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# Economic Efficiency and Total Factor Productivity of Defense Industries in NATO and EUROZONE

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**Abstract**

The main purpose of this study is to analyze the efficiency and total factor productivity (MTFP) of the 12 defense industries in NATO and the EUROZONE with the data of the 2013-2017 period. GDP, defense expenditures, import for the defense industry and logistics performance index were used as input variables; while total sales and export values of defense industry were used as output variables in accordance with the data acquired from World Bank (WB) and SIPRI. Static DEA and MTFP were applied to data. According to findings of the CCR models; the USA, UK, France, Germany, Spain, and Netherland were observed as efficient DMUs in all years; whereas the other six countries were inefficient ones. Additionally, according to BCC model, only Turkey and Canada were observed as inefficient ones for five years. MTFP analysis revealed that Turkey and Germany were the two countries experiencing TFP in all periods.

**Keywords**

Defense Industry of NATO and EUROZONE Countries
Data Envelopment Analysis,
Malmquist Total Factor Productivity Analysis

**About Article**

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# NATO ve EURO Bölgesindeki Savunma Sanayilerinin İktisadi Etkinliği ve Toplam Faktör Verimliliği

**Öz**

Bu çalışmanın amacı, NATO ve EURO bölgesindeki toplam 12 ülkenin savunma sanayinin karşılaştırmalı etkinlik ve toplam faktör verimliliğini 2013-2017 yıllarına ait verilerle analiz etmektir. Çalışmada, Dünya Bankası ve SIPRI kaynaklarından istifade ile girdi değişkeni olarak GSYİH, savunma sanayi harcamaları, savunma sanayi ithalatı, lojistik faktör endeksi; çıktı değişkeni olarak da savunma sanayi toplam satışları, savunma sanayi ihracatı kullanılmıştır. Analiz yöntemi olarak, Statik Veri Zarflama Analizi (VZA) ve Toplam Faktör Verimliliği Analizi (MTFA) kullanılmıştır. Elde edilen bulgulara göre; CCR modelinde bu beş yıllık dönemde ABD, İngiltere, Fransa, Almanya, İspanya ve Hollanda'nın tam etkinlik düzeyinde olduğu, diğer altı ülkenin ise tüm yıllarda etkin sınırının altında kaldığı gözlenmiştir. BCC model sonuçlarına göre ise Türkiye ve Kanada haricindeki tüm ülkelerin etkinlik sınırını yakaladığı gözlenmiştir. MTFA bulgularına göre, sadece Almanya ve Türkiye'nin bu beş yılı kapsayan dönemde pozitif yönde etkinlik artışı sağladığı gözlenmiştir.

**Anahtar Kelimeler**

NATO ve EURO Bölgesi Ülkeleri Savunma Sanayii
Veri Zarflama Analizi
MALMQUIST Toplam Faktör Verimliliği Analizi

**Makale Hakkında**

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## Introduction

One of the tools that states prefer in order to solve their problems or achieve their goals is diplomacy while the other one is military power (Duchacek and Thompson, 1960:596-597). It has been generally known and experienced that military power has been used in cases where diplomatic activities fail. Therefore, for a country, military readiness to different contingencies has always been important (Rosencrance, 1973:231). Examining the recent history, it is seen that there are so many conflicts and crises throughout the world. The crises and conflicts such as in Syrian, Palestinian, Iraq and Lebanon crisis in the Middle East; conflict in the Caucasus arising from the Russian invasion of Crimea; conflicts in African countries, especially in Nigeria and its neighboring countries Cameroon, Chad, and Niger, which were created by Boko Haram Terrorist Organization; clashes between China and its neighboring countries in the China Sea and the conflict created in Afghanistan by radical Islamist groups have been still remained unsolved. In this context; due to the countries' concerns of survivability, the existence of strong-armed forces and the strong defense industry that can support armed forces is still inevitable as it was in the past.

The defense industry, which provides high technology and high value-added products in every area of the manufacturing industry, has always maintained its importance for the country's economy with its dual usage and high export value. The production volume of the defense industry was approximately $ 375 billion in 2016 and the US and Western European countries seem to be the dominant players in this market (SIPRI, 2018a). Therefore, it has become inevitable that countries' defense industry should be unique and have a cost-effective structure. In other words, they cannot compete with the dominant ones due to increasing external dependency. In sum, it can be asserted that one of the basic requirements to compete in such a huge market is assuring production efficiency by using scarce resources more efficiently. In this context, the main purpose of the study is to measure the efficiency and total productivity level of 12 countries in NATO and developed Eurozone.

In this regard, in the first section of the study, the conceptual framework was explained. In the second section, the methodology of the study and thereafter in the third section, the findings obtained from Data Envelopment Analysis and Malmquist Total Factor Productivity Index were presented. Then in the fourth section, the findings obtained were discussed. In the last section, the limitations of the study and the field-specific suggestions were expressed.

## Conceptual Framework

Industry, which is characterized as the engine of economic growth, covers all production activities that transform raw materials and semi-finished goods into finished goods by processing them by means of labor and capital. In this respect, the defense industry is actually a sort of manufacturing (Karluk, 2005:205).

The literature shows that there has been quite a lot of study suggesting that the industrial sector has a driving role in economic growth throughout the historical process. Most of these studies have been carried out after the Second World War (Prebisch, 1950; Lewis, 1954; Chenery, 1960; Clark, 1961; Nurkse, 1966; Kuznets, 1966; Kaldor, 1966).

Kaldor (1966, 1968) 's first law is expressed in equations 1 and 2 below. The variable IND in the first equation refers to the amount of production realized in the industrial sector. Equation 1 can also be expressed as in the form of equation 2 by using the growth rates.

$$GDP = \beta_0 + \beta_1 IND + u_t \quad (1)$$

$$GDPR = \beta_0 + \beta_1 INDR + u_t \quad (2)$$

According to this basic law, there is a positive relationship between the economic growth rate and growth rate of the manufacturing industry sector. Due to the returns to the scale in the manufacturing industry sector, as the returns of capital accumulation and investments increase, this leads to economic growth by creating positive externalities. Hence, according to this law, the manufacturing industry can be characterized as the driving force of economic growth (Kaldor, 1966, 1968).

On the other hand, the defense industry can be defined as a branch of industry that is composed of public and private enterprises while producing goods in almost every field of the manufacturing industry. Besides, the products of the defense industry are of significance because of high and high-medium technology and dual usage.

In addition, the interaction between the defense industry and macroeconomic variables reveals that the defense industry has a very important role in the manufacturing industry and economic structure, primarily due to its high value-added share (Şenesen, 1989: 271).

Sweezy et al. (1975) found that defense expenditure has contributed significantly to support employment by increasing effective demand. Önder (2012) also explains that defense expenditure had a positive effect on employment.

Mcintosh (2006) states that if the capacity utilization in the manufacturing industry is low (i.e. unutilized capacity), there will be favorable economic outcomes with the establishment of the national defense industry. At this point, it can be argued that the establishment of the national defense industry will significantly increase demand in the economy through creating an increase in the demand of the products that are closely related to defense industry, such as chemical industry, plastic & rubber industry, petroleum industry, main metal industry, machine industry, electrical machine industry, metal goods industry, shipbuilding industry, motor (land and air) vehicle industry (Şenesen, 1989:268).

It is also known that the defense industry has different effects on the balance of payments in the short and the long run. In the short run, the industries, especially ones that are producing weapons systems requiring advanced technology will have characteristics of import substitution at the beginning. Accordingly, they will have inconveniences of the import substitution industrialization, because the production will probably require large amounts of external resources. However, the effect observed in the long-run is favorable in general. Investments in the developing countries, which create great pressure on the balance of payments at the beginning, become useful in the following years to compensate for the foreign exchange deficit (Şimşek, 1989:195)

The benefits of the R&D activities, which are thought to accelerate as a result of the improvements in the defense industry, can be summarized as follows: more efficient use of resources, prevention of brain drain and benefitting from labor force of researchers, increases in production, quality and standardization, more effective use of existing capacity together with the widespread use of new technologies and new investments, increases in competitiveness and export opportunities in foreign markets (Şimşek, 1989:193-194).

It is emphasized that defense expenditure has a significant impact on the manufacturing industry due to its positive contributions to the process of industrialization. These positive contributions have shown up, especially with positive externalities that defense expenditure has created through accelerating infrastructure investments. At this point, Kaldor (1976) states that defense expenditure causes high industrial growth and creates a modernization effect in important sectors such as iron and steel and aviation industry. Benoit (1978) also argues that the infrastructure investments made by means of defense expenditure and the labor power that specialized in this way can make a huge impact in the industrialization and modernization of the country.

The data of 2016, which shows the production value of this sector in terms of macroeconomic structure, indicates that 73 of the world's largest 100 firms are from the North American and Western European companies. Consequently, it can be said that this sector is dominated by companies from the US and Continental Europe (SIPRI, 2018b).

As of 2016, world defense industry production is approximately 375 billion dollars (SIPRI, 2018b). Table 1 presents the information about the arms sales of 12 NATO countries and the EURO region countries included in the study. These are the prominent countries in the defense industry production (approximately 81% of the total world volume in 2016). The total arms sales of these 12 countries are about 344 billion 703 million dollars as of 2017.

**Table 1**. Total Arms Sales of the Countries (billion $)

| Countries | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| **USA** | 269435 | 237280 | 228605 | 215170 | 237623 |
| **UK** | 44882 | 38353 | 39440 | 36110 | 39696 |
| **France** | 34700 | 18888 | 21370 | 18570 | 23382 |
| **Germany** | 6870 | 5213 | 5600 | 5980 | 5916 |
| **İtaly** | 19764 | 16496 | 17180 | 10100 | 15885 |
| **Spain** | 5150 | 710 | 737 | 710 | 1827 |
| **Turkey** | 1810 | 1715 | 1971 | 2703 | 2050 |
| **Canada** | 800 | 682 | 760 | 780 | 756 |
| **Finland** | 1000 | 556 | 432 | 530 | 630 |
| **Norvay** | 1080 | 735 | 730 | 770 | 829 |
| **Poland** | 827 | 1210 | 1190 | 1140 | 1092 |
| **Netherland** | 20360 | 14609 | 12776 | 12321 | 15017 |
| **Total** | 406678 | 336447 | 330791 | 304884 | 344703 |

**Source**: https://www.sipri.org/databases

Table 2 presents the world's largest arms exporter and importer countries between 2013-2017. As shown in Table 2, these 10 countries dominate the world exports and approximately 89.4% of the total exports are realized by these 10 countries. On the other hand, the top 10 arms importer countries perform about 51.4% of total imports.

**Table 2.** The Main Exporter and Importer (2013-2017)

| No. | Exporter | Share (%) | No. | Importer | Share (%) |
|---|---|---|---|---|---|
| **1** | **USA** | 34 | 1 | India | 12 |
| **2** | **Russia** | 22 | 2 | Saudi Arabia | 10 |
| **3** | **France** | 6.7 | 3 | Egypt | 4.5 |
| **4** | **Germany** | 5.8 | 4 | UAE | 4.4 |
| **5** | **China** | 5.7 | 5 | China | 4.0 |

| | | | | | |
|---|---|---|---|---|---|
| **6** | **UK** | 4.8 | 6 | Australia | 3.8 |
| **7** | **Spain** | 2.9 | 7 | Algeria | 3.7 |
| **8** | **Israel** | 2.9 | 8 | Iraq | 3.4 |
| **9** | **Italy** | 2.5 | 9 | Pakistan | 2.8 |
| **10** | **Netherland** | 2.1 | 10 | Indonesia | 2.8 |
| | **Total** | **89.4** | | **Total** | **51.4** |

**Source**: https://www.sipri.org/databases

As of 2017, world defense industry expenditure has reached approximately 1 trillion 739 billion dollars (SIPRI, 2018). The defense expenditure data of the above-mentioned 12 countries are presented in Table 3 (The share of the 12 countries in the total expenditures is approximately 50%).

**Table 3**. Defense Expenditure of the Countries (billion $)

| Countries | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| **USA** | 640221 | 609914 | 596010 | 611186 | 609758 |
| **UK** | 57891 | 59183 | 53862 | 48253 | 47193 |
| **France** | 61228 | 63614 | 55342 | 55745 | 55770 |
| **Germany** | 48790 | 46103 | 39813 | 41067 | 44329 |
| **İtaly** | 32657 | 31572 | 25295 | 27934 | 29236 |
| **Spain** | 12765 | 17179 | 14937 | 14893 | 16226 |
| **Turkey** | 19085 | 17772 | 15881 | 14803 | 18189 |
| **Canada** | 18460 | 17854 | 15317 | 15157 | 20567 |
| **Finland** | 3262 | 3599 | 3051 | 3246 | 3597 |
| **Norvay** | 7235 | 7334 | 5815 | 5998 | 6568 |
| **Poland** | 9257 | 10345 | 10213 | 9341 | 10009 |
| **Netherland** | 10328 | 10333 | 8668 | 9253 | 10048 |
| **Total** | 921179 | 894802 | 844204 | 856876 | 871490 |

**Source:** https://www.sipri.org/databases

When the literature is examined, it is seen that despite lots of studies on the manufacturing industry (Mok et al., 2007; Lai, 2007; Nandy, 2011; Memon and Tahir, 2011; Yang et al., 2012; Prusa, 2012; Docekalova and Bockova, 2013; Moon, 2013; Elshamy, 2013; Changjun and Qiaoyue, 2014; Bakırcı et al., 2014; Tatlı and Bayrak, 2016), the number of efficiency studies on the defense industry is limited. Bakırcı et al. (2016) analyzed the defense industry of the countries that have the largest 100 defense companies in the world by using MTFP. Bayrak et al. (2016) examined the effectiveness of the defense industry of 21 countries by using the static and dynamic DEA method. These two studies can be said the pioneers of efficiency studies in the defense industry.

In this context; assuming that these DMUs (countries) realize 81% of the world's defense industry production and about 50% of the total defense expenditure, and therefore they can be said to represent the population; the main purpose of this study was established to make a comparative analysis of these 12 countries, then to develop some suggestions to ensure resource efficiency. For this purpose, the research questions were determined as follows.

***Research Question 1:*** Compared the selected countries with each other, is it possible to assert that they are effective in terms of both resource utilization and total factor productivity?

*Research Question 2:* As a result of this comparison, if there is no economic efficiency, what should be done about resource management?

## Methodology

In this section, the variables and analysis method used was represented.

*Data*

Data and their sources are submitted in Table 4.

**Table 4.** Variables and Their Sources

| | Variable | Input/Output | Sources |
|---|---|---|---|
| 1 | **GDP** | Input | World Bank* |
| 2 | **Defense Expenditure (MEXP)** | Input | SIPRI** |
| 3 | **Arms Import (AIMP)** | Input | World Bank |
| 4 | **Logistic Performance Index (LPI)** | Input | World Bank |
| 5 | **Total Arms Sales (TAS)** | Output | SIPRI |
| 6 | **Arms Export (AEX)** | Output | World Bank |

* Worl Bank (WB), http://data.worldbank.org/indicator

** SIPRI. https://www.sipri.org/databases/milex

GDP, defense expenditure, arms import values for the defense industry and logistics performance index were included as input variables; while total sales of the defense industry and arms export values as output variables. These variables seem to have been used in some studies (Bakırcı vd., 2016; Bayrak vd., 2016) in the literature beforehand.

In order to prevent probable measuring biases and use homogenous values, all variables were attained from the same sources, World Bank and SIPRI. Additionally, DEAFrontier 2.0 program was employed for the Static DEA and Win4DEAP 1.1.2 program was employed for the MTFP.

*Analysis Method*

Data Envelopment Analysis (DEA) used in this study is a method based on the frontier approach. While covering the outliers, it is different from the regression equation which is compatible with the average of data (Arnade, 1994:8). This method was first developed by Charnes, Cooper ve Rhodes in 1978 (Banker, 1992:74) and mainly tries to measure the relative efficiency of homogenous decision-making units (DMU) using the same input and the same outputs (Ramanathan, 2003:19). In other words, based on frontier approach, DEA is a technique which measures relative efficiency of DMUs using different inputs and outputs defined in different kind of measures (Ramanathan, 2003:19). In that context, DEA can be described to be a non-parametric method that measures the efficiency of the homogenous Decision-Making Units-DMUs (Cullinane et al, 2006). One of the most important features of DEA is that it can provide us with the source and degree of the inefficiency of DMUs (Cooper et al, 2000:4).

The fractional CRR programming model is the first model developed by Charnes, Cooper, and Rhodes; and was formed by the proportion of weighted outputs to weighted inputs for each decision-making unit (Charnes et al, 1978:430).

The fractional programming model for CCR input, accepted as one of the DEA models in the literature, is defined as seen in equation 3. In the model, (m) is used as input number and while (s) is used as the output number. Efficiency value for DMUs, (n) times, is measured as the ratio of weighted inputs to weighted outputs (Zhu, 2003:77).

$$E_k = Maximum \frac{\sum_{r=1}^{s} u_{rk} Y_{rk}}{\sum_{i=1}^{m} v_{ik} X_{ik}} \tag{3}$$

Here, (s) is the number of produced output; (m) is the number of input used; (urk) is the weight given to the (rth) output by the decision unit (k); (Yrk) is (rth) amount of output produced by the decision unit (k); (vik) is the weight given to the (ith) input by the decision unit (k); (Xik) is (ith) amount of input used by the decision unit (k); (n) is the number of decision-making unit; ($E_k$) is the efficiency value of the decision unit (k).

As the efficiency scores cannot be more than "1", the restriction is described in equation 4.

$$\frac{\sum_{r=1}^{s} u_{rk} Y_{rk}}{\sum_{i=1}^{m} v_{ik} X_{ik}} \leq 1 \qquad k=1,\ldots,n \tag{4}$$

Inputs and output cannot be negative. So, these restrictions can be explained as follows.

$u_{rk} \geq 0$ ; r=1,…..,s

$v_{ik} \geq 0$ ; i=1,…..,m

Malmquist Total Factor Productivity Analysis, which was developed to overcome the restrictions emerging from the static structure of DEA, measures mainly the changes of Total Factor Productivity between two points while using distance functions (Griffel-Tatje and Lovell, 1995:169-175).

This index was first used in 1982 by Stan Malmquist (Grosskopf, 1993:175). It is defined to be the ratio of input and output distance function values to measure the change in total factor productivity of a firm between two time periods such as *s* and *t* (Coelli et al., 2005:289).

The output-oriented Malmquist TFP index is defined as shown in equity 5 (Färe, 1994:66-80).

$$M_0^{t+1}\,(x^t,\ y^t,\ x^{t+1}, y^{t+1}\,) = \sqrt{\left[\frac{D_0^t\,(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\ x\ \frac{D_o^{t+1}\,(x^{t+1}, y^{t+1})}{D_I^{1+t}(x^t, y^t)}\right]} \tag{5}$$

$M_0 > 1$ means that there is an increase in TFP from the period of "t" to "t+1"; $M_0 < 1$ explains that there is a decrease in TFP from the period of "t" to "t+1"; and $M_0 = 1$ describes that TFP remains constant from the period of "t" to "t+1" (Coelli, 1996:28).

Equation 5 can be defined to be equation 6 (Grosskopf, 1993:177).

$$M_0^{t+1}\,(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_0^{t+1}\,(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\ \mathrm{x} \sqrt{\left[\frac{D_0^t\,(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\ x\ \frac{D_o^{t+1}\,(x^{t+1}, y^{t+1})}{D_I^{1+t}(x^t, y^t)}\right]} \tag{6}$$

## Empirical Results

As seen in Table 5, considering the results of the CCR input-oriented model; the USA, UK, France, Germany, Spain, and Netherland seemed to be efficient DMUs for five years. These efficient countries were observed as the reference ones to the inefficient ones. The other six countries including Turkey were observed under the efficient frontiers.

**Table 5.** Results of CCR Input Oriented Model

| DMUs | Input Oriented Model | | | | |
|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 |
| **USA** | 100 | 100 | 100 | 100 | 100 |
| **UK** | 100 | 100 | 100 | 100 | 100 |
| **France** | 100 | 100 | 100 | 100 | 100 |
| **Germany** | 100 | 100 | 100 | 100 | 100 |
| **İtaly** | **87,81** | **88,76** | **86,92** | **84,84** | **84,55** |
| **Spain** | 100 | 100 | 100 | 100 | 100 |
| **Turkey** | **67,50** | **66,65** | **68,07** | **69,50** | **69,65** |
| **Canada** | **50,33** | **53,51** | **51,67** | **52,96** | **53,01** |
| **Finland** | **56,95** | **64,06** | **63,99** | **66,01** | **66,05** |
| **Norvay** | **42,63** | **43,76** | **66,68** | **47,20** | **47,11** |
| **Poland** | **48,90** | **53,37** | **54,79** | **55,26** | **56,33** |
| **Netherland** | 100 | 100 | 100 | 100 | 100 |
| **Average** | 79,51 | 80,84 | 82,67 | 81,31 | 81,39 |
| **Standart Deviation** | 24,10 | 22,62 | 19,94 | 21,59 | 21,46 |
| **Inefficient DMUs** | 6 | 6 | 6 | 6 | 6 |

**Source:** Created by the author.

According to the CCR Output-oriented model (Table 6); the USA, UK, France, Germany, Spain, and Netherland were observed to be efficient ones, while the others were inefficient.

**Table 6.** Results of CCR Output Oriented Model

| DMUs | Output Oriented Model | | | | |
|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 |
| **USA** | 100 | 100 | 100 | 100 | 100 |
| **UK** | 100 | 100 | 100 | 100 | 100 |
| **France** | 100 | 100 | 100 | 100 | 100 |
| **Germany** | 100 | 100 | 100 | 100 | 100 |
| **İtaly** | **88,81** | **92,76** | **89,91** | **87,85** | **88,11** |
| **Spain** | 100 | 100 | 100 | 100 | 100 |
| **Turkey** | **71,40** | **76,65** | **78,07** | **79,11** | 100 |
| **Canada** | **57,31** | **58,11** | **61,67** | **62,16** | **63,13** |
| **Finland** | **76,35** | **74,36** | **73,93** | **76,71** | **75,88** |
| **Norvay** | **52,73** | **53,36** | **56,65** | **57,50** | **58,71** |
| **Poland** | **58,95** | **57,57** | **59,69** | **61,86** | **61,77** |
| **Netherland** | 100 | 100 | 100 | 100 | 100 |
| **Average** | 83,79 | 84,40 | 84,99 | 85,43 | 87,30 |
| **Standart Deviation** | 19,29 | 19,22 | 17,92 | 17,24 | 17,35 |
| **Inefficient DMUs** | 6 | 6 | 6 | 6 | 6 |

**Source:** Created by the author.

Evaluating the results of the BCC model (Table 7) which was constructed in accordance with variable returns to scale; all countries except Turkey and Canada were efficient ones.

**Table 7.** Results of BCC Input and Output Oriented Models

| DMUs | BCC Input Oriented Model | | | | | BCC Output Oriented Model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2013** | **2014** | **2015** | **2016** | **2017** | **2013** | **2014** | **2015** | **2016** | **2017** |
| **USA** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **UK** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **France** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Germany** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **İtaly** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Spain** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Turkey** | **97,77** | **96,55** | **95,14** | **96,11** | **97,18** | **55,53** | **53,51** | **54,11** | **55,15** | **56,11** |
| **Canada** | **89,58** | **91,30** | **90,02** | **94,44** | **95,11** | **51,77** | **53,81** | **52,34** | **55,12** | **56,71** |
| **Finland** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Norvay** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Polond** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Netherland** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Average** | 98,94 | 98,98 | 98,76 | 99,21 | 99,35 | 92,27 | 92,27 | 92,20 | 95,52 | 92,73 |
| **Standart Deviation** | 3,01 | 2,61 | 3,08 | 1,87 | 1,56 | 18,05 | 18,03 | 18,21 | 17,46 | 16,96 |
| **Inefficient DMUs** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

**Source:** Created by the author.

The results of BCC models higher than that of the CCR model. This result consistent with the findings (Bayrak et al, 2016) in the literature.

Examining the values of improvement that help the inefficient ones reach the efficiency border; it can be stated that the defense expenditure of all countries should be approximately decreased by 9%, and arms import should be decreased nearly by 18%. Moreover, thinking about the improvements of the output variables; it can be asserted that total defense sales of the countries should be nearly increased by 50%, and arms export of them needs to be approximately increased by 43%.

**Table 8.** Total Improvements Values of the Countries* (%)

| Variables | 2013 | 2014 | 2015 | 2016 | 2017 | Average |
|---|---|---|---|---|---|---|
| **GDP** | - | - | - | - | - | - |
| **MEXP** | -8,11 | -8,23 | -9,11 | -8,98 | -8,99 | -8,68 |
| **AIMP** | -15,52 | -18,98 | -16,36 | -17,41 | -19,88 | -17,63 |
| **LPI** | - | - | - | - | - | - |
| **TAS** | 71,18 | 44,06 | 41,19 | 44,25 | 47,07 | 49,55 |
| **AEX** | 40,45 | 43,05 | 41,45 | 44,34 | 47.13 | 43,28 |

*Obtained from BCC Output Oriented Model.

**Source:** Created by the author.

Technical and technological efficiency values obtained from Malmquist Factor Productivity Analysis (MTFP) are presented in Table 9.

**Table 9**: Results of MTFP Analysis (2013-2017)*

| | DMUs | TECHNICAL EFFICIENCY CHANGE (TEC) | | | | TECHNOLOGICAL EFFICIENCY CHANGE (TC) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2013 2014 | 2014 2015 | 2015 2016 | 2016 2017 | 2013 2014 | 2014 2015 | 2015 2016 | 2016 2017 |
| 1 | USA | **1.000** | **1.000** | **1.000** | **1.000** | 1.274 | 0.984 | 0.969 | 1.123 |
| 2 | UK | **1.000** | **1.000** | **1.000** | **1.000** | 0.911 | 0.987 | 1.025 | 0.998 |
| 3 | France | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | 0.792 | 0.934 | 0.895 |
| 4 | Germany | **1.000** | **1.000** | **1.000** | **1.000** | 1.246 | 1.210 | 1.230 | 1.229 |
| 5 | İtaly | 0.688 | 1.264 | 0.746 | 0.917 | 1.115 | 1.219 | 1.056 | 1.196 |
| 6 | Spain | **1.000** | **1.000** | **1.000** | **1.000** | 1.233 | 1.143 | 1.017 | 1.129 |
| 7 | Turkey | 0.969 | 1.228 | 1.038 | 0.883 | 1.350 | 1.150 | 0.979 | 1.456 |
| 8 | Canada | 0.775 | 1.347 | 0.809 | 0.996 | 1.246 | 1.165 | 0.963 | 1.181 |
| 9 | Finland | 0.774 | 0.917 | **1.000** | 0.951 | 1.391 | 1.048 | 0.942 | 1.434 |
| 10 | Norway | 1.027 | 1.224 | 0.708 | 0.804 | 1.349 | 1.049 | 0.934 | 1.444 |
| 11 | Poland | **1.000** | 1.107 | 1.031 | 0.751 | 1.008 | 1.017 | 0.942 | 1.147 |
| 12 | Netherland | **1.000** | **1.000** | **1.000** | **1.000** | 1.369 | 1.467 | 0.764 | 1.241 |
| | **Minimum** | 0.688 | 0.917 | 0.708 | 0.751 | 0.911 | 0.792 | 0.764 | 0.729 |
| | **Maksimum** | 1.027 | 1.224 | 1.031 | 1.423 | 1.391 | 1.467 | 1.330 | 1.444 |
| | **Average** | 0.936 | 1.107 | 0.944 | 0.963 | 1.211 | 1.060 | 0.987 | 1.164 |
| | **Standart Deviation** | 0.117 | 0.166 | 0.117 | 0.168 | 0.162 | 0.165 | 0.129 | 0.220 |

**Source:** Obtained by the author with the Win4DEAP program.

* Conducted with Output Oriented Model in terms of Variable Return to Scale.

Assuming that the technical efficiency indicates the proceeding to the efficient border (Mahadevan, 2002:590); the values bigger than "1" means that the DMU gain improvements; the values smaller than "1" means that the DMU lose efficiency because of becoming distant from the efficient frontier; and finally, the values equal to "1" means that the efficiency of the DMU did not change for that period (Coelli, 1996:28).

In that context evaluating the findings in Table 9; the USA, UK, France, Germany, Spain, and Netherland were observed not to have experienced any efficiency changes for five years period. The others were seen to have fluctuated between positive and negative values.

Technological efficiency describes the shifting of the frontier which is termed Production Possibilities Curve-PPC (Mahadevan, 2002:590). As seen in Table 9; only Germany, Italy and Spain were observed to have experienced positive change. In other words, only these countries managed to shift their PPC right and they increased their production capacity. By the way, the others seemed to fluctuate between positive and negative efficiency gains.

Pure efficiency changes in the DMUs are presented in Table 10.

**Table 10:** Results of MTFP Analysis (2013-2017)*

| | DMUs | PURE EFFICIENCY CHANCE (PTEC) | | | | SCALE EFFICIENCY CHANGE (SEC) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017 | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017 |
| 1 | USA | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| 2 | UK | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| 3 | France | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | **Germany** | 1.445 | **1.000** | **1.000** | 0863 | 1.022 | **1.000** | **1.000** | 0.977 |
| 5 | **İtaly** | **1.000** | **1.000** | 0.831 | 0.939 | 0.668 | 1.264 | 0.898 | 0.893 |
| 6 | **Spain** | **1.000** | **1.000** | **1.000** | 1.027 | **1.000** | **1.000** | 0.775 | 1.434 |
| 7 | **Turkey** | **1.000** | **1.000** | **1.000** | **1.000** | 0.877 | 1.428 | 1.038 | 0.894 |
| 8 | **Canada** | 0.769 | 1.349 | 0.882 | **1.000** | 1.080 | **1.000** | 0.837 | 1.038 |
| 9 | **Finland** | **1.000** | **1.000** | **1.000** | 0.838 | 0.774 | 0.717 | 1.345 | 0.751 |
| 10 | **Norway** | **1.000** | **1.000** | **1.000** | **1.000** | 1.027 | 1.342 | 0.708 | 0.766 |
| 11 | **Poland** | **1.000** | **1.000** | **1.000** | **1.000** | 0.888 | 1.107 | 1.031 | 0.997 |
| 12 | **Netherland** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** | **1.000** |
| **Minimum** | | 0.769 | 1.000 | 0.831 | 0863 | 0.774 | 0.717 | 0.775 | 0.751 |
| **Maksimum** | | 1.445 | 1.349 | 1.000 | 1.000 | 1.027 | 1.342 | 1.345 | 1.434 |
| **Average** | | 1.017 | 1.029 | 1.976 | 0.972 | 0.944 | 1.071 | 0.969 | 0.979 |
| **S. Deviation** | | 0.150 | 0.100 | 0.056 | 0.060 | 0.120 | 0.193 | 0.160 | 0.171 |

**Source:** Obtained by the author with the Win4DEAP program.
* Conducted with Output Oriented Model in terms of Variable Return to Scale.

Having evaluated the pure efficiency results which are measured with the assumption of variable returns to scale; the USA, UK, France, Turkey, Norway, Poland and Netherland did not experience any change for that five years period.

Assuming that the relationship between pure efficiency change with the administrative ability of the DMUs (Lorcu, 2010:283); it can be stated that these seven countries could not obtain any administrative gains through the five years period as well. For that reason, it is so hard to interpret this result furthermore.

Taking into account the scale efficiency scores (see Table 10) which denotes the optimal scale gains that the countries obtained for this period; the USA, UK, France, and Netherland were observed to be stable, while others seemed to fluctuate between positive and negative values.

Total Factor Productivity (TFP) change is presented in Table 11.

**Table 11:** Results of MTFP Analysis (2013-2017)*

| | **DMUs** | **TOTAL FACTOR PRODUCTIVITY CHANGE (TFPC)** | | | |
|---|---|---|---|---|---|
| | | **2013-2014** | **2014-2015** | **2015-2016** | **2016-2017** |
| 1 | **USA** | 1.274 | 0.984 | 0.974 | 1.123 |
| 2 | **UK** | 0.911 | 0.988 | 1.057 | 1.998 |
| 3 | **France** | 1.344 | 0.938 | 0.938 | 0.895 |
| 4 | **Germany** | 1.342 | 1.112 | 1.385 | 1.234 |
| 5 | **İtaly** | 0.778 | 1.162 | 0.777 | 1.090 |
| 6 | **Spain** | 1.233 | 1.143 | 1.162 | 1.340 |
| 7 | **Turkey** | 1.309 | 1.445 | 1.064 | 0.870 |
| 8 | **Canada** | 0.921 | 1.466 | 0.741 | 0.706 |
| 9 | **Finland** | 1.076 | 0.765 | 1.459 | 0.799 |
| 10 | **Norway** | 1.398 | 1.444 | 0.662 | 0.810 |
| 11 | **Poland** | 0.759 | 1.123 | 0.959 | 0.861 |
| 12 | **Netherland** | 1.437 | 0.766 | 0.764 | 1.442 |
| **Minimum** | | 0.778 | 0.765 | 0.662 | 0.706 |
| **Maksimum** | | 1.542 | 1.466 | 1.459 | 1.442 |
| **Average** | | 1.165 | 1.113 | 0.970 | 1.061 |
| **S. Deviation** | | 0.267 | 0.243 | 0.246 | 0.373 |

**Source:** Obtained by the author with the Win4DEAP program.
* Conducted with Output Oriented Model in terms of Variable Return to Scale.

By evaluating the TFP change which is measured by the multiplication of the technical and technological efficiency change; Germany and Spain were the only ones experiencing positive values for that period.

## Conclusion and Discussion

This study was carried out for the comparative analysis of the economic efficiency of developed industries in NATO and EUROZONE. CCR and BCC models were used under the DEA's assumption of constant and variable returns to scale. In addition, Malmquist Total Factor Productivity Index was used under the assumption of variable returns to scale.

Within the scope of the first research question, "*whether the countries have achieved economic efficiency or not?*", the results of the analysis of both input and output-oriented methods of the CCR model revealed that while the US, England, France, Germany, Spain, and the Netherlands were at full efficiency level in all years; the other six countries could not provide resource efficiency. However; the results of both input and output-oriented BCC models showed that all countries, except Turkey and Canada, achieved the full efficiency level in all the years.

Within the scope of the second question, "*if there is no economic efficiency, what should be done about resource management?*", it was found that countries should reduce defense expenditures by approximately 9% and defense industry imports by around 18%; while they should increase the total defense sales by approximately 50% and defense products exports by about 43% in order to maintain economic efficiency.

According to the results of Malmquist Total Factor Productivity analysis, the technical efficiency values of the USA, England, France, Germany, Spain and the Netherlands did not change. In other words, it has been observed that these industrialized countries maintained their production efficiency. However, all countries' production possibilities curves shifted to the right in these four periods, which means all countries' defense industry production volumes increased. In terms of the optimal scale of production, only Germany experienced a positive scale efficiency. evaluating the total factor productivity, only Germany and Turkey seemed to experience positive (increasing) efficiency.

As for recommendations for policymakers; within the framework of Kaldor's first law, i.e. the positive impact of the manufacturing industry on growth, it can also be stated that the economic growth may be triggered by the improvements of all kinds of efficiencies (technical efficiency, technological efficiency, pure efficiency, scale efficiency, and total factor productivity).

## Limitations of the Study and Future Implication

This study is limited to these above-mentioned variables, dataset, data period and applied analysis method. Therefore, these efficiency values are not exact robust values, rather they are the relative values obtained just from this study.

Consequently, it can be asserted that the study can be expanded, and also the validity of these results can be increased by varying the data set, the variables, the period of data and the analysis method.

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