ang, K.L. Poh	Classification and summary of 100 publications related to the application of data envelopment analysis (DEA) techniques in energy and environmental (E&E) studies

5	2008	Data envelopment analysis (DEA) – Thirty years on	Wade D. Cook , Larry M. Seiford	Review of the major publications in DEA since 1978. The focus was on: the different models for efficiency measurement, approaches used to incorporate restrictions on multipliers, considerations regarding the status of variables, and modeling of data variation
6	2011	Handbook on Data Envelopment Analysis	Cooper, William W., Lawrence M. Seiford, and Joe Zhu, eds.	This publication discusses the basic DEA models and some of their extensions.
7	2011	Data envelopment analysis: History, models, and interpretations.	Cooper, William W., Lawrence M. Seiford, and Joe Zhu	this book have complete discussions about all DEA models and defines each of them individually.
8	2012	Environmental efficiency evaluation based on data envelopment analysis: A review	Malin Song , QingxianAn , WeiZhang , ZeyaWang, JieWu	Review of the work related to the theory of efficiency analysis and its applications in environmental efficiency assessment
9	2013	A Review of Ranking Models in Data Envelopment Analysis (Hosseinzadeh Lotfi et al., 2013).	F. Hosseinzadeh Lotfi, G. R. Jahanshahloo,M. Khodabakhshi, M. Rostamy-Malkhlifeh, Z.Moghaddas,and M. Vaez-Ghasemi	Ranking models in DEA are reviewed and divided into seven groups
10	2014	Sensitivity analysis on modified variable returns to scale model in Data Envelopment Analysis using facet analysis	Sahand Daneshvar , Gokhan Izbirak , Alireza Javadi	Development of a new sensitivity analysis method based on BCC model, modified by facet analysis. And determining of an extended stability region, particularly for DMUs placed on

				the intersection of weak efficient and efficient frontier. A numerical example is used to show the results
11	2014	Network data envelopment analysis: A review view	Chiang Kao	Review of studies on network DEA, and highlighting of possible studies directions in the future from the empirical point of view
12	2015	Human development and data envelopment analysis: A structured literature review	Enzo Barberio Mariano , Vinicius AmorimS obreiro , Daisy Aparecida do Nascimento Rebelatto	A review and a summary of the research in the database of Scopus and Web of Science, that used DEA approach in the development process, in addition to the assessment of the main gaps in each analysis dimension. The following dimensions were considered: DEA models and extensions used, units analyzed and depth of analysis, interfaces with other techniques, scope and bibliometrics
13	2015	Research fronts in data envelopment analysis	John S.Liu, LouisY.Y.Lu, Wen-MinLu	The literature of DEA between 2000 and 2014 is compared and grouped in four groups, by using a network clustering method. These groups are: undesirable factors, cross-efficiency and ranking, network DEA, dynamic DEA, SBM and boots

				trapping and two-stage analysis
14	2017	A comprehensive review of data envelopment analysis (DEA) approach in energy efficiency	Abbas Mardania, Edmundas Kazimieras Zavadskasb, Dalia Streimikienec,, Ahmad Jusoha, Masoumeh Khoshnoudi	A review and summary of 144 papers between 2006 and 2015, where various models of DEA were applied in the energy efficiency development
15	2017	Review of efficiency ranking methods in data envelopment analysis	Abdullah Aldamak , Saeed Zolfaghari	Review of DEA methods published before 2016, their advantages and disadvantages
16	2017	*Container port production and management*	Lu, Bo, and Shouyang Wang	This study has investigated the fundamentals of DEA and demonstrated how DEA can be applied to measure the efficiency of container terminals.
17	2018	Expected efficiency based on directional distance function in data envelopment analysis	Yang, Feng, Fangqing Wei, Yongjun Li, Ying Huang, and Yao Chen	this publication builds on the DDF model and propose *expected efficiency* in efficiency estimation.
18	2018	Operations research for sustainability assessment of products: A review	Christian Thies, Karsten Kieckhäfer , Thomas S. Spengler , Manbir S. Sodhi	The review of 142 articles using OR methods for product related sustainability assessments
19	2019	Transnational resource generativity: Efficiency analysis and target setting of water, energy, land, and food nexus for OECD countries	Mustapha D. Ibrahim, Diogo Cunha Ferreira , Sahand Daneshvar , Rui Cunha Marques	The efficiency of Organization for Economic Co-Operation and Development countries in terms of Water-Energy-Land-Food is evaluated, by introducing intrinsic and composite factors. It was shown by using DEA that the implementation of a win-win strategy is

				necessary to achieve the efficiency of WELF-Nexus

2.2.3 Economical Aspect

This definition surely avoids needs for any resource for price or weights, which are already selected and confined, and are supposed to reflect relative importance of inputs or outputs. Moreover, it does not need to specify any formal connections which we were supposed to find, between inputs and outputs. However, there is a basic kind of efficiency called "technical efficiency" that is related to economics, which can be extended to other types of efficiencies when the available data are in types like prices, unit costs, etc. (Feng, Fangqing, Yongjun, Ying, & Yao, 2018) Researchers from all sorts of firms use DEA as a practical approach for evaluating technical efficiencies related to their firms.

Inspections on DMUs will be done over different time periods, and also it is important to analyse the DMUs whenever there is a change in interest focus for any particular DMUs efficiency over time. Moreover, it is potentially achievable to find a DEA in a time period with usage of a moving average analogue, where a DMU in each different time-span is being handled as a different a completely different DMU. Precisely, any DMUs performance is different from that same DMU in a different time period, the same way it differs from other DMUs in case of their performance. (Feng, Fangqing, Yongjun, Ying, & Yao, 2018)

The main theory of DEA models are in direct interaction of micro-economics. Consequently, it is important to clarify the concept of DEA efficiency. This whole concept is somehow dependent on the production function: y = f(x). Next paragraph explains the production function.

Business firm usually combine numerous multipliers related to production with the aim of producing diverse goods and/or services. Although a lot of various multipliers are involved in the production process (or simply inputs), in most of the cases we use only two factors, labour and capital. Then, it is possible to decide whether it is reasonable to combine two inputs to make an output. The link between these inputs and output related to it is labelled the production function. The general equation dedicated to this matter is Q = f (L,K) where Q is the input, L is labour, K shows the capital and the f shows the functional relationship. In short term, we assume that the capital is irreplaceable. Therefore the only variable remaining is labour. (Lu & Wang, 2017)

Because of the advantages that DEA has, it has improved to be a method which is being frequently used in case of business management. First, it can use multiple inputs and outputs and is able to work with them all together; it also allows their units to be different. Secondly, there is no need of knowing the type of production function earlier. Howsoever, DEA also has some drawbacks and restrictions: the DMUs must be analogous to get the best results possible. Also, number of DMUs must be at least two times more than the number of inputs and outputs. Plus, they should be “isotonic”, meaning that the outputs should not diminish while the inputs are being increased. (Lu & Wang, 2017)

2.2.4 Production Possibility Set Definition

In business applications, Production Possibility Frontier (PPF) is an illustration of possible numbers showing the amount which can produced by two types of goods that both can be found in finite numbers from their manufacturer. It is usually shown in a shape of a curve.

It is especially important in economics, as it can come useful in illustration of the point in which any firm's economic situation can achieve the highest level of efficiency; it is shown for when firms produce only the best qualified products and trade them with other firms as an exchange of the rest of things they need. (Lu & Wang, 2017)

One other phrase which explains PPF is "Production Possibility Curve" or "Transformation Curve".

2.3 Charnes, Cooper, Rhodes (CCR/BCC)

2.3.1 CCR

The evaluation made to the DMUs can be from governmental agencies as well as non-profitable organizations or business firms. These improvements can also be dedicated to a wide range of firms such as educational institutes or hospitals, as well as police forces or even army units. Comparisons of performance are regularly being made among these firms.

We presume the number of DMUs to be **n**. Each of these **n** DMUs consume a number of **m** different inputs to produce number of **s** outputs. We assume that all of these inputs and outputs are an amount bigger than zero. And also, all of these DMUs have at least one input and one output. (Khaksar & Malakoutian, 2021)

Now we define "ratio-form" of DEA. In this form, Charnes, Cooper and Rhodes, the relation between inputs and outputs is being used to find relative efficiency of that specific DMU to be evaluated relative to the proportions of all the other DMUs. We can utilize the CCR construction to build up a single "virtual" input and single "virtual" output from the formal simple multiple-input/multiple-output situation for each DMU. For each of the DMUs, the relation between this single virtual output to single virtual input gives us a measurement of the efficiency that is used as function of multipliers. In mathematical based programming language, ratio of this output over the input for the same DMU is to be maximized. (Khaksar & Malakoutian, 2021)

CCR model also provide a relative "returns to scale" (CRS), which simply is the relationship between all the progresses of all inputs, to the progress of the outputs. (Khaksar & Malakoutian, 2021)

We can define the efficiency frontier form the collected set of efficient units. DEA computes the efficiency dedicated to each of observations based on the frontier that covers all of the views. Inefficient ones can advanced (to the efficient frontier) to the points along the frontier with strategic directions with accuracy. This distance from the point to the efficiency frontier defines the amount of efficiency. (Khaksar & Malakoutian, 2021)

2.3.2 Input and Output Oriented Models

Technically, data envelopment application is categorized into two different parts, input-oriented and output-oriented. Input-oriented reduces the amount of inputs to the minimum possible by considering that none of the outputs should be decreased or harmed. Conversely, output-oriented tries to increase amounts of outputs without adding to the inputs involved. Both of these models' purpose is to maximize overall output and minimize overall input and thus, maximizing the efficiency. Generally, input-oriented models focus more on the operational and managerial issues, when output oriented is more associated with planning and strategy. (Rajasekar & Deo , 2014)

2.3.3 Banker, Charnes and Cooper (BCC)

The efficiency of each individual DMU can be measured by the BCC model of DEA in for of envelopment. This model changes the formal Constant Returns to Scale (CRS) impression to Variable Returns to Scale (VRS). BCC model divides technical efficiency (TE) based on the CCR model into two parts:

- Pure Technical Efficiency (PTE): by connecting a DMU to unit of comparable scale, it specifies the effect of scale size, and also it forms the way a DMU develops its bases under the outer region. (Khaksar & Malakoutian, 2021)
- Scale Efficiency (SE): it determines if the scale size has positive or negative impressions on efficiency. If there was a change in two technical efficiencies, That DMU has a scaling efficiency and it can be designed by:

SE = TE/PTE

2.4 Malmquist Index

One of the most important parts of DEA toolbox is Malmquist Productivity change Index which was presented by Caves et al. in 1982. Although at first this method was introduced as a theoretic index regarding distance functions, these distance functions found their place as one useful practical tool. (Pang, 2006)

This thesis utilizes a systematic computation method using DEA-based Malmquist Productivity Index measure, for operating efficiencies of 19 OECD countries from 2013 to 2019. MPI were initially suggested by Malmquist as a quantity index for analysis of utilization of input materials. DEA-based MPI is believed to be a practical tool for measurement of changes in productivity of DMUs. For instance, changes in agricultural productivity in 18 different regions (Fulginiti & Perrin, 1997), telecommunications productivity and technology catchups for 74 nations (Madden & Savage, 1999), and measurement comparisons and alterations of 50 different sea ports. (Pang, 2006)

The original DEA originally the way a data-based activity analysis model can be solved using linear programming techniques to reach a performance which is productive. the distance function or likewise Farrell's measure of technical efficiency provides a good explanation for these issues. Fare et al. in (1989-1994) made connection of all the methods used before, and introduced the aforementioned DEA estimation method for the Malmquist Productivity Index. (Cooper, et al., 2011)

The original paper written in subject of Malmquist is by Caves, Christensen and Diewert (CCD), Malmquist defined a quantity index as ratios of distances/distance functions in which observations were graded based on their relative measurement to an indifference curve, since he was working with consumer-based indexes. The technology frontier was replaced with indifference curve by CCD, and for the purpose of defining a productivity index in the spirit of Malmquist's consumer quantity index. Precisely, in its description of output-oriented productivity index dedicated to Malmquist model, the output isoquant is being used as the reference to which measurements under investigation were being showed using an output distance function. Likewise, an input isoquant were chosen as reference for the input-based if the data were dedicated to the respective isoquants. (Cooper, et al., 2011)

Two theoretical indexes were introduced by 1982 which were named Malmquist input and output productivity indexes. These indexes follow the path of Sten Malmquist's quantity index. Malmquist index attempted using radical scaling to build his quantity index via comparison of two quantity vectors with a chosen indifference curve. Yet, Caves, Christensen and Diewert used radical input and output scaling to reach proper comparison between two input-output vectors and reference technology. These comparisons have been made for the input and output productivity indexes respectively. (Fare, Shawna, & Roos, 1998)

Professor Sten Malmquist claims that he realized that the economy of two nations could be compared based the knowledge. He used Malmquist Index (MI) as a bilateral means of comparing the production technology of two different economies with each of them having the exact same role on different sides of index. Thus, MI is a bilateral index which is being used for comparison of two different production technologies belonging to two economies. (Fare, Shawna, & Roos, 1998)

In order to get the MI of economy A with respect to economy B, we must substitute the labor and capital of first economy into the production function of second one, and vice versa.

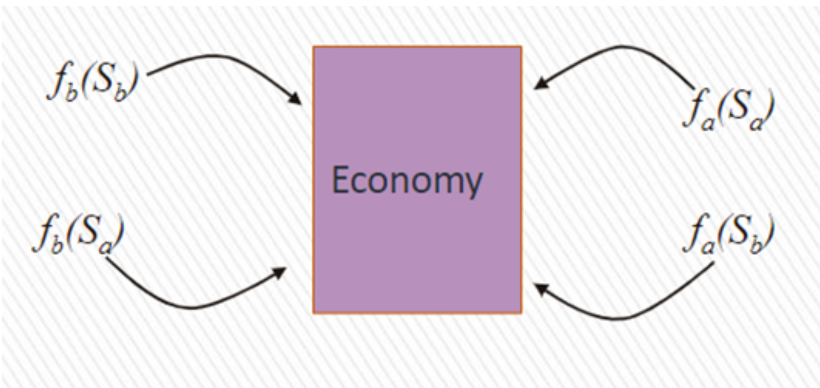

Figure 1: Malmquist Index on Economies

MI is a good method for recognizing any changes in productivity and breaking it down to their main elements. This has been applied to several fields such as, education, energy efficiency, or health care. (Bjurek, 1996)

MI has become the standard approach in productivity measurement, especially if there are any non-parametric specifications applied to the micro data. Fare, Grosskopf, Lindgren and Roos translated the idea of using the geometric mean of the indexes, and defined it for translog technologies to the non-parametric setting. (Bjurek, 1996)

2.5 DEA in R&D

R&D plays a vital role in measuring the national economies' developments, so the efficient using of R&D has become crucial for improving the productivity of related firms. Because of this, evaluating the R&D firms has become the centre of attention recently. The most known former methods for evaluating R&Ds based on their performance are by using DEA and SFA (stochastic frontier analysis). For instance, the use of SFA, Zhang, Zhang, and Zhao (Zhang, Zhang, & Zhao, 2003), has done some researches regarding the effects of ownership on R&D efficiency of Chinese firms. Wang and Wong (Wang & Wong, 2012) had used the same method to inspect the impact of foreign R&D investment on domestic technical efficiency. These were two of the cases in which they used DEA for their measurements. (Guo-Liang, Hui-Hui, Xiao-Xiao, & Yao-Yao, 2020)

In case of finding the relative efficiency for R&D for several countries to determine which one performed better in this case we apply a concept of nonparametric efficiency analysis: DEA. (Cullmann, Schmidt-Ehmcke , & Zloczysti , 2009) Usage of DEA has been increasing dramatically during the past few years; they are being used for different variety of entities involved in completely different activities, and also located in different countries. These applications were utilized to evaluate different types of entities and inputs, such as hospitals, US Air Force wings, universities, cities, courts, business firms, and others, including the performance of countries, regions, etc. Because this method is not based on assumptions, it is easily usable in the cases which are impossible to solve by other approaches, and also because of the fact that they are more adapted with more complex relations between multiple inputs and outputs. (Cooper, et al., 2011)

DEA have shown some particular privileges in terms of weighting the performance of R&D activities. First, R&D measuring issues commonly requires having to deal with multiple DMUs that each one contains multiple inputs, and they usually produce more than one output that should be measured. This issue is easily solved using DEA method. Secondly, DEA is particularly useful where it is somehow not reasonable to inspect the relative importance of each DMU, which is notable point while evaluating R&D performances in which the emphasis on R&D inputs and outputs has no consolidated view. And thirdly, in DEA methodology, DMUs are allowed to be measured without having to specify functional representation of the R&D production process. (Guo-Liang, Hui-Hui, Xiao-Xiao, & Yao-Yao, 2020)

An essential point for making an R&D firm more productive is for it to be able to be measure in case of its productivity. (Lee & Park, 2005)

In a study done by (Lee & Park, 2005) called “An international comparison of R&D efficiency: DEA approach” R&D productivity is measured in an international level so that R&D policy implications will be provided, particularly for Asian countries. This is done by analysing the characteristics of these Asian countries with respect to R&D productivity.

A paper published by (Griffith, Redding, & Reenen, 2004) provides econometric evidence on the importance of the two faces of R&D by evaluating and comparing the parameters related to productivity growth in numbers of industries across twelve OECD countries. The way R&D stimulates growth is directly through innovation and also in an indirect way through technology transfer. And so, this paper shows the great role of R&D in industries in OECD countries. (Griffith, Redding, & Reenen, 2004)

A paper published by (Weichiao & Wang, 2007) proposed a three-stage approach, which used DEA for estimating and Tobit regressions for controlling external environment. This paper uses each country as a DMU for the R&D process. It sets an inter-country R&D innovation production framework. Using a three-stage approach, this research identifies and separates internal technical inefficiencies in R&D process, from the external effects stemming from the environment, which is different for each individual country.

In a paper published by (Avraham , Boaz , & Eilat, 2008), a multi-criteria approach for R&D project evaluation is introduced, based on integration of two different innovative managerial methodologies. It uses DEA and Balance Scoreboard (BSC) together, which were believed to be useful tool for analysing any application. Values in this research are categorized as “benefits” (outputs), “costs” (inputs) and preferences. This model discriminates the projects involved with chosen characteristics and uses organizations’ priorities to classify them.

Chapter 3

METHODOLOGY

In this chapter we are going to define all the models which we use in this thesis starting with DEA and related models to it. As the Malmquist Index which is used for calculation in this thesis is DEA-Based, we will have an explanation about that. We also discuss the important factors which we use as input factors or output factors in this thesis.

3.1 DEA

DEA is an efficiency method that is non-parametric. It is being used to compare its parameters. Its purpose is to provide an estimation of production frontier (which is called production function) and to compare the production units (the factors dedicated to production, or inputs) and the good s or services that are considered as the products (outputs). DEA is about groups of technologies that are provided as sets of production plans, which are the technologically feasible outputs for given production factors. The objective function of the model is to maximize the efficiency, in order to estimate the production function. And production function gives us the same amount as the summation of weighted vectors dedicated to outputs divided by the weighted additions of the vectors dedicated to inputs. (Cooper, et al., 2011)

Figure 2 : DEA

3.1.1 DEA Approach Generalities

Principal of DEA approach is for comparison of the efficiency of DMU_o (which means the DMU under evaluation, $o = 1, \dots, n$) in which efficiencies related to other DMUs belong to the PPS (Production Possibility Set). Inputs and outputs must be the same in all the DMUs involved. Concept is that there is always DMUs which have the possibility to have better performances than the DMU under investigation. (Cooper, et al., 2011)

Assume that $inputs = 1, \dots, m$, and $outputs = 1, \dots, s$. In this case, number of DMUs should be calculated by:

$$n \geq 3 \times (m + s)$$

There are weights dedicated for each input and output in this method. The weights assigned to inputs are $(v_i, i = 1,2, \dots, m)$ and weights assigned to outputs are $(u_r, r = 1,2, \dots, s)$. These weights can for example be the expenses for inputs and the selling values for the outputs. Main objective of the DEA methodology is to try to discover an appropriate value for each of the inputs and outputs' weights. The efficiency is the ratio of virtual outputs over virtual inputs. (Cooper , Seiford , & Tone, 2007)

Virtual output: $\sum_1^s u_r \, y_{ro}$

Virtual input: $\sum_1^m v_i \, x_{io}$

The DMU under observation's efficiency: $\theta = \frac{\sum_1^s u_r y_{ro}}{\sum_1^m v_i x_{io}}$

Subject to $\frac{\sum_r u_r y_{rj}}{\sum_r v_i x_{ij}} \leq 1 \quad for\ j = 1, \dots, n$

$u_r, v_i \geq 0 \quad for\ all\ i\ and\ r$

And the relative efficiency of the DMU_o where **o** is dedicated to the DMU being measured is:

Max $\theta_o = \sum_{r=1}^{s} u_r y_{ro}$

Subject to $\sum_{i=1}^{m} v_i x_{io} = 1,$

$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{io} \leq 0, \quad \forall j,$

$u_r, v_i \geq 0 \qquad \forall\, r, i.$

3.1.2 Propositions (Basic CCR Model Assumption)

1- All of the DMUs belonging to the PPS

$$DMU_j \in PPS\ for\ j = 1,2, \dots, n$$

2- If $(x, y) \in PPS \rightarrow$ all activities $(\bar{x}, \bar{y})$ that $\bar{x} \geq x$ and $\bar{y} \leq y$, $(\bar{x}, \bar{y}) \in PPS$.

3- Constant returns to scale assumption CRS

If $(x, y) \in PPS \rightarrow \forall k \geq 0$ we can say, $(kx, ky) \in PPS$.

4- Convex linear combinations: If (x, y) and $(\bar{x}, \bar{y}) \in PPS \rightarrow \forall \lambda \in [0,1]$ we have $[\lambda(x, y) + (1 - \lambda)(\bar{x}, \bar{y})] \in PPS$.

5- PPS is the smallest group meeting 4 previous presumption.

$PPS = (x, y), x \geq \sum_{j=1}^{n} \lambda_j x_j$ And $y \geq \sum_{j=1}^{n} \lambda_j y_j$,where$\lambda_j \geq 0$.

A DMU can be called efficient if and only if its situation is on the line of the frontiers for PPF (production possibilities frontier).

3.1.3 The Basic CCR Model

CCR model assumes that there is no considerable connection between the size of enterprise and efficiency, by presuming constant returns to scale (CRS) and it will deliver the overall technical efficiency. The CRS hypothesis is only legitimate when all DMUs are operating at their best scale possible.

Every various multiplication for inputs, gives us the same multiple for outputs. If input called X produces output Y, then the Input λX Produces λY for $\lambda > 0$. To put it simply, if point (X, Y) is feasible, therefore $(\lambda X, \lambda Y)$ is feasible. And if with X inputs, we can produce Y outputs, then it is possible to produce λY outputs with number of λX inputs for $\lambda > 0$, and these (X, Y) and $(\lambda X, \lambda Y)$ are considered identical. (Wang & Lan, 2011)

Transformation dedicated to the linear fractional programming gives us (u, v) for which $\sum_{i=1}^{m} v_i x_{io} = 1$, and gives the equal LP problem in which the variables change from, (u, v) to (μ, v) and it is a result of the Charnes-Cooper transformations:

$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$

ST $\sum_{i=1}^{m} v_i x_{io} = 1$

$\sum_{i=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad j = 1, \ldots, n$

$\mu_r \geq 0 \qquad r = 1, \ldots, s$

$v_i \geq 0 \qquad i = 1, \ldots, m$

Now the Linear Programming dual problem would be:

$\theta^* = \min \theta$

ST

$\sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta x_{io} \; i = 1,2, \ldots, m;$

$\sum_{j=1}^{n} y_{rj} \lambda_j \leq y_{ro} \quad r = 1,2, \ldots, s;$

$\lambda_j \geq 0 \qquad j = 1,2, \ldots, n;$

3.2 DEA-based Malmquist Productivity Index (MPI)

Suppose that there are "n" DMUs that are going to be measure and compared with "m" inputs and "s" outputs. Denote by x_{ij}^{t} and y_{rj}^{t}as well as x_{ij}^{t+1} and $y_{rj}^{t+1}$the inputs and outputs of DMU_j at time periods t and t + 1, respectively, where $i = 1, \ldots, m$ and $r = 1, \ldots, s$ and $j = 1, \ldots, n$. The optimized DEA-based MPI needs the answer for the first two following CCR models and Linear Programming (LP) models which are the second two equations below (Wang & Lan, 2011):

$D_o^t(x_o^t, y_o^t) = \ Minimize\ \theta$

S.T $\quad \sum_{j=1}^{n} \lambda_j x_{ij}^t \leq \theta x_{io}^t, \qquad i = 1, \dots, m,$

$\sum_{j=1}^{n} \lambda_j y_{rj}^t \geq y_{ro}^t, \qquad r = 1, \dots, s,$

$\lambda_j \geq 0, \qquad j = 1, \dots, n,$

$D_o^t(x_o^{t+1}, y_o^{t+1}) = \ Minimize\ \theta$

S.T $\quad \sum_{j=1}^{n} \lambda_j x_{ij}^t \leq \theta x_{io}^{t+1}, \qquad i = 1, \dots, m,$

$\sum_{j=1}^{n} \lambda_j y_{rj}^t \geq y_{ro}^{t+1}, \qquad r = 1, \dots, s,$

$\lambda_j \geq 0, \qquad j = 1,2, \dots, n,$

$D_o^{t+1}(x_o^{t+1}, y_o^{t+1}) = \ Minimize\ \theta$

S.T $\quad \sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \leq \theta x_{io}^{t+1}, \qquad i = 1, \dots, m,$

$\sum_{j=1}^{n} \lambda_j y_{rj}^{t+1} \geq y_{ro}^{t+1}, \qquad r = 1, \dots, s,$

$\lambda_j \geq 0, \qquad j = 1, \dots, n,$

$D_o^{t+1}(x_o^t, y_o^t) = \ Minimize\ \theta$

S.T $\quad \sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \leq \theta x_{io}^t, \qquad i = 1, \dots, m,$

$\sum_{j=1}^{n} \lambda_j y_{rj}^{t+1} \geq y_{ro}^t, \qquad r = 1, \dots, s,$

$\lambda_j \geq 0, \qquad j = 1, \dots, n,$

In this model, $D_o^t(x_o^t, y_o^t)$ and $D_o^{t+1}(x_o^{t+1}, y_o^{t+1})$ measures the efficiencies of DMU_o ($o \in \{1,2, \dots, n\}$) in periods of t and t +1 ,respectively, $D_o^t(x_o^{t+1}, y_o^{t+1})$ measures its efficiency in the period t + 1, using the production of technologies in period t, that is labeled the growth index dedicated to DMU_o, and $D_o^{t+1}(x_o^t, y_o^t)$ which measures the efficiency of DMU_o in the period of t using production technology for period t + 1. (Wang & Lan, 2011)

As an illustration, we can put all this factors in the figure 1, that is shown in chapter 2 (Literature Review), in which the formulas mentioned above perfectly fits in it; as an example, for one of the factors, the inputs for time period t and the$f_a(S_a)$ is equal to $D_o^t(x_o^t, y_o^t)$. For the next factor, the $f_a(S_b)$ is equal to $D_o^t(x_o^{t+1}, y_o^{t+1})$. And the same goes for $f_b(S_a)$ and $f_b(S_b)$, which are respectively equal to $D_o^{t+1}(x_o^t, y_o^t)$ and $D_o^{t+1}(x_o^{t+1}, y_o^{t+1})$.

As efficiencies that were shown previously, a DEA-Based MPI was proposed:

$$MPI_o = \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} . \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^t, y_o^t)}\right]^{1/2}$$

It measures the changes in productivity of DMU_o for periods t and $t + 1$. According to the former studies, $MPI_o > 1$ indicates that productivity has been increased. $MPI_o = 1$, shows that the productivity has remained untouched, and $MPI_o < 1$, shows that the productivity has decreased. (Wang & Lan, 2011)

To eliminate the former assumptions of $D_o^t(x_o^t, y_o^t)$ and $D_o^{t+1}(x_o^{t+1}, y_o^{t+1})$ should be as same amount as the unity and for allowance of technical inefficiency, the MPI was decomposed in two components by Fare et al.:

$$MPI_o = \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} . \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^t, y_o^t)}\right]^{\frac{1}{2}} = \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} \left[\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} . \frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}\right]^{\frac{1}{2}}$$

The first component:

$$EC_o = \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)}$$

This describes the measurement for Efficiency Change (EC) of the specific DMU_o. If this number is more than 1 (EC > 1) it means that the efficiency has experienced an improvement, otherwise (EC < 1) it has declined. The second component:

$$TC_o = \left[\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} \cdot \frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}\right]^{\frac{1}{2}}$$

This one measures the technical change (TC) of DMU_o in the time period of t to $t+1$.

The second component TC_o, needs further investigations because efficiency frontiers have multiple faces and might have different shifts in their different regions; for instance, downward in one of them and upward in the other one. (Wang & Lan, 2011)

3.3 Inputs and Outputs Characteristics

in this section we select the sample we are going to use, and we discuss the reason why we use these specific units to evaluate. Further, we discuss the qualities which we consider for evaluating and the reasons they are important for the evaluation process. And then, we will talk about the reasons we consider each of these qualities as inputs or outputs for the purpose of this thesis.

3.3.1 OECD Countries

The data used in this paper is related to the OECD countries from the time period of 2013 to 2019. The main reason that this paper is focused on OECD countries is because they account for over 90% of measured R&D investments globally, and that is a great point for considering it as a suitable test-ground for the validity of R&D-based models related to growth. Consequently, rest of the countries can be treated as importers of the innovations and technologies developed in OECD countries. (Zachariadis, 2004)

The countries considered in this paper are selected from the OECD countries which showed the most activity in the selected time period. The countries are Canada, Denmark, Finland, France, Germany, Japan, Norway, Sweden, Russia, Turkey, China, Austria, Czech Republic, Ireland, Netherlands, Poland, Poland, UK, Italy and Spain.

3.3.2 Inputs and Outputs

3.3.2.1 Gross Domestic Product (Current PPP $)

Staying connected to the clients. **Selling** is crucial for planning and final finishing stages. Supposedly, the stages of operations dedicated to the clients are:

1) Determining specific needs,

2) Selling ideas, budgets, and time period of completion, and

3) Performing a final confirmation of clients' acceptance when the project has been ended. (Pinto & Slevin, 1989)

3.3.2.2 Total R&D Personnel

Finding suitable people for the project is important. Employing, choosing and tutoring people who has the skills, technical or administrative, necessary for the job is a vital fact that should be considered and it is influencing the final result for the project's success. Moreover, in the perception stage, the connection between Personnel and Success rate of the project is positive, as it is expected. During the stages of research, one important issue is either there are enough personnel suitable for the job, possessed by the organization, because it has a huge impact on either the organization will implement successfully or not. (Pinto & Slevin, 1989) in this thesis, number of personnel is considered as one of the inputs as it can be imagined as human resource invested in R&D section.

3.3.2.3 GERD at Constant Prices and PPP $

One important factor in R&D projects is gross domestic expenditure. The success rate of R&D projects often depends on the organizations utilizing the appropriate technologies in order to promote their capabilities further. Also, the amounts invested in these projects have to be just enough to meet their needs for any external resource.

It is during the actual projects that the importance of right technologies and equipment come into play. (Pinto & Slevin, 1989)

3.3.2.4 Number of Patent Families

If the count of papers published is being used as productivity measure, professionals are prone to publish small scale contributions. Still, a new event like inventions, discoveries, or theories which has believed to contain functional utility is considered as technical innovation. Scientists believe that technical innovation, dissimilar to publications can be used to define the outcomes of engineering or scientific projects. (Ganotakis & Love, 2011)

3.3.2.5 Amount of Import/Export in Computer, Electronics and Optical Companies

On one hand, whenever the competition gets tense in foreign markets in any industry or firm, it motivates and forces firms to invest in R&D sections so that they can improve their products and processes and thus be able to take part in the competition. This may also include the need of a firm to launch the R&D section in order to adapt to different sets of requirements other countries, like different technical standards. Moreover, basically there is a high chance of "learning by exporting" for the firms. The reason is being exposed to the knowledge coming from sources other than the known ones which boosts the productivity in R&D firms. And, scale of the market also has a huge impact in R&D productivity. (Ganotakis & Love, 2011)

On the other hand, R&D of countries has been scaled by their exporting performances in many cases in many papers. As the competition with developing countries has become more extreme, more developed and powerful countries have to put more effort to maintain their international competitiveness. There are some reasons to it: First, exporter firms are on average, larger scaled than the non-exporter ones. Secondly, they tend to be more productive than the non-exporter ones. Thirdly, they tend to be more active corroborating previous research. And finally, exporters seem to have more networking channels comparing to the non-exporter ones. (Tomiura, 2007)

3.3.2.6 Value Added to the Industry

The projects that only aim partly for potential yearly earnings are being discounted by the scale of R&D projects which is huge. For instance, a program which is aimed to cover a huge area of opportunity and only is successful to have a hazy relation with the potentials is not comprehensive. So, it is great characteristic for a project to be futuristic, so that it would foresee the value which will be added to the overall worth of the projects it is concerned with. (Pinto & Slevin, 1989)

3.3.3 Defining Inputs and Outputs

For the purpose of this thesis there are considered 3 inputs and 3 outputs to evaluate the productivity of these 19 countries in the 6-year time-period. **Gross Domestic Products, Total personnel** and **GERD at constant prices** are the ones dedicated as our inputs; Gross domestic products can be used as confirmation which often appear as an official representation of the project impacts the intended users. So, we use it for the year before as an input factor for our investigation. Total personnel also are considered as human resource and technically it is being considered as resources dedicated and it appears in the inputs. And finally, firms make investments as GERD in the hope of finding profit in return. So, it is considered as an input in this thesis. One of the results that is hoped to be achieved from R&D projects are the **patents** in which can be used in the firms, so it is definitely considered an output. **Amount of export in technological companies** also is a factor which demonstrates the success rate of a country in the related field; value **added to the industry** is also an accomplishment for a country and it is we can estimate a countries success in R&D firms by evaluating this factor and so, this is why we use it as an output factor in this thesis.

3.3.4 The Data Sets

Table 3 : Data Related to Time Period of 2013

	2013					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	26.266,68	232.910,00	1.554.122,75	622,47	14.901,86	997.625,42
Denmark	7.961,71	57.744,00	262.368,12	264,36	6.787,48	151.613,79
Finland	7.604,52	52.972,10	225.679,98	271,10	3.522,42	127.981,53
France	59.574,43	416.687,35	2.608.523,50	2.425,58	37.574,61	1.504.248,16
Germany	106.323,26	588.615,00	3.628.559,34	4.909,98	115.791,24	2.299.307,70
Japan	167.814,18	865.523,00	5.021.591,10	17.654,40	99.529,56	3.566.122,10
Norway	5.349,21	38.536,00	340.137,93	103,57	3.269,67	221.602,92
Sweden	14.625,43	80.957,00	444.616,54	587,84	14.984,34	276.918,76
Russia	36.684,67	826.733,00	3.741.783,37	76,44	3.766,00	2.414.979,97
Turkey	14.752,41	112.969,07	1.703.669,60	41,53	3.292,95	1.167.683,92
China	309.205,06	3.532.816,80	16.185.062,52	2.191,86	678.850,59	13.706.912,20
Austria	12.524,27	66.186,10	406.370,24	379,62	11.089,04	264.027,04
Czech Republic	6.233,84	61.975,86	324.029,98	31,54	24.229,47	217.781,07
Ireland	3.738,77	31.870,00	221.412,81	94,34	11.938,34	153.432,68
Netherlands	17.761,43	135.555,00	827.475,79	1.138,58	72.260,75	540.421,45
Poland	8.294,24	93.750,80	934.552,98	59,88	15.399,68	658.641,12
UK	42.696,12	377.342,90	2.560.720,87	1.828,88	36.261,88	1.558.886,96
Italy	28.932,22	246.764,00	2.187.376,61	772,74	16.800,86	1.334.075,41
Spain	19.637,09	203.302,03	1.512.074,43	230,28	5.816,84	930.330,31

Table 4 : Data Related to Time Period of 2014

	2014					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	27.159,47	236.470,00	1.621.396,71	591,66	14.569,51	1.046.146,13
Denmark	7.937,06	58.361,00	270.330,61	307,99	7.256,22	156.880,08
Finland	7.289,89	52.130,20	228.058,64	313,21	3.900,46	129.152,06
France	61.189,70	423.902,75	2.662.032,87	2.495,74	37.118,87	1.533.004,47
Germany	110.276,33	605.252,00	3.807.114,52	4.657,68	121.607,94	2.424.686,00
Japan	173.010,87	895.285,00	5.034.454,62	17.617,59	96.206,75	3.586.371,22
Norway	5.532,77	40.297,00	338.506,04	111,00	3.440,23	217.473,43
Sweden	14.283,89	83.473,00	457.507,76	676,20	14.890,80	285.834,61
Russia	38.576,74	829.190,00	3.763.536,92	111,36	5.304,27	2.426.263,49
Turkey	16.326,41	115.444,15	1.860.470,92	27,49	3.669,58	1.290.013,00
China	336.250,72	3.710.580,00	17.121.277,10	2.837,60	678.634,94	14.451.189,71
Austria	13.159,03	70.138,00	417.059,52	401,82	11.708,07	271.351,05
Czech Republic	6.643,15	64.443,50	342.099,84	43,76	26.401,57	234.396,35
Ireland	3.943,27	33.494,00	238.264,09	107,89	12.271,89	167.539,98
Netherlands	18.158,24	136.174,00	830.318,43	1.286,86	75.271,97	538.099,66
Poland	9.249,07	104.359,20	968.368,10	53,83	18.293,15	682.180,58
UK	44.476,02	396.280,80	2.667.371,06	1.678,16	37.215,19	1.618.507,42
Italy	29.760,98	249.467,00	2.200.256,41	818,77	16.477,97	1.339.991,70
Spain	19.392,09	200.232,64	1.558.307,00	256,01	6.492,53	961.409,76

Table 5 : Data Related to Time Period of 2015

	2015					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	27.004,70	244.880,00	1.594.850,84	590,21	14.258,19	1.004.821,07
Denmark	8.515,67	60.243,00	278.748,36	324,63	6.404,79	162.308,02
Finland	6.687,87	50.367,20	232.867,60	267,30	3.183,79	131.847,23
France	61.629,12	428.642,89	2.718.495,13	2.298,50	33.723,11	1.570.322,33
Germany	114.097,56	640.516,00	3.889.081,90	4.751,59	111.624,93	2.477.877,65
Japan	168.514,03	875.005,00	5.199.915,22	17.774,82	87.648,38	3.726.977,86
Norway	6.061,83	42.409,00	313.230,60	101,48	3.088,62	194.470,56
Sweden	15.489,05	83.551,00	481.170,72	729,83	12.856,81	303.743,01
Russia	38.818,63	833.654,00	3.526.234,31	90,43	4.022,73	2.382.232,01
Turkey	17.734,27	122.288,40	2.022.397,78	50,47	3.237,27	1.407.714,44
China	366.080,93	3.758.847,60	17.796.747,04	3.251,15	675.164,54	14.874.048,82
Austria	13.143,43	71.396,00	430.975,92	400,20	9.699,73	279.476,63
Czech Republic	6.852,95	66.433,40	357.503,88	52,59	24.133,21	245.602,18
Ireland	3.839,39	34.346,40	324.635,97	100,52	12.296,77	247.819,50
Netherlands	18.281,97	139.382,00	851.884,70	1.134,50	61.645,71	554.537,17
Poland	10.232,02	109.249,00	1.020.392,78	80,99	17.697,31	725.567,46
UK	45.665,95	413.860,00	2.771.840,35	1.682,50	34.413,44	1.670.880,39
Italy	29.994,85	259.167,00	2.240.922,48	826,02	15.523,75	1.368.414,94
Spain	19.815,27	200.866,00	1.621.069,83	290,14	6.228,47	1.010.191,91

Table 6 : Data Related to Time Period of 2016

	2016					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	27.846,73	228.590,00	1.678.093,40	636,54	13.721,55	1.044.077,50
Denmark	8.901,06	62.859,00	297.719,06	290,99	6.504,12	174.669,22
Finland	6.522,65	47.429,30	246.928,49	269,27	3.299,42	140.183,61
France	61.077,23	432.245,00	2.864.105,63	2.043,43	32.936,50	1.648.925,78
Germany	116.904,24	657.894,00	4.165.169,90	4.718,73	115.019,55	2.656.206,31
Japan	162.386,67	872.340,00	5.158.900,41	17.561,63	88.201,43	3.681.071,22
Norway	6.258,00	43.918,00	308.522,09	138,87	2.589,09	185.802,38
Sweden	15.948,89	90.690,00	500.423,67	739,80	12.696,66	311.176,21
Russia	38.947,81	802.317,00	3.538.975,30	110,84	4.076,75	2.384.605,82
Turkey	19.603,76	136.953,00	2.116.398,30	62,08	2.675,70	1.460.483,77
China	399.390,16	3.878.056,80	18.712.097,15	3.395,49	617.601,40	15.439.956,95
Austria	13.698,78	75.164,90	460.282,65	358,48	9.175,39	298.021,24
Czech Republic	6.121,90	65.782,99	381.420,34	54,17	23.663,79	261.120,90
Ireland	3.882,07	34.373,80	340.945,90	102,53	16.810,44	259.730,70
Netherlands	18.724,02	144.482,00	890.488,56	912,22	62.848,07	574.771,98
Poland	10.133,76	111.789,00	1.075.392,66	74,50	16.095,06	758.807,78
UK	46.829,63	417.390,00	2.896.753,12	1.583,81	32.586,52	1.744.373,08
Italy	31.016,53	290.040,00	2.420.672,14	894,92	15.541,97	1.486.645,28
Spain	19.883,44	205.872,89	1.733.213,64	313,98	6.740,59	1.083.768,92

Table 7 : Data Related to Time Period of 2017

	2017					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	27.980,77	232.030,00	1.765.763,15	663,48	14.045,89	1.107.884,21
Denmark	8.674,06	60.240,00	319.130,17	316,21	7.050,57	187.308,96
Finland	6.739,42	48.998,50	262.026,56	268,96	3.686,43	151.748,95
France	61.945,41	441.509,00	2.983.010,67	1.978,41	34.735,01	1.709.948,57
Germany	124.577,40	686.349,00	4.376.927,67	4.757,24	130.315,97	2.786.305,33
Japan	169.095,88	890.749,00	5.262.254,97	17.596,01	96.580,95	3.769.218,22
Norway	6.682,85	46.234,00	337.993,79	147,88	2.396,37	206.413,24
Sweden	16.939,89	88.928,00	522.476,82	768,05	12.627,28	325.260,80
Russia	39.921,02	778.155,00	3.807.099,41	94,29	4.512,45	2.588.076,11
Turkey	21.401,61	153.552,00	2.264.269,34	72,63	2.728,78	1.603.343,26
China	430.329,70	4.033.597,20	19.887.035,11	4.052,31	674.209,68	16.331.333,10
Austria	13.758,28	76.010,00	476.563,99	372,52	9.705,92	309.566,90
Czech Republic	6.818,15	69.735,65	411.327,86	57,95	27.991,62	278.460,59
Ireland	4.421,04	35.991,92	378.128,17	107,75	16.101,83	291.775,25
Netherlands	19.517,70	150.399,00	943.739,62	990,01	68.567,06	608.490,65
Poland	11.410,03	144.103,00	1.141.694,01	84,56	18.686,09	806.104,53
UK	48.267,51	443.597,00	3.021.843,67	1.649,80	33.339,82	1.840.185,92
Italy	31.619,50	317.628,00	2.517.184,47	918,67	16.892,35	1.553.672,24
Spain	20.817,68	215.744,47	1.841.779,72	325,02	7.640,63	1.160.660,12

Table 8 : Data Related to Time Period of 2018

	2018					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	28.547,73	238.050,00	1.862.154,11	682,13	14.446,71	1.170.538,73
Denmark	8.966,98	59.778,00	332.918,43	325,09	7.228,62	196.651,71
Finland	6.895,06	50.011,30	274.425,75	272,42	4.059,44	158.601,31
France	62.812,84	452.970,00	3.128.336,85	1.915,36	37.157,08	1.787.759,29
Germany	128.823,96	707.703,67	4.556.073,25	4.771,61	141.895,04	2.899.401,77
Japan	172.609,99	896.901,00	5.363.113,05	17.648,71	100.456,25	3.826.527,36
Norway	6.813,51	46.601,00	370.296,24	152,36	2.456,80	227.637,94
Sweden	17.055,94	92.011,00	544.916,38	819,94	12.946,24	337.833,63
Russia	36.616,39	758.462,00	4.211.362,88	99,45	3.714,49	2.856.744,45
Turkey	23.713,29	172.119,40	2.300.825,73	78,11	2.768,44	1.644.463,54
China	464.705,24	4.381.443,70	21.746.510,71	5.014,40	742.616,55	17.753.708,53
Austria	14.271,84	80.750,00	504.354,99	383,06	10.567,29	328.454,34
Czech Republic	7.557,02	74.969,49	437.252,43	58,87	34.712,85	293.108,94
Ireland	4.571,73	35.816,52	413.286,51	110,63	17.394,94	322.272,63
Netherlands	19.613,78	156.875,00	997.729,78	979,45	75.132,02	639.243,58
Poland	14.051,92	161.993,10	1.214.376,60	88,40	22.089,75	855.521,16
UK	50.274,93	463.476,30	3.133.332,40	1.677,17	34.742,67	1.919.456,35
Italy	33.119,05	345.668,80	2.605.604,59	942,94	18.899,89	1.601.232,93
Spain	21.864,32	225.696,40	1.905.614,46	337,61	7.848,77	1.197.495,97

Table 9 : Data Related to Time Period of 2019

	2019					
	IN1	IN2	IN3	OUT1	OUT2	OUT3
Canada	27.563,23		1.904.502,92	692,67	14.710,92	1.198.967,55
Denmark	9.055,97	62.229,00	350.812,06	323,72	7.070,66	209.672,12
Finland	7.084,69	51.493,50	284.674,87	272,15	4.047,48	164.976,99
France	64.052,84	463.738,50	3.336.886,58	1.856,57	36.469,19	1.908.040,39
Germany	132.511,18	735.584,41	4.644.164,14	4.620,67	137.393,13	2.936.154,74
Japan	171.854,29	903.367,00	5.416.302,29	17.702,38	94.818,41	3.864.477,35
Norway	7.020,92	48.723,00	365.502,33	149,28	2.749,44	220.043,59
Sweden	17.743,12	91.172,00	568.811,74	852,05	13.194,77	354.171,27
Russia	39.201,26	753.796,00	4.283.892,18	100,14	4.771,19	2.902.202,95
Turkey	24.827,01	182.846,94	2.279.166,32	79,73	2.754,51	1.622.018,08
China	514.797,66	4.800.768,30	23.523.357,39	5.596,60	721.718,19	19.134.046,62
Austria	14.653,18	83.659,90	520.804,08	384,71	9.651,86	338.924,53
Czech Republic	7.903,67	79.245,00	458.949,66	57,97	36.321,89	306.089,48
Ireland	5.084,06	36.906,10	441.284,83	110,16	20.419,91	343.512,94
Netherlands	20.423,31	160.422,00	1.035.058,85	957,29	74.335,62	657.180,99
Poland	16.078,89	164.006,00	1.299.683,80	87,68	20.371,78	908.478,92
UK	51.701,89	486.088,00	3.242.466,17	1.690,12	34.843,99	1.986.310,89
Italy	34.254,45	355.853,90	2.678.904,14	947,41	17.768,79	1.644.866,93
Spain	22.468,12	231.413,30	1.988.354,74	342,80	8.244,45	1.252.701,64

3.3.5 Correlation Check

To make sure that all the factors we considered as influential for the DMUs, we have to do a correlation check. The way to do so is to check the numbers in each row of each year and take their correlation with each other to find if increase in one of them is related to the increase in the other one and vice versa.

Table 10 : Correlation for Time Period 2013 – 2014

2013-2014	*Input1*	*Input2*	*Input3*
Output1	0,52557627	0,24405194	0,29841512
Output2	0,91613799	0,96404661	0,95218459
Output3	0,94833796	0,99577618	0,99585043

As an example, second input which belongs to "*total R&D personnel*" has a direct and obvious connection with second and third output which are respectively "*total Export-computer and optical industry*" and "*value added to the industry*". For the third input also all of three outputs are justifiable with the numbers shown in table 10.

From the other tables available in Appendix also, it can be seen that all the inputs have almost good co-ordinance with the outputs and all the numbers are approximately over 0.9 and that is a sign that they are good factors to consider as a group. all except the first output which belongs to "*number of triadic patents*". All the tables are attached in the Appendix.

Table 11 : Correlations for Time Periods 2013 to All Other Years

period	Input1	Input2	Input3	Output1
13-14	0,55319697	0,27718287	0,32973144	1
13-15	0,57124898	0,29794708	0,35000921	1
13-16	0,5798522	0,30841285	0,36027354	1
13-17	0,60767939	0,34102035	0,39186264	1
13-18	0,64695648	0,3882927	0,4374185	1
13-19	0,6685136	0,41585605	0,46363202	1

Further, it can be seen in table number 3.9 that, although the numbers do not show a good connection for the short periods, like one- or two-year period, as the time period under investigation expands, the numbers get more and more suitable for considering the same factor as one of our outputs.

As it can be seen in the other similar tables for different starting years, the numbers for correlations of the first output with the all inputs are being changed to better number (closer to 1) as we increase the distance between years (for example 2013 to 2015 or to 2016 or … 2019), and that is a sign that these inputs even though do not have an instant effect on the "*number of patents*", they gradually will influence it. That is why it can be a good fit in this investigation.

Chapter 4

RESULTS AND ANALYSIS

In this chapter we start computing investigating the data using the methods explained in the previous chapter and make comparisons which will help us better understand the data gathered related these 19 countries.

The first step is to normalize the data; and that can be achieved by dividing the numbers in tables 3 to 9 To do that, we find the largest number in each column, then we divide all the other numbers by it. This step is called **Normalization** and it helps better understanding the ratios related to the numbers of each input column and the country which has the biggest amount and which one has the lowest. And also, it is needed for applying the numbers in the methods used in this thesis. In other words, models are can be applied more easily on the normalized tables rather than the regular ones.

First, we take a quick look at the efficiencies regarding our country group. after that we consider weights as it is an important factor in identifying the significant inputs and outputs; these terms show us which countries inputs and outputs are most important in making decision and have more impact on the process. Then, we explain some information about the lambda for these countries and show the countries which can be used as benchmarks among this group of countries. Next step is to set some targets in which countries have to achieve in order to experience improvements in their performances and some explorations for countries which actually reached these targets. And finally, we compare the Malmquist Indexes for all the time periods in this thesis and do some explanations regarding the numbers calculated in this matter.

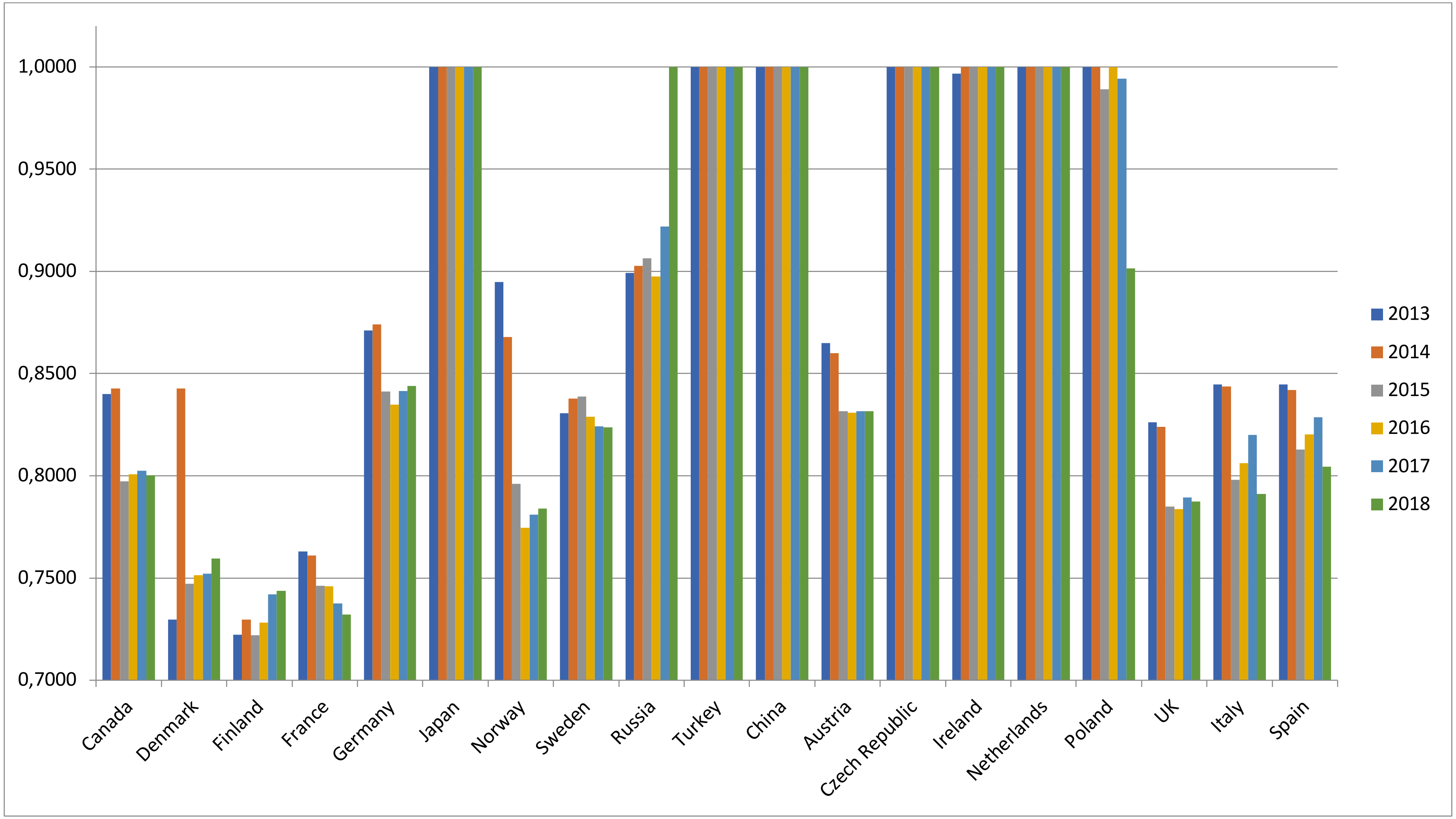

Figure 3 : Efficiencies

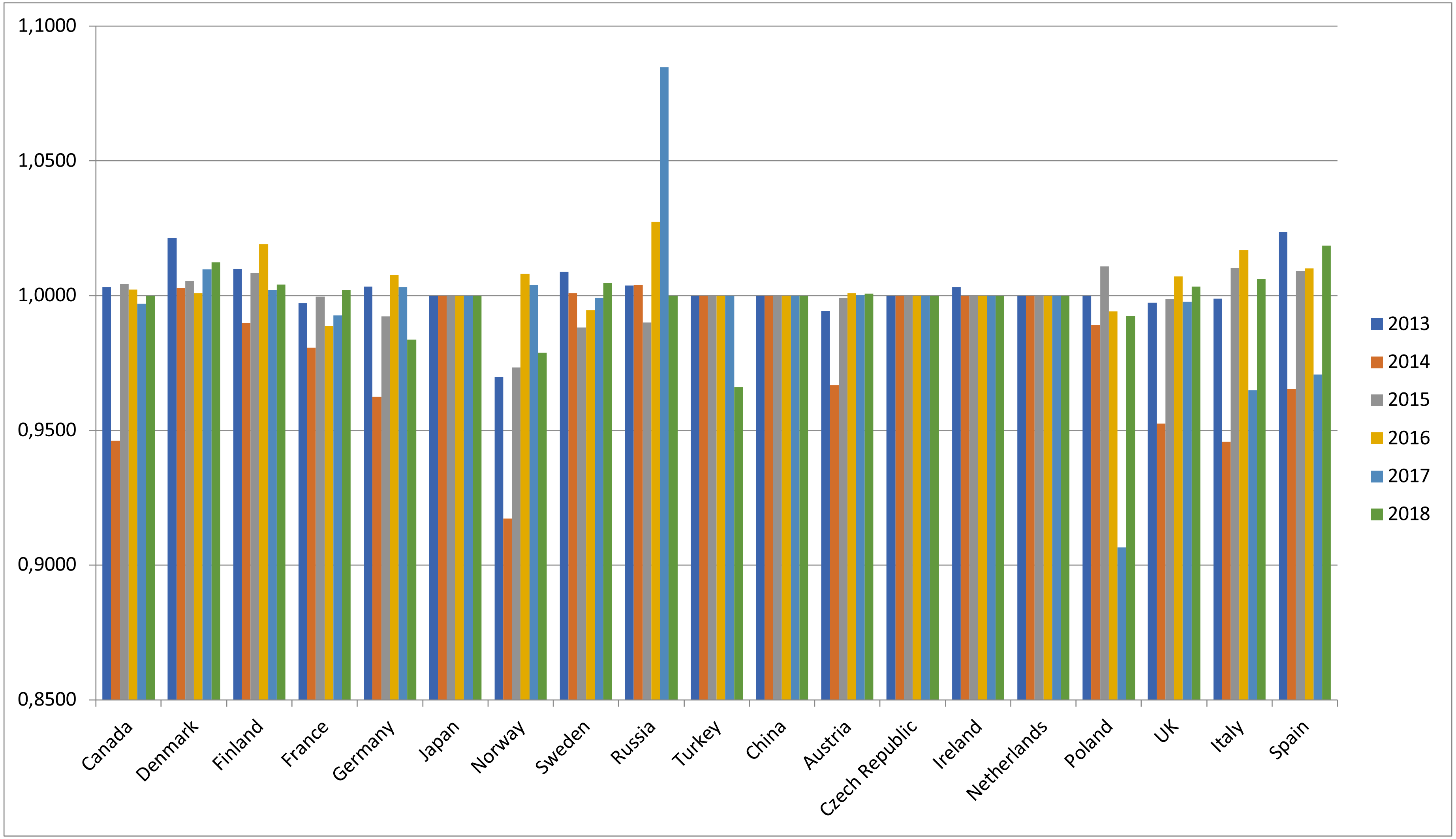

Figure 4 : OECs During the Period

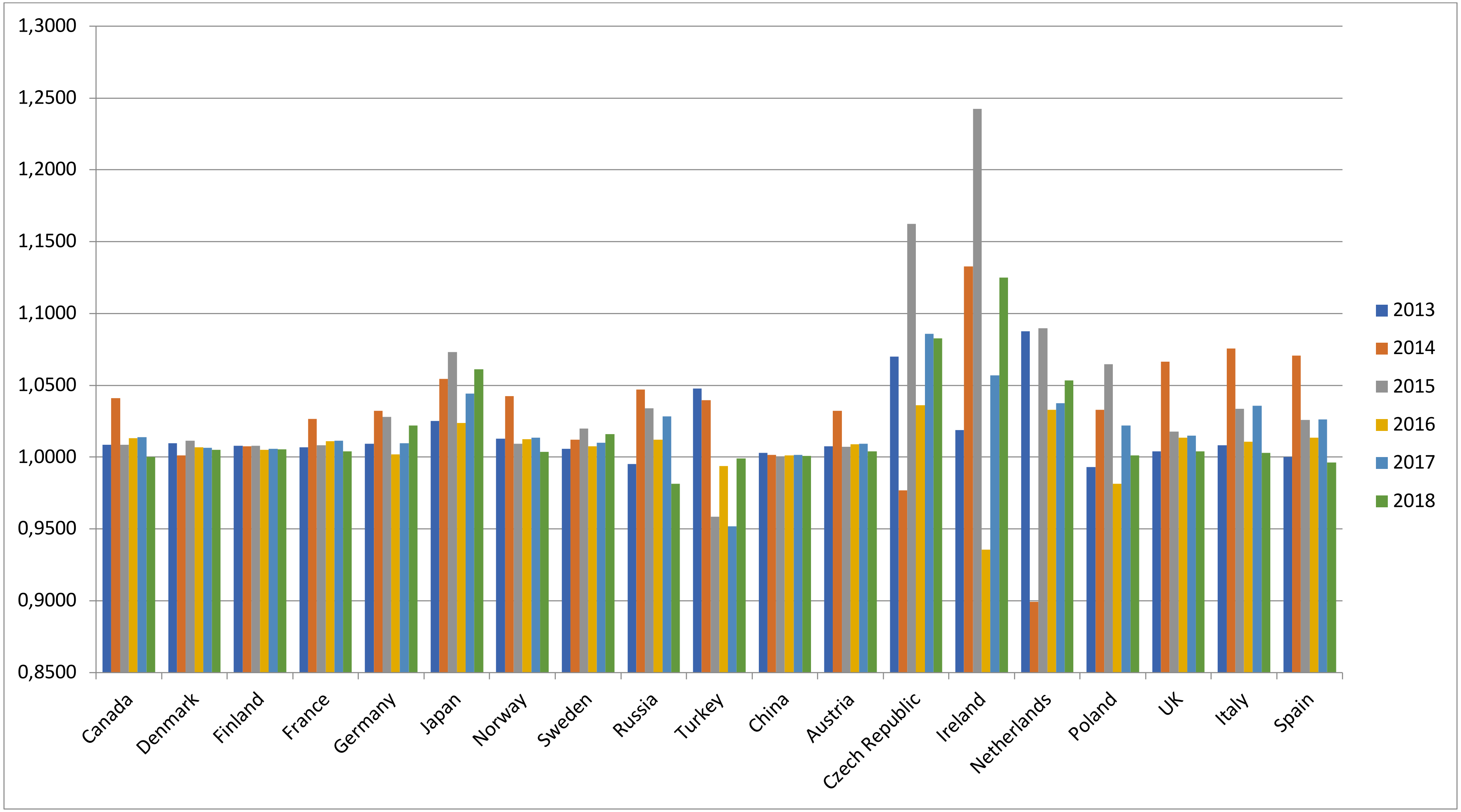

Figure 5 : OTCs During the Period

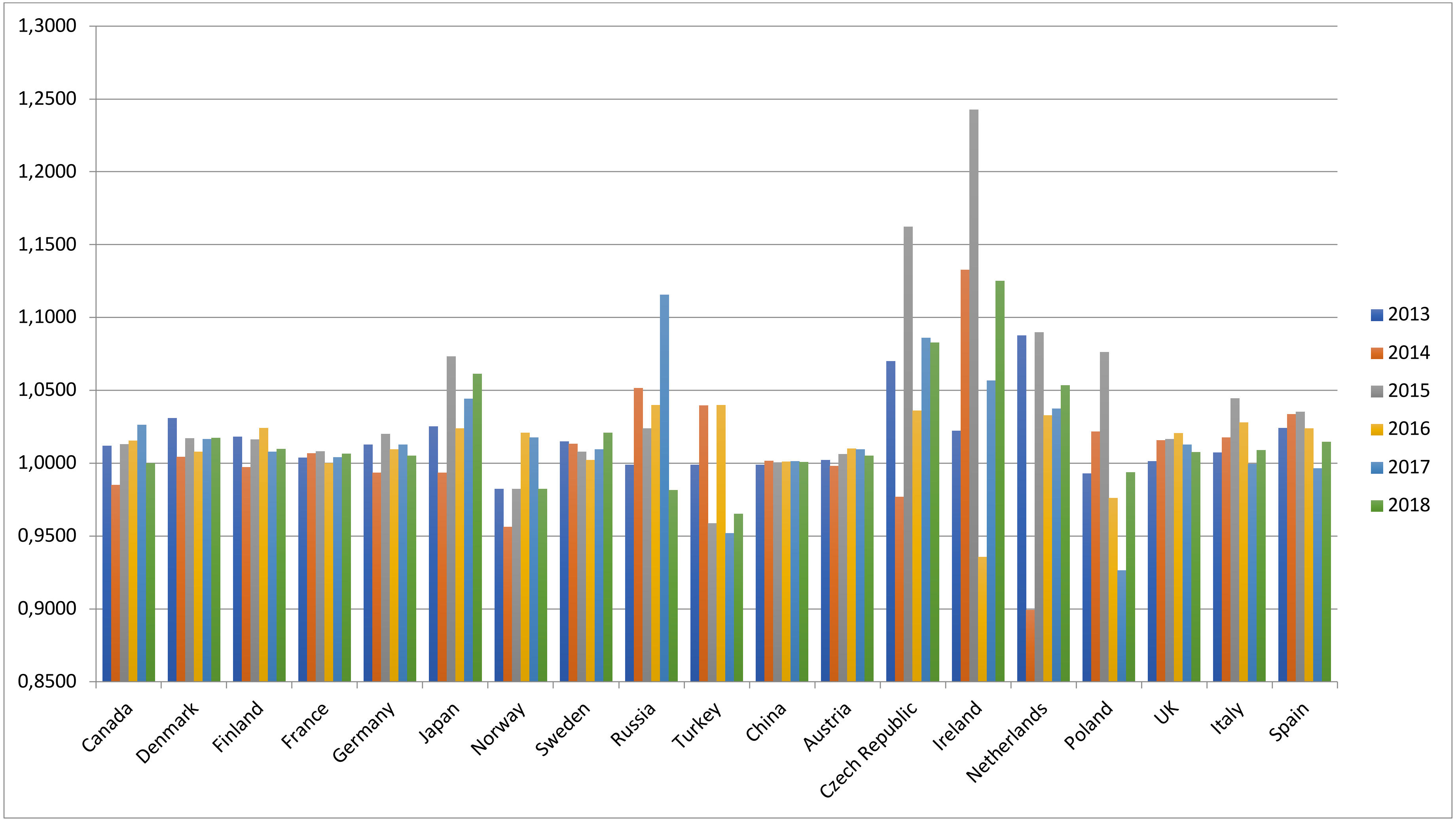

Figure 6 : MPIs During the Period

4.1 Efficiencies of OECD Countries

For better understanding of the situation in which countries we selected, first we have to consider their efficiencies, so that we understand which country has the most efficient situation and what are other countries' efficiencies in comparison to that particular one.

As it can be seen from Figure 3, the countries which appeared the greatest number of times as efficient ones, are Japan, Turkey, China, Czech Republic and Netherlands as they showed Efficiency of 1.00 in all the time periods under our supervision. Poland an Ireland also showed relatively good efficiencies as they appeared as countries with efficiency of 1 in almost the whole period, have done slightly worse job in one year or two years. The countries with the worst efficiencies in this period are Finland, France and Denmark respectively with efficiencies around 0.7 to 0.75. However, Denmark had an unusual shift in its efficiency for better in year 2014 which had shown an efficiency of around 0.85. All the remaining countries show a relatively average efficiency of around 0.75 to 0.85 during the whole time period of 6 year.

4.2 Weights and Significant Inputs/Outputs

Provisions which have to be made for the factor weight as an extension of DEA can provide useful information, which can be considered as an effective tool in measuring efficiency. (Roll & Golany, 1993) The indexes assigned to factors in each DMU, generally have the form of a weighted sum for variables which can facilitate the process of making decisions about the evaluation of each input/output.

Table 12 : Weights Table – 2013 to 2014 Period

	Input1	Input2	input3	Output1	Output2	Output3
Canada	0	3,17	8,24	0,38	0	11,36
Denmark	0	0	61,69	4,04	7,18	54,01
Finland	0	0	71,72	3,71	0	71,26
France	0	1,86	4,84	0,22	0	6,68
Germany	0	1,76	3,15	0,18	0,36	4,53
Japan	1,84	0	0	1	0	0
Norway	0	15,24	39,67	1,81	0	54,69
Sweden	0	13,9	24,81	1,4	2,86	35,67
Russia	1,6	0	3,5	0	0	5,1
Turkey	1,97	1,8	8,06	0,96	0	11,71
China	0	0,36	0,64	0,04	0,07	0,92
Austria	0	15,74	28,09	1,59	3,24	40,38
Czech Republic	21,54	2,59	25,99	0	10,29	39,83
Ireland	2,53	30,87	50,5	0	9,01	74,9
Netherlands	0	7,71	13,77	0,78	1,59	19,8
Poland	3,48	3,18	14,24	1,7	0	20,69
UK	2,14	0	4,46	0,85	0	6,49
Italy	1,41	1,29	5,76	0,69	0	8,37
Spain	2,01	1,84	8,21	0,98	0	11,93
total	38,52	101,31	377,34	20,33	34,6	478,32

The weights assigned to each index helps us understand the importance of each of the inputs in the process, as well as the role each of the outputs are playing. The bigger the weight dedicated to one index, the more significance it is. Therefore, they are an important factor in analyzing data sets.

For instance, from the first row of table 12 can be concluded that the factors which had the most significant impact on the performance of industries in Canada in 2013, were "Gross Domestic Products" and "total R&D personnel". The remaining input which is "GERD at constant prices" actually had no effect on the outcome of this DMU. And also, the only output with a positive weight assigned is "Value added to the industry". So, it can be said that other two had negligible effects in making decisions for this DMU. Moreover, It can be seen that the most significance input among the three inputs provided is the third one which is defined as “Gross Domestic Products”, which is understandable. The most significant output on the other hand is the third one as it shows huger numbers for different countries in this specific year; this output is labeled “Added value to the industry”. The second most important input and output in this year are respectively “Total R&D personnel” and “Number of ‘triadic’ patent families”. So, it is grasped that the factors mentioned had the most impact on the outcome of DMUs related to this year, and also the DMUs which showed the most relation in DMUs for this year were the two mentioned above.

Table for year 2014 also shows similar results; the most significant input and output are “Gross Domestic Products” and “Value added to the industry”. Unsurprisingly, the same goes for years 2015, 2016, 2017, 2018, 2019. Therefore, it can be concluded that the most significant inputs and outputs are the ones mentioned above.

4.3 Benchmarking

One more vital information which DEA can provide is the details on Benchmarking. This information can be useful in studying models based on the efficient targets which are most achievable by (in other words closest to) the inefficient ones, and are somehow related with the least distance from each other. This enables us to identify easier ways to achieve the efficient frontier situation by the inefficient DMUs. (López-Espín, Aparicio, Giménez, & Pastor, 2014)

What can be understood from this Table 13 is for example, even though Czech Republic were showed as an efficient DMU during this time period, none of the other DMUs used it as benchmark. On the other hand, China, Japan and turkey after them were the efficient countries which in that specific time period, seemed reasonable to be used as a benchmark for other countries in the table because most of the cells in the column dedicated to these countries show positive numbers; unlike the column dedicated to Czech Republic. Furthermore, it can be grasped that for example, if Canada has purpose of increasing its efficiency, it is reasonable to compare its parameters mostly with Turkey as in the row for Canada the largest index belongs to Turkey. And in case of Germany, the best fit is Netherlands with Index of 0,83.

Table 13 : Lambdas' Table – 2013

	Japan	Turkey	China	Czech	Netherlands	Polan
Canada	0,03	0,32	0,04	0	0	0
Denmark	0,01	0	0,01	0	0,01	0
Finland	0,01	0	0,01	0	0	0
France	0,13	0,33	0,05	0	0	0
Germany	0,22	0,35	0,05	0	0,83	0
Japan	1	0	0	0	0	0
Norway	0	0,12	0	0	0	0
Sweden	0,03	0,01	0,01	0	0,09	0
Russia	0	0	0,02	0	0	3,27
Turkey	0	1	0	0	0	0
China	0	0	1	0	0	0
Austria	0,02	0,05	0,01	0	0,05	0
Czech	0	0	0	1	0	0
Ireland	0	0,03	0	0	0,14	0,03
Netherland	0	0	0	0	1	0
Poland	0	0	0	0	0	1
UK	0,1	0	0,03	0	0	1,26
Italy	0,04	0,54	0,02	0	0	0,42
Spain	0,01	0,16	0,03	0	0	0,56

Also, further investigation in Table 13 indicates that the countries which showed efficiency 1 among all the DMUs are Japan, Turkey, China, Czech Republic, Ireland, Netherlands and Poland. Amongst these countries, Czech Republic and Ireland were not believed to be worthy of being used as a benchmark; it is obvious from the multipliers shown in their column. The most suitable ones for this purpose, are just like the previous table, Japan, China and Turkey in the third place. If we want to consider the importance of countries to set for benchmark for Canada, it is preferably Turkey with index of 0,32; Japan and China's indexes in the row dedicated for Canada are respectively 0,03 and 0,04. To take another example, Poland's multiplier as a benchmark for Russia is 3.27 and this is a good indication of the suitable choice.

The rest of tables are attached to the appendix. In the year 2015, the country which is suitable for most of the countries to be compared to is Ireland. The least interesting ones for this purpose are also Czech Republic and Turkey respectively. Canada and Germany's benchmark this year is also better to be Ireland like most of the DMUs.

By considering year 2016, again the most usable DMU amongst others is Ireland; as the countries Turkey, Czech Republic and Netherlands are literally practically useless in this subject. Almost the same situation matches the numbers shown for table 2017, with Poland being the most appropriate one to be considered as benchmark and Czech Republic and Netherlands as the least useful ones.

In year 2018's table, the country which appears in most rows is Ireland so again this country is the most usable one as benchmark; and this time, although Russia showed up as an efficient DMU, but it is not suggested as benchmark for any of the other DMUs. And for the final year – 2019 – Ireland is believed to be the most suitable one according to the data illustrated in the table, and after that come Japan and China. And let us mention that even though Canada entered to the group of efficient countries, it did not appear as useful in being benchmark, just like Netherlands and Czech Republic.

4.4 Performance Improvement

To illustrate the improvements made to the efficiencies of different DMUs, DEA can be useful as it can easily provide practical information based on the production frontier. (Chen & Wang, 2020) One other data which can be extracted from DEA method is the targets in which each of the countries have to set for themselves in order to have better performance the next coming year; and this data is particularly useful if we want to compare for example “the amount they should have invested in one of the inputs”, with “the amount they actually invested”. This way we can explain the improvements of countries within the specified time period.

Table 14 : Targets' Table for Year 2013

Name	Input1 Value	Input1 Target	Input1 Gain(%)	Input2 Value	Input2 Target	Input2 Gain(%)	Input3 Value	Input3 Target	Input3 Gain(%)	Output1 Value	Output1 Target	Output1 Gain(%)	Output2 Value	Output2 Target	Output2 Gain(%)	Output3 Value	Output3 Target	Output3 Gain(%)
Canada	0,08	0,07	-18,46	0,07	0,06	-15,99	0,1	0,08	-15,99	0,04	0,04	0	0,02	0,04	99,6	0,07	0,07	0
Denmark	0,03	0,02	-41,6	0,02	0,01	-33,64	0,02	0,01	-27,04	0,01	0,01	0	0,01	0,01	0	0,01	0,01	0
Finland	0,02	0,01	-45,18	0,01	0,01	-39,21	0,01	0,01	-27,77	0,02	0,02	0	0,01	0,01	47,84	0,01	0,01	0
France	0,19	0,13	-30,36	0,12	0,09	-23,69	0,16	0,12	-23,69	0,14	0,14	0	0,06	0,07	23,03	0,11	0,11	0
Germany	0,34	0,23	-32,75	0,17	0,15	-12,89	0,22	0,2	-12,89	0,28	0,28	0	0,17	0,17	0	0,17	0,17	0
Japan	0,54	0,54	0	0,24	0,24	0	0,31	0,31	0	1	1	0	0,15	0,15	0	0,26	0,26	0
Norway	0,02	0,01	-24,16	0,01	0,01	-10,52	0,02	0,02	-10,52	0,01	0,01	0	0	0,01	25,45	0,02	0,02	0
Sweden	0,05	0,03	-39,11	0,02	0,02	-16,95	0,03	0,02	-16,95	0,03	0,03	0	0,02	0,02	0	0,02	0,02	0
Russia	0,12	0,11	-10,07	0,23	0,11	-54,81	0,23	0,21	-10,07	0	0,01	210,59	0,01	0,09	1579	0,18	0,18	0
Turkey	0,05	0,05	0	0,03	0,03	0	0,11	0,11	0	0	0	0	0	0	0	0,09	0,09	0
China	1	1	0	1	1	0	1	1	0	0,12	0,12	0	1	1	0	1	1	0
Austria	0,04	0,02	-43,06	0,02	0,02	-13,5	0,03	0,02	-13,5	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0
Czech Republic	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,04	0,04	0	0,02	0,02	0
Ireland	0,01	0,01	-0,32	0,01	0,01	-0,32	0,01	0,01	-0,32	0,01	0,01	74,86	0,02	0,02	0	0,01	0,01	0
Netherlands	0,06	0,06	0	0,04	0,04	0	0,05	0,05	0	0,06	0,06	0	0,11	0,11	0	0,04	0,04	0
Poland	0,03	0,03	0	0,03	0,03	0	0,06	0,06	0	0	0	0	0,02	0,02	0	0,05	0,05	0
UK	0,14	0,11	-17,38	0,11	0,09	-20,23	0,16	0,13	-17,38	0,1	0,1	0	0,05	0,07	32,79	0,11	0,11	0
Italy	0,09	0,08	-15,53	0,07	0,06	-15,53	0,14	0,11	-15,53	0,04	0,04	0	0,02	0,04	57,53	0,1	0,1	0
Spain	0,06	0,05	-17,75	0,06	0,05	-17,75	0,09	0,08	-17,75	0,01	0,01	0	0,01	0,04	368,6	0,07	0,07	0

The tables for the Targets can all be found in the appendix. For instance, in Table 14 we can see that, the value for the first input value which is labelled as “GERD at constant prices” for country Canada, is approximately 0.08; and the target set using this method is 0.07. in other words, this country could enhance its performance by decreasing the amount allocated to the first input by 18% approximately. Now if we look at the table 16 which shows the actual numbers for year 2014, we see that the amount for first input value for Canada, almost has not changed; and so, we can guess that this country has not experience any progress from this input value.

However, for the same country, in 2013 the target value set for the second input, is 0.06 while the actual input was on 0.07. so, this method suggested to diminish the amount allocated to second input which is “Total R&D Personnel” by around 16%. Interestingly enough, this is exactly what happened in the one-year period and in year 2014, Canada’s index for second input is 0.06. Hence, it can be said that decreasing total R&D personnel by Canadian authorities, actually helped enhancing the efficiency in this field for year 2014.

Another example that can be extracted from this table is the country Spain: this table suggests that in order to enhance its performance, this country should decrease “GERD at constant prices”, “Total R&D personnel” and “Gross Domestic Products” by 17%. Doing so, as it appears in the table, will help country to experience an advancement in “total exports in computer and optical industry” by over 350 percent.

To take another example, by checking the data given in table for 2018 in the Appendix, in the row for country Russia, we find out that target values for all inputs/outputs are exactly the same amount which is appeared as the actual value; so, in a way, it is suggesting that if this country, keeps every aspect mentioned in the table the same, logically, this Russia should appear as an efficient country the next year. And that is what happened; you can see that the inputs and outputs barely changed in this time period and so, this country has kept its place as an efficient country in the next year.

As shown in two examples above, this set of tables is particularly useful to give suggestions for different DMUs involved about how to make changes in the amounts dedicated to any of Inputs/Outputs in order to make improvements in their efficiency. Of course, these were only few conclusions that could be made with these tables.

Table 15 : The DEA-based Malmquist Productivity Index Values for the Nineteen DMUs(countries) for 2013-2014 Period.

	2013	OEC	OTC	MPI
Canada	0,8401	1,0031	1,0087	1,0118
Denmark	0,7296	1,0213	1,0095	1,0310
Finland	0,7223	1,0100	1,0079	1,0180
France	0,7631	0,9971	1,0067	1,0038
Germany	0,8711	1,0034	1,0093	1,0127
Japan	1,0000	1,0000	1,0252	1,0252
Norway	0,8948	0,9698	1,0128	0,9822
Sweden	0,8305	1,0089	1,0059	1,0149
Russia	0,8993	1,0038	0,9952	0,9989
Turkey	1,0000	1,0000	1,0477	0,9989
China	1,0000	1,0000	1,0028	0,9989
Austria	0,8650	0,9943	1,0077	1,0020
Czech	1,0000	1,0000	1,0700	1,0700
Ireland	0,9968	1,0032	1,0190	1,0223
Netherlands	1,0000	1,0000	1,0875	1,0875
Poland	1,0000	1,0000	0,9930	0,9930
UK	0,8262	0,9973	1,0040	1,0013
Italy	0,8447	0,9989	1,0084	1,0073
Spain	0,8447	1,0237	1,0002	1,0240

In the tables 15 to 20, Optimistic Efficiency Change has shown as OEC. If OEC is more than one, it means that the efficiency in that specific DMU in time period of **t** to **t+1** has experienced improvements. If OEC has value less than one, we can conclude that this DMU has experienced diminution in efficiency. And of course, if OEC is equal to one, it is obvious that it has not changed in time period of t to t+1.

Similarly, Optimistic Technical Change is defined as OTC. So, OTC value of over one shows the technical progress of the DMU in the time period of **t** to **t+1**. OTC less than one shows the technical regression experience by that DMU in specified time period. And finally, OTCs equal to one show that no technical change has occurred to that DMU in the time period of t to t+1.

Malmquist Productivity Index (MPI) is the result of multiplication of the Optimistic Efficiency change (OEC), and Optimistic Technical Change (OTC).

Tables 15 to 20 show OEC, OTC and MPI for countries under investigation, in time periods 2013 to 2019. To be specific the numbers shown for the first table is for Changes made in time period 2013 to 2014, second table shows changes made in time period 2014 to 2015 and so on.

From table 15, it is seen that the productivity changes of DMUs dedicated to countries Canada, Denmark, Finland, France, Germany, Japan, Sweden, Austria, Czech Republic, Ireland, Netherlands, UK, Italy and Spain are bigger than one, while the DMUs for countries Norway, Russia, Turkey, China and Poland are all smaller than one. This informs us that the Productivity in countries which have an index more than one, have seen improvements in the specified time period, while in the countries with indexes less than one, the productivity has decreased.

Also, it can be seen that the OEC dedicated to the countries Denmark, Finland and Spain show bigger number among others and that shows that these countries had the biggest Efficiency changes in the time period between 2013 to 2014. And the lowest OEC between all the evaluated countries belong to Norway, so it is the country with lowest change in efficiency. In case of technical changes, the DMUs having considerably large value of OTC, are respectively, Netherlands, Czech Republic, Turkey and Japan in the fourth place. This means that these were countries with biggest technical changes in time period of 2013 to 2014. None of the countries showed noticeable diminishing technical change in this period.

Table 16 : The DEA-based Malmquist Productivity Index Values for the Nineteen DMUs(countries) for 2014-2015 Period.

	2014	OEC	OTC	MPI
Canada	0,8427	0,9461	1,0410	0,9849
Denmark	0,8427	1,0029	1,0013	1,0043
Finland	0,7296	0,9898	1,0074	0,9972
France	0,7609	0,9807	1,0266	1,0067
Germany	0,8740	0,9625	1,0321	0,9934
Japan	1,0000	1,0000	1,0544	0,9934
Norway	0,8678	0,9173	1,0423	0,9561
Sweden	0,8379	1,0009	1,0122	1,0131
Russia	0,9027	1,0040	1,0472	1,0514
Turkey	1,0000	1,0000	1,0396	1,0396
China	1,0000	1,0000	1,0015	1,0015
Austria	0,8601	0,9669	1,0322	0,9981
Czech	1,0000	1,0000	0,9769	0,9769
Ireland	1,0000	1,0000	1,1326	1,1326
Netherlan	1,0000	1,0000	0,8993	0,8993
Poland	1,0000	0,9892	1,0329	1,0217
UK	0,8240	0,9525	1,0665	1,0158
Italy	0,8438	0,9458	1,0758	1,0175
Spain	0,8420	0,9653	1,0708	1,0337

Table 16 shows different results: countries which have shown growth in productivity are Denmark, France, Sweden, Russia, Turkey, China, Ireland, Poland, UK, Italy and Spain. These countries have shown Productivity Changes' numbers more than one. Conversely, Canada, Finland, Germany, Japan, Norway, Austria, Czech Republic and Netherlands show Productivity Change rate less than one so they have all decreased productivity rate in the time period of 2014 to 2015. The most obvious fluctuation is for Ireland with 12 percent increase in the Productivity change.

In the OEC row, it can be seen that the countries with lowest amounts of optimistic efficiency changes are Norway with the lowest amount, Italy and Canada with almost the same amount, and UK, Germany and Austria after them. There are not many DMUs with OECs bigger than one and the ones that do show the amount more than one are negligible. For OTCs, Ireland has the biggest value, of over 110 percent, Italy and Spain comes right after, and UK and Japan respectively have shown the most considerable values. So, these were the countries with biggest technical improvements in time period of 2014 to 2015. This year, Netherlands showed the lowest value amongst all considered countries so it is the only country with noticeable reductive technical change. Czech Republic also shows the amount of approximately 0.97 which is much bigger in comparison with Netherlands.

It is shown in table 17 that Canada, Denmark, Finland, France, Germany, Japan, Sweden, Russia, China, Austria, Czech Republic, Ireland, Netherlands, Poland, UK, Italy and Spain have Productivity Changes more than one and so, they are the ones experiencing increase in Productivity. The change of the country "Ireland" is the most obvious one for this time period too, with percentage of over around 25 percent. Czech

Republic comes second with around 16 %. There are only 2 countries left with Productivity changes less than one and they are Norway and Turkey.

It is shown in table 17 that Canada, Denmark, Finland, France, Germany, Japan, Sweden, Russia, China, Austria, Czech Republic, Ireland, Netherlands, Poland, UK, Italy and Spain have Productivity Changes more than one and so, they are the ones experiencing increase in Productivity. The change of the country “Ireland” is the most obvious one for this time period too, with percentage of over around 25 percent. Czech Republic comes second with around 16 %. There are only 2 countries left with Productivity changes less than one and they are Norway and Turkey.

Table 17 : The DEA-based Malmquist Productivity Index Values for the Nineteen DMUs(countries) for 2015-2016 Period.

	2015	OEC	OTC	MPI
Canada	0,7973	1,0044	1,0085	1,0129
Denmark	0,7473	1,0055	1,0114	1,0169
Finland	0,7221	1,0084	1,0078	1,0163
France	0,7462	0,9997	1,0084	1,0082
Germany	0,8413	0,9924	1,0279	1,0201
Japan	1,0000	1,0000	1,0732	1,0732
Norway	0,7960	0,9733	1,0092	0,9823
Sweden	0,8387	0,9882	1,0199	1,0079
Russia	0,9064	0,9900	1,0341	1,0238
Turkey	1,0000	1,0000	0,9586	0,9586
China	1,0000	1,0000	1,0004	1,0004
Austria	0,8316	0,9992	1,0071	1,0063
Czech	1,0000	1,0000	1,1624	1,1624
Ireland	1,0000	1,0000	1,2425	1,2425
Netherlan	1,0000	1,0000	1,0897	1,0897
Poland	0,9892	1,0109	1,0646	1,0762
UK	0,7849	0,9986	1,0178	1,0164
Italy	0,7981	1,0103	1,0337	1,0444
Spain	0,8128	1,0091	1,0259	1,0353

It is shown in table 17 that Canada, Denmark, Finland, France, Germany, Japan, Sweden, Russia, China, Austria, Czech Republic, Ireland, Netherlands, Poland, UK, Italy and Spain have Productivity Changes more than one and so, they are the ones experiencing increase in Productivity. The change of the country "Ireland" is the most obvious one for this time period too, with percentage of over around 25 percent. Czech Republic comes second with around 16 %. There are only 2 countries left with Productivity changes less than one and they are Norway and Turkey.

The biggest OEC for time period of 2015 to 2016 belongs to Italy which is still not as big as the numbers for year 2013-14. Moreover, France was the worst country in case of improvements in efficiency; which again, does not show a considerable amount lower than one. In case of OTCs, Ireland and Czech Republic are the countries with scalable numbers of 1.24 and 1.16, and so they are the ones with biggest technical improvements; Netherlands and Poland come after them with much smaller improvements. The only country with worsening technical change is Turkey, which shows a decent diminishing number of around 95 percent for time period of 2015 to 2016.

Table 18 : The DEA-based Malmquist Productivity Index Values for the Nineteen DMUs(countries) for 2016-2017 Period.

	2016	OEC	OTC	MPI
Canada	0,8008	1,0022	1,0132	1,0154
Denmark	0,7514	1,0010	1,0069	1,0079
Finland	0,7282	1,0191	1,0050	1,0241
France	0,7460	0,9887	1,0112	0,9998
Germany	0,8349	1,0077	1,0018	1,0095
Japan	1,0000	1,0000	1,0238	1,0238
Norway	0,7747	1,0081	1,0126	1,0208
Sweden	0,8288	0,9946	1,0076	1,0022
Russia	0,8974	1,0273	1,0123	1,0399
Turkey	1,0000	1,0000	0,9937	1,0399
China	1,0000	1,0000	1,0011	1,0011
Austria	0,8309	1,0009	1,0091	1,0100
Czech	1,0000	1,0000	1,0360	1,0360
Ireland	1,0000	1,0000	0,9357	0,9357
Netherland	1,0000	1,0000	1,0328	1,0328
Poland	1,0000	0,9942	0,9816	0,9760
UK	0,7838	1,0071	1,0134	1,0206
Italy	0,8063	1,0169	1,0108	1,0279
Spain	0,8202	1,0101	1,0135	1,0237

Likewise, it can be seen from table 18 that the countries showing improvements in their productivity are Canada, Denmark, Finland, Germany, Japan, Norway, Sweden, Russia, Turkey, China, Austria, Czech Republic, Netherlands, UK, Italy and Spain. Even though there were no notable change for any of these countries. On the other side the countries which show deteriorations are Poland, Ireland and France. The most significant one of them is Ireland with approx. 6% of change.

What can be said for changes in Efficiency is that Russia shows the most improvement in this time period, and Finland and Italy come right after. The worst situation for changes in efficiency seems to be for France with around 98 percent. The biggest amount of technical change is for the country Czech Republic and after that comes Netherlands, Spain and UK respectively. And the most reductive technical changes belong to Ireland and Poland, which Ireland's index is much more considerable than Poland.

Table 19 : The DEA-based Malmquist Productivity Index Values for the Nineteen DMUs(countries) for 2017-2018 Period.

	2017	OEC	OTC	MPI
Canada	0,8026	0,9970	1,0139	1,0264
Denmark	0,7521	1,0098	1,0066	1,0164
Finland	0,7421	1,0021	1,0057	1,0078
France	0,7376	0,9926	1,0115	1,0040
Germany	0,8414	1,0031	1,0095	1,0127
Japan	1,0000	1,0000	1,0441	1,0441
Norway	0,7810	1,0039	1,0137	1,0176
Sweden	0,8243	0,9993	1,0100	1,0093
Russia	0,9219	1,0848	1,0284	1,1156
Turkey	1,0000	1,0000	0,9518	0,9518
China	1,0000	1,0000	1,0014	1,0014
Austria	0,8317	1,0001	1,0093	1,0094
Czech	1,0000	1,0000	1,0860	1,0860
Ireland	1,0000	1,0000	1,0568	1,0568
Netherland	1,0000	1,0000	1,0375	1,0375
Poland	0,9942	0,9066	1,0219	0,9265
UK	0,7894	0,9977	1,0151	1,0128
Italy	0,8200	0,9650	1,0356	0,9993
Spain	0,8286	0,9708	1,0264	0,9965

And for Table 19 which shows the time period 2017 to 2018, countries with Productivity change more than one are Canada, Denmark, Finland, France, Germany, Japan, Norway, Sweden, Russia, China, Austria, Czech Republic, Ireland, Netherlands and UK. These were countries which showed progress in their Productivity. The countries with negative progress in their Productivity are Spain, Italy, Poland and Turkey. Russia did experience the most considerable increase with 11 percent and Poland's decrease were approximately 8%.

Most of the numbers dedicated to OECs in time period of 2017 to 2018 are equal or less than one and the only country which can be said to have a considerable optimistic efficiency change more than one is Russia with changes over 8% increase. Meanwhile, the country with most decreasing change in efficiency is Poland with rate of 90% and after that comes Italy with 96 percent and the rest of the DMUs OEC are around 1. In case of Optimistic Technical change, the country which shows the most increasing amount is Ireland with 12 percent improvement, and after that comes Czech Republic, Japan and Netherlands respectively. And the only worsening technical change belongs Russia with 95 percent, which is not as huge number as for the DMUs previous years. This shows that none of the countries experience steep diminishing technical changes in this time period.

And for the last year of investigation which is time period of 2018 to 2019, countries with Productivity change more than one are Denmark, Finland, France, Germany, Japan, Sweden, China, Austria, Czech Republic, Ireland, Netherlands, UK, Italy and Spain. Even though these countries' productivity has been improved in this period, but the amount of increase in some of their productivities are negligible as it is shown in the table. For instance, Austria and China show less than 0.5 percent change. The ones having considerable changes are Ireland with over 12% increase and Czech Republic with around 8% change Anyways, the countries showing productivity change less than one is Norway (less than 2%), Russia (less than 2%), Turkey (around 4%) and Poland (less than 1%).

Table 20 : The DEA-based Malmquist Productivity Index Values for the Nineteen DMUs(countries) for 2018-2019 Period.

	2018	EC	TC	MPI
Canada	0,8002	1,2497	1,0000	1,0000
Denmark	0,7595	1,0123	1,0050	1,0174
Finland	0,7437	1,0041	1,0055	1,0097
France	0,7321	1,0021	1,0042	1,0064
Germany	0,8440	0,9836	1,0219	1,0052
Japan	1,0000	1,0000	1,0612	1,0612
Norway	0,7840	0,9789	1,0036	0,9824
Sweden	0,8237	1,0047	1,0160	1,0208
Russia	1,0000	1,0000	0,9814	0,9814
Turkey	1,0000	0,9661	0,9991	0,9653
China	1,0000	1,0000	1,0007	1,0007
Austria	0,8317	1,0008	1,0042	1,0050
Czech	1,0000	1,0000	1,0828	1,0828
Ireland	1,0000	1,0000	1,1251	1,1251
Netherland	1,0000	1,0000	1,0535	1,0535
Poland	0,9014	0,9925	1,0011	0,9936
UK	0,7875	1,0034	1,0040	1,0074
Italy	0,7912	1,0061	1,0029	1,0090
Spain	0,8044	1,0185	0,9962	1,0147

The only country with noticeable advancements in case of efficiency changes is Canada with around 25% change, and the most diminishing efficiency change belongs to Turkey with around 96%. And, as for technical changes, Ireland has the biggest index of 1.12, after that comes Czech Republic with approximately 1.08, and Japan and Netherlands with indexes 1.06 and 1.05 respectively. The smallest numbers in case of OTC belongs to Russia with index of around 98 percent.

Chapter 5

CONCLUSIONS

R&D has become one of the interesting areas of study among scholars and researchers during the past couple of years. Although, the studies done until now mostly focus on efficiencies of the R&D sections during specific points in time, this thesis attempts to investigate these factors in long period of 6 years (Specifically in the time period of 2013 to 2019). As countries are trying to win over each other in this technological and scientific competition, it is important to figure the countries which have experienced the most amount of progress in the past few years in order to find the reasons behind their success. This thesis attempts to use DEA-based MPI (Malmquist Productivity Index) for a group of 19 countries which has been selected from OECD countries; this group consists of Canada, Denmark, Finland, France, Germany, Japan, Norway, Sweden, Russia, Turkey, China, Austria, Czech Republic, Ireland, Netherlands, Poland, UK, Italy and Spain.

The inputs for this research are GERD (Gross Expenditure on R&D), the R&D personnel and GDP (Grand Domestic Product), and the outputs of this paper are consisted of number of 'triadic' patent families, total exports in the computer and optical industries and value added to the country's industries overall. As the results show, the countries which show good deal of productivity are first of all Ireland, then Czech Republic, Netherlands, Japan, Italy and Spain; of course, these countries experienced some years in which they did not have a good overall performance. For instance, Ireland in time period of 2016 to 2017 and Czech Republic in 2014 until 2015. Conversely, the countries with worst performance regarding Productivity index are Norway, Poland and Turkey.

The most important factors influencing the productivity of these countries is “Gross Domestic Products” and the factor which is the most influenced by the inputs is “the value added to the industries” because of their weights in calculations. And as the calculations about Lambda suggests, the suitable countries among the efficient one for being considered as Benchmarks are mostly China, Ireland and Japan. And there are some tables provided for the targets which countries will have to try to hit so they can reach their peak performance.

To check some of these condition for the countries, for instance, it is written in the Irish Times official website that in an optimistic view, in the time period of 2013 - 2014, the conditions for the tourism industry in Ireland had shown more productivity than past five years, says Irish Tourist Industry Confederation (ITIC). Also, Dublin’s transactions have increase year by year in the mentioned time period. Also, it is mentioned in the “Fun-facts Business news Centre” in the year 2015 that the manufacturing industries’ production were 1.7 percent higher in comparison to March 2015. On an annual basis, production rate dedicated to April 2015 were 9.7 percent more successful than April 2014.

Regarding country Czech Republic, as a publication by “Cross Thematic Analyses unit” had written, the rise in performance of industries in 2013 in this country, is mostly driven by the business sector. Year 2014, is considered as a year in which strong manufacturing industry had returned Czech Republic’s economy to growth trajectory; also, “ministry of industry and trade” for this country explains that the most important reasons for this manufacturing growth are productions of motor vehicles, and manufacturing of computers. and for example, for the period of 2018 to 2019, the growth of Czech’s economy slows down, but remains strong enough to be higher than the Eurozone and EU average.

Netherlands also shows rather a steady amount of growth in industries in almost all the time periods. Much of the strong growth in period of 2013 – 2015 were due to very high car sales because of the changing of CO2 limits. Also, considering revised national accounts data, in year 2018 to 19, Netherlands economy grew in even faster pace in yearly terms than it was estimated, and some of the reasons are domestic demand shifting into a higher gear, private consumption expansion and decrease of unemployment rates.

Next country in the list is Japan. As it shown in the graph in chapter 4, this country follows rather a stable pattern. Nevertheless, this country’s graph, experiences rather a sudden fall in period 2014 – 2015 and as it is written in BBC’s official website, it is believed to be because of a “Sales tax delay”, and the “Expected Election”.

The fluctuation of the year 2017 in Poland was probably affected by the new government setting and the Government Developments Strategies which were replaced by this new government. The main reason for the fall of production in 2015 of country Norway was because of a quite steep fall of 17 percent in petroleum-related industries as there were lower investment activities in the North Sea. And in case of Turkey, the fall which happened in last recent years, were the result of contractions in mining and quarrying and manufacturing sectors.

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APPENDICES

Appendix A: Normalized Raw Data

Table 21 : Normalized Data for Inputs and Outputs for Year 2013

	2013					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,084949	0,065928	0,096022	0,035259	0,021952	0,072783
Denmark	0,025749	0,016345	0,016211	0,014974	0,009998	0,011061
Finland	0,024594	0,014994	0,013944	0,015356	0,005189	0,009337
France	0,192670	0,117948	0,161169	0,137392	0,055350	0,109744
Germany	0,343860	0,166614	0,224192	0,278117	0,170570	0,167748
Japan	0,542728	0,244995	0,310261	1,000000	0,146615	0,260170
Norway	0,017300	0,010908	0,021016	0,005866	0,004816	0,016167
Sweden	0,047300	0,022916	0,027471	0,033297	0,022073	0,020203
Russia	0,118642	0,234015	0,231187	0,004330	0,005548	0,176187
Turkey	0,047711	0,031977	0,105262	0,002353	0,004851	0,085189
China	1,000000	1,000000	1,000000	0,124154	1,000000	1,000000
Austria	0,040505	0,018735	0,025108	0,021503	0,016335	0,019262
Czech Republic	0,020161	0,017543	0,020020	0,001787	0,035692	0,015888
Ireland	0,012092	0,009021	0,013680	0,005344	0,017586	0,011194
Netherlands	0,057442	0,038370	0,051126	0,064492	0,106446	0,039427
Poland	0,026824	0,026537	0,057742	0,003392	0,022685	0,048052
UK	0,138084	0,106811	0,158215	0,103594	0,053417	0,113730
Italy	0,093570	0,069849	0,135148	0,043770	0,024749	0,097329
Spain	0,063508	0,057547	0,093424	0,013044	0,008569	0,067873

Table 22 : Normalized Data for Inputs and Outputs for Year 2014

	2014					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,080771	0,063729	0,094701	0,033583	0,021469	0,072392
Denmark	0,023605	0,015728	0,015789	0,017482	0,010692	0,010856
Finland	0,021680	0,014049	0,013320	0,017778	0,005748	0,008937
France	0,181976	0,114242	0,155481	0,141662	0,054696	0,106082
Germany	0,327959	0,163115	0,222362	0,264377	0,179195	0,167785
Japan	0,514529	0,241279	0,294047	1,000000	0,141765	0,248171
Norway	0,016454	0,010860	0,019771	0,006301	0,005069	0,015049
Sweden	0,042480	0,022496	0,026722	0,038382	0,021942	0,019779
Russia	0,114726	0,223466	0,219816	0,006321	0,007816	0,167894
Turkey	0,048554	0,031112	0,108664	0,001561	0,005407	0,089267
China	1,000000	1,000000	1,000000	0,161066	1,000000	1,000000
Austria	0,039135	0,018902	0,024359	0,022808	0,017252	0,018777
Czech Republic	0,019757	0,017368	0,019981	0,002484	0,038904	0,016220
Ireland	0,011727	0,009027	0,013916	0,006124	0,018083	0,011594
Netherlands	0,054002	0,036699	0,048496	0,073044	0,110917	0,037236
Poland	0,027506	0,028125	0,056559	0,003055	0,026956	0,047206
UK	0,132270	0,106798	0,155793	0,095255	0,054838	0,111998
Italy	0,088508	0,067231	0,128510	0,046474	0,024281	0,092725
Spain	0,057672	0,053963	0,091016	0,014532	0,009567	0,066528

Table 23 : Normalized Data for Inputs and Outputs for Year 2015

	2015					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,073767	0,065148	0,089615	0,033205	0,021118	0,067555
Denmark	0,023262	0,016027	0,015663	0,018264	0,009486	0,010912
Finland	0,018269	0,013400	0,013085	0,015038	0,004716	0,008864
France	0,168348	0,114036	0,152752	0,129312	0,049948	0,105575
Germany	0,311673	0,170402	0,218528	0,267322	0,165330	0,166591
Japan	0,460319	0,232785	0,292183	1,000000	0,129818	0,250569
Norway	0,016559	0,011282	0,017600	0,005709	0,004575	0,013074
Sweden	0,042310	0,022228	0,027037	0,041060	0,019042	0,020421
Russia	0,106038	0,221784	0,198139	0,005088	0,005958	0,160160
Turkey	0,048444	0,032533	0,113639	0,002839	0,004795	0,094642
China	1,000000	1,000000	1,000000	0,182908	1,000000	1,000000
Austria	0,035903	0,018994	0,024217	0,022515	0,014366	0,018790
Czech Republic	0,018720	0,017674	0,020088	0,002959	0,035744	0,016512
Ireland	0,010488	0,009137	0,018241	0,005655	0,018213	0,016661
Netherlands	0,049940	0,037081	0,047867	0,063826	0,091305	0,037282
Poland	0,027950	0,029064	0,057336	0,004556	0,026212	0,048781
UK	0,124743	0,110103	0,155750	0,094656	0,050970	0,112335
Italy	0,081935	0,068949	0,125918	0,046471	0,022993	0,092000
Spain	0,054128	0,053438	0,091088	0,016323	0,009225	0,067916

Table 24 : Normalized Data for Inputs and Outputs for Year 2016

	2016					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,069723	0,058944	0,089680	0,036246	0,022217	0,067622
Denmark	0,022287	0,016209	0,015911	0,016570	0,010531	0,011313
Finland	0,016332	0,012230	0,013196	0,015333	0,005342	0,009079
France	0,152926	0,111459	0,153062	0,116358	0,053330	0,106796
Germany	0,292707	0,169645	0,222592	0,268696	0,186236	0,172035
Japan	0,406587	0,224943	0,275699	1,000000	0,142813	0,238412
Norway	0,015669	0,011325	0,016488	0,007908	0,004192	0,012034
Sweden	0,039933	0,023385	0,026743	0,042126	0,020558	0,020154
Russia	0,097518	0,206886	0,189128	0,006312	0,006601	0,154444
Turkey	0,049084	0,035315	0,113103	0,003535	0,004332	0,094591
China	1,000000	1,000000	1,000000	0,193347	1,000000	1,000000
Austria	0,034299	0,019382	0,024598	0,020413	0,014856	0,019302
Czech Republic	0,015328	0,016963	0,020384	0,003085	0,038316	0,016912
Ireland	0,009720	0,008864	0,018221	0,005838	0,027219	0,016822
Netherlands	0,046882	0,037256	0,047589	0,051944	0,101762	0,037226
Poland	0,025373	0,028826	0,057470	0,004242	0,026061	0,049146
UK	0,117253	0,107629	0,154806	0,090186	0,052763	0,112978
Italy	0,077660	0,074790	0,129364	0,050959	0,025165	0,096286
Spain	0,049785	0,053087	0,092625	0,017879	0,010914	0,070192

Table 25 : Normalized Data for Inputs and Outputs for Year 2017

	2017					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,065022	0,057524	0,088790	0,037706	0,020833	0,067838
Denmark	0,020157	0,014935	0,016047	0,017971	0,010458	0,011469
Finland	0,015661	0,012148	0,013176	0,015285	0,005468	0,009292
France	0,143949	0,109458	0,149998	0,112435	0,051520	0,104704
Germany	0,289493	0,170158	0,220090	0,270359	0,193287	0,170611
Japan	0,392945	0,220832	0,264607	1,000000	0,143251	0,230797
Norway	0,015530	0,011462	0,016996	0,008404	0,003554	0,012639
Sweden	0,039365	0,022047	0,026272	0,043649	0,018729	0,019916
Russia	0,092768	0,192918	0,191436	0,005359	0,006693	0,158473
Turkey	0,049733	0,038068	0,113857	0,004128	0,004047	0,098176
China	1,000000	1,000000	1,000000	0,230297	1,000000	1,000000
Austria	0,031971	0,018844	0,023964	0,021171	0,014396	0,018955
Czech Republic	0,015844	0,017289	0,020683	0,003293	0,041518	0,017051
Ireland	0,010274	0,008923	0,019014	0,006123	0,023883	0,017866
Netherlands	0,045355	0,037287	0,047455	0,056263	0,101700	0,037259
Poland	0,026515	0,035726	0,057409	0,004806	0,027716	0,049359
UK	0,112164	0,109976	0,151950	0,093760	0,049450	0,112678
Italy	0,073477	0,078746	0,126574	0,052209	0,025055	0,095134
Spain	0,048376	0,053487	0,092612	0,018471	0,011333	0,071070

Table 26 : Normalized Data for Inputs and Outputs for Year 2018

	2018					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,061432	0,054331	0,085630	0,038650	0,019454	0,065932
Denmark	0,019296	0,013643	0,015309	0,018420	0,009734	0,011077
Finland	0,014837	0,011414	0,012619	0,015436	0,005466	0,008933
France	0,135167	0,103384	0,143855	0,108527	0,050035	0,100698
Germany	0,277216	0,161523	0,209508	0,270366	0,191074	0,163312
Japan	0,371440	0,204704	0,246619	1,000000	0,135273	0,215534
Norway	0,014662	0,010636	0,017028	0,008633	0,003308	0,012822
Sweden	0,036703	0,021000	0,025058	0,046459	0,017433	0,019029
Russia	0,078795	0,173108	0,193657	0,005635	0,005002	0,160910
Turkey	0,051029	0,039284	0,105802	0,004426	0,003728	0,092626
China	1,000000	1,000000	1,000000	0,284123	1,000000	1,000000
Austria	0,030712	0,018430	0,023192	0,021705	0,014230	0,018501
Czech Republic	0,016262	0,017111	0,020107	0,003336	0,046744	0,016510
Ireland	0,009838	0,008175	0,019005	0,006269	0,023424	0,018152
Netherlands	0,042207	0,035804	0,045880	0,055497	0,101172	0,036006
Poland	0,030238	0,036973	0,055842	0,005009	0,029746	0,048188
UK	0,108187	0,105782	0,144084	0,095031	0,046784	0,108116
Italy	0,071269	0,078894	0,119817	0,053428	0,025450	0,090191
Spain	0,047050	0,051512	0,087629	0,019129	0,010569	0,067450

Table 27 : Normalized Data for Inputs and Outputs for Year 2019

	2019					
	Input1	Input2	Input3	Output1	Output2	Output3
Canada	0,053542	0,000000	0,080962	0,039128	0,020383	0,062661
Denmark	0,017591	0,012962	0,014913	0,018287	0,009797	0,010958
Finland	0,013762	0,010726	0,012102	0,015374	0,005608	0,008622
France	0,124423	0,096597	0,141854	0,104877	0,050531	0,099720
Germany	0,257404	0,153222	0,197428	0,261020	0,190370	0,153452
Japan	0,333829	0,188171	0,230252	1,000000	0,131379	0,201969
Norway	0,013638	0,010149	0,015538	0,008433	0,003810	0,011500
Sweden	0,034466	0,018991	0,024181	0,048132	0,018282	0,018510
Russia	0,076149	0,157016	0,182112	0,005657	0,006611	0,151677
Turkey	0,048227	0,038087	0,096889	0,004504	0,003817	0,084771
China	1,000000	1,000000	1,000000	0,316150	1,000000	1,000000
Austria	0,028464	0,017426	0,022140	0,021732	0,013373	0,017713
Czech Republic	0,015353	0,016507	0,019510	0,003275	0,050327	0,015997
Ireland	0,009876	0,007688	0,018759	0,006223	0,028293	0,017953
Netherlands	0,039672	0,033416	0,044001	0,054077	0,102998	0,034346
Poland	0,031233	0,034162	0,055251	0,004953	0,028227	0,047480
UK	0,100431	0,101252	0,137840	0,095474	0,048279	0,103810
Italy	0,066540	0,074124	0,113883	0,053519	0,024620	0,085965
Spain	0,043645	0,048203	0,084527	0,019365	0,011423	0,065470

Appendix B: Weight Tables

Table 28 : Tables Regarding Weights Dedicated to Data for Year 2013

2013	Input1	Input2	input3	Output1	Output2	Output3
Canada	0	3,17	8,24	0,38	0	11,36
Denmark	0	0	61,69	4,04	7,18	54,01
Finland	0	0	71,72	3,71	0	71,26
France	0	1,86	4,84	0,22	0	6,68
Germany	0	1,76	3,15	0,18	0,36	4,53
Japan	1,84	0	0	1	0	0
Norway	0	15,24	39,67	1,81	0	54,69
Sweden	0	13,9	24,81	1,4	2,86	35,67
Russia	1,6	0	3,5	0	0	5,1
Turkey	1,97	1,8	8,06	0,96	0	11,71
China	0	0,36	0,64	0,04	0,07	0,92
Austria	0	15,74	28,09	1,59	3,24	40,38
Czech Republic	21,54	2,59	25,99	0	10,29	39,83
Ireland	2,53	30,87	50,5	0	9,01	74,9
Netherlands	0	7,71	13,77	0,78	1,59	19,8
Poland	3,48	3,18	14,24	1,7	0	20,69
UK	2,14	0	4,46	0,85	0	6,49
Italy	1,41	1,29	5,76	0,69	0	8,37
Spain	2,01	1,84	8,21	0,98	0	11,93
total	38,52	101,31	377,34	20,33	34,6	478,32

Table 29 : Tables Regarding Weights Dedicated to Data for Year 2014

2014	Input1	Input2	input3	Output1	Output2	Output3
Canada	0	2,95	8,58	0,39	0	11,46
Denmark	0	0	63,34	3,72	6,29	56,44
Finland	0	0	75,08	3,59	0	74,5
France	0	1,76	5,14	0,23	0	6,86
Germany	0	1,62	3,31	0,18	0,33	4,57
Japan	1,94	0	0	1	0	0
Norway	0	14,62	42,55	1,93	0	56,86
Sweden	0	12,95	26,52	1,47	2,62	36,61
Russia	1,73	0	3,65	0	0	5,38
Turkey	3,61	0,28	7,51	1,36	0	11,18
China	0	0,33	0,67	0,04	0,07	0,93
Austria	0	14,54	29,77	1,64	2,95	41,1
Czech Republic	12,64	8,97	29,75	0	7,36	44
Ireland	0	28,26	53,53	0	7,97	73,81
Netherlands	0	7,35	15,06	0,83	1,49	20,78
Poland	5,11	3,21	13,6	2,18	1,23	20,34
UK	2,31	0	4,46	0,85	0	6,63
Italy	2,77	0,21	5,76	1,04	0	8,58
Spain	3,98	0,3	8,28	1,5	0	12,33
total	34,09	97,35	396,56	21,95	30,31	492,36

Table 30 : Tables Regarding Weights Dedicated to Data for Year 2015

2015	Input1	Input2	input3	Output1	Output2	Output3
Canada	0	1,92	9,77	0,39	0	11,61
Denmark	0	0	63,85	3,85	8,44	54,7
Finland	0	0	76,42	3,33	0	75,81
France	0	1,12	5,71	0,23	0	6,79
Germany	0	0,66	4,06	0,23	0,55	4,13
Japan	2,17	0	0	1	0	0
Norway	0	9,9	50,47	2,02	0	60
Sweden	0	5,3	32,63	1,88	4,39	33,19
Russia	3,07	0	3,41	0	0	5,66
Turkey	0	3,96	7,66	0	0	10,57
China	0	0	1	0,06	0,13	0,86
Austria	0	7,02	35,79	1,43	0	42,55
Czech Republic	0	0	49,78	0,47	9,26	40,44
Ireland	0	8,23	50,7	2,92	6,82	51,57
Netherlands	0	0	20,89	1,26	2,76	17,9
Poland	35,78	0	0	0	4,04	18,11
UK	1,19	0	5,47	0,5	0	6,57
Italy	1,51	0	6,96	0,64	0	8,35
Spain	2,44	0	9,53	0	0	11,97
total	46,16	38,11	434,1	20,21	36,39	460,78

Table 31 : Tables Regarding Weights Dedicated to Data for Year 2016

2016	Input1	Input2	input3	Output1	Output2	Output3
Canada	0	1,65	10,07	0,37	0	11,64
Denmark	0	0	62,85	3,22	7,65	54,58
Finland	0	0	75,78	2,96	0	75,21
France	0	0,96	5,84	0,21	0	6,75
Germany	0	0	4,49	0,23	0,55	3,9
Japan	2,46	0	0	1	0	0
Norway	0	8,93	54,52	2	0	63,06
Sweden	0	0	37,39	1,92	4,55	32,47
Russia	4,3	0	3,07	0	0	5,81
Turkey	0	5,27	7,19	0	0	10,57
China	0	0	1	0,05	0,12	0,87
Austria	0	5,9	36,01	1,32	0	41,65
Czech Republic	5,86	0	44,65	0	11,4	33,31
Ireland	0	0	54,88	2,87	6,9	47,28
Netherlands	0	0	21,01	1,1	2,64	18,1
Poland	15,07	0	10,75	0	0	20,35
UK	0,98	0	5,72	0,4	0	6,62
Italy	1,2	0	7,01	0,49	0	8,12
Spain	1,92	0	9,76	0	0	11,69
total	31,79	22,71	451,99	18,14	33,81	451,98

Table 32 : Tables Regarding Weights Dedicated to Data for Year 2017

2017	Input1	Input2	input3	Output1	Output2	Output3
Canada	1,39	0	10,25	0,6	0	11,5
Denmark	0	2,09	60,37	2,82	7,46	54,35
Finland	0	8,24	68,3	2,35	0	76
France	0	0,74	6,13	0,21	0	6,82
Germany	0	0,15	4,42	0,21	0,55	3,98
Japan	2,54	0	0	1	0	0
Norway	0	6,56	54,41	1,87	0	60,54
Sweden	0	1,28	36,99	1,73	4,57	33,3
Russia	4,35	0	3,12	0	0	5,82
Turkey	0	5,84	6,83	0	0	10,19
China	0,04	0	0,96	0,05	0,12	0,87
Austria	0	4,6	38,11	1,31	0	42,41
Czech Republic	1,38	0	47,29	0,92	6,98	41,48
Ireland	2,02	0	51,5	2,77	6,35	46,53
Netherlands	0,8	0	20,31	1,09	2,5	18,35
Poland	37,72	0	0	0	1,99	19,02
UK	0,81	0	5,98	0,35	0	6,71
Italy	13,61	0	0	3,85	0	6,51
Spain	8,71	0	6,25	0	0	11,66
total	73,37	29,5	421,22	21,13	30,52	456,04

Table 33 : Tables Regarding Weights Dedicated to Data for Year 2018

2018	Input1	Input2	input3	Output1	Output2	Output3
Canada	1,05	0	10,93	0,54	0	11,82
Denmark	0	4,98	60,88	1,96	0	65,31
Finland	0	6,04	73,78	2,37	0	79,15
France	0	0,54	6,57	0,21	0	7,04
Germany	0	0,08	4,71	0,2	0,57	4,16
Japan	2,69	0	0	1	0	0
Norway	0	4,57	55,87	1,8	0	59,93
Sweden	0	0,65	39,36	1,7	4,77	34,76
Russia	6,97	0	2,33	0	0	6,21
Turkey	0	14,62	4,02	0	0	10,8
China	0,02	0	0,98	0,05	0,12	0,87
Austria	0	3,31	40,48	1,3	0	43,43
Czech Republic	0,97	0	48,95	2,29	5,92	43,34
Ireland	1,03	0	52,08	2,44	6,3	46,12
Netherlands	0,43	0	21,4	1	2,59	18,95
Poland	1,74	0	16,97	0	0	18,7
UK	0,62	0	6,47	0,32	0	7
Italy	0,76	0	7,9	0,39	0	8,54
Spain	1,11	0	10,82	0	0	11,93
total	17,39	34,79	464,5	17,57	20,27	478,06

Table 34 : Tables Regarding Weights Dedicated to Data for Year 2019

2019	Input1	Input2	input3	Output1	Output2	Output3
Canada	0	6,5	12,35	0,97	0	15,36
Denmark	0	4,84	62,85	1,83	0	67,11
Finland	0	5,96	77,35	2,25	0	82,6
France	0	0,52	6,7	0,19	0	7,15
Germany	0	0	5,07	0,18	0,39	4,62
Japan	3	0	0	1	0	0
Norway	0	4,72	61,28	1,78	0	65,43
Sweden	0	0	41,36	1,49	3,15	37,74
Russia	7,56	0	2,33	0	0	6,59
Turkey	19,52	1,54	0	0	0	11,4
China	0,09	0	0,91	0	0	1
Austria	0	3,28	42,59	1,24	0	45,47
Czech Republic	5,13	0	47,22	3,59	6,92	40,01
Ireland	5,48	0	50,42	3,84	7,39	42,73
Netherlands	2,25	0	20,7	1,58	3,03	17,54
Poland	1,71	0	17,13	0	0	18,84
UK	0,66	0	6,78	0,3	0	7,34
Italy	15,03	0	0	3,6	0	7,02
Spain	14,34	0	4,43	0	0	12,51
total	74,77	27,36	459,47	23,84	20,88	490,46

Appendix C: Lambda Tables

Table 35 : Tables Regarding Benchmarking Dedicated to Data for Year 2013

2013	Japan	Turkey	China	Czech Republic	Netherlands	Poland
Canada	0,03	0,32	0,04	0	0	0
Denmark	0,01	0	0,01	0	0,01	0
Finland	0,01	0	0,01	0	0	0
France	0,13	0,33	0,05	0	0	0
Germany	0,22	0,35	0,05	0	0,83	0
Japan	1	0	0	0	0	0
Norway	0	0,12	0	0	0	0
Sweden	0,03	0,01	0,01	0	0,09	0
Russia	0	0	0,02	0	0	3,27
Turkey	0	1	0	0	0	0
China	0	0	1	0	0	0
Austria	0,02	0,05	0,01	0	0,05	0
Czech Republic	0	0	0	1	0	0
Ireland	0	0,03	0	0	0,14	0,03
Netherlands	0	0	0	0	1	0
Poland	0	0	0	0	0	1
UK	0,1	0	0,03	0	0	1,26
Italy	0,04	0,54	0,02	0	0	0,42
Spain	0,01	0,16	0,03	0	0	0,56

Table 36 : Tables Regarding Benchmarking Dedicated to Data for Year 2014

2014	Japan	Turkey	China	Czech Republic	Ireland	Netherlands	Poland
Canada	0,03	0,32	0,04	0	0	0	0
Denmark	0,02	0	0,01	0	0	0,02	0
Finland	0,02	0	0	0	0	0	0
France	0,13	0,31	0,04	0	0	0	0
Germany	0,19	0,4	0,05	0	0	0,89	0
Japan	1	0	0	0	0	0	0
Norway	0,01	0,1	0,01	0	0	0	0
Sweden	0,03	0,01	0,01	0	0	0,09	0
Russia	0	0	0,01	0	0	0	3,27
Turkey	0	1	0	0	0	0	0
China	0	0	1	0	0	0	0
Austria	0,02	0,04	0,01	0	0	0,05	0
Czech Republic	0	0	0	1	0	0	0
Ireland	0	0	0	0	1	0	0
Netherlands	0	0	0	0	0	1	0
Poland	0	0	0	0	0	0	1
UK	0,09	0	0,03	0	0	0	1,33
Italy	0,04	0,41	0,02	0	0	0	0,64
Spain	0,01	0,07	0,02	0	0	0	0,9

Table 37 : Tables Regarding Benchmarking Dedicated to Data for Year 2015

2015	Japan	Turkey	China	Czech Republic	Ireland	Netherlands
Canada	0,02	0	0,03	0	2,04	0
Denmark	0,02	0	0,01	0	0	0,01
Finland	0,01	0	0,01	0	0	0
France	0,11	0	0,04	0	2,47	0
Germany	0,22	0	0,05	0	2,56	0,39
Japan	1	0	0	0	0	0
Norway	0	0	0	0	0,54	0
Sweden	0,04	0	0,01	0	0,15	0,05
Russia	0	0,42	0	0	7,21	0
Turkey	0	1	0	0	0	0
China	0	0	1	0	0	0
Austria	0,02	0	0,01	0	0,35	0
Czech Republic	0	0	0	1	0	0
Ireland	0	0	0	0	1	0
Netherlands	0	0	0	0	0	1
Poland	0	0,27	0	0	1,37	0
UK	0,07	0	0,02	0	4,55	0
Italy	0,02	0	0,01	0	4,91	0
Spain	0	0	0	0	3,87	0

Table 38 : Tables Regarding Benchmarking Dedicated to Data for Year 2016

2016	Japan	Turkey	China	Czech Republic	Ireland	Netherlands	Poland
Canada	0,02	0	0,02	0	2,54	0	0
Denmark	0,01	0	0,01	0	0,06	0	0
Finland	0,01	0	0,01	0	0	0	0
France	0,09	0	0,04	0	2,81	0	0
Germany	0,24	0	0,06	0	3,55	0	0
Japan	1	0	0	0	0	0	0
Norway	0	0	0	0	0,4	0	0
Sweden	0,04	0	0	0	0,4	0	0
Russia	0	0	0	0	7,51	0	0,57
Turkey	0	1	0	0	0	0	0
China	0	0	1	0	0	0	0
Austria	0,02	0	0,01	0	0,37	0	0
Czech Republic	0	0	0	1	0	0	0
Ireland	0	0	0	0	1	0	0
Netherlands	0	0	0	0	0	1	0
Poland	0	0	0	0	0	0	1
UK	0,06	0	0,03	0	4,38	0	0
Italy	0,02	0	0	0	5,21	0	0
Spain	0	0	0	0	4,13	0	0

Table 39 : Tables Regarding Benchmarking Dedicated to Data for Year 2017

2017	Japan	Turkey	China	Czech Republic	Ireland	Netherlands
Canada	0,02	0	0,02	0	2,45	0
Denmark	0,02	0	0,01	0	0,01	0,01
Finland	0,01	0	0,01	0	0,02	0
France	0,09	0	0,04	0	2,58	0
Germany	0,22	0	0,06	0	2,83	0,39
Japan	1	0	0	0	0	0
Norway	0	0	0	0	0,41	0
Sweden	0,04	0	0,01	0	0,15	0,02
Russia	0	0,83	0	0	4,28	0
Turkey	0	1	0	0	0	0
China	0	0	1	0	0	0
Austria	0,02	0	0,01	0	0,35	0
Czech Republic	0	0	0	1	0	0
Ireland	0	0	0	0	1	0
Netherlands	0	0	0	0	0	1
Poland	0	0,3	0	0	1,11	0
UK	0,06	0	0,02	0	4,5	0
Italy	0,02	0	0	0	5,05	0
Spain	0	0,12	0	0	3,34	0

Table 40 : Tables Regarding Benchmarking Dedicated to Data for Year 2018

2018	Japan	Russia	Turkey	China	Czech Republic	Ireland	Netherlands
Canada	0,02	0	0	0,02	0	2,36	0
Denmark	0,02	0	0	0,01	0	0,05	0
Finland	0,01	0	0	0,01	0	0,03	0
France	0,08	0	0	0,04	0	2,42	0
Germany	0,24	0	0	0,05	1,11	2,51	0
Japan	1	0	0	0	0	0	0
Norway	0	0	0	0	0	0,44	0
Sweden	0,04	0	0	0,01	0,04	0,13	0
Russia	0	1	0	0	0	0	0
Turkey	0	0	1	0	0	0	0
China	0	0	0	1	0	0	0
Austria	0,02	0	0	0,01	0	0,3	0
Czech Republic	0	0	0	0	1	0	0
Ireland	0	0	0	0	0	1	0
Netherlands	0	0	0	0	0	0	1
Poland	0	0	0	0	0	2,52	0
UK	0,06	0	0	0,02	0	3,95	0
Italy	0,02	0	0	0	0	4,52	0
Spain	0	0	0	0	0	3,56	0

Table 41 : Tables Regarding Benchmarking Dedicated to Data for Year 2019

2019	Canada	Japan	Russia	China	Czech Republic	Ireland	Netherlands
Canada	1	0	0	0	0	0	0
Denmark	0	0,02	0	0,01	0	0,08	0
Finland	0	0,01	0	0,01	0	0,04	0
France	0	0,08	0	0,04	0	2,71	0
Germany	0	0,22	0	0,02	0	5,1	0
Japan	0	1	0	0	0	0	0
Norway	0	0	0	0	0	0,35	0
Sweden	0	0,04	0	0	0	0,29	0
Russia	0	0	1	0	0	0	0
Turkey	0	0	0,01	0	0	4,68	0
China	0	0	0	1	0	0	0
Austria	0	0,02	0	0,01	0	0,29	0
Czech Republic	0	0	0	0	1	0	0
Ireland	0	0	0	0	0	1	0
Netherlands	0	0	0	0	0	0	1
Poland	0	0	0	0	0	2,42	0
UK	0	0,06	0	0,02	0	4,08	0
Italy	0	0,03	0	0	0	4,5	0
Spain	0	0	0,04	0	0	3,35	0

Appendix D: Target Values Tables

Table 42 : Tables Regarding Target Values Dedicated to Data for Year 2013

2013	Input1 Value	Input1 Target	Input1 Gain(%)	Input2 Value	Input2 Target	Input2 Gain(%)	Input3 Value	Input3 Target	Input3 Gain(%)	Output1 Value	Output1 Target	Output1 Gain(%	Output2 Value	Output2 Target	Output2 Gain(%	Output3 Value	Output3 Target	Output3 Gain(%
Canada	0,08	0,07	-18,46	0,07	0,06	-15,99	0,1	0,08	-15,99	0,04	0,04	0	0,02	0,04	99,6	0,07	0,07	0
Denmark	0,03	0,02	-41,6	0,02	0,01	-33,64	0,02	0,01	-27,04	0,01	0,01	0	0,01	0,01	0	0,01	0,01	0
Finland	0,02	0,01	-45,18	0,01	0,01	-39,21	0,01	0,01	-27,77	0,02	0,02	0	0,01	0,01	47,84	0,01	0,01	0
France	0,19	0,13	-30,36	0,12	0,09	-23,69	0,16	0,12	-23,69	0,14	0,14	0	0,06	0,07	23,03	0,11	0,11	0
Germany	0,34	0,23	-32,75	0,17	0,15	-12,89	0,22	0,2	-12,89	0,28	0,28	0	0,17	0,17	0	0,17	0,17	0
Japan	0,54	0,54	0	0,24	0,24	0	0,31	0,31	0	1	1	0	0,15	0,15	0	0,26	0,26	0
Norway	0,02	0,01	-24,16	0,01	0,01	-10,52	0,02	0,02	-10,52	0,01	0,01	0	0	0,01	25,45	0,02	0,02	0
Sweden	0,05	0,03	-39,11	0,02	0,02	-16,95	0,03	0,02	-16,95	0,03	0,03	0	0,02	0,02	0	0,02	0,02	0
Russia	0,12	0,11	-10,07	0,23	0,11	-54,81	0,23	0,21	-10,07	0	0,01	210,59	0,01	0,09	1579	0,18	0,18	0
Turkey	0,05	0,05	0	0,03	0,03	0	0,11	0,11	0	0	0	0	0	0	0	0,09	0,09	0
China	1	1	0	1	1	0	1	1	0	0,12	0,12	0	1	1	0	1	1	0
Austria	0,04	0,02	-43,06	0,02	0,02	-13,5	0,03	0,02	-13,5	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0
Czech Republic	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,04	0,04	0	0,02	0,02	0
Ireland	0,01	0,01	-0,32	0,01	0,01	-0,32	0,01	0,01	-0,32	0,01	0,01	74,86	0,02	0,02	0	0,01	0,01	0
Netherlands	0,06	0,06	0	0,04	0,04	0	0,05	0,05	0	0,06	0,06	0	0,11	0,11	0	0,04	0,04	0
Poland	0,03	0,03	0	0,03	0,03	0	0,06	0,06	0	0	0	0	0,02	0,02	0	0,05	0,05	0
UK	0,14	0,11	-17,38	0,11	0,09	-20,23	0,16	0,13	-17,38	0,1	0,1	0	0,05	0,07	32,79	0,11	0,11	0
Italy	0,09	0,08	-15,53	0,07	0,06	-15,53	0,14	0,11	-15,53	0,04	0,04	0	0,02	0,04	57,53	0,1	0,1	0
Spain	0,06	0,05	-17,75	0,06	0,05	-17,75	0,09	0,08	-17,75	0,01	0,01	0	0,01	0,04	368,6	0,07	0,07	0

Table 43 : Tables Regarding Target Values Dedicated to Data for Year 2014

2014	Input1 Value	Input1 Target	nput1 Gain(%	Input2 Value	Input2 Target	nput2 Gain(%	Input3 Value	Input3 Target	nput3 Gain(%	Output1 Valu	Output1 Targ	utput1 Gain(%	Output2 Valu	Output2 Targ	utput2 Gain(%	Output3 Valu	Output3 Targ	utput3 Gain(%
Canada	0,08	0,07	-17,48	0,06	0,05	-15,73	0,09	0,08	-15,73	0,03	0,03	0	0,02	0,04	99,51	0,07	0,07	0
Denmark	0,02	0,02	-35,67	0,02	0,01	-31,7	0,02	0,01	-25,49	0,02	0,02	0	0,01	0,01	0	0,01	0,01	0
Finland	0,02	0,01	-37,87	0,01	0,01	-37,22	0,01	0,01	-27,04	0,02	0,02	0	0,01	0,01	23,98	0,01	0,01	0
France	0,18	0,13	-29,11	0,11	0,09	-23,91	0,16	0,12	-23,91	0,14	0,14	0	0,05	0,07	19,83	0,11	0,11	0
Germany	0,33	0,22	-33,82	0,16	0,14	-12,6	0,22	0,19	-12,6	0,26	0,26	0	0,18	0,18	0	0,17	0,17	0
Japan	0,51	0,51	0	0,24	0,24	0	0,29	0,29	0	1	1	0	0,14	0,14	0	0,25	0,25	0
Norway	0,02	0,01	-23,7	0,01	0,01	-13,22	0,02	0,02	-13,22	0,01	0,01	0	0,01	0,01	26,74	0,02	0,02	0
Sweden	0,04	0,03	-31,84	0,02	0,02	-16,21	0,03	0,02	-16,21	0,04	0,04	0	0,02	0,02	0	0,02	0,02	0
Russia	0,11	0,1	-9,73	0,22	0,11	-52,75	0,22	0,2	-9,73	0,01	0,01	92,85	0,01	0,1	1202,08	0,17	0,17	0
Turkey	0,05	0,05	0	0,03	0,03	0	0,11	0,11	0	0	0	0	0,01	0,01	0	0,09	0,09	0
China	1	1	0	1	1	0	1	1	0	0,16	0,16	0	1	1	0	1	1	0
Austria	0,04	0,02	-42,11	0,02	0,02	-13,99	0,02	0,02	-13,99	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0
Czech Republi	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,04	0,04	0	0,02	0,02	0
Ireland	0,01	0,01	0	0,01	0,01	0	0,01	0,01	0	0,01	0,01	0	0,02	0,02	0	0,01	0,01	0
Netherlands	0,05	0,05	0	0,04	0,04	0	0,05	0,05	0	0,07	0,07	0	0,11	0,11	0	0,04	0,04	0
Poland	0,03	0,03	0	0,03	0,03	0	0,06	0,06	0	0	0	0	0,03	0,03	0	0,05	0,05	0
UK	0,13	0,11	-17,6	0,11	0,09	-19,37	0,16	0,13	-17,6	0,1	0,1	0	0,05	0,08	38,47	0,11	0,11	0
Italy	0,09	0,07	-15,62	0,07	0,06	-15,62	0,13	0,11	-15,62	0,05	0,05	0	0,02	0,04	70,75	0,09	0,09	0
Spain	0,06	0,05	-15,8	0,05	0,05	-15,8	0,09	0,08	-15,8	0,01	0,01	0	0,01	0,04	336,26	0,07	0,07	0

Table 44 : Tables Regarding Target Values Dedicated to Data for Year 2015

2015	Input1 Value	Input1 Target	nput1 Gain(%	Input2 Value	Input2 Target	nput2 Gain(%	Input3 Value	Input3 Target	nput3 Gain(%	Output1 Valu	Output1 Targ	utput1 Gain(%	Output2 Valu	Output2 Targ	utput2 Gain(%	Output3 Valu	Output3 Targ	utput3 Gain(%
Canada	0,07	0,06	-20,83	0,07	0,05	-20,27	0,09	0,07	-20,27	0,03	0,03	0	0,02	0,07	225,55	0,07	0,07	0
Denmark	0,02	0,01	-37,71	0,02	0,01	-33,75	0,02	0,01	-25,27	0,02	0,02	0	0,01	0,01	0	0,01	0,01	0
Finland	0,02	0,01	-35,33	0,01	0,01	-35,71	0,01	0,01	-27,78	0,02	0,02	0	0	0,01	51,97	0,01	0,01	0
France	0,17	0,11	-32,8	0,11	0,09	-25,38	0,15	0,11	-25,38	0,13	0,13	0	0,05	0,1	92,79	0,11	0,11	0
Germany	0,31	0,2	-35,38	0,17	0,14	-15,87	0,22	0,18	-15,87	0,27	0,27	0	0,17	0,17	0	0,17	0,17	0
Japan	0,46	0,46	0	0,23	0,23	0	0,29	0,29	0	1	1	0	0,13	0,13	0	0,25	0,25	0
Norway	0,02	0,01	-38,61	0,01	0,01	-20,4	0,02	0,01	-20,4	0,01	0,01	0	0	0,01	198,81	0,01	0,01	0
Sweden	0,04	0,03	-34,73	0,02	0,02	-16,13	0,03	0,02	-16,13	0,04	0,04	0	0,02	0,02	0	0,02	0,02	0
Russia	0,11	0,1	-9,36	0,22	0,08	-64,09	0,2	0,18	-9,36	0,01	0,04	725,08	0,01	0,13	2138,2	0,16	0,16	0
Turkey	0,05	0,05	0	0,03	0,03	0	0,11	0,11	0	0	0	0	0	0	0	0,09	0,09	0
China	1	1	0	1	1	0	1	1	0	0,18	0,18	0	1	1	0	1	1	0
Austria	0,04	0,02	-42,62	0,02	0,02	-16,84	0,02	0,02	-16,84	0,02	0,02	0	0,01	0,02	18,6	0,02	0,02	0
zech Republi	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,04	0,04	0	0,02	0,02	0
Ireland	0,01	0,01	0	0,01	0,01	0	0,02	0,02	0	0,01	0,01	0	0,02	0,02	0	0,02	0,02	0
Netherlands	0,05	0,05	0	0,04	0,04	0	0,05	0,05	0	0,06	0,06	0	0,09	0,09	0	0,04	0,04	0
Poland	0,03	0,03	-1,08	0,03	0,02	-26,27	0,06	0,06	-2,05	0	0,01	86,77	0,03	0,03	0	0,05	0,05	0
UK	0,12	0,1	-21,51	0,11	0,08	-30,14	0,16	0,12	-21,51	0,09	0,09	0	0,05	0,11	118,8	0,11	0,11	0
Italy	0,08	0,07	-20,19	0,07	0,05	-20,6	0,13	0,1	-20,19	0,05	0,05	0	0,02	0,1	324	0,09	0,09	0
Spain	0,05	0,04	-18,72	0,05	0,04	-27,46	0,09	0,07	-18,72	0,02	0,02	38	0,01	0,07	701,39	0,07	0,07	0

Table 45 : Tables Regarding Target Values Dedicated to Data for Year 2016

2016	Input1 Value	Input1 Target	nput1 Gain(%	Input2 Value	Input2 Target	nput2 Gain(%	Input3 Value	Input3 Target	nput3 Gain(%	Output1 Valu	Output1 Targ	utput1 Gain(%	Output2 Valu	Output2 Targ	utput2 Gain(%	Output3 Valu	Output3 Targ	utput3 Gain(%
Canada	0,07	0,05	-24,65	0,06	0,05	-19,92	0,09	0,07	-19,92	0,04	0,04	0	0,02	0,09	315,55	0,07	0,07	0
Denmark	0,02	0,01	-39,96	0,02	0,01	-34,49	0,02	0,01	-24,86	0,02	0,02	0	0,01	0,01	0	0,01	0,01	0
Finland	0,02	0,01	-29,75	0,01	0,01	-27,33	0,01	0,01	-27,18	0,02	0,02	0	0,01	0,01	44,48	0,01	0,01	0
France	0,15	0,1	-33,04	0,11	0,08	-25,4	0,15	0,11	-25,4	0,12	0,12	0	0,05	0,13	138,5	0,11	0,11	0
Germany	0,29	0,19	-36,2	0,17	0,14	-17,11	0,22	0,19	-16,51	0,27	0,27	0	0,19	0,19	0	0,17	0,17	0
Japan	0,41	0,41	0	0,22	0,22	0	0,28	0,28	0	1	1	0	0,14	0,14	0	0,24	0,24	0
Norway	0,02	0,01	-36,29	0,01	0,01	-22,53	0,02	0,01	-22,53	0,01	0,01	0	0	0,02	275,81	0,01	0,01	0
Sweden	0,04	0,02	-40,18	0,02	0,02	-29,59	0,03	0,02	-17,12	0,04	0,04	0	0,02	0,02	0	0,02	0,02	0
Russia	0,1	0,09	-10,27	0,21	0,08	-59,85	0,19	0,17	-10,27	0,01	0,05	632,95	0,01	0,22	3221,84	0,15	0,15	0
Turkey	0,05	0,05	0	0,04	0,04	0	0,11	0,11	0	0	0	0	0	0	0	0,09	0,09	0
China	1	1	0	1	1	0	1	1	0	0,19	0,19	0	1	1	0	1	1	0
Austria	0,03	0,02	-43,39	0,02	0,02	-16,91	0,02	0,02	-16,91	0,02	0,02	0	0,01	0,02	45,48	0,02	0,02	0
zech Republi	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,04	0,04	0	0,02	0,02	0
Ireland	0,01	0,01	0	0,01	0,01	0	0,02	0,02	0	0,01	0,01	0	0,03	0,03	0	0,02	0,02	0
Netherlands	0,05	0,05	0	0,04	0,04	0	0,05	0,05	0	0,05	0,05	0	0,1	0,1	0	0,04	0,04	0
Poland	0,03	0,03	0	0,03	0,03	0	0,06	0,06	0	0	0	0	0,03	0,03	0	0,05	0,05	0
UK	0,12	0,09	-21,62	0,11	0,08	-28,19	0,15	0,12	-21,62	0,09	0,09	0	0,05	0,15	189,66	0,11	0,11	0
Italy	0,08	0,06	-19,37	0,07	0,05	-27,04	0,13	0,1	-19,37	0,05	0,05	0	0,03	0,15	490,31	0,1	0,1	0
Spain	0,05	0,04	-17,98	0,05	0,04	-29,75	0,09	0,08	-17,98	0,02	0,02	35,7	0,01	0,11	936,92	0,07	0,07	0

Table 46 : Tables Regarding Target Values Dedicated to Data for Year 2017

2017	Input1 Value	Input1 Target	nput1 Gain(%	Input2 Value	Input2 Target	nput2 Gain(%	Input3 Value	Input3 Target	nput3 Gain(%	Output1 Valu	utput1 Targ	utput1 Gain(%	Output2 Valu	utput2 Targ	utput2 Gain(%	Output3 Valu	utput3 Targ	utput3 Gain(%
Canada	0,07	0,05	-19,74	0,06	0,05	-20,45	0,09	0,07	-19,74	0,04	0,04	0	0,02	0,08	288,73	0,07	0,07	0
Denmark	0,02	0,01	-30,42	0,01	0,01	-24,79	0,02	0,01	-24,79	0,02	0,02	0	0,01	0,01	0	0,01	0,01	0
Finland	0,02	0,01	-27,08	0,01	0,01	-25,79	0,01	0,01	-25,79	0,02	0,02	0	0,01	0,01	49,47	0,01	0,01	0
France	0,14	0,1	-30,99	0,11	0,08	-26,24	0,15	0,11	-26,24	0,11	0,11	0	0,05	0,11	118,47	0,1	0,1	0
Germany	0,29	0,19	-35,16	0,17	0,14	-15,86	0,22	0,19	-15,86	0,27	0,27	0	0,19	0,19	0	0,17	0,17	0
Japan	0,39	0,39	0	0,22	0,22	0	0,26	0,26	0	1	1	0	0,14	0,14	0	0,23	0,23	0
Norway	0,02	0,01	-33,35	0,01	0,01	-21,9	0,02	0,01	-21,9	0,01	0,01	0	0	0,01	312,3	0,01	0,01	0
Sweden	0,04	0,03	-35,45	0,02	0,02	-17,57	0,03	0,02	-17,57	0,04	0,04	0	0,02	0,02	0	0,02	0,02	0
Russia	0,09	0,09	-7,81	0,19	0,07	-63,72	0,19	0,18	-7,81	0,01	0,03	453,91	0,01	0,11	1479,34	0,16	0,16	0
Turkey	0,05	0,05	0	0,04	0,04	0	0,11	0,11	0	0	0	0	0	0	0	0,1	0,1	0
China	1	1	0	1	1	0	1	1	0	0,23	0,23	0	1	1	0	1	1	0
Austria	0,03	0,02	-40,35	0,02	0,02	-16,83	0,02	0,02	-16,83	0,02	0,02	0	0,01	0,02	35,88	0,02	0,02	0
zech Republi	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,04	0,04	0	0,02	0,02	0
Ireland	0,01	0,01	0	0,01	0,01	0	0,02	0,02	0	0,01	0,01	0	0,02	0,02	0	0,02	0,02	0
Netherlands	0,05	0,05	0	0,04	0,04	0	0,05	0,05	0	0,06	0,06	0	0,1	0,1	0	0,04	0,04	0
Poland	0,03	0,03	-0,58	0,04	0,02	-40,23	0,06	0,06	-3,59	0	0,01	67,22	0,03	0,03	0	0,05	0,05	0
UK	0,11	0,09	-21,06	0,11	0,07	-34,74	0,15	0,12	-21,06	0,09	0,09	0	0,05	0,13	171,68	0,11	0,11	0
Italy	0,07	0,06	-18,01	0,08	0,05	-36,81	0,13	0,1	-19,69	0,05	0,05	0	0,03	0,12	393,53	0,1	0,1	0
Spain	0,05	0,04	-17,15	0,05	0,03	-36,04	0,09	0,08	-17,15	0,02	0,02	13,18	0,01	0,08	607	0,07	0,07	0

Table 47 : Tables Regarding Target Values Dedicated to Data for Year 2018

2018	Input1 Value	Input1 Target	nput1 Gain(%	Input2 Value	Input2 Target	nput2 Gain(%	Input3 Value	Input3 Target	nput3 Gain(%	Output1 Valu	Output1 Targ	utput1 Gain(%	Output2 Valu	Output2 Targ	utput2 Gain(%	Output3 Valu	Output3 Targ	utput3 Gain(%
Canada	0,06	0,05	-19,98	0,05	0,04	-22,41	0,09	0,07	-19,98	0,04	0,04	0	0,02	0,08	295,35	0,07	0,07	0
Denmark	0,02	0,01	-31,83	0,01	0,01	-24,05	0,02	0,01	-24,05	0,02	0,02	0	0,01	0,01	3,36	0,01	0,01	0
Finland	0,01	0,01	-27,06	0,01	0,01	-25,63	0,01	0,01	-25,63	0,02	0,02	0	0,01	0,01	46,17	0,01	0,01	0
France	0,14	0,09	-30,88	0,1	0,08	-26,79	0,14	0,11	-26,79	0,11	0,11	0	0,05	0,11	113,52	0,1	0,1	0
Germany	0,28	0,18	-35,39	0,16	0,14	-15,6	0,21	0,18	-15,6	0,27	0,27	0	0,19	0,19	0	0,16	0,16	0
Japan	0,37	0,37	0	0,2	0,2	0	0,25	0,25	0	1	1	0	0,14	0,14	0	0,22	0,22	0
Norway	0,01	0,01	-32,64	0,01	0,01	-21,6	0,02	0,01	-21,6	0,01	0,01	0	0	0,01	346,72	0,01	0,01	0
Sweden	0,04	0,02	-32,56	0,02	0,02	-17,63	0,03	0,02	-17,63	0,05	0,05	0	0,02	0,02	0	0,02	0,02	0
Russia	0,08	0,08	0	0,17	0,17	0	0,19	0,19	0	0,01	0,01	0	0,01	0,01	0	0,16	0,16	0
Turkey	0,05	0,05	0	0,04	0,04	0	0,11	0,11	0	0	0	0	0	0	0	0,09	0,09	0
China	1	1	0	1	1	0	1	1	0	0,28	0,28	0	1	1	0	1	1	0
Austria	0,03	0,02	-39,15	0,02	0,02	-16,83	0,02	0,02	-16,83	0,02	0,02	0	0,01	0,02	31,42	0,02	0,02	0
zech Republi	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,05	0,05	0	0,02	0,02	0
Ireland	0,01	0,01	0	0,01	0,01	0	0,02	0,02	0	0,01	0,01	0	0,02	0,02	0	0,02	0,02	0
Netherlands	0,04	0,04	0	0,04	0,04	0	0,05	0,05	0	0,06	0,06	0	0,1	0,1	0	0,04	0,04	0
Poland	0,03	0,03	-9,86	0,04	0,02	-37,61	0,06	0,05	-9,86	0,01	0,02	229,2	0,03	0,06	106,62	0,05	0,05	0
UK	0,11	0,09	-21,25	0,11	0,07	-35,73	0,14	0,11	-21,25	0,1	0,1	0	0,05	0,12	164,69	0,11	0,11	0
Italy	0,07	0,06	-20,88	0,08	0,04	-43,19	0,12	0,09	-20,88	0,05	0,05	0	0,03	0,11	340,36	0,09	0,09	0
Spain	0,05	0,04	-19,56	0,05	0,03	-38,03	0,09	0,07	-19,56	0,02	0,02	20,86	0,01	0,09	715,78	0,07	0,07	0

Table 48 : Tables Regarding Target Values Dedicated to Data for Year 2019

2019	Input1 Value	Input1 Target	nput1 Gain(%	Input2 Value	Input2 Target	nput2 Gain(%	Input3 Value	Input3 Target	nput3 Gain(%	Output1 Valu	Output1 Targ	utput1 Gain(%	Output2 Valu	Output2 Targ	utput2 Gain(%	Output3 Valu	Output3 Targ	utput3 Gain(%
Canada	0,05	0,05	0	0	0	#NUM!	0,08	0,08	0	0,04	0,04	0	0,02	0,02	0	0,06	0,06	0
Denmark	0,02	0,01	-29,34	0,01	0,01	-23,12	0,01	0,01	-23,12	0,02	0,02	0	0,01	0,01	8,44	0,01	0,01	0
Finland	0,01	0,01	-26,86	0,01	0,01	-25,32	0,01	0,01	-25,32	0,02	0,02	0	0,01	0,01	44,43	0,01	0,01	0
France	0,12	0,09	-29,29	0,1	0,07	-26,63	0,14	0,1	-26,63	0,1	0,1	0	0,05	0,12	142,02	0,1	0,1	0
Germany	0,26	0,14	-44,91	0,15	0,1	-36,03	0,2	0,16	-16,98	0,26	0,26	0	0,19	0,19	0	0,15	0,15	0
Japan	0,33	0,33	0	0,19	0,19	0	0,23	0,23	0	1	1	0	0,13	0,13	0	0,2	0,2	0
Norway	0,01	0,01	-31,94	0,01	0,01	-23,25	0,02	0,01	-23,25	0,01	0,01	0	0	0,01	289,09	0,01	0,01	0
Sweden	0,03	0,02	-35,76	0,02	0,01	-21,22	0,02	0,02	-17,24	0,05	0,05	0	0,02	0,02	0	0,02	0,02	0
Russia	0,08	0,08	0	0,16	0,16	0	0,18	0,18	0	0,01	0,01	0	0,01	0,01	0	0,15	0,15	0
Turkey	0,05	0,05	-3,39	0,04	0,04	-3,39	0,1	0,09	-8,45	0	0,03	546,72	0	0,13	3367,55	0,08	0,08	0
China	1	1	0	1	1	0	1	1	0	0,32	0,32	0	1	1	0	1	1	0
Austria	0,03	0,02	-38,08	0,02	0,01	-16,76	0,02	0,02	-16,76	0,02	0,02	0	0,01	0,02	45,83	0,02	0,02	0
zech Republi	0,02	0,02	0	0,02	0,02	0	0,02	0,02	0	0	0	0	0,05	0,05	0	0,02	0,02	0
Ireland	0,01	0,01	0	0,01	0,01	0	0,02	0,02	0	0,01	0,01	0	0,03	0,03	0	0,02	0,02	0
Netherlands	0,04	0,04	0	0,03	0,03	0	0,04	0,04	0	0,05	0,05	0	0,1	0,1	0	0,03	0,03	0
Poland	0,03	0,03	-10,53	0,03	0,02	-33,7	0,06	0,05	-10,53	0	0,02	229,78	0,03	0,07	156,82	0,05	0,05	0
UK	0,1	0,08	-20,98	0,1	0,06	-39,72	0,14	0,11	-20,98	0,1	0,1	0	0,05	0,14	192,97	0,1	0,1	0
Italy	0,07	0,05	-20,39	0,07	0,04	-46,84	0,11	0,09	-20,69	0,05	0,05	0	0,02	0,13	430,91	0,09	0,09	0
Spain	0,04	0,04	-18,07	0,05	0,03	-35,06	0,08	0,07	-18,07	0,02	0,02	8,59	0,01	0,09	731,03	0,07	0,07	0

Appendix E: Correlations Between Inputs and Outputs

Table 49 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2013

2013	input1	Input2	Input3
Output1	0,52557627	0,24405194	0,29841512
Output2	0,91613799	0,96404661	0,95218459
Output3	0,94833796	0,99577618	0,99585043

Table 50 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2014

2014	Input1	Input2	Input3
Output1	0,53294931	0,27504448	0,31646458
Output2	0,92402952	0,96545471	0,95512688
Output3	0,95355435	0,99578849	0,99620729

Table 51 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2015

2015	Input1	Input2	Input3
Output1	0,51171	0,28903895	0,33724427
Output2	0,93774383	0,96782735	0,95970023
Output3	0,96565333	0,99500222	0,99684591

Table 52 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2016

2016	Input1	Input2	Input3
Output1	0,47900349	0,29409029	0,3338958
Output2	0,95613169	0,97039925	0,96244603
Output3	0,97461365	0,99589111	0,99711029

Table 53 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2017

2017	Input1	Input2	Input3
Output1	0,49920043	0,324513	0,35540005
Output2	0,96036458	0,97273387	0,96322856
Output3	0,97472332	0,99698349	0,99734262

Table 54 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2018

2018	Input1	Input2	Input3
Output1	0,52639293	0,35957112	0,38612713
Output2	0,96388645	0,97569339	0,96422316
Output3	0,97527346	0,99817851	0,99763919

Table 55 : Tables Regarding Correlation of Inputs and Outputs Dedicated to Data for Year 2019

2019	Input1	Input2	Input3
Output1	0,52113555	0,37208808	0,40053143
Output2	0,97102788	0,97838647	0,96726053
Output3	0,98040557	0,99862487	0,99787043

Table 56 : Correlations for First Output (Patents) Different Year Periods

period	Input1	Input2	Input3
13-14	0,55319697	0,27718287	0,32973144
13-15	0,57124898	0,29794708	0,35000921
13-16	0,5798522	0,30841285	0,36027354
13-17	0,60767939	0,34102035	0,39186264
13-18	0,64695648	0,3882927	0,4374185
13-19	0,6685136	0,41585605	0,46363202